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INNOVATION POLICY AND COMPANY STRATEGY

Harry Maier and Jennifer Robinson
Editors

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
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FOREWORD

This book is one major outcome of a research program on innovation that was initiated in the Management and Technology Area at the International Institute for Applied Systems Analysis (IIASA) in the summer of 1978 under the leadership of Professor Harry Maier. The general direction of the work was to develop an understanding of the underlying patterns of innovation, so as to assist those advising industry and government on issues related to innovation. As we developed the research we found that this was one of those universal problems facing all countries large and small and of all political complexions. It was also a question that needed active collaboration with researchers from many countries. We have done this in many ways, notably through short term assignments at IIASA and through the workshop which is reported in this volume.

The workshop, which was attended by 55 representatives from 17 countries, was, we believe, something of a watershed in the development of this subject. It enabled the IIASA team to present their ideas in public for the first time, but more importantly it brought together many of the leading experts in a new environment, so as to identify fully our present state of knowledge and understanding. The workshop did not solve the problem: innovation remains imperfectly understood. But we now have a clearer idea of what we do not know, and of the most hopeful directions for research. In particular, there is a major need for reliable comparative data on the impact of government policy on industry, and IIASA is now launched on a collaborative international research study to provide such information. We hope, in any case, that as a result of our workshop there will be significant advances in research, leading to better understanding and action. That is, in the end, the only justification for our work.

Rolfe Tomlinson
Area Chairman
Management and Technology Area
(1977–1980)

PREFACE

The problems of technological innovation are facing most countries and corporations today. Some countries are concerned about how much priority should be given to innovation, others are concerned with improving innovation capability in order to increase efficiency in production and to help mitigate resource shortages. Other countries are now in the first stages of incorporating innovation activities within the industrial process and are assimilating knowledge from external sources in order to improve their overall economic performance.

In this way innovation becomes a universal, even a global, problem. Without technological innovation it will be impossible to solve these most urgent problems facing mankind today:

- The growing imbalance between natural and human resources: by the year 2000 we shall have to feed 2 billion more people than at the present
- Anticipated shortages of energy, minerals, land, and other natural resources and the inadequacy of technology in substituting artificial resources for scarce natural resources
- The inappropriateness of current technologies in the use of human resources, especially in the developing countries
- The need to generate net real capital at a much higher annual rate than that of today in order to solve the resource problem and to support the industrialization of the developing countries
- The need to improve the conditions of work, life, education, culture, and health for people in both developing and developed countries.

These problems cannot be solved with today's technologies (much less so with yesterday's). Nor will they be solved with a change in hardware alone. We need new social and managerial approaches to technological innovation to give it a more direct orientation toward human needs and national and global commitments and to help alleviate resource problems in the future.

To identify the new problems in the management of innovation on the firm and national level, to compare experiences in this field, and to give some hints for the improvement of the relationship between national innovation policy and firm strategy was the target of the IIASA workshop "Innovation Policy and Firm Strategy" held in December 1979.

The workshop had more than 60 participants from 17 countries — both decision makers at the firm and governmental level as well as researchers in the field of innovation. Great interest was shown in the topics under discussion, especially in the development of the relationship between macroeconomic and microeconomic stability during the innovation cycle, the change in the organization pattern during the innovation process, the role of different kinds of innovation and the requirement of different managerial skills and measures to cope with them, the influence of government technology pull and technology push action on the innovation process, and the possibility of finding an appropriate combination between them.

Workshops in the field of innovation are normally under pressure from two sides: at one extreme some people assume that they can produce a perfect recipe for the successful management of innovation on the national and firm level; at the other extreme, others are skeptical that such a complex process as innovation can or should be managed at all. If you are in agreement with either of the above then you will be disappointed with the results of our workshop. Most of the participants were confident that there is no single measure or algorithm that could automatically achieve a high rate of innovativeness for a company or country. However, the participants were also confident that government innovation policy and firm strategy have a commitment to provide more information about the future field of innovation, to steer innovation toward meeting human needs and national necessities, and to improve the climate and infrastructure for innovation activities. In this context the question of the appropriate analytical tools and social procedures to identify the place of a company or a country within the field of innovation activities and the appropriate strategy to improve or maintain its position in this field is important.

These and many other questions were discussed, and we hope that publication of the proceedings of our workshop will stimulate discussions between people interested in social and technological innovation.

Harry Maier

ACKNOWLEDGMENTS

As editor, I should like to express my gratitude to the members of the Innovation Task Group — a unique research group that included researchers from planned and market economies, and of which I am honored to have been Leader. In particular, I should like to thank Jennifer Robinson (USA), Heinz-Dieter Haustein (GDR), Alvin Harman (USA), and Peter Markowich (Austria) for their help in the preparation of the workshop and the publication of the proceedings. Jenny Robinson did an extremely good job in editing the papers and shaping the book into its present form, as well as writing the introduction to each of the four parts. Heinz-Dieter Haustein and Alvin Harman were responsible for the epilogue which we hope will stimulate further research in this field.

Harry Maier

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PART ONE

INNOVATION POLICY AND COMPANY STRATEGY: NEW CHALLENGES AND OPPORTUNITIES

INTRODUCTION

Jennifer Robinson

What is innovation policy? What can it do? What should it do? What are the real problems toward which it should be directed? What policy means are available to effect innovation?

There are no absolute answers to these questions. Both the environment within which innovation takes place and the functions that innovation might serve vary greatly over time and space. Innovation policy before the energy crisis was different from innovation policy after the energy crisis, and innovation policy in a small, open economy is different from innovation policy in a large, relatively closed economy.

Moreover, the field is imprecise. Established terminology and means of measurement for technological innovation are missing, and each person is left to define the terms in which he will view technology for himself. This results in great divergence of perspectives. One person sees innovation in terms of economic efficiencies, another in terms of international division of labor, and a third in terms of possible means to deal with specific problems, such as energy shortages, hunger, or poverty.

This first Section presents five rather different perspectives on the general problem of technological innovation and its management. The first two papers approach innovation as a question of efficiency and efficiency change.

The opening paper, by Harry Maier, the leader of the IIASA Task Group "Management of Innovation," from the German Democratic Republic, sets forth a theoretical model which views technological innovations in terms of their power to increase efficiency. He postulates three kinds of innovations: basic innovations, which open technological niches for efficiency gain; improvement innovations, which exploit the niche spaces opened by basic innovations; and pseudo-innovations, which create change without creating significant efficiency gain. He then relates the three kinds of innovations to a lifecycle concept of efficiency change, and draws some policy conclusions related to the conceptual framework he has laid out.

The second paper, by Walter Goldberg of the University of Gothenburg, Sweden, focuses on the later and more problematic side of efficiency change, stagnation, and seeks more to organize and interpret empirical observation than to theorize. In his introduction Goldberg notes that stagnation is not a uniform phenomenon; it may appear on any level from supranational to segments of an enterprise, and stagnation on one level can be coupled with rapid growth on another level. He also discusses the problem of measurement and the pitfalls therein. The main body of Goldberg's text describes, by means of examples, three distinct types of stagnation: long-term stagnation, such as found in many segments of the textile industry, medium-term stagnation, such as found in the printing industry, and drastic, dramatic, short-term stagnation, such as found in the shipbuilding industry.

Goldberg closes with speculation on stagnation as a generalized condition in economies that are leveling off. He writes: "The present situation in the shipbuilding industry may be a valuable crystal ball when it comes to depicting a situation of more general stagnation in which many industries will fight vigorously not only to defend their shares of existing markets, but also to try to enter into market segments which are already occupied by others... It seems to be quite urgent to extend research into the problems of leveling off economic systems and into objectives, methods, and instruments of industrial policy under such conditions."

Joel Hirshhorn, of the US Office of Technology Assessment, Washington, DC, locates the problem as the changing nature of technological innovation, rather than in changes in its effects. His basic concern is that the modern economic environment is driving industry away from the use of technological innovation as a means of competitive strategy. He attributes this change to five environmental factors: the increased speed of technology transfer, which reduces the rewards to those promoting major innovations; inflation, which increases the rate of return that an innovation must draw in order to be commercially attractive; large currency exchange fluctuations, which create random disturbances of an order of magnitude that overshadows the potential gain to be had through innovation; increased social concern over societal effects of technology, and concurrent regulations, which add costs, delays, and uncertainty to the innovation's prospects; and changes in the size and institutional structure of firms, which inhibit the risk-taking, entrepreneurial spirit necessary for innovation.

In closing, Hirshhorn voices the opinion that governments may help reverse the trends which are antithetical to technological innovation by taking on more of the costs of basic research and commercialization.

The following two papers, by Ernst Braun of the Technology Policy Unit, University of Aston (UK), and Lech Zacher of the Polish Academy of Sciences, take two extremely different views of the government role in managing innovation. The contrast between the two papers provides a good illustration of how different technological innovation appears from a market economy perspective and from a planned economy perspective.

Braun's approach is essentially skeptical. He opens with the observation that industrialized countries are asking a lot from technological innovation these days, and that most governments now feel it their duty to support the innovative process by suitable policies. He proceeds to describe and catalogue a representative sample of the sorts of policy measures used in industrialized market economies to attempt to stimulate (or to remove impediments from) technological innovation. This leads to a review of critical evaluations of policy measures available for management of innovation, and from there to the conclusion that "Government has a large range of measures in its armory by which to influence innovation. The efficiency of the various measures is, however, largely unknown." In closing Braun notes that underlying basic questions, such as what kinds of innovation are desirable and optimal, and what measures will attain the desired sort of innovation, deserve greater thought.

Zacher, in contrast, takes it for granted that innovation should, and indeed must, be managed in planned economies. So it has been in the CMEA economies. "The founders of Marxism stressed the importance of technology in the structure of production forces." Planning for technological change has necessarily been part of state planning. The nature of the planning that has had to be done has been a product of the historical circumstances in the CMEA countries, most of which were economically backward at the end of World War II, and which faced further managerial difficulties due to hostility during the "cold war." The need to overcome backwardness rapidly has, in the past, driven the CMEA countries to adopt dehumanizing and environmentally degrading technologies from the capitalist economies.

This trend will not necessarily continue. Zacher expresses the opinion that socialist countries have reached, or are near to reaching, a state of development in which they can better afford actively to implement the Marxist concern with humanization of technology. In the last section of his paper he discusses specific institutions that are being used and might be developed to that effect. This includes discussion of how research and development policy is currently formulated and how technology assessment might be worked into present planning mechanisms to give society greater goal-directed control of its technological development.

The last paper in this Section is by Gerhard Mensch and Alfred Kleinknecht, from the International Institute of Management, Berlin (West). The authors try to identify the situation in which the innovation process is currently managed. Their assumption is that the economic potential, which was created through basic innovation of the thirties, forties, and fifties, is currently absorbed through improvements in innovation. This is the reason for the current situation which is characterized by a pause in the creation of basic innovation labeled as "Stalemate in Technology." They see the greatest challenge for the national innovation and firm strategy as finding an adequate place for the country or company in the next basic innovative push, which will possibly occur in the latter half of this decade.

NEW PROBLEMS AND OPPORTUNITIES OF GOVERNMENT INNOVATION POLICY AND COMPANY STRATEGY

Harry Maier

NEW CHALLENGES

Innovation, the process of creation, development, use, and diffusion of a new product or process for new or already identified needs, has become one of the central themes for both developed and underdeveloped countries. The causes and motivation for the growing concern about the status of innovative ability are different.

Some countries which have taken the superiority of their technological ability for granted are now faced with a slowdown in the rate of productivity advance, with weakness in international competitiveness, high-priced energy and other natural resources, unemployment, inflation, and a tendency to stagnate. Other countries, which in the past were successful in generating social and technological change, now have to realize that the current economic environment, especially the resource situation, needs new technological, managerial, and social approaches in order to deal with the new circumstances and thus fulfill the social goals which arise out of the nature of their society. Developing countries are faced with growing imbalances between their responsibility to secure and improve the living conditions of more and more people and their technological and social capability to use their natural and human resources to achieve this. Despite the fact that shaping and promoting technological innovations has become a universal problem, the causes of the growing concern about innovation are not fully understood.

Several studies have tried to explain the growing concern with the slowdown of expenditure on R&D in some countries, the decline in competitiveness in the products of several countries, the diminishing rate of increase in labor productivity, the low rates of new capital formation connected with low rates of return on invested capital, the decline of the total number of patents issued annually, the increasing ability to exploit and imitate advanced technologies in a growing number of countries, the impossibility of protecting monopoly returns from advanced technologies against imitators, etc. All these problems are real and it is understandable that researchers and decision makers in many countries are trying to find appropriate responses to them.

Despite the fact that it is in the nature of the technological innovation that nobody can be sure that his position in advanced technology can be held indefinitely, we have to realize that a lot of the above-mentioned problems are consequences of deeper structural problems in the world economy. Obviously in the current structure of world economy, imbalances and contradictions exist which indicate a lack of social and technical innovations.

If we try to assess our innovative capability we have not only to think about the problems facing us in our countries, but also about how we are prepared to deal with the new circumstances, the global problems, which are the results of change in the structure of the world economy, and how we can shape this structure with technical and social innovation in such a way as to solve these problems.

We should use the growing technical capabilities of an increasing number of countries, the rapid development of the industrial sector of a number of developing countries, the beginnings of international technological and scientific cooperation, and the different forms of technology and knowledge transfer between different world regions to cope with the crucial problems which are now facing mankind. We should try to improve our innovation policy by giving it a more concrete orientation toward human needs to avoid disadvantages and undesirable side effects of technology, and secure the interlinkage between technological and social innovation.

SOME REMARKS ON THE DEVELOPMENT OF OUR THINKING ABOUT INNOVATIONS

The exploration of innovation is a process which has run through different phases of investigation in which different topics and analytical tools were dominant. The scientific results of all stages are now embodied in our current thinking about innovation. I assume that it is possible to distinguish between three phases in our efforts over the last two decades to understand the innovation process:

Phase 1: In the beginning of the 60s problems of management planning and forecasting of R&D activities, vertical and horizontal allocation of R&D resources within the national economy between the different types, disciplines, and stages of R&D, and the creative character of the innovation process, were the main problems of investigation. At this time many new research disciplines and new research directions were created, such as "the science of science," and "the economics of research." More and more scholars were starting to identify the contribution of technological progress to meet national needs. The "production and distribution of knowledge" and the attempt to measure its contribution to economic growth were main subjects of research at that time.

Phase 2: The next step began with the recognition that higher expenditure on R&D does not automatically result in a higher rate of innovation. It was especially recognized that any innovation is the result of a combination of need factors and technological means of meeting a given or latent demand. This puts the attention of analysis on those factors which are influencing the creation of innovations. In this context it was obvious that an important time lag exists between inventions and their technical and commercial utilization. The result of this was a sequential model which stressed that R&D is only one phase of the innovation process and that technical realization and commercialization are crucial for successful innovations. It was obvious that corporations and countries which are very successful in the first phase of the innovation process do not automatically gain the benefits of their R&D efforts. Therefore many studies at that time put emphasis on the better understanding of the links between different phases of the innovation process: invention, technical realization, and commercialization.

Phase 3: The third phase of the innovation process, which started in the first half of the 70s, began with the recognition that the demand for innovation of a production unit very much depends on the economic environment in which it has to operate and from the stage of development of that production unit. It was found that the relationship between innovations and the efficiency of the production unit which has adopted them has changed during the time of the production unit's development. One of the most important findings was that a high level of output and efficiency is not equal to a high innovation rate. To understand this, it was necessary to investigate more carefully the development of the efficiency of the production unit which has adopted the innovation in comparison with the average efficiency of production units as a whole in the production field. With this approach it was possible to understand better the role of the different kinds of innovation during the innovation cycle, and the role of basic, improvement, pseudo-innovation, product, and process innovations and their influence on efficiency. This does not mean that we are trying to ignore the advantages which were gained in the other phases of research or that we are of the belief that the problems which were explored in the first two phases have now lost their importance. We have only tried to demonstrate the direction which our efforts to understand the innovation process better were taking in the past, without ignoring the results which we found in this way.

We are now faced with the need for a new step in the innovation process, with the following problems becoming crucial in the investigation of the innovation process:

(1) The influence of innovation on the macro- and micro-stability of the society

(2) The interlinkage between technological and social innovation
(3) The creation of a social control procedure for unintentional, indirect or delayed disadvantages of technology
(4) The contribution of innovation in solving global problems.

INNOVATION AND EFFICIENCY

The key problem for the management of innovation is the relationship between innovation and efficiency. How do we measure this relationship?

Innovation is not a goal in itself, and it is not possible to measure the rate and importance of innovations by calculation of their frequency or by identifying the input and output characteristics of a single innovation. Average efficiency coefficients, like labor productivity, capital coefficient, or labor intensity of capital, are unable to reflect the impact of innovation in a clear form. We have also to take into account that the importance of the different input and output characteristics have changed during recent years.

To understand the nature of the innovation process, it is important to distinguish between two kinds of efficiency:

(1) *Dynamic efficiency:* the efficiency of the production unit that has adopted the innovation

$$[e(i)t]$$

(2) *Average efficiency:* the efficiency of the entire production field

$$[\tilde{e}(t)]$$

We then define the relative efficiency as the coefficient of the dynamic and the average efficiency

$$x(t) = \frac{e(i)^t}{\tilde{e}(t)}$$

The dominance of special types of innovation (basic, improvement, or pseudo-innovation), the role of product and process innovations, the typical barriers and stimuli, and appropriate management skills and tools very much depend on the stage of development of the ratio between these different types of efficiency. Therefore, with the help of the relative efficiency coefficient we can understand better the direction of the development of the economic performance of a company, industry, or country.

Let us explain the relationship between these two coefficients in a more formal way.

We consider the set of all productive units

$$\{pu_1, \ldots, pu_n\}$$

which produce a commodity that fulfills the same customer's need, and assume that the subset

$$\{pu_1, \ldots, pu_r\}$$

adopts a certain innovation and the subset

$$\{pu_{r+1}, \ldots, pu_n\}$$

does not. Now we are interested in the development of the efficiency of the innovative subset

$$\{pu_1, \ldots, pu_r\}$$

compared with the efficiency of the whole productive system

$$\{pu_1, \ldots, pu_n\}$$

We define $e_i(t)$, the efficiency of the unit pu_i at time t, and get:

$$e_i(t) = \frac{O_i(t)}{I_i(t)}$$

where O_i is the output to pu_i, and I_i is the input. Furthermore, the efficiency of e_1 of the innovative subset is equal to

$$\sum_{i=1}^{r} e_i(t) p_i$$

and the efficiency of the noninnovative subset is

$$\sum_{j=r+1}^{n} e_j(t) p$$

where $\{p_1, \ldots, p_n\}$ are weights which fulfill $0 < p_i < 1$.

Let us call

$$\tilde{e}(t) = \sum_{i=1}^{n} e_i(t)p_i$$

the efficiency of the whole system, so we get:

$$\frac{e_1^r(t)}{\tilde{e}(t)} = \frac{\sum_{i=1}^{r} e_i(t)p_i}{\sum_{i=1}^{n} e_i(t)p_i}$$

as the ratio of efficiencies.

If we look at average efficiencies, we get:

$$\overline{e_1^r}(t) = \frac{\sum_{i=1}^{r} e_i(t)r_i}{\sum_{i=1}^{r} p_i}$$

$$\overline{\tilde{e}}(t) = \frac{\sum_{i=1}^{n} e_i(t)p_i}{\sum_{i=1}^{n} p_i}$$

and resulting from that

$$x = \frac{\overline{e_1^r}(t)}{\overline{\tilde{e}}(t)} = \frac{\overline{O_1^r}(t)\overline{I_1^n}(t)}{\overline{I_1^r}(t)\overline{O_1^n}(t)}$$

where $\overline{O_1^j}(t)$ resp $\overline{I_1^j}(t)$, the average output resp input of the subset, is $\{pu_1, \cdots, pu_j\}$.

Let me talk a little about $x(t)$, the relative efficiency. Figure 1 demonstrates that the development of $x(t)$ during the innovation cycle can indicate three fundamentally different situations for the firm.

Where $x > 1$, the dynamic efficiency is higher than the average efficiency. That means that the economic performance is improving and that the influence of the efficiency factors of production growth is increasing.

Where $x = 1$, the efficiency of the production units which have adopted the innovation is becoming equal to the average efficiency: that means that the former innovative production units have lost their advantage in dynamic efficiency and are approaching a situation which some

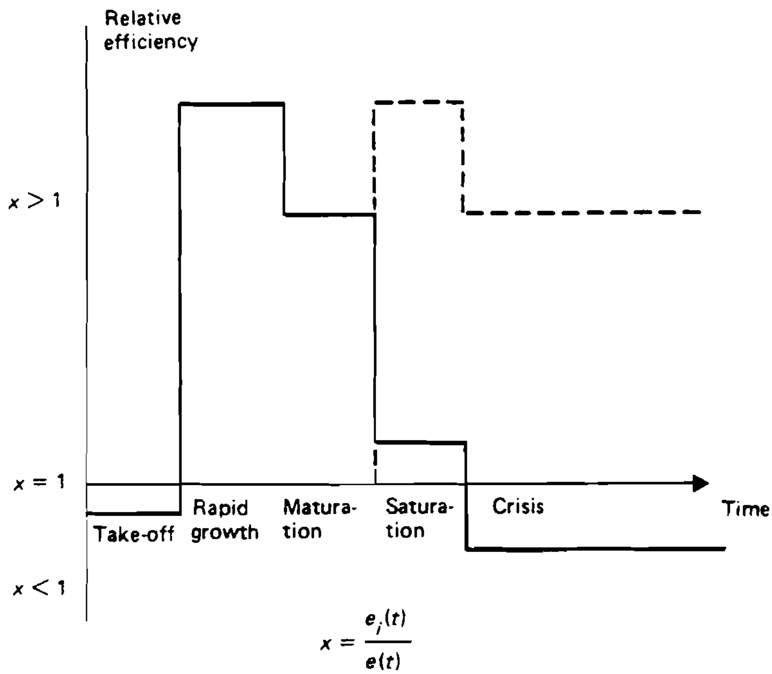

FIGURE 1 Development of the relative efficiency in the main stages of an innovation process. $e_i(t)$, efficiency coefficient of production unit i, which adopted the innovation at time t; $e(t)$, efficiency coefficient of the production system as a whole at time t; x, relative efficiency of an innovation process.

critics have labeled as "stalemate of technology" or "productivity dilemma."

In the case of $x < 1$, the influence of efficiency factors on the production growth is declining.

Unfortunately we have as yet no appropriate instrument to measure the development of the relative efficiency of innovation in a clear-cut way.

For the innovation strategy of a firm or country, two kinds of information are decisive: (1) What is the place of the production unit in the development of efficiency of the production field in which it is incorporated? (2) What options are available to improve or to maintain that production unit's position in its production field, or should it abandon the production field?

To acquire such information we should carefully investigate the situation in the different stages of innovation cycles in order to find the appropriate strategies of growth, change, and survival. From my point of view, it is useful to distinguish the following five stages in the development of the production unit which has adopted the innovations.

Stage I

This is the take-off stage of a basic innovation.

Normally the basic innovation will be very expensive initially, relatively crude, unreliable, and with only limited application. Most production units will be unable to recognize their efficiency potential and their range of possible applications.

In many cases the efficiency of the production unit which adopted the new innovation will be lower than the average efficiency of the production system as a whole.

The decision to start with the innovation will very much depend on the assessment of efficiency potential, and on the capability of the innovation to meet future needs and to overcome shortages, which is crucial for the whole economy. However, the criteria for efficiency on the firm and on the national level are very different. Firm strategy tends to underestimate the long-term and social effects of an innovation.

This is a fluid situation in which there are many technological options. The market share is very low, costs are high, production is unstable, and the products are far from being competitive.

Product design plays a decisive role at the start-up phase of a basic innovation which is a major product innovation. The production process at this time is still dominated by traditional process technologies.

Most companies follow a "wait and see" strategy, because they think that no matter how glorious it may be to be first, it is more profitable to let someone else assume the costs and risks of product development.

The role of government innovation policy is crucial in providing information about national needs, gaps, and coming shortages, and in creating conditions for taking courageous decisions to implement an innovation.

Example

Early transistors were expensive and had poor temperature stability and frequency response, but they were light, rugged, and had low power requirements. Thus they were ideal for such wide ranging uses as missile guidance and for hearing aids.

Stage II

In this stage the basic innovations become more and more efficient.

Production units which apply the basic innovation first gain high efficiency in comparison with the average efficiency. The opportunity of gaining a "monopoly rent" or "extra high efficiency growth" from the innovation is very important as a stimulus for the decision to implement an innovation.

Many other enterprises will try to imitate and to improve on the basic innovation. In this stage the decisive factors for the rise of efficiency are the new qualities, functions, and features of the product, and they are well protected by patents.

Typically there is a shortage of qualified people with specialized knowledge and the experience to apply it. The recruitment of competent people with the necessary knowledge is decisive.

Example

L.M. Ericsson, the Swedish engineering multinational, overcame the first difficulties in making the shift from electromechanical to electronic telephone exchanges and was able to more than double its output of computerized telephone exchanges within 2 years to become the market leader in this, one of the most competitive high technology businesses.

Stage III

In this stage properties and features of the basic innovation are very important, but the improvement innovations become more and more important.

Improvement innovations tempt more and more firms to participate in the use of the basic innovation. Major process innovations especially become more and more important.

The market expands and there is accelerated investment and employment.

A lot of production units improve their ability to imitate product and process innovations which were generated in other production units.

The greater the advantages of adopting one innovation in terms of productivity increase, product quality, and process uniformity, the more rapidly its diffusion will occur. On the other hand, as a greater number of production units adopt the innovation the disadvantages for production units which do not adopt the innovation will become greater and greater.

Production tends to become standardized, and general purpose equipment which requires highly skilled labor will be replaced step by step by special purpose equipment which is mostly automatic.

Example

It is especially possible through major process improvement at this stage to realize a high rate of productivity. The cost of incandescent light bulbs, for example, has fallen by more than 80% since their introduction (Utterback 1979). Airline operating costs were cut by half through the development and improvement of the DC3 (Utterback 1979). Semiconductor prices have been falling by 20 to 30% with each doubling of cumulative production (Bodde 1976). The trend towards increasing the packing density and the number of functions per semiconductor chip is as yet unbroken. Figure 2 shows the rapid increase in the number of logic functions per chip versus the resulting decrease in costs within the period from 1962 to 1980. Also entered are the years in which some important semiconductor technologies such as TTL and MOS, and a number of outstanding devices, were introduced. According to this curve, semiconductor manufacturers are expecting very large scale integrated circuits of a

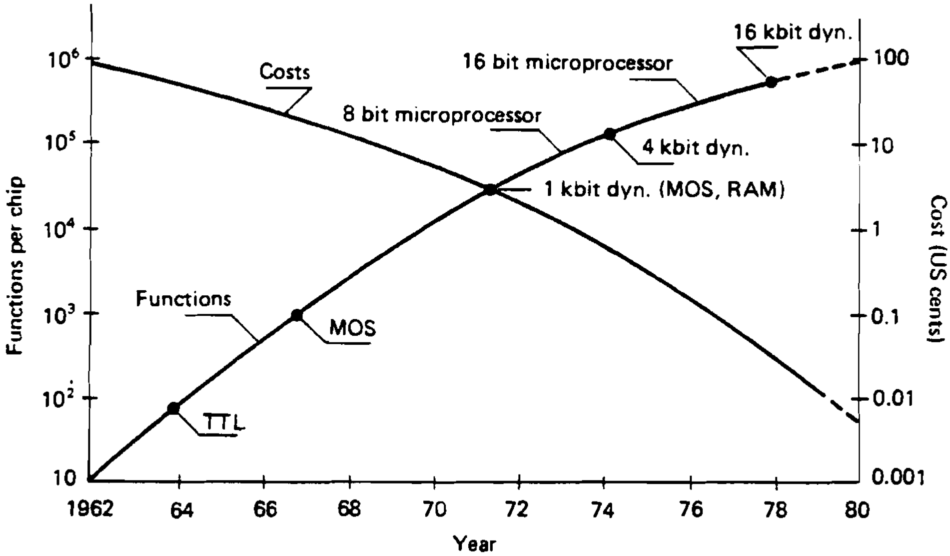

FIGURE 2 IC semiconductor trends. Source: Ernst (1978).

million transistor functions per chip in the early 1980s. For the systems engineer and the management of innovation this raises the question of how to use the efficiency potential which is created through such a component in the process automation sector.

Stage IV

This is the mature stage, where improvement innovations play a dominant role.

Incremental innovations especially become more and more important. These are the extensions of existing technologies which improve product performance, cost, or quality step by step.

Cost reduction and the increase of labor productivity are the main results. For example, more than half the decrease in costs of the production of rayon over a period of years was traced to incremental innovations. The findings were the same in studies about light bulbs, liquid propelled rocket engines, automobiles, and computer core memories (Utterback 1979).

While production has become capital intensive and large scale, the implementation of major change in either product or process is very difficult. It appears disruptive and challenges the existing structure of production and organization.

This makes these production units more and more vulnerable for alternative technical solutions, but this is also the last point at which a new direction of production can be started.

Otherwise the production unit will sooner or later run into stagnation, "productivity dilemma" (Abernathy 1978), or "stalemate of technology" (Mensch 1975).

Examples

The lower flexibility of mature production units is often the reason why major manufacturers are not initiators of basic product innovations in their branches. For example, major manufacturers of mechanical typewriters did not introduce the electric typewriter. Few major manufacturers of mechanical calculators are now manufacturing electronic calculators. And few manufacturers of vacuum tubes were successful in making the shift to transistors (Utterback 1979).

Stage V

This is the "stage of crisis."

Production units which were not able to respond creatively to the new circumstances and the new radical technological options will now try to hold their position through product differentiation, design variations, larger efforts in marketing and advertising, and through improvement of the old technology. But these are ineffectual efforts. For example, under the pressure of electric incandescent lamps, the efficiency potential of gas lighting was completely absorbed.

Improvement or incremental innovations are now unable to compensate for the diminishing efficiency because of higher resource and infrastructure costs or the performance and cost advantages of new technologies which have been ignored by the production unit.

Production units which have not been able to adopt the new product and process innovation of their production field now find themselves in a state of crisis.

Table 1 gives a summary of the most important events in the different phases of the innovation cycle.

We are trying to prove our hypothesis about the importance of different kinds of innovations with the help of empirical data. For the purpose of this presentation our findings about the "employment and productivity" effect of the different kinds of innovation is especially interesting. We can identify the two effects with the help of data gathered from the Institut für Arbeitsmarkt und Berufsforschung in Nürenberg, Federal Republic of Germany. This is data from 2266 technological changes within 909 firms from four industrial branches (plastics, metalwork industry, food industry, wood and furniture industry) in the Federal Republic of Germany during the period 1970–1973. By the employment effect of innovation we mean the relationship between workplaces created and eliminated because of technological change.

The productivity effect is the contribution of the different kinds of innovation to labor productivity growth as a result of technological change.

TABLE 1 Innovation cycle and management requirements.

	Take-off	Rapid growth	Maturation	Saturation	Crisis
1 Example	Liquid fuel	Microelectronics	Plastics	Automobile engineering	Shipbuilding
2 Dynamic efficiency	Negative	Very high	High	Medium	Negative
3 Absolute benefits	Negative	High	Very high	High	Negative/low
4 Predominant type of change in production	New establishments	Enlargements	Total modernization	Product differentiation and rationalization	Capacity reduction, product differentiation
5 Employment effect	Positive	Positive	Positive	Negative	Negative
6 Investment	Positive	Positive	Positive	Negative	Negative
7 Degree of technology change					
Product	Very high	High	Medium	Low	Low
Process	Low	Medium	High	Medium	Low
8 Risk anticipation of the management	Very high	Medium	Low	Medium	Very high

Figure 3 demonstrates that basic and major improvement innovations have the highest employment effect, and a high contribution to productivity growth too. Among them the implementation of new products had the highest employment effect. It created 31.7 times more new working places than it eliminated. But its contribution to labor productivity

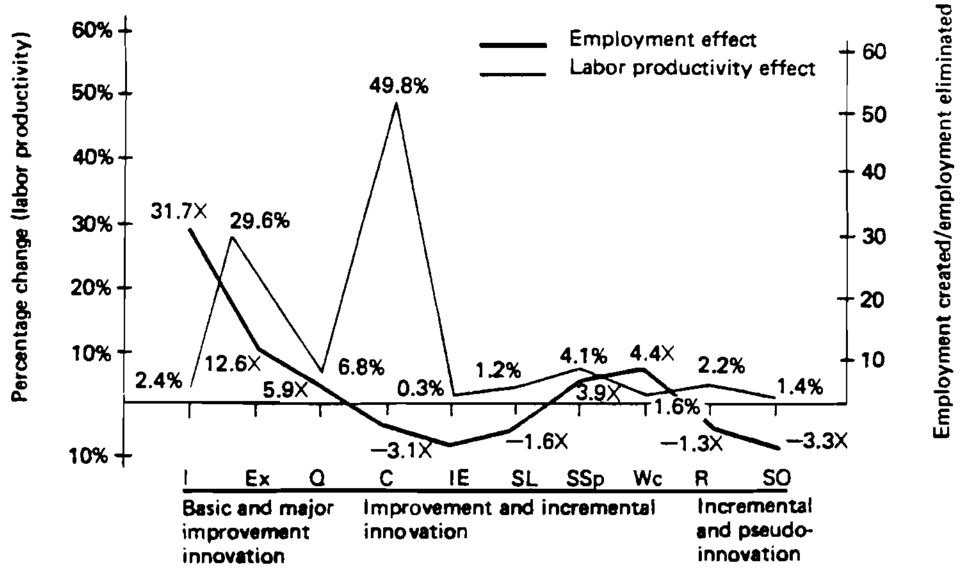

FIGURE 3 The employment effect and the labor productivity effect of different kinds of innovation. (Results of an investigation of 2260 technological changes within 909 firms in four industrial branches of the Federal Republic of Germany, 1970–1973.) I, implementation of new products; Ex, extension of capacity; Q, new quality of products; C, cost reduction innovation; IE, improvement of efficiency; SL, reduction on shortage of labor; SSp, reduction on shortage of space; Wc, improvement of working conditions; R, replacement of product equipment; SO, shortage of orders.

growth through technological change was relatively low —only 2.4%. This is a typical activity in the take-off stage of the innovation cycle. The extension of innovations — an activity in the rapid growth stage of the innovation cycle —is able to contribute significantly to labor productivity growth (29.6%) and is also able to secure a high employment effect (12.6×). Major improvement in the quality of the product has been able to contribute to labor productivity growth by 6.8% and to create 5.9 times more working places than it eliminates. It is important to realize that basic innovation is doing both —i.e., creating many more working places than any other type of technical change and contributing significantly to productivity growth.

Improvement innovations devoted to cost reduction have naturally the highest contribution to labor productivity growth (49.8%), but they are the starting point from which the employment effect becomes negative. They eliminate 1.4 times more working places than they are able to create. Only in the case of improvement of working conditions and production space is the employment effect positive again, for obvious reasons.

But in other types of technical change due to medium improvement and incremental innovation, which occur in the fourth phase of the innovation cycle, the employment and productivity effects are very low. For example, the short-term reaction of a shortage of workers has an employment effect of only –3.3x and a productivity effect of only 1.4%.

This proves our hypothesis that a low employment effect is not so much a result of the development of labor productivity — which is what some of our colleagues have claimed up to now — as the result of the dominance of medium improvement and incremental innovation in economic activities. This could also explain why, at the present time, some of the industrially developed market economies are faced with both a decline in productivity growth rates and a high rate of unemployment.

CONCLUSIONS FOR NATIONAL INNOVATION POLICY AND COMPANY STRATEGY

(1) The first conclusion that can be drawn from the mental model of the innovation cycle is that a high degree of efficiency and output of production is not an insurance against future disadvantages through an invasion of new technological options. The highest degree of efficiency, a large market share, and a high degree of standardization and vertical integration represent the last opportunity for a production unit, if it is also to gain in future economic vitality, to search for new ways of satisfying a latent demand or to satisfy an existing demand with better and less expensive alternatives. Today's examples for this concept of missing the right moment for change are the shipbuilding and steel industries. The main concern of the innovation policy of a country or corporation should be to maintain the right mixture between business activities in the different stages of the innovation cycle. Countries or firms whose main concerns are innovation activities in the maturation and saturation stage will lose, in the foreseeable future, their advantages in dynamic efficiency and run into stagnation. One of the most important experiences in the management of innovation in all industrialized countries is the importance of a close interdependence between government innovation policy and firm strategy. Government actions to stimulate innovations must not only be designed taking into account the change of attitude of production units as a result of the development of their efficiency, but also the adverse effects which may arise from the application and diffusion of technology for the working conditions, environmental security, and health of the people. On the other hand, the corporations have to improve their ability to find appropriate responses to national needs and coming shortages, and to avoid not only primary but also secondary and tertiary adverse effects of innovations. This system of interdependence is far from being perfect.

(2) The relationship between product and process innovation is very much determined by the stage of development innovation process. In recent years many systems analysts have tried to find possible combinations between process and product innovation. What shall a decision maker do with information, for example, that there are more than five million possible combinations of product and process innovations? However, with our approach it is much easier to understand the role of product and process innovation in the different stages of the innovation cycle. We have seen above that on the level of the production unit the distinction between major product, major process and incremental innovation is very important. But on the macroeconomic level it is very difficult to distinguish between major product and major process innovation. This is because that which is a product of one firm may be the process equipment, components for assembly, or materials used by another firm. Therefore we think that on the macroeconomic level the distinction between basic, improvement, and pseudo-innovation is much more important (Haustein and Maier 1979). Basic innovations are innovations which create a new efficiency potential, and open new fields and directions for economic activities. The main function of improvement innovations is absorption of this efficiency potential through balancing and improving the given system. Most of them are incremental innovations. The improvement innovations become pseudo-innovations at the point when they are unable to secure higher efficiency of the production unit than the average efficiency of the whole system. Currently a growing number of innovation experts are arguing that the decrease in the growth rates of productivity in industry is the result of the absorption of the efficiency potential, which was established through basic innovation in the thirties, forties, and fifties. Certainly, we have different factors influencing the industrial efficiency in the different countries. But if we take a look at countries where industrial performance is very closely connected to their innovations, it is not difficult to find an indicator of the declining rate of basic innovation and the growing influence of improvement and incremental innovation.

(3) An important issue in the relationship "innovation and dynamic efficiency" is the development of the share and structure of investment. In several studies and statements we can find very one-sided interpretations of the relationship "investment and innovation." Mostly, people assume that innovation is a function of investment. The statement is "If we have enough investment, then we will have enough innovation." The recommendation for government policy is consequently: "All we have to do is to create the conditions for higher returns on investment." But the returns on investment are very much dependent on the efficiency potential of innovation, which is incorporated in investment. Obviously, we have to distinguish here between two kinds of innovations:

(a) *Innovations which are driven from investments*. These are the improvement and incremental investments.

(b) *Innovations which are driving investment*. These are the basic innovations which open new fields for investment activities with high potential efficiency rewards. That is the reason why the recommendation to put more emphasis on the stimulation of extensionary investments, with the target of new employment opportunities, is one-sided. Extensionary investments without adequate innovation will have an adverse effect on the efficiency of investments and only a short-term employment effect. Obviously we have seen in the last few years in market economies a very important change in the direction of investment. Investment has been directed more and more towards basic innovation. Figure 4 shows the development of the relationship between investment and employment. The case of the Federal Republic of Germany is here typical for OECD countries.

In the European socialist countries we have the opposite situation. Through high demand for industrial goods and high growth rates in industrial production, there has been a great deal of expansionary investment.

However, the demand for higher flexibility and structural change create different situations in different industries. Figure 5 shows us the situation in GDR industry as a whole and the rather different situations in the textile and electroengineering industries in the GDR. The textile industry of the GDR obviously had a high share of rationalization investment with a significant release of the work force. In the electroengineering industry the expansionary investments were dominant, with the effect of creating a large number of work places. At the present time, the effect of creating work places through the influence of demand and efficiency factors in the industries of the CMEA countries is higher than the release effect of investment.

The result of this is that in socialist countries like the GDR and Czechoslovakia we have significant shortages in the labor force or many vacant work places. For this reason the desire for improvement and rationalization innovation is very high and these countries are therefore trying to increase the share of rationalization and replacement investment. But this must be understood as an attempt to strengthen the economic performance of these countries and to improve their capability to implement basic, urgent innovations in the fields of energy, microelectronics, the machine tool industry, etc.

Therefore, I think it is dangerous to ignore both the linkage between expansionary, rationalization, and replacement investment and the linkages between basic, improvement, and incremental innovations. Basic innovations are preconditions for improvement innovation and improvement innovations create the economic power for implementation of basic innovations. A parallel relationship exists between expansionary investment and rationalization investment. Therefore recommendations which only put emphasis on expansionary investment without taking into account their interrelationship and their linkage to special types of innovation fail to give appropriate guidance for the management of innovation. For example, the increase in expansionary investment without basic innovation will have an adverse effect on the efficiency of investment and only a short-

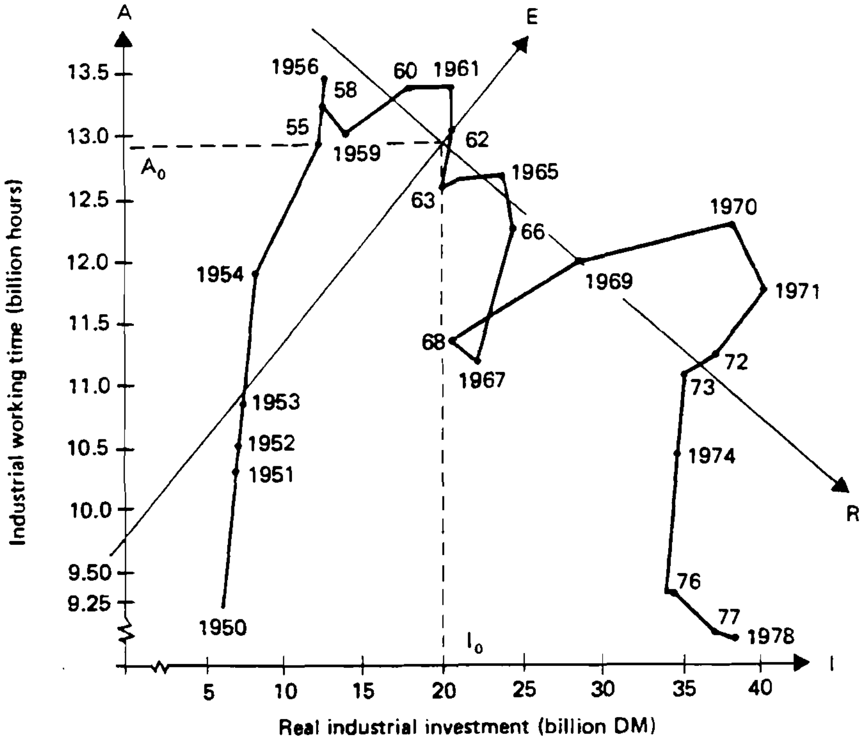

FIGURE 4 Labor hours and real investment capital input in West German Industries, 1950–1978. Adopted from Mensch *et al.* (1980). A, industrial working hours (10^9 h); I, real industrial investment (10^9 DM); E, index of expansionary investment; R, index of rationalizing investment; u, labor capacity utilization ratio, based on 4% "full employment overload" = 100/104 = 0.962; $I_0 = I_{1961} = 20.7 \times 10^9$ DM; $A_0 = uA_{1961} = 12.9 \times 10^9$ h.

term employment effect. Rationalization and replacement investment which is not connected to improvement innovation to adopt the efficiency potential created by basic innovation will make the existing work places vulnerable to any attack from an innovative rival or will create working places with lower efficiency which only exist because of the protection policy of the government.

From the nature of the innovation process we can draw one conclusion: to secure the better use of human resources we need efforts to coordinate the innovation cycle. If the main industries are approaching the saturation stage, then there will necessarily be a gap between the release of working places and the re-employment capability of industry. It is without doubt that this is one reason for the employment problem in some market economies.

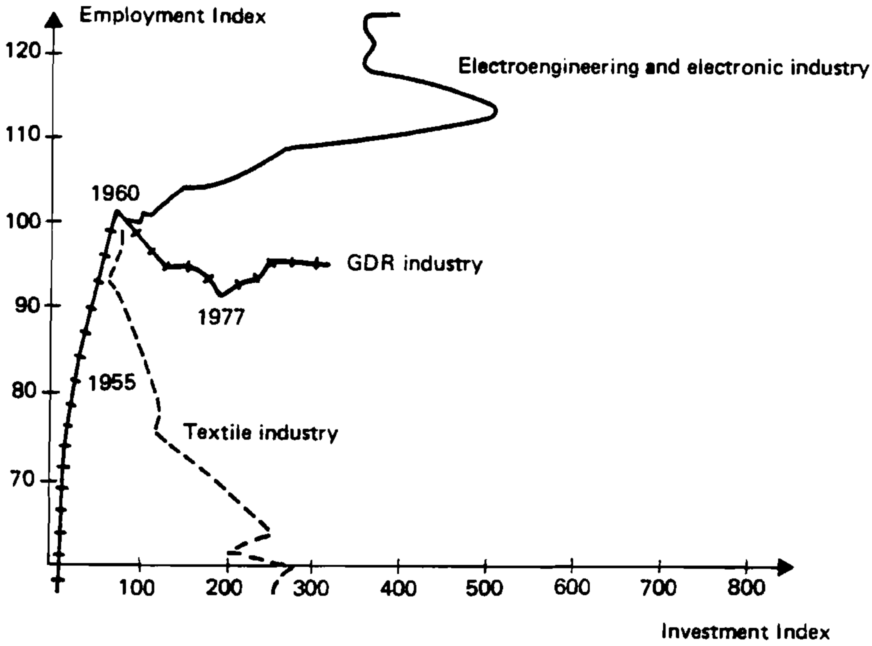

FIGURE 5 The relation between employment and investment in GDR industry.

However, coordination of the innovation cycle calls for planning and coordination of the innovation process. In this way innovation policy is becoming more and more unified with structural employment policy. Perhaps the most important precondition to reduce the degree of uncertainty of investment and to secure a reasonable balance of risks and rewards is to provide better information about the future fields of basic innovation.

(4) It is beyond the scope of this paper to discuss the problems of the existence of "long waves." Important indications of their existence were discovered by Kondratieff early this century (Kondratieff 1926). Other scholars have confirmed these findings. However, the explanation for the driving force of this phenomenon still remains an unsolved problem. A great deal of effort was made to create a body of ideas and data so that we now have some evidence that allows us to assume that the relationship between innovation and structural change is an important driving force of the "long wave" phenomenon. The relationship between the resource basis and the efficiency of industrial and agricultural production is especially important within this context. This can also explain why the development of resource and food prices is an important indicator for the existence of "long waves."

It is evident that the world economy is not currently in an upward swing. Problems which face us, such as shortages of energy and food, environmental degradation, diminishing growth rates of efficiency, significantly lower returns of investment, etc., are very clear indications of this. Only with the help of appropriate basic technological and social innovations is it possible to change this situation. This means that we need technological innovations which are able to open new directions for better use of natural and human resources, and for the creation of new technological options to find substitutes for scarce resources and more rational combinations between existing resources.

On the other hand we need social innovations which are able to stimulate creation, realization, and diffusion of these technological options and to avoid the undesired effects of wastage of resources through parasitic forms of consumption.

(5) Innovation cannot be a goal in itself. The diffusion of an innovation spreads the advantages of the innovation through many production units and countries. The result of this will be that the "monopoly rent" or "extra profit" of the first innovative production will be relatively short. However, on the other hand, this will improve the average efficiency in many countries, and the capability of more production units to produce more rationally to save resources and to supply more goods to meet needs as yet unsatisfied.

To save their benefits from innovations, corporations in market economies try to transfer mature, standardized technologies, and to use lower wages and nonexistent or laxly enforced government regulations on environment, health, and safety requirements. They have established a network of subsidiaries located in developing countries. The result of this is the well-known "dual economy" in developing countries which is not able to contribute significantly to solving the problems which face these countries (Haustein, Maier, and Robinson 1979). The necessity obviously exists to find a new way of transferring technology which on the one hand is able to help developing countries to develop their own technological basis, and on the other hand to improve the average efficiency of the entire resource-using system of the world economy. Such a technology transfer could be the global dimension of the innovation policy.

(6) The global dimension of the innovation policy has to play an important part in improving the capability of society to deal with new circumstances and situations through the development of new procedures for social innovative learning. It could be disastrous and fatal in our time of growing global interdependence to learn only by shock. Social innovative learning means that our main concern should not be to find the best from given alternatives but to emphasize the creation of new options which are able to solve the fundamental problems which now face us. Social innovative learning could not be adaptive but must be anticipatory (Club of Rome 1979). Whereas adaptive learning is only our reaction to external pressure, anticipatory learning tries to create new alternatives at a time when events, circumstances, and environment are not yet irreversible. But anticipatory social learning requires not only the

judgments of experts and technocrats, it also requires the participation of people who are the subject and object of the innovation process. In all countries there is significant demand by the people for their participation. A growing portion of the population wants to be involved in the process of judgment, assessment, and decision about technology, which have tremendous consequences for their and mankind's future. This is a positive response to the growing complexity and international interdependence of the technological innovation process. If this is sometimes reflected in a rather irrational way, this only indicates our commitment to search for new forms for the creation and distribution of knowledge, cooperation, and dialogue with a broader range of the population about the social consequences of innovation. But this also requires the openness to re-evaluate the given social and economic structure, social and cultural values, and goals. I am convinced that the investigation of innovative learning of social systems on the firm, national, and global level will become one of the most important problems for future research about innovation.

(7) Social, organizational, and technical innovations are different parts of a joint system. Without technological change it is impossible to alter the organizational and social system. However, technological innovations without organizational and social innovations will not improve the living conditions within the national and global framework. The need to consider both the social and technical sides of innovation has important consequences for our methodological approach. We can start from single technological change and look at its social consequences and implications, or at the governmental measures needed to ensure its efficiency. This, for example, is the main aim of technology assessment. Alternatively, we can go out from social needs and goals, from existing and forthcoming leaks and bottlenecks in resource processing systems, and then look at the given field of technical possibilities for a technological fix. We could call this latter approach socioeconomic opportunity analysis (SOA).

SOA is especially important for finding out future innovation fields to identify new alternatives for structural change to solve problems facing national economies and the entire world economy. This makes SOA an important tool for innovative learning in society and the global community. The IIASA Energy Study is an interesting example of SOA of global problems (Häfele 1979, Maier 1979).

Innovation is a combination of user need and technological means of meeting that need. Often the information of the need development or technological feasibilities lies outside the organizations which are able to generate and implement the innovation. Therefore one of the most important measures in promoting and shaping innovation from the government point of view must be to provide and to distribute information about the development of regional, national, and global needs. It is necessary to make national and global needs more evident for the firm, to avoid contradictions between short-term corporation goals and long-term national needs. Therefore government innovation policy — as the major part of the economic policy of a country — cannot only be concerned with the flow of resources toward high productivity industries, but must also try to identify the future fields of innovation and create a social procedure to ensure that the country's economy is prepared for dealing with new national and global circumstances.

The degree of openness to new ideas about needs and technical options is an important precondition for innovation activities of the firm. This requires an efficient information flow between organizations. The recognition of needs often stimulates entrepreneurs to search for technical resources and information to meet the needs. It is not so much the establishment of formal "pipelines" of knowledge from different sources, but more the establishment of close interaction between basic research institutes, applied research institutes, and also between production units which is necessary.

(8) The adoption of innovation tends very much to depend on the degree of qualifications of management and labor forces within production units.

Most developed countries have had a significant improvement in the quality of human resources over the last two decades. A higher quality of human resources is an important precondition for technological and social innovation, but at the same time it is not possible to approach a higher quality in human resources without social and technological innovations. The creation of conditions in which the quality of human resources can grow and become a decisive social and economic force is a crucial factor in national innovation policy.

An important problem thereby is the employment of working people according to their qualifications and the use of these qualifications to implement, control, and manage technical innovations. For this two important preconditions are necessary:

(a) It is necessary to make the education process more creative. If the supply of knowledge is not connected with the development of the capability of independent thinking, with the production of sound educational motives, then these faculties, which are decisive for dealing with social and technological innovation, remain underdeveloped. Innovative learning demands the development of the capability of independent and creative thinking and an optimistic attitude in participating in the solution of technical, social, and cultural problems.

(b) The educational system must be used better for the transfer of technology and in developing skills to recognize needs and technological feasibilities and to assess the different sides of technical innovations. This should be an especially important part of in-service training. If in-service training is too tightly bound to direct organizations and tasks of the workplace it cannot fulfill its function of stimulating creative thinking and innovative skills.

The high efficiency of social expenditure for education and qualifications can also be seen in the close connection between increased qualification level and a growing contribution of the innovator's movement to the efficiency of the national economy. The benefit of the innovator's movement in the GDR (more than 50% of the prime cost reduction in GDR industry results from it) per unit of educational funds was 2.5 times higher in 1971–1975 than during the period 1960–1965.

(9) Another lesson from the innovation cycle model is that national innovation policy and corporate strategies which try to achieve "stable development of efficiency in connection with the necessary structural changes; competitiveness of production while avoiding resource wastage and securing working places and avoiding stagflation" will have to put more emphasis on the coordination of the innovation cycle.

National innovation policy especially must take into account that the stimulation of different kinds of innovation needs different kinds of action. Despite the aforementioned measures to improve the climate and conditions for innovation, national innovation policy can influence the innovation process through two types of action.

(a) *Technology Push Actions*. That is, actions that directly support the development of new technology or modification of existing technology.

(b) *Technology Pull Actions*. Such as product characteristics interventions and market modification actions.

It is beyond question that the current status of nuclear energy, computer, aircraft, and space technology, and communication systems is very much the result of the technology push actions of government. In the future technological push will also remain important, especially in stimulating the take-off for various synthetic fuel technologies, coal gasification, and technologies to protect the environment, and to improve the communication system. Technology pull actions through product characteristics interventions are used in both market and planned economies to achieve better use of resources and to avoid undesirable side effects. For example, the GDR 5-year plan (1976–1980) required from firms a reduction in the final energy coefficient of production of 4.7–5% through regulations on the environment, pollution, material and energy consumption, etc., and this has played an important role in shaping technological development.

Market modification with the help of price policy plays an important role in stimulating innovations, but obviously it is necessary to define clearly the purpose and to identify side effects of such actions. In this context it is necessary to know what will be the impact of the actions of the entire innovation cycle and the firm attitude in special phases of that cycle. Otherwise government actions will not produce the results which they were ostensibly intended to achieve.

It is not possible to stimulate innovations with technology push actions only. The risk is too high to support a technology which will not be accepted by the market. But it is also dangerous to wait for the impact of market forces because we may not receive a suitable solution at the right moment, or when the moment is right we might not receive the right solution.

It is obvious that technology push actions could be very helpful in the innovation process in Stage I and Stage II, but they will have no influence on Stages III, IV, and V. Technology pull actions can be helpful in Stages II, III, and IV, but they be may misleading to management in Stage V (productionism) and uninfluential in Stage I.

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STAGNATION AND INNOVATION: RELEVANT POLICY QUESTIONS

Walter Goldberg

When one examines innovation and stagnation in the terms of this workshop, that is in terms of "Innovation Policy and Firm Strategy" and "new challenges for governmental innovation policy and firm strategy," four questions of policy type come to mind: Is stagnation caused by too little innovation? Can stagnation be overcome by more/better innovation? Are there any means or instruments for the alleviation of stagnation? What may we learn from the (active or passive) adaptive behavior of stagnant firms and industries?

This paper cannot possibly answer such general questions. Rather, some approaches to their exploration will be outlined. The paper first asks what stagnation is and how, if it exists, stagnation should be measured. It then presents some typical cases of stagnation, and closes with speculation on the nature of the stagnation that the world is likely to experience in coming decades.

The approach in this paper is tentative. The thoughts developed are based on hybrids of quantitative data (not presented in the paper) and qualitative cases. The paper should be understood as referring to the pre-hypothesis formulation level.

WHAT IS STAGNATION?

Stagnation, like growth, is a relative phenomenon. As a matter of fact it is tied to growth and describes the leveling off of economic activities after a phase of growth. It is to be measured against some criterion/criteria.

Leveling off may be observed at various levels, ranging from supranational, to national economy, to regional, to industry, to line of industry, regional line of industry, enterprise, and even part of enterprise. Situations in which growth on some levels occurs simultaneously with stagnation at other levels are not uncommon.

Biological analogies come to mind when one talks about stagnation; in particular, lifecycle models in which stagnation and decline follow after development and growth. Though such models may help visualize stagnation, they lack predictive properties and are not useful for predicting forthcoming phases of the "lifecycle" on the basis of known parameters. Only through *ex post facto* analysis can one recognize the lifecycle pattern of a product, a market, a functional property of a product, a brand, a firm, an industry, etc. Only rarely does the actual cycle take the famous bell shape of the theoretical lifecycle.

Stagnation implies that, after a phase of growth, conditions of and rewards from economic activity deteriorate. Factual stagnation of flow of resources, of demand, of activities, of (monetary, physical or psychological) net gain, usually also implies a deterioration of psychological conditions; whereas during a growth phase the outlook is positive (rewards, better or more rewards are to be expected; the motivation to participate and to perform is positive). Stagnation usually means that expectations have to be reduced or cut back and that fewer rewards are available for distribution.

Thus stagnation implies changes in both the objective and subjective conditions of an organization and its members, internally as well as externally. Even the environment in which the organization acts will behave differently vis-a-vis a growing as compared with a stagnant organization.

Stagnation is not a uniform phenomenon. It appears in different shapes and forms, is stronger or weaker, appears at short notice or in a longer perspective. A differentiated treatment of the phenomenon is thus required (in combination with the already mentioned vertical differentiation with respect to levels).

HOW TO MEASURE STAGNATION

Several criteria are to be applied to measure the existence or non-existence of the phenomenon "stagnation:" turnover market share, value added, profit (yield), employment, factor price (share of factor yield or gross yield). It is simultaneously possible to find growth on some and stagnation on other criteria. For example, one frequently finds that a growing turnover goes together with reduced employment. It is thus necessary to specify the measurement criteria on the basis of which one finds stagnant conditions or stagnant performance. Amongst the many problems of measurement some particularly applicable in cases of stagnation should be mentioned.

Definition and delineation of the object and unit of measurement are required. The time span of measurement, that is, whether observations are made on a scale of years or decades, must be decided upon. These choices should be explained.

There are also reliability problems. When using monetary data, inflation very often hides the actual development. Certain standards of measurement and classification standards developed, for example, in accounting, have distortive effects on the description of a real situation. They should thus be explained with regard to both their character and their possible distortive effects. The same applies to rules of valuation, of cost distribution, etc.

Other measurement problems are introduced by interdependences between factors. It would be desirable — though difficult — to establish a set of measures that would permit observation and measurement of these interdependences, as well as observation of the effects of environmental context on stagnation.

STAGNATION: THREE TYPICAL CASES

The phenomenon of stagnation as well as its "medication" through innovation is illustrated in the following three cases, each of which represents a different type of stagnation: the textile industry and related industries which show long-term stagnation, the printing industry which shows mid-term stagnation phenomena, and the shipbuilding industry which shows drastic and dramatic short-term stagnation.

The Textile Industry: Long-Term Stagnation

Stagnation in the textile, ready-made suit, and shoe and leather industries is of a long-term type; that is, it has been observed for a long time and is expected to continue for a long time. It has drastically reduced the numbers of both jobs and enterprises. Profitability in the industry is generally below the industrial average (there are, however, cases where single enterprises far surpass the performance of the industry as a whole). The life expectation of existing and new firms is shorter than in other industries.

Stagnation first hit the textile industry in the traditional centers of textile production whose economies were heavily dominated by textile-related activities. During the Industrial Revolution such areas had typically enjoyed a comparative advantage for textile production due to availability of hydropower, cheap labor, or other resources. With the introduction first of steam and later of electrically powered textile equipment, as well as increased competition from textile industries in regions with very low wages, these regions have lost their former comparative advantage. However, owing to a combination of tradition and the persistence of the infrastructure, which developed during the growth phase of the industry (schools, but also the particular vertical specialization and segregation of ownership of the industry) the textile industry has not moved out of these areas. As a result they have become depressed regions with serious employment problems. Many policy measures have been directed toward ameliorating these problems, but results have generally been disappointing.

Several reasons for the long-term stagnation of the textile industry are listed in the following.

(1) In many regions the textile industry is the oldest, most mature industry. According to the lifecycle assumption it thus should be stagnant or even disappearing, in particular as the innovation potential of the industry may be declining because of its age.

(2) Despite the fact that large proportions of it have become technologically rather complex and advanced, the textile industry continues to be a low-wage industry. The industry employs a small but slowly growing share of skilled workers; however, the skills needed by the majority of the employed workers are still unsophisticated in nature and can be acquired within a few weeks. It is thus possible to move the labor-intensive parts of the industry, in which the cost of labor matters, to regions with cheap labor. For example, regular cotton bed sheets are no longer produced in high-wage countries. The development policy of some major industrialized countries explicitly accepts or stimulates the growth of textile industries in the developing countries at the expense of the textile industry in advanced industrialized countries.

(3) Changes in consumption behavior have a strong influence on the structure of the industry. For example, people dress much more lightly because of better heating and increased motorization. Heavy wool has nearly disappeared; wool is losing to the advantage of cotton and of blends. Furthermore, demand has expanded for textile products, such as light fashion goods of limited lot sizes, which require individuality. Such goods are produced in small lot sizes and cannot be produced by conventional mass production techniques.

(4) Structural factors have blocked vertical integration, and the depressed segments of the industry have been unable to increase productivity through system integration and system rationalization. Attempts to obtain control of preceding or following production processes by purchase (e.g., backward integration of weaving mills, buying spinning mills) quite often result in losses because of diseconomy of scale and consequent noncompetitiveness of both units.

These and other factors are known. Their development is predictable, as is the gradual change within the industry, the reduction of the number of workplaces and firms. The general awareness of belonging to a troubled industry has triggered a great number of innovations of all major types, from the invention of new fibers and processes to the development of new markets and uses. Many of these innovations have been developed in cooperation with technicians in the industry and innovators of the textile machinery industry (as well as other industries). However, the machine producers serve the entire textile industry of the world and must, in order to recover the cost of product innovation and development, sell to competitors of their customers. The single enterprise in the industry in highly industrialized countries is in principle forced to innovate at a pace which few firms are capable of maintaining over a long period of time.

The foregoing discussion of the textile industry suggests two conclusions:

(1) The stagnation of the textile industry in mature industrialized countries is not necessarily a consequence of too little innovation (of either basic or rationalization or process or product type). Rather, the combination of rapid pace of innovativeness and the rather short and continuously shrinking payoff time for physical investment in innovation seems to limit the industry's potential to survive. Only those firms which manage simultaneously to keep up a high pace of innovation and to adopt market strategies that permit recovery of the financial investment required for continuous innovation will survive. One may be tempted to conclude that only large firms will have the stamina to keep abreast of the imitators over long periods of time. Empirical evidence, however, seems to give medium-sized firms a fair chance if they are flexible and persistent enough. Only very few small firms in the industry will be able to survive.

(2) Government and firm innovation policies must be flexible and persevering. Evidence is inadequate to say whether these tentative conclusions may be generalized to apply to other industries manifesting long-term predictable stagnation and decline. It seems plausible, however, that construction and other industries face similar, but not identical, conditions, and require similar policies.

The Printing Industry: Mid-Term Stagnation

The printing industry, like the textile industry, has a long-standing technical tradition. In contrast to the textile industry, it has been subject to drastic technological change over a limited period of time. Major technological innovations have occurred before (linotype, offset printing, etc.) yet the old printing methods survive together with the new methods. Computerization, however, is thoroughly changing the structure of the industry. Printers who fail to perceive or understand the challenge or who lack the resources to adapt, and who therefore do not adopt computerized techniques, will have little or no chance of surviving. Similar conclusions apply to producers of mechanical as opposed to electronic calculators, typewriters, watches, etc.

The situation of the firm in the printing industry is rather different from that of the firm in the textile industry. When a major innovation strikes the industry, producers have only 5 to 8 years to respond to its threats and opportunities. Response requires strategic reorientation and a keen managerial mind because of the nature of the technological change: computerization. This computerization:

(1) implies a shift away from a traditional "visible and tangible" craft technology to an at least partly invisible "iceberg technology" (program and computer technology)

(2) means a "systems innovation" in the sense that all phases of the entire production process must be reorganized and reshaped

(3) pens a wide variety of opportunities, thus requiring a substantial number of strategic choices that are of vital importance to the enterprise's future.

Computerization thus not only requires a thorough technological reorientation of printing enterprises but also causes revolutionary change in the demands placed on management. So far there is little empirical evidence to predict how the industry will develop based on electronic technology. It seems reasonable to assume that computerization will set off a wave of secondary process and product innovations. The firms in the industry will be confronted with accelerated change on many fronts (markets, products, production methods, etc.).

The above description of technical change in the printing industry suggests the following.

(1) Innovations in other (and in particular in loosely related) sectors may create radical threats and opportunities to an industry and its enterprises.

(2) About 5 to 10 years will be available for adaptation to computerization: thereafter, return to the earlier leisurely pace in the industry is most unlikely. Rather, a sequence of more or less thorough innovations around and in support of the new process is likely to follow.

(3) Computerization's affect on management goes far beyond purely technical aspects. A radical change in managerial thinking and acting is prerequisite for survival.

(4) Computerization will strongly affect virtually all personnel categories of the firm. The personnel policy of these firms must cater for adaptation to new requirements, by retraining etc.

(5) The pattern of the change in the printing industries may apply to many other industries, in particular to those which are of standardized mass production character (production of many quite uniform units, to order or to stock).

(6) The change implies a drastic reduction, in the span of a few years, in the market demand for traditionally produced products. On the other hand, computerized production, owing to technological convenience and to drastic cost and price reduction, will achieve remarkable market expansion.

The Shipbuilding Industry: Short-Term Drastic Stagnation

The stagnation in the shipbuilding (steel etc.) industries is quite different in character from the previous two prototypes.

Firstly this is because government intervention in many countries has distorted the market at large. This includes the Japanese public/private policy to boost shipbuilding in order to cut prices, because of the dependence of Japan on cheap sea transportation facilities. Today Japan, to some extent at least, is the victim of its own policy, since this has been and will be copied by other countries.

The global establishment of new shipyards in the 1960s and 1970s inevitably resulted in market collapse. The situation in the steelmaking industry was very similar, with one exception: shipbuilding is dependent on markets in which speculation plays a most important role. The price mechanisms in the industry in its relations to the buyers are susceptible to severe distortions because of speculation.

The steel industry to some extent, in particular during the years 1972 to 1974, was affected indirectly but nevertheless substantially by the order boom in the shipbuilding industry and the consequent forward contracting boom for steel plates from the shipbuilders.

Secondly, although shipbuilding is a mature industry, it has experienced several substantial process innovations and a major product innovation (very large and ultralarge crude carriers). Those innovations triggered a landslide. The vast majority of shipyards rushed into the tanker building business because of both the boom in demand and the almost exclusive applicability of new process innovations to the production of tankers. This resulted in substantial overordering and overproduction of tankers. The deflation of the boom would have occurred without the oil price crisis of 1973 (and 1979), but it was drastically amplified by this, as well as by some changes in the transportation patterns for oil and other commodities.

Finally, stagnation in the shipbuilding industry was exacerbated by international currency exchange fluctuations. Virtually all contracts for ships (and cargo) were concluded in US dollars, whereas production and financial costs in the industry were in most cases incurred in currencies which stayed firm (or at least firmer) than the US dollar after the collapse of the Bretton Woods Agreement.

It is claimed again that the most important reason for the drastic mismatch between supply and demand in both the shipbuilding and the steel industries is governmental intervention in many countries. One estimate, which as yet lacks support by hard data (these will only become available in 6 to 7 years from now), is that the most affected steel and shipbuilding industries were those in countries in which governmental interference was either very strong or virtually nonexistent before the crisis occurred.

Most surprising and puzzling, however, is the fact that the crisis was perfectly predictable, but that virtually all actors proceeded as if the outlook was very bright and secure.

This final conclusion makes one question the usefulness of public forecasting and early warning systems presently under development in many highly industrialized countries. If such systems (Strukturberichterstattung etc.) really should produce valid forecasting information, it remains questionable whether enterprises will use the information they produce. Abundant evidence seems to support the assumption that managers will not act uniformly. Many of them in fact will react counterintuitively, since almost any threat in economic life will be interpreted by businessmen as a potential opportunity for business.

Stagnation in the steel industry has not primarily been triggered by technological or other innovation, nor does it, for several reasons, seem to be curable by innovations of any type in the short or medium term. Major innovations do not occur at short notice and the industry in its present shape is in no position to finance and to produce major innovations.

The intended move of many shipbuilders into new nonshipping markets is an interesting phenomenon. If it had taken place 8 or 10 years ago it could have rendered new markets of some durability. The late and massive move into new markets of limited size or into market segments which are already occupied by traditional tenants in command of considerable experience seems neither to be very promising nor likely to be of any great durability.

STAGNATION AND INNOVATION UNDER CONDITIONS OF AN ECONOMY LEVELING OFF

The present situation in the shipbuilding industry may be a valuable crystal ball when it comes to understanding the nature of more general economic stagnation. It depicts a situation in which many industries fight vigorously not only to defend their shares of existing markets, but also to try to enter market segments which are occupied by others.

Many highly industrialized countries, and many industries, will very probably face similar conditions: that is, general and longer-lasting stagnation. It can be envisaged that in such a situation there will be turbulent, dynamic trends of a sort quite unlike what we have seen in the past. Our experimental understanding comes from a period of rather static growth in which very few drastic changes in intersectoral conditions have taken place. Even sectors subject to long-lasting stagnation have not suffered substantial or any real losses. It may be true that the primary sector has declined quite rapidly and that the industrial sector recently has been leveling off as well. There have been no obstacles to intersectoral or interindustry migration of labor and other resources. Rather, there has been a pull for resources from the growing sectors and industries.

If there is little or no general growth, the conditions will change drastically. The role of the state as an equalizer of incomes will change, as long as fewer and fewer surpluses have to be distributed to fill bigger and bigger gaps. In a generally stagnant economy the race for new markets, new product uses, new geographic markets, new customers, etc. will be much more severe than we have experienced hitherto. This will lead to attempts to innovate more or less thoroughly. Many attempts are expected to break new ways in order to gain dominance over certain market sectors for some time to come, in order to recoup the cost of innovation incurred and to let the next innovation mature. However, the time horizon or the lifecycle of innovation is most likely to shrink. More capital for more risky ventures will be required. The yields to be expected will become less and less certain.

The description of such a context is very incomplete, maybe even incorrect. In any case, the situation will require policies, instruments, and methods of strategic character for industries, for the state, and for individual enterprises, of types we today neither have access to nor even can imagine.

It seems to be quite urgent to extend research into the problems of leveling off economic systems and into objectives, methods, and instruments of industrial policy under such conditions.

INNOVATION AND INTERNATIONAL COMPETITIVENESS

Joel Hirschhorn

INTRODUCTION

This paper is based on two premises: (1) innovation does not simply occur, rather it is used by firms as a strategy to increase industrial competitiveness; and (2) technological innovation is less used as a means of increasing competitiveness than it has been in the past.

In the following I discuss the five factors which I believe to be most important today in explaining the reduced strategic use of innovation, without attaching any special significance to their order nor implying that the list is all inclusive. They are, however, factors with substantially different and more powerful roles today than ever before, as well as having particular association with international realities. I therefore discuss what governments might do to counteract these factors.

TECHNOLOGY TRANSFER

One of the most important and complex but least-studied factors affecting innovation and industrial competitiveness is technology transfer among both nations and firms. Barriers to technology transfer during the past decade have steadily been removed, and the trend appears to be accelerating. The net effect has been to reduce the economic benefit of innovating — of being "first." Why, strategically, should a firm invest and plan for innovation when technology transfer has removed the set of advantages of being first with the innovation?

There are two sides to this dilemma. First, if a firm does innovate, then there are substantial economic and perhaps political pressures to sell its innovation either to other firms within its country or to firms in other nations. Sales revenues are not the motive for selling; under today's realities it is becoming increasingly risky not to sell innovative technology. The increasing internationalization of all markets, constant flow of people and information, high costs and long times necessary to defend patent positions, sophisticated technology which permits quick "reverse engineering," rapidly changing consumer tastes and market conditions, and trade barriers all work to push firm managements toward selling their innovation.

Ever increasing emphasis on short-term profits contributes further to pressure to sell innovations. Management sees the immediate rewards of selling the innovation and finds it exceedingly difficult to quantify the long-term negative impacts of selling what might be a competitive edge. There are so many uncertainties about the future that the choice easily swings to immediate economic rewards.

My main point is that the strategy of transferring innovations, in leading to a rapid diffusion of the new technology, gives a very new meaning to innovation. If innovations are quickly sold, generally available, and quickly applicable, then they do not significantly affect the relative competitive positions of firms. Innovation has become a mercenary activity rather than a competitive strategy. Historically, innovations have been developed by firms which have used them as a means of gaining competitive advantage. Today innovations are increasingly developed by firms or institutions which serve an industry, and by firms which have moved from their historic role as innovators to the creation and marketing of innovations. When a firm purchases an innovation from such an institution, often with the necessary capital equipment it is purchasing minimum or comparable competitiveness, not competitive advantage.

Now consider the other side of the innovation transfer dilemma. In a world in which rapid technology transfer and widespread diffusion of innovations nullifies any competitive advantage resulting from early entry into the market or being higher up on the learning curve, why should a firm embark on the costly and risky strategy of innovating when it can assume that with minimal cost and risk it can buy innovations? True, this buying of innovations will not improve its competitive position, but it does assure that the firm will not lose its competitiveness. The strategy of not innovating is especially attractive under the following conditions:

- the nature of innovations for the firm, based on historical evidence, is incremental rather than "radical"
- the nature of pertinent innovations is more "process" than "product"
- the industry is capital intensive, hence new firms are not likely to enter the marketplace
- there is already an established network of information and personnel flow as well as technology transfer for the firm's industry

-- the nature of the firm's productive processes and products is "mature" so that the cost and difficulty of obtaining significant innovations is high
-- there is a problem of capital availability, probably associated with low profitability, which makes investment in long-term R&D projects unattractive
-- the firm's market is not expanding at a rapid rate
-- there are increasing pressures on the firm to diversify
-- the firm deals with a product or products whose prices are under government control.

In sum, technology transfer reduces the use of innovation strategy to gain competitive advantage. The very nature of innovations is also likely to be affected by this innovation transfer process, spurred of course by industrialized nations. Innovations of this type are likely to be more suited to industrialized rather than developing nations, and they are likely to reduce traditional comparative economic advantages among nations — another step towards the internationalization and homogenization of the world economy. By the very nature of the innovation transfer process, innovations must be designed to maximize their adoption among all potential user firms and nations. The process of innovation transfer is antithetical to "appropriate technology" suited for particular locations, natural resources, market needs, and infrastructure limitations.

Another factor is that quick innovation transfer promotes incremental rather than radical technological changes. If your aim is to create an innovation which can be sold to a large number of firms, then you are likely to emphasize innovations which can be put in place with minimum capital by existing firms. This is in stark contrast to the strategic measure, now disappearing, of destroying competing firms by monopolizing an innovation, but it is consistent with a general trend to reduce risks. In other words, innovation transferring is consistent with maximizing small rewards with little risk, rather than attempting to get very large rewards at considerable cost and risk.

Finally, I sense that this process of technology transfer in a subtle and complex way shifts competitive emphasis from technological to market sales factors. Consequently, firms which continue to use innovations will tend to shift emphasis from R&D to marketing, to reduce or eliminate all R&D efforts and the role of scientists and engineers within the firm, and to rely on outside sources for technology and technical expertise. I doubt that this situation will lead to more meaningful technological innovations. Use of external sources of innovation splits the world of production from the world of creating innovation. This will surely reduce the insights and "wisdom" which have played an important role in the traditional innovation process.

INFLATION

Although inflation is not new to the world, its unpredictable rise and decline among nations and its high numerical rates in some economies can have large impacts on the strategic use of innovation. First, high inflation rates increase the economic benefits required to justify an innovation. Therefore, easier-to-obtain, incremental innovations are less likely to yield a meaningful benefit. Where once an innovation that reduced production costs by 5% to 10% was significant, with inflation at 15% or higher such an innovation may not be worth the cost of creating, refining, and adopting it.

For many firms, the costs of obtaining and implementing an incremental innovation would lead to a net disadvantage in comparison with a competitive firm with existing plant producing an acceptable product. Conversely, it can be argued that this same inflationary world increases the value of a "radical" innovation which might reduce the inflationary impact of some input, or which shifts dependence to less affected inputs or resources. But, since by its very nature the process of creating and adopting a major technological innovation is a high cost and high risk endeavor, the same inflation is likely so to increase the costs of this innovation process that it becomes impractical economically.

The net effect of high inflation, then, for both incremental and radical types of innovation, is to reduce the likelihood of a firm improving its competitive position by means of innovating. I want to emphasize that it is not merely the existence of a high rate of inflation which deters innovation, but also the uncertainty which management must deal with. The perception of a possible onset or continuation of inflation is sufficient to deter the relatively high cost, long-term, and high risk efforts associated with using innovation as a means to improve firm competitiveness. It should be noted that the situation with innovation is different from the often-heard argument regarding capital investment in times of high inflation. For the latter it may be true that immediate investment in productive capacity which can be utilized will yield a substantial competitive advantage over other firms which invest at a later time. However, this strategy depends on having sufficient capital available and on perceiving relatively low risks associated with future demand. Investing capital in the long-term process of creating innovation and the risky act of actually adopting an innovation is quite different, and when viewed as an alternative to the aforementioned process of investing in existing technology is likely to be judged a poor choice in a period of high inflation. Rather than using innovations, a firm is likely to employ marketing and sales tactics to increase its market share and, if any investment is made, to attempt to achieve benefits by utilizing existing technology and greater economy of scale to gain competitive advantage.

CURRENCY EXCHANGE RATES

In internal markets, changing currency exchange rates are an extremely potent force determining firm competitiveness vis-a-vis firms of other nations attempting to sell in the same market. Any private sector action or government policy which affects currency ratios alters competitive relationships, thereby detracting from the perceived effectiveness of innovation as a competitive strategy.

At one time shifting exchange rates reflected, to a large degree, differences in inflation rates, costs of production, and productivity movements, as well as other determinants of industrial competitiveness. In more recent times, however, rather than acting as a balancing device, exchange rates have become as uncontrollable and unpredictable as the speculative forces which move them. For example, virtually all analyses conclude that the recent rapid decline in the value of the dollar on foreign markets was far greater than can be explained by an actual higher inflation rate or lagging productivity in the United States. Instead, it is explained by widespread loss of confidence in the United States economy. The gain in the competitiveness of US firms resulting from this change in exchange rates overshadows most potential gains that might result from technological innovation. US managers can easily observe that advantages they gained from this devaluation exceeded those they had from investments in innovations. And from the perspective of other nations, investments in innovation strategies can easily be nullified by such devaluation of a trading partner's currency. Consider the following data for steelmaking costs as influenced by currency devaluations (see Table 1). They demonstrate how ineffective or unnecessary innovations

TABLE 1 Estimated steelmaking costs at different currency values for the first quarter of 1979.

	Actual exchange rate (per $)	Pretax costs ($/tonne)	Pretax costs with 20% devaluation against $ ($/tonne)	Change in costs (%)
United States	–	421	421	–
Japan	¥201.5	407	355	−12.8
West Germany	DM1.85	470	410	−12.8
United Kingdom	£0.496	513	434	−15.4
France	FF4.27	459	396	−13.8

SOURCE: Marcus and Kirsis (1979).

can be relative to the effects of changing exchange rates. The loss of competitiveness a strong currency can suffer is illustrated by data for 1969–1976 for steel industries. In their home currencies Japan and West Germany had per annum pretax cost increases of 6.8% and 5.6% respectively. However, in dollars those increases were 12.7% and 13.0% respectively. In both cases during this period there had been heavy investment in creating and using technological innovations by the respective steel industries. Yet both nations lost competitiveness in a lucrative export market, the United States, owing to currency exchange rate changes.

SOCIETAL IMPACTS

The costs and benefits of innovations have become more difficult to predict because of the increasing attention by governments and the public to secondary societal impacts of technological changes. The impact of an innovation on the environment, on worker and consumer health and safety, on geographical distribution of production facilities and labor shifts, on relationships with other nations, and on consumer rights and values tend to make the innovation process more risky. The following observations correctly point out the magnitude of the problem:

> In the chemical industry, many companies have given up all research on food additives as too risky. Research into new and better pesticides has also declined. And the number of newly developed drugs has been cut by more than half. Between 1948 and 1962, 641 new drug products were introduced in the US; since then, only 247 new drugs have hit the market. (*Newsweek*, June 4, 1979.)

Even if a firm attempts to deal from the very outset with secondary impacts, the costs of the innovation must escalate sharply. Additionally, firms often find they lack the range of professionals and expertise necessary to deal with these factors. In the United States there has been an explosion of consulting companies providing services to firms attempting to anticipate and measure the extent and cost of secondary impacts, as well as to deal with government bureaucracies.

Assessing impacts is made both difficult and costly by the unpredictability of government regulations and policies concerning secondary impacts. Perhaps this is unavoidable, since impacts of technological changes cannot be totally anticipated and assessed before the fact. The increasing tendency of governments to hold firms liable for secondary impacts also leads to a growing need for costly forms of liability insurance. Thus, the firm which goes ahead with an innovation risks creating new, unforeseen impacts which may then become cause for government action, which in turn may lead to new and often large costs for the firm. This is a significant factor in explaining the increasing reluctance on the part of firms "to be first," and the increasing use of funds and personnel for "defensive" R&D rather than on bold new ideas.

In addition to increasing costs and risks, secondary impacts have greatly increased the time span between invention and commercial success. Public hearings, government studies and assessments, laboratory testing, and other such endeavors all lead to extensive delays. This situation increases the likelihood of events occurring which can make an innovation useless or unprofitable. For example, other innovations can enter the marketplace which directly or indirectly reduce the demand for or novel aspect of the development or, as already discussed, "exogenous" factors such as changing inflation and currency exchange rates can eliminate the anticipated benefits of the innovation. Equally significant is the potential for competitor firms discovering much about the innovation during lengthy public examinations of it.

I believe concern over possible secondary impacts has a net effect of making major or radical innovations less attractive in comparison to smaller, incremental changes. The increases in risk, cost, and time make radical innovations simply too difficult to justify. Furthermore, assessing the secondary impacts of incremental innovations is somewhat easier and less costly than dealing with truly major innovations.

Also in this world of heightened public awareness of and sensitivity to secondary impacts, a firm risks great damage to its public image by using an innovation which may lead to a well-publicized adverse impact. This effect can go far beyond the direct costs which may be covered by liability insurance, and can take years of costly advertising, public relations work, marketing, and lobbying of government to offset.

At one time firms might have circumvented problems of secondary impacts by moving riskier phases of their activities to Third World nations. However, this means of escape has (rightly) been frowned upon by international banking and financial institutions, under the prodding of some industrialized nations. Thus, there is a general trend toward reducing the competitive advantage of developing nations in which adverse secondary impacts may be accepted in order to obtain short-term economic gain.

FIRM STRUCTURE: SIZE, DIVERSIFICATION, AND MULTINATIONALS

A number of factors related to firm size and structure appear to be eroding the use of innovation as a competitive strategy. A large firm can provide extensive support for R&D efforts in profitable firms, but it also tends to inhibit the risk-taking, entrepreneurial spirit of individuals that is necessary for innovation. The very nature of a large bureaucracy makes it more difficult to shepherd an idea through the lengthy process of research, invention, demonstration, and marketing. Also, huge investments in existing technology and plant can act as obstacles to radical innovation, and large industries and firms generally make the entry of new, small firms with innovative technology very difficult.

In order to reduce business risks many firms diversify. Diversification and its capital needs tends to reduce the attractiveness of long-term innovation investments. There is greater appeal to acquire other companies who have already invested in an innovation and brought it close to commercial success, if not actually already to that point. Diversification often leads to formation of a holding company or conglomerate in which individual profit centers are likely to be less inclined to invest in long-term innovation. This attitude results from the competition among such profit centers to show immediate and high returns on investments and the problem that innovations might lead to types of business outside currently defined boundaries.

Both highly diversified companies and multinational firms have increasingly emphasized large cash flows, fast payback from capital investments, use of marketing tactics to gain competitive advantage, acquisitions to obtain new products or processes, and the use of lobbying to influence government policies which affect competitiveness. All these factors lead to a declining importance of innovation, especially of major types of technological change. Of special importance is the decline in basic research which would stimulate more radical innovations; between 1967 and 1977 expenditures on basic research by industry declined by about a quarter. In fact, much of what industry defines as R&D is really sales and marketing related, or even plant engineering.

CONCLUSIONS AND SUGGESTIONS

I chose to discuss the loss of innovation's importance in firm strategy to achieve more competitiveness; not surprisingly, I constantly found that declining innovation can be linked to several contemporary factors. Perhaps of greater significance is the observation that major or radical innovations are particularly affected by technology transfer, inflation, currency exchange rates, societal impacts and changes in firm structure. Because many types of firms have always been biased toward incremental innovations, this increased shift to incremental innovations resulting from trends largely ignored in previous analyses is of even greater concern. The increasing shift to incremental innovations aggravates a number of problems, including the following: reduced economic growth, slow improvements in energy and raw material utilization and conservation, and decline of noteworthy improvements in and diversity of products and production processes.

One way to help reverse this trend would be shifting more of the effort and cost of making major innovations, especially carrying out basic research, to universities and other institutions funded jointly by governments and the industrial sector.

At the other end of the innovation spectrum, there may be a need for government assistance to pilot demonstration and other activities associated with the final stage of commercialization. Such assistance must be carefully justified and should not be solely in terms of funding, but rather in changing policies and regulations so as to reduce risks and project durations. The emphasis of such programs should be to encourage major, risky innovations.

More specific policy responses to the five innovation-stifling factors discussed here are briefly reviewed in Table 2. These are not options necessarily recommended, but merely those which appear to have been used by some nations and which appear to have some potential for coping with the causes discussed. My thesis is that the use of innovation strategy is becoming more influenced by what are traditionally viewed as "external" factors — factors not directly related to the nature of the market which pulls innovations or to the technology itself. Another way of looking at this evolving situation is that the "system" in which innovations must be developed, judged, and used has grown both larger and more

TABLE 2 National policy options to increase innovation effectiveness.

Factor reducing innovation effectiveness	National policy options to promote innovation
Increasing technology and innovation transfer	To prevent innovation transfer until a competitive advantage has been gained by domestic firm(s) To help finance equity positions of domestic firms in foreign operations purchasing innovations To ensure continued efforts to create new innovations to maintain competitive advantage
Inflation	Provide rapid depreciation write-offs and other tax assistance for radical innovation expenses Fund basic research Facilitate cooperative R&D efforts by firms
Currency appreciation	Provide direct aid for innovation activities Use trade barriers to block imports to maintain domestic firm profitability
Societal impacts	Promote use of technology assessments Provide consistent, long-range policies Offer special exemptions for major innovations Use cost–benefit analyses to prevent high cost, minimally effective laws and regulations Facilitate low cost liability insurance
Firm structure	Limit acquisitions and mergers Provide special assistance to small firms attempting to enter an industry Require multinational corporations to fund domestic R&D activities in proportion to domestic sales

dynamic. The benefits of innovations can now be erased quickly by fast-moving developments far removed from the firm and its market. The current situation has been accurately described by James R. Bright, as follows:

> Today we are in absolute turmoil technically and economically and the assumptions by which you approach a technology today are invalidated by tomorrow's developments .... The reason is not that the nature of the technology changed. What happened is the outside world changed. (*Iron Age*, October 15, 1979.)

History shows that industrialization, economic growth, major increases in standard of living, and, hopefully, improvements in the quality of life for society as a whole have been linked to technological innovations in industrial firms. That is, the social rate of return for innovating firms may be greater than the private rate of return. What we need is greater recognition of the impact of so many of today's economic and political trends and decisions on the strategic use of innovation. Mere economic and political solutions which miss the heart of the matter will not suffice. Necessity may indeed be the mother of invention, but we need a father to inseminate the invention so that an innovation is born. The father of innovation may be long-range risk taking facilitated by government policies.

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GOVERNMENT POLICIES FOR STIMULATING TECHNOLOGICAL INNOVATION

E. Braun

INTRODUCTION

Technological innovations and technological fixes have been given great social responsibility. In the industrialized countries it is generally believed that flagging economies can be revived by opening up fresh avenues of economic activity (e.g., Mensch 1976, Freeman 1979). It is further believed that each economy must retain or achieve a competitive advantage over newly industrialized countries and over its technically developed competitors by producing every new sophisticated product by increasingly efficient new methods. The saturation of markets for some goods, such as television receivers, is used to support a belief that new goods, which create new needs, are required. Finally, it is considered that unless the spectrum of products is constantly increased, productivity advances in old products will erode the employment market; yet innovation is also often undertaken to ease bottlenecks in the availability of labor.

Environmental and resource (energy) problems have added specialized branches to the pursuit of innovations and technological fixes. Innovations are called for to save energy (particularly imported energy), to develop new energy sources, and to substitute abundant raw materials for scarce ones. Innovations are also called for to protect the environment and to maintain, if not reverse, the environmental consequences of new technologies.

As the importance of technological innovation became more widely recognized, the literature on the subject grew. One body of literature has arrived at a reasonable degree of consensus on the important steps through which an invention must proceed to become an innovation (e.g., Freeman 1974, Mansfield 1968). Another body of literature discusses, with a lesser degree of agreement, the sources of ideas which may have become innovations (e.g., Jewkes *et al.* 1958).

PUBLIC POLICY OPTIONS

Most governments now feel that it is their duty to support the innovative process by suitable policies and indeed most governments have instigated a number of measures designed to stimulate innovation. Before reviewing some of the measures that have been or are being used, we shall attempt to define what measures are, in principle, available to government. There are, of course, many possible classifications and we shall not explore all of these. It may be useful to distinguish between measures which:

(a) influence the general environment in which innovators operate
(b) influence industrial performance (either specific sectors or industry in general)
(c) stimulate innovation in general
(d) stimulate specific innovations.

Bearing these distinctions in mind, we can list classes of possible measures, though some overlap is difficult to avoid, and give some examples of each class. This is done in Table 1.

Some of the examples listed can fall into all or several of the categories (a) to (d), others fit only into one of these. A more elaborate matrix of possible measures could be devised and undoubtedly the level of generality and of abstraction could be increased, though it is doubtful whether the utility of the scheme would increase in proportion.

Perhaps it ought to be emphasized that policy measures can act at any point of the innovation process from the pre-invention stage to the stage of full commercialization. Invention can be encouraged by educational and information measures, by financial rewards, and by esteem afforded to inventors. The research and development phase can be eased by a widely available research and technical information system, by financial grants, contracts, or loans, by liaison services, etc. Decisions about innovation can be eased by government risk sharing, by procurement promises, or by market information services. The stage between prototype and production can be aided by loans, grants, purchases, provision of manufacturing facilities, tax incentives, advisory services, etc.

Thus policy measures need not only be specifically designed to stimulate innovation, they can also be aimed at removing difficulties at specific points of the innovation process. Hence an understanding of the process, or theory, of innovation is an integral part of innovation policy.

TABLE 1 Measures available to governments that are designed to stimulate innovation.

Type of measure	Examples
Financial	Grants, loans, conditional grants, subsidies, financial sharing arrangements, loans and gifts of equipment, provision of free services, provision of buildings
Taxation	Company, personal, indirect, payroll taxation, tax allowances
Legal and regulatory	Patents, environmental regulations, health regulations, inspectorates, protection of designs, arbitration services, monopoly regulations
Educational	General education, universities, technical education, apprenticeship schemes, continuing, and further education
Procurement	Defense purchases, central government purchases and contracts, local government, public corporations, R&D contracts, prototype purchases
Information	Information networks and centers, libraries, radio and television, freedom of information, advisory services, statistical services, government publications, data bases, museums, exhibitions, liaison services
Public enterprise	Innovation by publicly owned industries, setting up of new industries, pioneering use of new techniques by public corporations, correction of imbalances by public enterprise, participation in private enterprise
Public services	Purchases, maintenance, supervision and innovation in health service, public building, construction, transport, consumer protection, telecommunications
Political	"Atmosphere", honors system, planning, regional policies, innovation by decree
Scientific and technical	Technical standards, research laboratories, testing stations, support for research associations, learned societies, professional associations, research grants
Commercial	Trade agreements, tariffs, currency regulations

In summary, government has many tools at its disposal for the stimulation of technological innovation, ranging from fiscal and legal measures to direct industrial participation. These tools can aim principally at four different target areas: the general "environment;" industry;

general technological innovation; and specific innovations. All tools are, or may be, interrelated. Tables 1 and 2 give a few examples from the very large range of possible measures.

EXAMPLES OF RECENT POLICY MEASURES

In the following, some characteristic policy measures used to stimulate innovation are shown, together with a partial listing of the relevant literature. The review excludes general ambience measures; it is taken for granted that all developed countries have a complex structure of elementary, intermediate, and higher education, a network of government laboratories, patent and other legislation, and a web of standards, regulations, and inspectorates; it is also assumed that all governments make substantial purchases ranging from paperclips to computers and from policemen's helmets to fighter aircraft. It is further assumed that all these countries have developed transportation and communication systems, including road, rail, air, telephone, telex, radio, television, etc.

The present review cannot, and is not intended to, give a complete list of individual measures taken by individual governments for the purpose of fostering technological innovation. All that can be achieved is to give a few characteristic examples of current measures in two countries which illustrate the most common features of such measures. It should be said, without apology, that most real measures contain a mix of theoretically possible tools and do not fit neatly into single pigeonholes of our classification. Many government measures consist of packages containing more than one tool and many try to fulfill several aims at once. The classification may nevertheless be a useful tool for analysis and understanding.

Amongst the more specific measures for the stimulation of innovation we shall look at only a few countries and use the classifications shown in Tables 1 and 2.

Financial

An example of a financial support program aimed at general innovative activity, perhaps with special emphasis on small and medium-sized enterprises (SME) is the "Erstinnovationsprogramm" of the Federal Ministry for Economic Affairs (FRG) (Hagedoorn and Prakke 1979, p.54). In this program the Ministry pays 50 percent of R&D and preproduction costs for "important programs of high risk, which would not be launched without aid or would progress much more slowly." If the project is commercially successful, the grant has to be repaid within 10 years.

In a somewhat similar scheme by the Federal Ministry for Research and Technology (FRG), aimed purely at research and development contracts placed by small firms with external organizations, the Ministry will pay 30 percent of the cost up to DM120,000 per enterprise per year (Forderfibel 1979). The measure is to promote "... R&D contracts which aim at obtaining technically new, or improved products or processes and which contribute to an improvement in the economic performance of the enterprise." The scheme is an instrument of public policy in that it

TABLE 2 Target areas for government measures which stimulate innovation.

Measure	Target			
	General ambience	Industrial policy	General innovation	Specific innovation
Financial		Investment in regional factory building	Making venture capital readily available	Supporting specific R&D programs
Taxation	Supporting entrepreneurial spirit	Making investment allowances	Allowances for innovative investments and R&D expenditure	
Legal and regulatory	Patent laws, monopoly regulations	Factory legislation	Health and safety regulations	
Educational	General educational provision, support for higher education	Technical training schemes		Training schemes in specific new areas
Procurement	Level of public expenditure	"Buy at home" policies	Procurement specifications	Orders for specific new equipment
Information	Libraries, broadcasting, government statistics	Technical information services	Liaison services	
Public enterprise		Active regional policies	Participation in new ventures, innovative policy in state industry	Public enterprise in new technology, use of specific innovations
Public services	Transport and communications			Use of specific innovations
Political	Access to information, public opinion, government laboratories		R&D availability from public sources	
Scientific and technical	Technical standards		R&D availability from public sources	Specific R&D support

supports innovation, but excludes R&D contracts "... which run counter to the public interest...."

In the UK, technology policy employs a wide range of financial measures. Only a few are mentioned here (see e.g. Hagedoorn and Prakke 1979). One such instrument is apparently the result of the Rothschild Report of some 8 years ago. Many departments of government now have their own Chief Scientist who supervises the work of Research Requirement Boards. These boards have a number of industrial and other independent members. In the Department of Industry there are nine such boards for different industrial sectors. "Their objective is to improve the technological base of the industry by helping to fund R&D projects carried out by companies and research organizations, including research associations."

The Boards generally prefer to fund projects in direct support of the government's industrial strategy, i.e., they give preferential treatment to projects in support of technologies singled out by the Department of Industry as being of high priority. Generally, projects should "yield financial returns and improve the manufacturing performance in terms of international competitiveness, added value per employee, and energy conservation." What more could one ask?

Quite large sums are dispensed in this way. For example the Mechanical Engineering and Machine Tools Requirement Board has an annual budget of 10 million pounds sterling.

The financial schemes mentioned so far are aimed at aiding the process of innovation at the R&D stage. Indeed Gerstenfeld (1977) estimates that the German Federal Government pays for about 50 percent of all industrial R&D. Several schemes go further: for example, the UK Product and Process Development Scheme of July 1977 provides 50 percent government funding from the design stage up to the point of commercial production. The scheme allows either for grants of up to 25 percent of qualifying costs or for a 50 percent contribution coupled with a levy on sales. Furthermore, the Department of Industry can buy prototype equipment and lend it to an industrial user. The user has the option of buying on favorable terms or returning the equipment after a certain period.

The schemes described so far fall into the category of general financial help for innovation, although there is some limited vetting and priority allocation and, in that sense, the schemes aid specific innovations. There are, however, much more specific schemes, financed almost entirely from public funds. Under this category fall schemes like the recent British program for the promotion of microelectronics, or of innovations like supersonic transport aircraft. Most other governments have similar programs.

The microelectronics program is a deliberate and many-pronged policy instrument. It aims to strengthen the production and application (with some stress on the latter) of this particular new technology. The instruments used fall into many categories: an information campaign, grants and loans for research projects, financial help with the launching of new products, and the founding of a public corporation for the manufacture of microelectronic components. The overall hope is to increase innovative activity in products using microelectronics as control elements. The public involvement in the manufacture of components is less an instrument of innovation policy and more one of industrial strategy, although motivations in this area, as in most others, tend to be mixed.

An important aspect of financial help for innovation is public provision, or public support for private provision, of venture capital. In the Federal Republic of Germany the Government has provided a venture capital cooperation, the Deutsche Wagnisfinanzierungsgesellschaft, financed by a consortium of banks, which carries risk up to 75 percent of the losses for the first 15 years of its operations.

In the UK, one of the aims of the National Research and Development Corporation (NRDC) is the provision of venture capital and it is allowed to borrow directly from the Department of Industry for this purpose.

Tax Incentives

Again, only a few examples of the kind of policies that have been used will be mentioned. In the UK capital expenditure on plant and machinery used for R&D purposes is completely tax deductible for the first year. Similarly, revenue expenditure on R&D, wages, etc. is deductible and costs of license fees and patents may be written off over a number of years (Hagedoorn and Prakke 1979).

In the FRG, research and development facilities receive a tax-free subsidy of 20 percent of allowable costs up to DM500,000 and 7.5 percent for further costs. For investments which are aimed particularly at energy savings there is an additional subsidy of 7.5 percent (Forderfibel 1979).

Patents, Liaison, and Information Services

In the FRG there are four sets of measures specifically designed to increase the utilization of patents (Hagedoorn and Prakke 1979, pp. 30–31). The Patentstelle für die Deutsche Forschung provides a consulting service and credits for inventors to patent their work and to find industrial sponsors. The Max Planck Gesellschaft owns Garching Instrumente GmbH, which mediates the licensing of patents and develops and sells prototypes of equipment invented in MPG laboratories. There are two further patent information centers: the Arbeitsgruppe Patentverwertung is establishing a system to inform industry about patents resulting from government-funded projects, while the Technologieverwertungsstelle der Grossforschungszentrum aims at selling patents resulting from research at major laboratories.

The Patent Office itself offers to produce, at a cost, surveys of patents existing in any specified area of technology even for companies not seeking to patent an invention.

In the UK, one of the tasks of the NRDC is the patenting and patent management of inventions originating in the public sector, particularly in government research laboratories and in universities.

A large variety of other sources of technical information is generally supported from public funds. A Central Office of Information Pamphlet (1978) lists: general library services, British Library, National Reference Library of Science and Invention, National Central Library, National Lending Library for Science and Technology, information services provided by the Department of Industry, the United Kingdom Atomic Energy Authority (e.g., Technology Reports Centre, Ceramics Centre, Non-Destructive Testing Centre) etc., etc. The only item missing from the list is an information center on information centers.

One of the widely quoted success stories of a mainly advisory and information system is a special working party set up by the German Federal Ministry for Research and Technology (BMFT), the central "applied science" research organization (Fraunhofer Gesellschaft), the user industry, trade unions, and manufacturers' organization to advise the clock and watch industry on technological change. Assistance has been given to firms in the watchmaking, clockmaking, sensor, weighing machine, and office and sales equipment areas. Services available under this scheme include advice on applications and diversification, technical advice and provision of knowhow, preliminary assessments of development projects, and advice on the availability of public funding. Fifty percent cost sharing in R&D and innovation projects is also available under a BMFT scheme (Hagedoorn and Prakke 1979, p.37). Table 3, reproduced from Hagedoorn and Prakke, shows the funds available over the years in the UK and the FRG for projects identified by the authors as policy measures in support of technological innovation. These funds are exclusive of the very large sums spent on general industrial policy schemes and in government procurement schemes.

The total spent by governments in support of innovation can only be guessed at. Pavitt and Walker (1976) have neatly summarized estimates of the ratio between total UK government expenditure on industrial support and on industrial R&D. The figures give an indication of the relationship between general direct support and R&D support for industry (see Table 4).

SOME CRITICAL EVALUATIONS OF POLICY MEASURES

No policy measures escape criticism, but it may be worth remembering that the criticisms can be aimed at two fundamentally different aspects. It is possible to criticize a policy because of disagreement with its aims or because of doubts about its effectiveness in achieving these aims. Additionally policies attract criticism because of the unintended, unwarranted, or unforeseen effects which they may cause.

A simple, devastating criticism of innovation policies has been made by Gaudin (1977): "As a civil servant managing research contracts, I can tell you that most work in economics of innovation is completely irrelevant and useless."

TABLE 3 Government funds available for innovation in current prices (millions of national currency units).

	1972	1973	1974	1975	1976	1977	1978	1979
Germany, Federal Republic								
Patentstelle für die Deutsche Forschung	0.5	0.6	0.7	0.9	1.1	1.2	1.5	
Technologieverwertungstellen der Grossforschungszentren							±1.0	
Deutsches Patentamt	95	101	104	117	123	125	131	
RKW	30	32	34	40	41	42		
Fraunhofer Gesellschaft	62	68	82	90	108	126	138	
Technological Advisory Services to SMEs						0.5	2.6	3.0
VDI Technologie-Zentrum						0.7	0.7	1.0
R&D Manpower Grant Program								300
BMFT-Projectförderung					1269	~1500	~1500	
Vertragsforschung							6.0	10.0
Wagnisfinanzierungsgesellschaft						0.8	1.8	5.5
Erstinnovationsprogramm	3.9	7.2	6.0	7.3	9.9	12.1	16.0	19.5
United Kingdom								
NRDC (revolving fund)	4.46	3.84	2.49	3.17	4.14	4.39	6.48	7.03
Low Cost Automation Centres	0.10	0.10						
Industrial Liaison Services Centres	0.50	0.20						
Small Firm Information Centres	0.03	0.5	0.5	0.38	0.5	0.5	0.42	0.43
Research Associations	2.90	2.8	3.2	4.7	6.6	8.0	11.0	11.5
Small Firm Counselling Service					0.03	0.05	0.34	0.35
Manufacturing Advisory Service						0.23	1.86	1.64
Requirement Boards		0.30	0.70	1.80	2.00	2.20	10.00	11.00
Collaborative Development Contracts	4.496	8.416	10.388	10.141	10.343	11.125	14.862	16.571
Preproduction Order Assistance							0.38	
Product and Process Development Scheme							0.27	0.6
Software Products Scheme	0.033	0.057	0.114	0.310	0.273	0.200	0.400	
Microelectronics Support Scheme						0.210	6.0	6.0

SOURCE: Hagedoorn and Prakke (1979).

TABLE 4 R&D and total government financial aid to manufacturing industry in the UK.

	R&D (1970–71)	Other (1969–70)	Total
Chemicals	0.2	14.8	15.0
Metal manufacture	0.1	8.5	8.6
Engineering	7.1	10.4	17.5
Vehicles (including aircraft)	16.3	20.7	37.0
Textiles	0.1	4.6	4.7
Other	1.2	16.0	17.2
TOTAL	25.0	75.0	100.0

SOURCE: Pavitt and Walker (1976).

In fairness, this is not so much a criticism of innovation policies as of the theories they might be based on. Gaudin goes on to criticize the assumption that research is the prime mover of innovation: "... most innovations are not the result of research...." Here again, in fairness, it needs to be said that most recent theories of innovation do not identify research as the sole source of invention but only as a component of the innovative system. Most case studies of innovations support this view (see e.g. Braun and MacDonald 1978, Langrish, *et al.* 1970).

Another line of criticism questions the thesis that innovation is desirable, or if desirable, whether it is taking the right course. Some critics question both the desirability of innovation, or at any rate of a forced pace of innovation, and the ability of government to influence it greatly. A characteristic comment, critical of both the aims and the efficiency of innovation policies, comes from R.G. Noll (1977):

> "... the literature does not establish either that too little innovative activity takes place, or that government can be particularly effective in devising cost-effective strategies to promote more R&D..."

However, in the same publication Lederman (1977) writes about "persuasive evidence that R&D and technological innovation have had a significant positive effect on growth of productivity... (and that the US is) probably underinvesting in civilian R&D."

Much controversy surrounds the question of whether government aid for specific technological innovations is more or less effective than general measures to stimulate industrial or innovative activity. A characteristic comment on these issues is:

> Data presented in this report have strongly suggested that general measures (e.g., tax, safety) have a greater impact on industrial innovation than R&D specific measures. It seems that unless the general social and economic environment is favorable specific R&D innovation-related measures will have only a

limited impact.... (Rothwell and Zegveld 1978).

Leaving aside fundamental criticisms and essential doubts about innovation in general and innovation policies in particular, a number of recent reports have concentrated on proposals for improved innovation policies. All these proposals are firmly based on opinions, and all too often the opinions closely reflect the vested interests of those who express them.

A recent report by the UK Advisory Council for Applied Research and Development (1978) (ACARD) makes, *inter alia*, the following specific recommendations:

(a) increased tax incentives for a limited period for investment in new manufacturing plant and machinery

(b) money additional to the science budget for a build-up in Science Research Council programs in support of manufacturing technology

(c) an expansion of the Department of Industry Manufacturing Advisory Service

(d) provision of financial and other support to Research Associations and the appropriate Engineering Institutions for the study, research, and publicizing of the sciences supporting highly efficient, internationally competitive manufacture.

Many nations place great emphasis on the role of the small firm in innovation. Although there is certainly no unanimity in the matter, there is a large body of opinion which believes that some innovations are most efficiently carried out by small entrepreneurial firms (see e.g., Rothwell and Zegveld 1978). This view is reflected in the ACARD report and some of its recommendations.

The government should do more to foster the special contributions which small firms make to industrial innovation by providing additional support through:

(a) arranging that any losses from small business enterprises be allowed against the personal tax liability of the shareholders;

(b) reducing capital gains tax on the appreciation of founder's holdings;

(c) examining the feasibility of setting up special tax arrangements which might make it attractive to large companies to spawn or help to support small businesses.

One of the hotly debated issues of the day is the role of government regulations in innovation. As regulations concerning safety, environmental pollution, working conditions, descriptions of goods, etc. became more pervasive, so their opponents began to argue that so much money had to be spent by manufacturers on complying with regulations that none was left for innovation. On the other hand it is argued that the need to comply with them gives a fillip to new products and processes. While dispassionate writers such as Lederman (1977) say that no consensus exists on whether, on the whole, regulations are beneficial or detrimental to innovation, many members of a recent US Domestic Policy Review of

Innovation (1978) were extremely critical. Amongst the recommendations of the subcommittee on Industry Structure and Competitors (p.4) is the following:

> Each regulatory agency should issue a long range statement of regulatory intent... . Where a company has related compliance requirements controlled by more than one law, consultations must occur between the agencies. No doubt, some confusion and changes of direction can cause difficulties. The main thrust of the argument, however, is directed against regulations which prescribe solutions instead of prescribing performance standards.

Innovation is negatively impacted by regulating the means rather than the ends (p.6). Regulations should only prescribe the standards of performance to be achieved, not the means by which they are to be achieved (p.7). Small firms again become the subject of special pleading.

Smaller firms, historically the source of significant contributions to innovation, suffer disproportionately greater injury from the overall costs of regulation than do larger firms (p.21).

The subcommittee on Federal Procurement Policy makes similar points in relation to procurement policy. The recommendations of this committee on general policy include the following:

(a) express needs and program objectives in mission terms and not equipment terms to encourage innovation... ;

(b) ... allow competitive exploration of alternative system design concepts... .

Different subcommittees of the same Domestic Policy Review of Innovation view obstacles to innovation and the role of the state very differently. The Labor Advisory Committee states "The best stimulus to innovation comes from a healthy full employment economy — not from weakening protections." The Subcommittee on Public Interest, on the other hand, states: "We do not accept the widely held industry assumption that regulations impede innovation" (p.2). "Moreover, job security is a fundamental aspect of innovation. Frightened workers, worried about whether another job will be available if a specific new idea is implemented, often oppose innovation" (p.4).

Regulation and innovation is obviously a highly politicized issue. Interested groups clearly have a different view not only of what influences innovation and how the mechanisms operate, but also, mostly implicitly, of what direction innovation should take. Only one group, however, states this: "From the public interest perspective, the rate of innovation is subservient to the question of the direction of innovation" (Subcommittee on Public Interest, p.6).

So much then, for opinion; but what about actual research findings on the efficiency of government policies for the stimulation and direction of innovation? Knowledge in this field is sparse. One of the few serious attempts to investigate these questions (OECD Report 1978, p.80 ff.) used the method of questionnaires addressed to government officials administering the various schemes identified by the report. The conclusions are somewhat confused, but on the whole officials either felt unable to answer certain questions or answered in a spirit of rosy self-satisfaction. The questions were directed in the main at the attainment of the intermediate rather than final objectives.

Allen *et al.* (1978) investigated 164 innovation projects in several industries and several countries. They found that nearly half the projects were affected by Government policies, but found no indication that the government contribution influenced project success or failure. Projects involving a response to regulations tended, on the whole, to have an above average rate of success.

Rubenstein *et al.* (1977) investigated management perception of the role of government incentives to technological innovation in the UK, France, West Germany, and Japan. On the whole, they found that managers tended to regard government incentives with great scepticism, although Japanese and German managers less so than their British and French counterparts.

Jones and Willett (1977) discuss the difficulties in evaluating the costs and benefits of government laboratory research and information services. On the whole they believe these services to have positive results, but find a rigorous examination of all costs and benefits too complex to be cost effective.

CONCLUSIONS

The conviction that technological innovation is a powerful driving force which gives dynamism to an economy is widespread. Considerable controversy centers around issues of what directions innovation should take and how government should stimulate it. There can be no doubt that the process of innovation is extremely complex and varied and therefore any simple prescription or description is likely to be widely off mark.

Government has a wide range of measures in its armory by which to influence different aspects and stages of innovation. The efficiency of the various measures, however, is largely unknown.

The stimulation of technological innovation undoubtedly forms an important part of any government's industrial and economic policy and much more thought must be given to questions such as:

- what kind of innovation is desirable
- what rate of innovation is optimal
- what government measures would be most effective in achieving the objectives arising from answers to the above questions

It is impossible to obtain complete answers to the above questions, but it is perhaps worth trying to come a little closer to approximate and partial answers.

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THE MANAGEMENT OF TECHNOLOGY IN THE CMEA COUNTRIES

Lech Zacher

HISTORICAL BACKGROUND AND SOCIOECONOMIC AND POLITICAL CONTEXT

The Council for Mutual Economic Assistance (CMEA) countries believe that scientific and technological developments can be used to create a better future. In other words, they believe that science and technology are important factors in socioeconomic growth which will ensure them economic power and improve social welfare. These countries are still more growth oriented than growth impact oriented. They do not share the fashionable catastrophic view of the technological future of the world.

The present situation in the CMEA countries in terms of technology and its assessment evolved out of the strategy of liquidation of historical blocks to development, which resulted in rapid industrialization and urbanization. This development was important. Before these countries embarked on the socialist road of development most of them were quite backward; only the GDR and Czechoslovakia had reached an advanced level of industrial development. The CMEA countries assimilated the available technology as it was. They had no choice but to use the environmentally degrading and dehumanizing technologies developed by technologically and economically leading countries of the capitalist world. However, the socialist production system has been able to limit the negative side-effects of technology.

Technological and economic change in socialist countries resulted in radical social transformation, including changes in social and professional structure, education, lifestyle, mentality, culture, etc., accompanied by technological, structural and economic changes. Technology was a powerful force in achieving that transformation. The CMEA countries have now attained a high level of development in science, technology, and industry. The Soviet Union's position as a scientific and technical power is beyond question. The standard of living in CMEA countries has increased, as is evidenced by mass education and greater availability of industrial consumer goods, such as automatic washing machines, radio and TV sets, stereos, cars, etc.

Society, appropriately, has become fascinated with technology as an instrument of progress. This fascination has contributed to the successes of many projects in the accepted strategy of development. Nuclear power stations were set up, sputniks were launched, and military equipment that could rival Western achievements was produced.

The founders of Marxism stressed the importance of technology in the structure of production forces. Karl Marx wrote in *das Kapital* that technological improvements that increase worker productivity result in an increase of surplus value, which in turn increases capital accumulation and expedites growth and development. Oskar Lange, in developing the law of advancing development of productive forces, pointed out that technology plays a crucial role in the creation of man's artificial environment. Lenin's political slogan that "socialism is the power of Soviets plus electrification" was also a comment on the economic importance of technological development. The large-scale plan of Russia's electrification (GOELRO) was a historical event without precedent in the planning of technology.

However, this should not be interpreted, as some Western writers argue, to mean that technoeconomic determinism is the basis of Marxism. This is a distortion of the truth. Historically there have been times when Marx was interpreted mechanistically. However, human and social goals have always been the pillars of Marxist philosophy and they are regarded today as the highest values of socialist ideology. It was Marx in his youth who established the basic principles of socialist humanism and the concept of multifaceted development of human personality.

One of the general practical tasks of the socialist societies is to overcome disorderly tendencies in socioeconomic and technological development. This is a long-term and probably unending process, since social processes cannot be fully controlled "mathematically and technically." They should not be treated mechanically. Planning is a powerful tool in social practice and an essential characteristic feature of socialism.

Planning takes place in definite historical conditions. These conditions are subject to objective factors such as the state of science and technology, available human and material resources, etc., as well as to subjective ones, such as political will, management skills, experience, aspirations, etc. Historical conditions for the development of planning in CMEA countries have been unfavorable. Russia's October Revolution took place in a genuinely undeveloped, semifeudal country, with no democratic traditions whatsoever, mass illiteracy, etc. Other socialist countries, except the GDR and Czechoslovakia, were among the less developed countries in Europe before World War Two. The historical conditions mentioned included:

- technological and economic backwardness
- the level of education and skills and the traditional human mentality
- lack of experience in planning and managing a noncapitalist economy
- the predominance of economic and security goals.

In addition these countries were ravaged during World War Two and faced with hostility from the capitalist countries after the war (the cold war, embargoes, discrimination, etc.). These factors are generally underplayed by critics of socialism.

A nationwide planning system proved to be an effective means of managing and controlling socioeconomic development. Planning has evolved but it still has a long way to go. Its future evolution will see computerized assistance and wide citizen participation.

It should be noted that few economic plans in the CMEA countries have been implemented exactly in accordance with directive guidelines. Some tasks are overfulfilled, others unfulfilled. Indeed, plans have never been treated mechanically or taken literally in planned economies. The "command economy" is a myth. It was partially true in the 1950s, when administrative means of centralization and control were quite effective, particularly during the great postwar structural transformations of the economy (basic industrialization, big military R&D, the investment programs, etc.), when central planning was substituted for the competition market mechanism and private initiative.

Planning and socialist democracy are developing step by step in accordance with the material and intellectual development of socialist society; they are also sensitive to external conditions. There is no ready-made prescription for a "good socialism." The founders of Marxism were not prophets; they just discovered some basic regularities or laws of the development of mankind and learned how to use dialectics to analyze, understand, and control social processes.

Two main processes are under way in the socialist countries:

- the continuation of basic industrialization (in the terms of Kuznets's "modern industrialization"); and
- the early stages of the so-called scientific and technological revolution.

This latter phase entails a form of broad modernization (in Kalecki's terms, changing capital ratio) which integrates indigenous R&D technologies and organizational patterns into vast technology transfer from the West. The transferred technology is in most cases dehumanizing and environmentally degrading, but there is no other way to be highly productive at home and competitive abroad. The centrally planned economies have not entirely escaped from their historical (capitalist) heritage with its absence of effective coordination of various human activities; the capitalist environment also continues to influence the CMEA countries through technology transfer, foreign trade, etc. The lack of long-term experience of the CMEA countries is also visible in, and to a great extent responsible for, the shortcomings in governing science and technology. While negative side-effects of the scientific and technological revolution are usually unintended and difficult to predict, sometimes they are simply the effects of inadequate assessment or judgment based on inappropriate values and criteria*.

Often social directions are affected by psychological factors. Poor, uneducated country people who associate nature with hard, dawn-to-dusk outdoor work and with flood, drought, and catastrophe do not understand why nature should be protected. Thus under socialism we find people who are attracted by patterns of the most advanced countries, who strive for prestige, consumption, fast cars, tower blocks, and asphalt motorways and streets, and who do not mind pollution, noise, or a lack of trees.

In fact degradation of the natural and human environment, the rise of technocracy, and discrepancy between technological and social change also endanger planned economies. Not even the least developed countries are spared the threat of nuclear destruction and the menance of rising armaments.

However, one ought to emphasize that uses and abuses of science and technology are exactly determined by the social and political goals of society. There is an apparent feedback between the goals and uses of science of technology and the sociopolitical system. This general statement assumes a substantial difference between the capitalist and socialist systems. Critics of planned economic systems often unjustly accentuate the divergence between socialist theory and practice. In so doing they ignore the historical factors involved, forget that socialism, being a new system, is by definition an experiment on a very large scale, and fail to realize that the goals of a society must be appropriate to its stage of development. The high aspirations for humanity and society that are stressed in socialist theory and ideas can only be effectively implemented at a certain stage of economic and technological as well as intellectual and political advancement. We now believe that the Soviet Union and Eastern European countries are actually presently approaching this stage.

It is worth noting that the socialist countries have begun placing great emphasis on humanization of work and technology, on using science for the material and intellectual benefit of society as a whole and on the multidimensional development of every individual. This includes emphasis on permanent education, common (not mass) culture, and democratic participation in decision making processes of every kind. To ignore this phenomenon or to devalue it as mere political propaganda is to ignore not only the new programs but also the newly emerging reality.

*It is noteworthy that most decision makers in the CMEA countries have technical education, yet they do not constitute a technostructure as described by J.K. Galbraith; they are very often first generation intelligentsia. In contrast with capitalist countries, technocratic and economocratic attitudes in socialist societies are not primarily connected with profit orientation and competition. The result is not utopian. People in socialist countries seem to be "learning a system" markedly conditioned by historical as well as other factors and events. As a matter of fact, there is no such thing as a recipe for socialism. There is no simple, prepared operational prescription that will make people good, humanistic, democratic, respectful of ecological laws, etc.

The technological planning of the future will presumably have greater emphasis on the achievement of socialist ideals. This will probably entail a shift in orientation from profit, productivity, novelty goods, and hard technology to pure, environmentally harmonious, and creativity-oriented technologies. Since Marx's concept of development of the individual personality is deeply human and multidimensional, humanization and promotion of creativity will be among the ultimate goals for a "developed" socialist society. Rejection of the concept of technological determinism and the challenge to technocracy and bureaucracy are important features of the contemporary socialist societies.

TECHNOLOGY ASSESSMENT IN SOCIALIST NATIONS

Many scholars advance the belief that socialist and capitalist nations are converging to a common system. We believe that view is not justified; in particular, we believe that the management of technology is an area in which capitalist and socialist nations will diverge. By integrating technology assessment (TA) into central planning the socialist nations will be able to steer their development away from some of the errors and blind alleys of contemporary capitalism, thereby contributing to a divergence.

How does technology assessment fit into socialist thought and action? In a sense the concept of technology assessment is implicit in planning for long-term development. Almost all fields of man's activities are considered (but not necessarily planned) in the planning process in socialist countries. Important fields of planning include industry, construction, exploitation of resources, spatial and urban development, protection of the natural environment, social welfare, and medical care. Such fields as education, R&D activity, and cultural development are also built into the planning system, but with a higher degree of flexibility.

Technology assessment, in the sense of considering and planning for the effects of technological change, is implicit in the planning of all these areas. Most of this de facto technology assessment is incorporated in planning for other social and economic problems and therefore does not take place in specialized institutions.

Different socialist countries use different institutional and political decision making frameworks for controlling technology (and everything else). In what follows, a structure is presented based on the Polish experience, where the basic factors are (as shown in Figure 1) the ruling party, the parliament, the government and its agencies, the R&D sector, public/social bodies, local organizations, and consultation with society (especially with industrial workers).

In the socialist countries, general guidelines of social development, especially in the sphere of the economy and technology, are included in the program of action agreed upon by the periodically held congresses of the communist parties. The parties steer economic, technical, and other development in directions that are consistent with the general guidelines of social development set forth in socialist ideology; while at the same time ensuring that these actions answer the needs of the population. Programs established by Party congress are carried out by the government

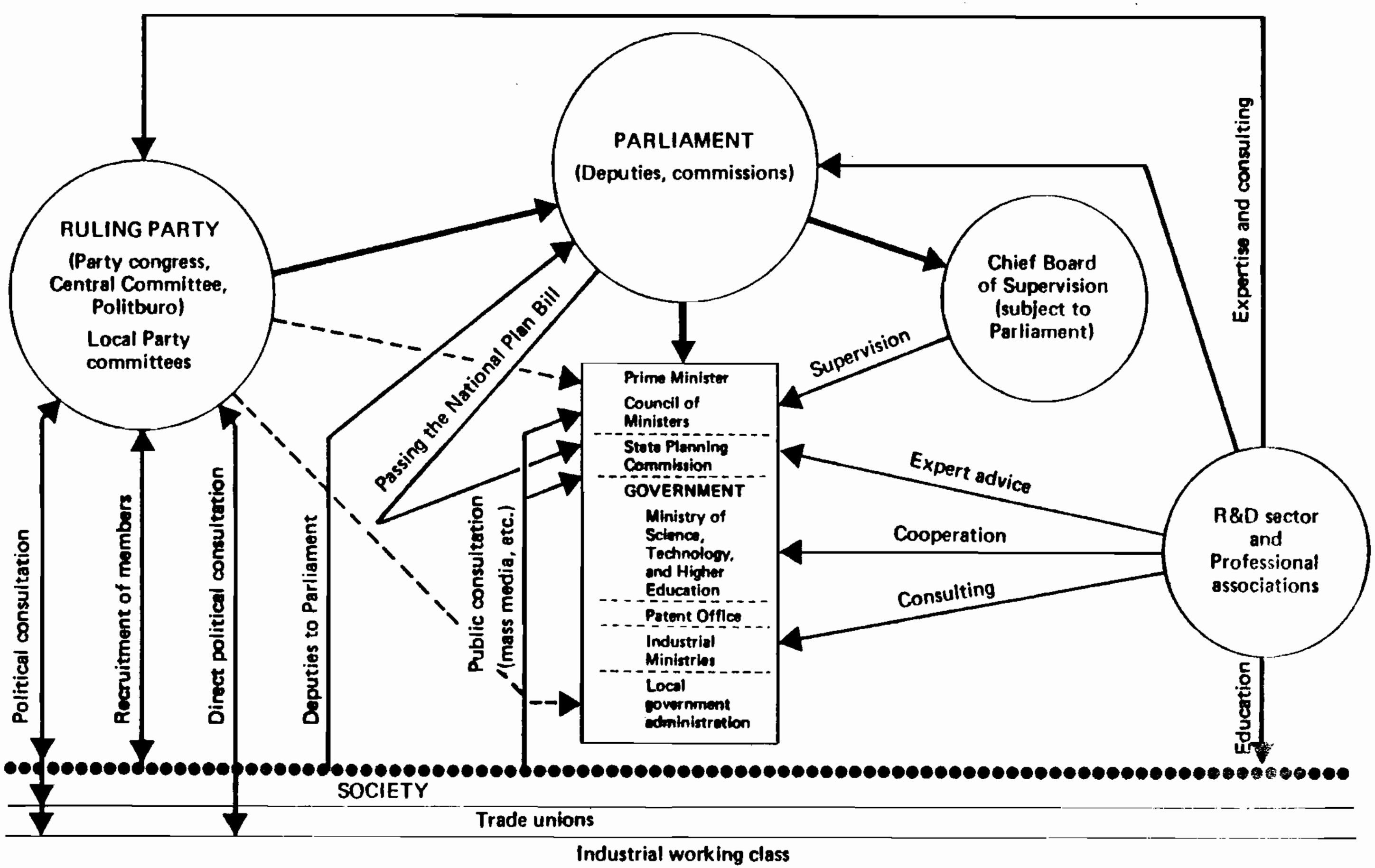

FIGURE 1 Scheme of the institutional and political framework of choice and the decision making and consulting process (national socioeconomic planning, technology assessment, political choices, etc.).

acting under the control of the Party leadership and of Parliament. By showing the nation the prospects of development in the years to come, the program mobilizes citizens and creates at the same time a political framework for long-term plans being drawn up by the government, basic elements of which are then submitted for adoption by the Parliamentary forum.

These long-term plans are a basis for one-year plans, worked out by the government and then adopted by Parliament. In Poland, annual and long-term plans are prepared by the Planning Commission of the Council of Ministers. At present this commission is working on a prospective plan to the year 1990. The research and forecasting involved in this work are carried out by the Committee of Research and Prognostics "Poland 2000" of the Polish Academy of Sciences.

The plans of technical development are guidelines for technological policy and are subject to the general plan of social development. The plans for the realization of technological achievements in various fields of the national economy are prepared by respective ministries; research and development plans are developed by the Ministry of Science, Higher Education and Technology, which also carries out technological and scientific policy based on these plans.

The main concern of research and development policy in recent years has been to increase and make better use of the R&D potential. Special attention has been given to work covering the complete development cycle, from research and development to coordination plans worked out with accuracy sufficient to synchronize them with economic plans when it comes to the practical application of their results in the economy. As a rule of thumb long-term plans should be accurate at least within the one year time limit as regards their final implementation and no less than 50 percent of industrial research should be devoted to works with complete development cycles.

Considerable importance is also attached to the closest possible link between the cycle of research and development work, on the one hand, and practical application and popularization on the other, because the experience of many countries, including Poland, shows that practical application and popularization are the least efficiently operating links within the development cycle.

The activities of technology assessment fit into this framework in approximately the following fashion and sequence. The governing Party first recognizes and defines a social problem; then experts, especially in the R&D sector, assess the technological development involved. The results of the assessment are then transmitted by the Party to the public and decision makers through consultation with the working class, society, government bodies, etc. This may lead to Parliamentary action in the form of legislative and administrative decisions. Thereupon the decision is transmitted into the planning process through the State Planning Commission or Parliament, whereupon suitable government institutions are called upon to implement it. The government, meanwhile, observes and measures the progress made in implementing the plan. The Chief Board of Supervision (a Parliamentary Agency) and the ruling Party authorities oversee and control program implementation.

These steps work iteratively. Information gained in observation of performance and control feeds back into every stage of the problem solving process, thereby allowing for possible modifications as required. Such continuous observation and analysis is necessary to update technology assessment periodically and to keep it tuned to changing circumstances. This sort of information-guided control process is widely and successfully used in the socialist countries to develop and implement plans. The updating process often leads to progressive improvements above and beyond simple control. When this happens the system becomes a learning system.

Technology assessment could, potentially, be applied to a wide number of areas including monitoring negative unintended side effects of existing technologies, recycling of natural resources, environmental protection, spatial and urban planning, assessment of technology transfer, R&D activity, and programming new desirable technologies. So far its use has mainly been confined to environmental protection and spatial and urban planning.

SOME REMARKS ON TECHNOLOGICAL STRATEGY AND POLICY

The directions of technological policy must be appropriate to the current economic and social situation. So, for instance, the rapid technological development of the Soviet Union in the 1930s was aimed both at a more satisfactory fulfillment of people's needs and at building up the country's military force to resist a Nazi invasion, and, in alliance with other countries, to destroy the power that menaced the whole world. Similarly, during the Cold War period, the socialist countries were concerned with mapping out defensive aims for themselves.

At present technological progress and the development of the economy have given rise to new dialectic contradictions in the socialist countries. Wide application of material incentives in these countries, although indispensable for rapid technological development and production growth, and thus for more satisfactory fulfillment of people's needs, tends to focus young people's aspirations on the satisfaction of material requirements; such attitudes are reinforced, moreover, by the patterns of social behavior prevailing in the capitalist countries. This type of contradiction seldom becomes antagonistic in character, but it does compel decision makers to pay special attention to ideological instruction, particularly among the young, in order to develop the awareness that the increasing satisfaction of social needs should not be the ultimate aim, but rather a means whereby the future communist society is to be built.

CONCLUSIONS

On the basis of available literature, the knowledge of Western solutions, and the current state of affairs, the following conclusions and postulates concerning the role and place of technology assessment research in the socialist countries (particularly Poland) can be put forward.

1. In the Sphere of Methodology and Research

(a) It seems necessary to elaborate an expertise on the existence and functioning of technology assessment elements in the system of planning and decision making.

(b) Each country should work out its own specific methods of technology assessment giving due attention to the present advanced achievements of other countries.

(c) It seems indispensable to set up specialized institutions (or to create appropriate means in the existing organizational structure of science) dealing with technology assessment in the broad sense.

(d) It is necessary to develop interdisciplinary research not only on the technological future of the country in connection with introducing new technology but also on the assessment of the present and past adverse effects of technology, in order to eliminate these and to draw proper conclusions in the future.

(e) The coordination of research, decisions, and ventures connected with the analysis of basic problems of technology and their aftermath up until 2000 and beyond (within the frames of the government research programs and with the expertise of the Committee "Poland 2000" of the Polish Academy of Sciences) is a matter of special importance.

2. In the Sphere of Planning and Forecasting as a Preparatory Phase of the Plan

(a) It seems desirable to select technology assessment research in planning practice as a result of selecting "the field of technological choices."

(b) It seems desirable to promote the problems of technological choice not only as regards investment choice but also regarding the types and directions of technological progress and its social consequences (i.e., forecasting and perspective planning).

3. In the Organizational and Political Sphere

(a) The value and possibility should be reviewed of setting up new specialized institutions or small organizational units within the existing structures which would be competent in the field of decisions related to technological development. In Poland, organizational units or independent workshops for technology assessment could be set up at the Parliament's commission, the Office of the Council of Ministers, the Chief Board of Supervision, the Planning Commission, special interbranch or suprabranch committees, the Central Committee of the Polish United Workers' Party, and the Central Council of Trade Unions.

(b) It is indispensable to create a system of technological, statistical, and planning information for technology assessment.

(c) It seems desirable to raise the political prestige of the problem of technological choice in a developed socialist society and to have them included in the program of democratic consultations with society, and with the industrial working class in particular.

4. In the Economic Sphere

(a) It is necessary to build technology assessment into the innovation process.

(b) Technology transfer should be the subject of detailed evaluation by means of technology assessment methods.

5. In the Sphere of Social Education

(a) It is necessary to promote the technical education of society in order to manifest various facets of technology, especially its less-well-known threats, and to arouse interest in the future alternatives for technological development of the country.

(b) It is necessary to introduce on a broad scale interdisciplinary studies at universities and in postgraduate courses to increase capabilities for the social evaluation of technology, such as, for example, technology and social values, technology and the world future, technology and man's personality, technology and politics, etc.

6. In the International Sphere

(a) The problems of technology assessment should be taken into account in the process of coordination of the socioeconomic development plans of the CMEA countries.

(b) It is necessary to develop international cooperation, both bilateral and multilateral, in technology assessment.

BASIC INNOVATION AND INDUSTRIAL GROWTH

Gerhard Mensch and Alfred Kleinknecht

GENERAL VIEW: DISCONTINUITY

Our concept of industrial evolution (stagnation = lack of basic innovations) was conceived at a time (1970–71) when economic research was still projecting incessant economic growth, and when science and technology policy were expected to produce the right kind and appropriate volume of new technology to nurture this industrial development (Mensch 1971, pp. 295–314). From that time stems our awareness of some fundamental properties of the evolutionary process of socioeconomic change, which then indicated that the next downturn of the business cycle would bring disappointment to those who relied on the prognosis of "just a mild recession." Among the early indicators of a coming depression were labor market and capital market trends as well as indicators of change in the international division of labor and of technological change and substitution.

In modern industrial civilization, the boundary between nature and culture becomes increasingly fuzzy, and many of the socioeconomic forces manifest themselves in the use and creation of artifacts. Therefore, indicators on the rate and direction of industrial innovations can be expected to tell us a good deal about change within a changing economy. We suggest a metamorphosis model of long-term socioeconomic change (Mensch 1979). The following propositions characterize the industrial metamorphosis, which we view as a stream of various kinds of innovations with considerable variation within the innovation mix over time.

Types of Innovation

We distinguish the following types of innovations (Mensch 1972, pp. 291–297):

(1) Basic innovations, which establish new branches of industry, and radical improvement innovations, which rejuvenate existing branches. Both tend to occur discontinuously in time, namely in rushes. For a survey of the observed clusters of basic innovations see Figure 1.

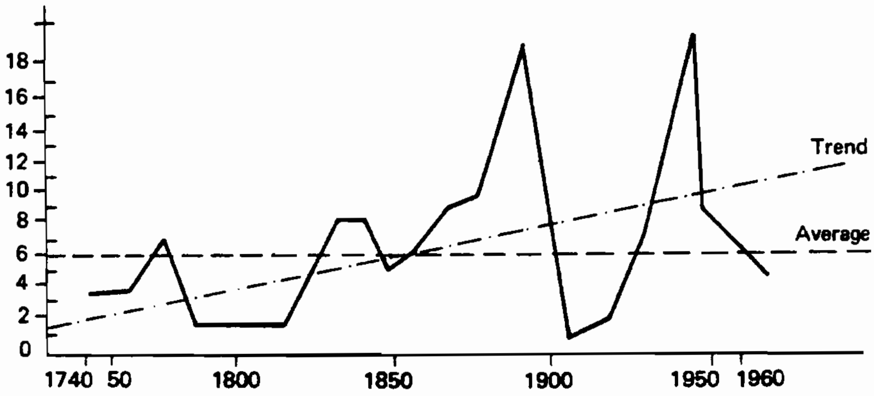

FIGURE 1 Frequency of basic innovation, 1740–1960.

(2) Within those new or renewed branches, the pioneering innovations are followed by series of improvement innovations. The improvement effects of these successive innovations are governed, on the demand side, by the law of diminishing marginal utility and, on the supply side, by the law of diminishing marginal returns on investment.

This means that in the course of time, as certain technological potentials become fully used and certain technologies increasingly perfected, and there are more and more pseudo-innovations that do not benefit buyers and suppliers to the extent they once did. Also, owing to power, inertia, and other decisive reasons, investors tend to favor pseudo-innovations over basic innovations. Consequently, reading (1) and (2) together, we can expect certain lulls to emerge in the course of industrial evolution. We call such a pause in the busy creation of basic innovations "stalemate in technology."

In an obvious way, our concept of basic innovation is related to Kuznets's concept of epochal innovation, although an epochal innovation will be considered by most as a particularly fundamental basic innovation:

> An epochal innovation may be described as a major addition to the stock of human knowledge which provides a potential for sustained economic growth — an addition so major that its exploitation and utilization absorb the energies of human societies and dominate their growth for a period long enough to constitute an epoch in economic history. (Kuznets 1973.)

And in a similarly obvious way, the dynamics of exploitation and exhaustion of the technological potential of some basic innovations can be formulated in terms of diminishing demand side and supply side returns on technology (Giarini and Louberge 1978), leading to pseudo-innovation and no innovation.

This typology, and the previously mentioned interplay between types of innovations, give rise to the following scenario about the end of the current stalemate in technology.

A Bold Projection into the Future

In the course of history, several such stalemates have occurred. They developed from a temporary lack of basic innovations, and ended with a new spurt of basic innovations. It appears that the world economy has again become ready for another spurt of basic innovation. If the relevant parameters of the macroprocess of industrial evolution stay as they are set now, then we can offer a conditional pattern prediction on the next cluster of basic innovations:

> Approximately two thirds of the technological basic innovations that will be produced in the second half of the twentieth century will occur in the decade around 1989. (Mensch 1979, p. 197.)

Even if this pattern prediction fails to hold owing to unexpected changes in the conditions upon which it has been based, we must come to the systems analysis of needs, the chances and the risks involved, and the appropriate policies to be taken. Our immediate aim, however, is to point at two macroconditions upon which this projection has been based: acceleration and slowdown of production and employment growth in the course of diffusion of industrial innovation, and structural instability of the economic system in the later phase of this diffusion, including the emerging state of "structural readiness for another spurt of basic innovation."

OBSERVATIONS ON GROWTH AND CHANGE

Main Hypotheses

Taking the clustering of basic innovation as an empirically observed phenomenon, the statistical significance of which has been found to be fairly high, we may treat it as our starting point and derive the following two hypotheses on the rate and direction of change:

H_1: Within those branches of industry which had been mostly affected by the cluster of basic innovations in the years around 1935, a particularly fast growth should be observable for the prosperity period after the war, and a slowdown toward the average within the recession period of the last 10 years or more.

H_2: Within industry as a whole, the prosperity period should be characterized by a dominance of expansionary improvement innovations (product innovations) over rationalizing improvement innovations (process innovations), with a reversal of this dominance during the recession period (the Imbalanced Technical Change Hypothesis).

This Imbalanced Technical Change Hypothesis H_2 we have dealt with elsewhere, where we have collected several sets of data which all indicate that the hypothesized development has indeed taken place (Mensch *et al.* 1980). And as a further result, we have deduced that both retardation and acceleration of the speed of change can be partly attributed to inertia or to sudden structural adjustments. These factors, however, should be viewed in connection with the general speed of growth tendencies. Therefore, the hypothesis H_1 we shall deal with here and now.

Acceleration and Slowdown in Industrial Production

Here, we deal with the Speed of Growth Hypothesis and illustrate it for the industry of the Federal Republic of Germany. To the degree that the above hypotheses are realistic, it must be possible to demonstrate that in periods of stronger growth, those industries which then can be designated as growth industries are just those which were affected by basic innovations during the previous period of weaker growth, or which were founded during that period as a result of basic innovations. At the same time, it should become evident that the end phase of a period of stronger growth is characterized by a tendency to relative stagnation of these "innovation industries."

In what follows we will draw from an article by Kleinknecht in which the above hypothesis H_1 has been empirically tested and validated on the basis of West German industry data between 1950 and 1977 (Kleinknecht 1979).

As a first step (see Table 1), the individual basic innovations were categorized according to the industries which are principally concerned with the production of the respective new products, or those in whose production the process innovations play a major role. The Index of Industrial Groups and Branches, which also serves as a basis for the series of statistical data for 48 industrial branches in manufacturing and mining published by the DIW (German Institute for Economic Research) was used as a grid (Krengel *et al.* 1978). From this series, the indicators on industrial production (Table 2) were also derived.

Inspection of Table 1 reveals that 34 out of 42 basic innovations affected the following industries: plastics manufacturing, petroleum refining, aircraft construction, electrical equipment, chemicals, and the automobile industry. One must make yet further differentiations within these industries. While in the plastics manufacturing, petroleum refining and aircraft construction industries the innovations affected virtually the

TABLE 1 Basic innovations and industrial lines.

Innovation event	Innovation year	Industry affected
Wrinkle-free fabrics	1932	Chemical industry (plastics manufacture)
Insulin	1922	Chemical industry
Kodachrome	1935	Chemical industry
Plexiglass	1935	Chemical industry (plastics manufacture)
Neoprene	1931	Plastics manufacture (chemical industry)
Nylon/perlon	1938	Plastics manufacture (chemical industry)
Penicillin	1941	Chemical industry
Polyethylene	1933	Chemical industry (plastics manufacture)
Silicones	1946	Plastics manufacture (chemical industry)
Streptomycin	1944	Chemical industry
Synthetic detergents	1928	Chemical industry
Terylene polyester fiber	1955	Chemical industry (plastics manufacture)
Tungsten carbide	1926	Chemical industry
Rollpoint pen	1938	Plastics manufacture (chemical industry)
Watertight cellophane	1926	Plastics manufacture
Fluorescent lighting	1934	Electrical equipment
Magnetic taperecording	1937	Electrical equipment
Radio	1922	Electrical equipment
Television	1936	Electrical equipment
Transistor	1950	Electrical equipment
Synthetic light polarizer	1932	Electrical equipment
Cinerama	1953	Electrical equipment
Automatic drive	1939	Vehicle construction
Automatic clutch	1937	Vehicle construction
Power steering	1930	Vehicle construction
Catalytic cracking of petroleum	1935	Petroleum refining
No-knock gasoline	1935	Petroleum refining
Jet engine	1941	Aircraft construction
Helicopter	1936	Aircraft construction
Rockets	1935	Aircraft construction
Radar	1934	Aircraft construction (precision engineering and optical industry)
Gyrocompass	1909	Precision engineering and optical industry (aircraft construction)
Zipper	1923	Precision engineering and optical industry
Diesel locomotive	1934	Machinery construction
Sulzer loom	1945	Machinery construction
Cotton picker (Rust)	1941	Machinery construction
Cotton picker (Champbell)	1942	Machinery construction
Xerography	1950	Printing and duplicating industry
Continuous hot strip rolling	1923	Iron and steel industry
Continuous steel casting	1948	Iron and steel foundries
Titanium	1937	Nonferrous metals

SOURCE: Kleinknecht (1979, p. 323).

TABLE 2 Rankings of percentile production growth per cycle.[a]

	A		B		C		D		E		F		G	
	1950 1969		1950 1955		1955 1960		1960 1964		1964 1969		1969 1973		1973 1977	
1	LB	64.5	LB	66.7	LB	142.8	LB	45.8	K-V	13.8	OELG	13.3	ZUCK	6.5
2	K-V	20.8	SCHB	29.6	MINV	17.0	K-V	17.2	OELG	13.1	K-V	12.5	BMDV	6.4
3	MINV	15.5	K-V	26.6	K-V	24.7	MINV	15.4	LB	10.4	BMDV	11.7	GLAS	4.5
4	OELG	15.2	OELG	23.6	FB	14.1	OELG	11.4	CHEM	10.3	H-V	9.0	K-V	4.5
5	FB	13.3	FB	22.9	OELG	12.0	FO	10.1	MINV	8.0	ELT	8.5	OM	3.7
6	ELT	11.9	MINV	21.7	ELT	11.6	CHEM	9.3	ZKWW	7.5	CHEM	7.7	FB	3.2
7	CHEM	10.5	ELT	21.1	CHEM	11.1	FB	8.0	ELT	7.4	LB	7.7	MUSS	3.1
8	METG	9.9	MUSS	20.5	METG	9.7	BM	7.7	FB	7.3	GLAS	6.6	SCHB	2.8
9	FO	9.6	STV	19.0	GLAS	9.2	STE	7.4	SCHB	7.3	STE	5.5	ELT	2.7
10	BM	9.3	METG	18.7	BM	8.3	ELT	6.3	KA	6.9	FB	5.4	R.NG	2.7
11	SCHB	9.1	BM	17.9	R.NG	8.0	PV	6.3	GLAS	6.3	OM	5.4	ZP	2.4
12	MUSS	8.8	FO	17.7	P-V	7.8	GLAS	6.2	METG	5.6	MINV	4.9	METH	1.9
13	ZKWW	8.7	MB	16.9	DV	7.8	R.NG	6.0	METH	5.5	ZP	4.9	S.NG	1.9
14	KA	8.6	BEKL	16.2	ZKWW	7.5	S.NG	5.9	NE-M	5.5	R.NG	4.7	EBM	1.6
15	GLAS	8.2	L-V	14.9	EBM	7.5	T-V	5.8	ZP	5.5	STB	4.3	NE-M	1.5
16	MB	8.3	ZKWW	14.7	S.NG	7.4	MUSS	5.7	FO	5.4	METH	4.1	CHEM	1.5
17	STV	8.1	KA	14.6	NE-M	7.4	DV	5.5	ESCH	5.3	SH	4.1	DV	1.5
18	NE-M	7.8	ESBM	14.2	KA	7.2	H-V	5.4	P-V	5.3	ZUCK	4.1	ESBM	1.4
19	ESBM	7.6	FK	13.9	METH	6.9	KA	5.2	STV	5.2	S.NG	4.1	KA	1.2
20	EBM	7.6	NE-M	13.8	H-V	6.8	BEKL	5.1	H-V	5.1	EBM	3.8	MUEL	1.2
21	METH	7.4	OM	13.1	ESBM	6.7	ZUCK	5.1	DV	5.1	P-V	3.7	SH	1.1
22	P-V	7.2	METH	12.9	ZUCK	6.6	EBM	4.9	EST	4.9	NE-M	3.4	STV	1.1
23	BEKL	7.2	ESCH	12.8	ESCH	6.5	METG	4.6	ESBM	4.8	KA	3.4	L-E	1.0
24	DV	7.1	EBM	12.8	MB	6.5	STB	4.5	EBM	4.7	ESBM	3.3	FO	0.6
25	R.NG	7.1	EST	12.7	T-V	6.5	MB	4.4	T-V	4.6	DV	3.3	P-V	0.5

26	ESCH	7.0	CHEM	12.6	STE	5.7	ZKWW	4.1	MB	4.5	ESCH	3.2	BM	0.5
27	S.NG	7.0	KS	12.0	ZP	5.7	ESBM	4.1	S.NG	4.4	ZKWW	3.0	H-V	0.4
28	T-V	6.9	ESTG	12.0	SCHU	5.7	L-V	3.9	R.NG	4.4	T-V	2.9	T-V	0.4
29	EST	6.6	GLAS	11.5	BEKL	5.7	NE-M	3.8	SH	4.4	BM	2.4	METG	0.0
30	H-V	6.6	STB	11.4	EST	5.6	METH	3.6	MUSS	3.9	EST	2.3	KS	−0.2
31	STE	6.4	STE	11.0	FO	5.0	KS	3.5	TEXT	3.6	STV	2.1	TEXT	−0.2
32	FK	6.2	T-V	10.4	L-V	5.0	FK	3.1	KS	3.5	TEXT	2.1	MB	−0.6
33	ZP	6.1	P-V	10.1	STV	4.9	ZP	3.0	FK	3.5	MB	1.9	FK	−0.8
34	L-V	6.0	S.NG	10.0	TEXT	4.8	TEXT	3.0	S.BB	3.2	S.BB	1.7	L-V	−1.0
35	KS	5.6	R.NG	9.7	MUSS	4.5	ESCH	2.5	BM	3.0	FO	1.7	OELG	−1.1
36	STB	5.2	DV	9.6	LED	4.1	SH	2.4	OM	2.7	KS	1.6	MINV	−1.5
37	TEXT	5.2	ZP	9.5	STB	3.8	EST	2.3	ESTG	1.9	SCHB	1.1	LED	−2.5
38	ZUCK	5.2	H-V	9.0	EIBB	3.5	STV	2.1	STE	1.7	MUEL	0.9	BEKL	−2.5
39	ESTG	4.4	TEXT	9.0	FK	3.5	LED	2.0	SCHU	1.6	METG	0.7	ZKWW	−2.6
40	SCHU	4.0	EIBB	8.1	SH	3.4	SCHU	1.7	BEKL	1.4	FK	0.3	STB	−2.6
41	LED	3.6	ZUCK	8.2	KS	2.9	S.BB	1.3	ZUCK	0.9	BECK	0.2	ESTG	−2.9
42	OM	3.6	LED	7.5	ESTG	2.3	KBB	0.7	STB	0.8	ESTG	−1.2	STE	−3.0
43	SH	3.3	SCHU	6.7	MUEL	1.6	OM	0.7	LED	0.6	MUSS	−1.8	KBB	−3.8
44	S.BB	2.4	S.BB	6.3	KBB	0.2	ESTG	0.5	L-V	−0.4	KBB	−2.0	EST	−3.8
45	L-E	0.9	KBB	4.7	SCHB	0.2	L-E	0.3	L-E	−0.6	L-V	−2.5	ESCH	−4.2
46	MUEL	0.5	L-E	4.0	L-E	−0.3	SCHB	−1.4	MUEL	−2.0	EIBB	−3.6	SCHU	−4.4
47	KBB	0.1	MUEL	3.7	S.BB	−1.4	MUEL	−1.4	KBB	−4.9	LED	−6.1	S.BB	−4.8
48	EIBB	−1.2	SH	2.9	OM	−2.7	EIBB	−10.4	EIBB	−7.8	SCHU	−6.8	LB	−5.3
49											L-E	−9.3	EIBB	−16.9
	GES	7.6	GES	12.5	GES	7.1	GES	5.4	GES	5.0	GES	4.4	GES	0.6

[a] Abbreviations overleaf.

SOURCE: Kleinknecht (1979, pp. 328ff.); calculations on the basis of the data of Krengel *et al.* (1978).

Abbreviations in Table 2 (previous pages)

KBB = Coal mining
STBB = Hard coal mining
BRBB = Lignite coal mining
EIBB = Iron ore mining
KS = Potash and rock salt mining
OELG = Petroleum and natural gas extraction
S.BB = Other mining
STE = Building materials industry
EST = Iron and steel industry
ESCH = Iron making industry
ESTG = Iron and steel foundries
ZKWW = Steel drawing and cold-rolling mills
NE-M = Nonferrous metals industry
METH = Nonferrous metals smelters refineries, secondary smelters, semi-manufacturing industry
METG = Nonferrous metals foundries
CHEM = Chemical industry (including coke oven by-products and chemical fiber production)
MINV = Petroleum refining
KA = Rubber and asbestos manufacture
SH = Saw mills and timber processing
ZP = Woodworking, cellulose, paper and board industry
STB = Steel construction
MB = Machinery construction
BMDV = Production of office and data-processing machines
FB = Vehicle construction
SCHB = Shipbuilding
LB = Aircraft construction
ELT = Electrical equipment
FO = Precision engineering and optical industry (including watches)
ESBM = Hardware and metal goods, including steel forging
STV = Steel forging
EBM = Hardware and metal goods industry
FK = Fine ceramic industry
GLAS = Glass industry
H-V = Wood manufacture
MUSS = Musical instruments, toys, jewelry, and sports articles
P-V = Paper and board manufacture
DV = Printing and duplicating
K-V = Plastics manufacture
LED = Leather industry
L-E = Leather manufacturing industry
L-V = Leather processing industry
SCHU = Shoe industry
TEXT = Textile industry
BEKL = Clothing industry
MUEL = Grain milling
OM = Edible oils and margarine industry
ZUCK = Sugar industry
BM = Brewing and malting
S.NG = Other goods and beverages
T-V = Tobacco manufacture
R.NG = Food and beverages, other

whole product palette, in the electrical equipment industry, chemistry and vehicle construction industry, the influence of basic innovations is likely to be less significant because these lines were already fairly well developed before World War Two. In the statistics of these industries for the 1950s and 60s, old and new products are mixed together. We assume, however, that the probable growth effect of the innovations will be evident here nevertheless (if to a lesser degree). On the other hand, we must presume that the influence of the other 8 basic innovations, which are distributed among the machinery, precision instruments and optical industry, printing and duplicating, iron and steel, and non-ferrous metals industries, cannot be investigated at the given level of aggregation. More finely aggregated data are difficult to obtain from the official statistics; for this reason, the effect of these basic innovations on growth has been omitted in this paper.

For the purpose of testing the growth-intensity of 48 branches of West German industry (manufacturing and mining), the growth rates of industrial net production at constant prices from the study of Krengel *et al.* quoted above were taken. For a better overview, the arithmetical averages of annual growth rates for the entire period of the "economic miracle" as well as for subperiods have been calculated (see Table 2). The subperiods between 1950 and 1969 are identical with the economic cycles, dated from peak to peak. The growth rates of industrial net production served as rough indicators of cyclical development; their respective maxima mark the upper turning points (for further details see Kleinknecht 1979, pp.326ff.). A first result is given in Table 1.

In Table 2, the arithmetical averages of the yearly percentile growth rates for the individual subperiods are compared with those for the long period 1950–1969. The 48 industries have been arranged in each column according to their ranking by rate of growth. This rank order we call the cross-sectional growth hierarchy.

The hierarchy in Table 2 confirms that the "innovation industries" which we have identified in Table 1 are identical with the top-ranked growth industries. This is evident both from the general overview of 1950–69 (column A), as well as from the subperiods (columns B–E), although with slight modification. The first cycle (1950–55) occupies a somewhat special position: because of structural change processes initiated by the division of Germany, as well as the special conditions of the postwar reconstruction, numerous industries which later lie in the middle or even in the lower end of the scale still demonstrate a relatively high average growth rate (a total of 26 out of 48 industries lie above the general average of 12.5%). In spite of this relatively broad distribution of growth rates, five out of the six innovation industries are located at the top. Only the chemical industry falls back – despite its 12.8% growth rate – to 26th place. In the second cycle (1955–60), the aforementioned influences appear to lessen: here all six innovation industries occupy the top positions on the rank scale (oil drilling can be categorized for our purposes as part of the petroleum industry). Only in the third cycle does the precision instruments and optics industry move up to 5th place; in the fourth cycle the extrusion and cold-rolling mills come up to 6th place. Since both of these industries occupy the middle ranks in the rest of the cycles, the hierarchy of growth rates up to 1969 is hardly affected thereby. Thus, the acceleration phenomenon stated in the Speed of Growth Hypothesis H_1 is valid.

Also the slowdown phenomenon stated there must be taken as an empirical fact. The growth rate hierarchy begins to dissolve after 1969, as is documented by the rising number of exceptions; by the last time period (1973–1977), it has disappeared entirely: accelerated growth has leveled out. However, we should interpret the data for the latest period 1973–77 with a certain degree of caution, since this period covers no complete cycle (downswing and upswing). As investment goods industries in general are subject to greater fluctuations in the course of the cycle than are consumer goods industries, it is not surprising that within this incomplete cycle a series of consumer industries have climbed to the top of the scale. Thus, the obvious diminution of the growth impetus of the prior innovations may appear somewhat overestimated by these data. When the data for 1978 and 1979 (and possibly for 1980, depending upon how long the present upswing lasts), are included, it is quite possible that the position of electrical equipment or of aircraft construction will still improve. Nevertheless, it can be expected that the process of relative decline in the ranking of the innovation industries will persist. It is also significant in this connection that the "production of office and dataprocessing machine" (BMCV), a "newcomer" among the innovation industries (it has been separated out of the machinery industry since 1970), has already achieved a position at the top of the ranking.

A further confirmation of the acceleration–stagnation pattern results if one reads Table 2 vertically: the growth industries should demonstrate growth rates over all economic cycles from 1950 to 1969 which lie above the general average. This criterion is relatively rigorous, because the above-average growth rates themselves are included in that average. If we apply this longitudinal criterion, the cross-sectional hierarchy already observed is reconfirmed. Besides a group of nine industries* which consistently achieve above-average growth rates in three out of four cycles, only the six innovation industries show above-average growth rates in all four cycles.

Figure 2 and Table 3 summarize the dominant influence of the "innovation industries" on the whole industrial sector. During the 1950s and 60s the weighted average growth rate of the "innovation industries" was much higher than that of the other industrial lines. In the late 60s and the 1970s, the relative slowdown of the innovation industries is documented by decreasing differences of their growth rate from the average growth rate of the other sectors. Thus the Speed of Growth Hypothesis ought to be taken as an empirically established fact.

An open question remains in this context: does the industrial train slow down because the locomotive (the innovation industries) doesn't pull as fast as it used to, or does the engine actually brake, as is suggested by the sharper downturns of the broken line in Figure 2 ?

*This concerns the following industries: extrusion and cold-rolling mills, nonferrous metal processing, rubber and asbestos manufacturing, precision mechanics and optics, glass, paper and cardboard processing, printing and duplicating, and the brewing industry.

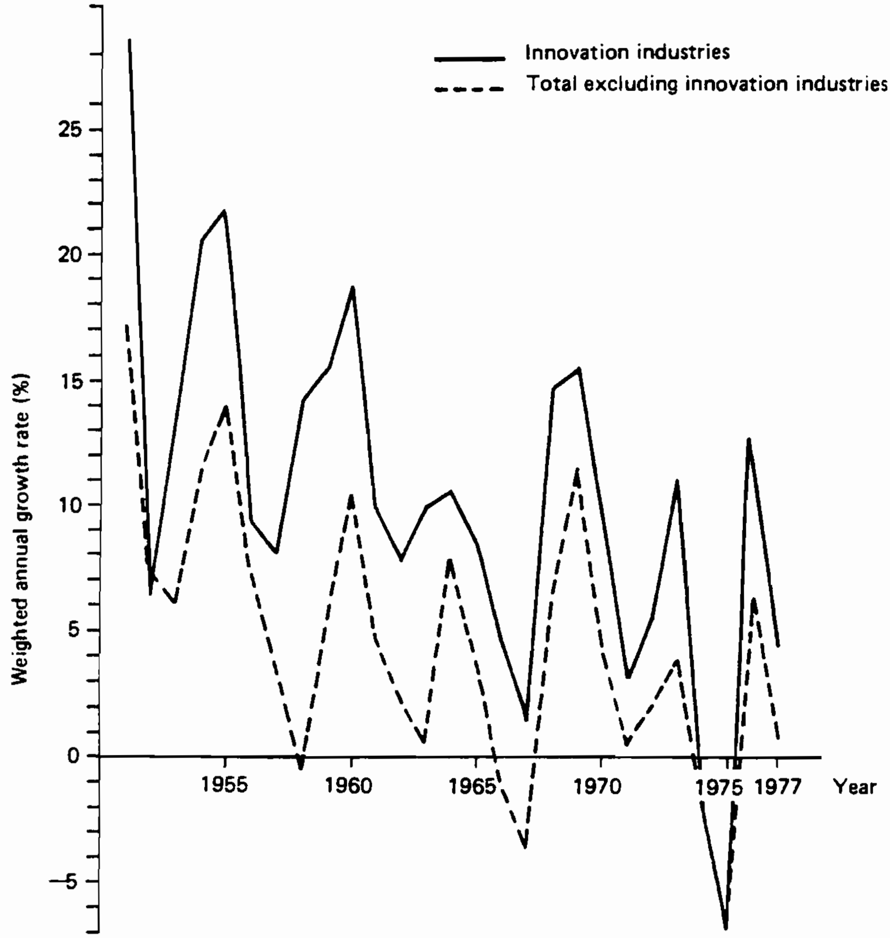

FIGURE 2 Influence of the innovation industries on the industrial sector.

CONCLUSION AND OUTLOOK

We have taken the general view of a cyclically changing course: instability of the economic system will result in a spurt of basic innovations, which will provide for additional growth potentials. These will then be exploited at the typical dynamics often described by means of the lifecycle concept.

This scenario emerged from observation of the past. Statistical analysis of the industrial production data of West German industry 1950–77 reveals that the Speed of Change Hypothesis is valid: those branches of industry which were most affected by basic innovations in the

TABLE 3 Comparison of annual weighted growth rates of total industry, innovation industries, and total industry excluding innovation industries.

Year	1	2	3	4 = 2 − 1	5 = 2 − 3	6 = 1 − 3
1951	19.1	28.7	17.1	9.6	11.6	2.0
52	7.1	6.5	7.2	−0.6	−0.7	−0.1
53	7.4	13.5	6.1	6.1	7.4	1.3
54	13.1	20.6	11.3	7.5	9.3	1.8
1955	15.6	21.9	14.0	6.3	7.9	1.6
56	7.9	9.3	7.5	1.4	1.8	0.4
57	4.5	8.1	3.5	3.6	4.6	1.0
58	2.9	14.1	−0.5	11.2	14.6	3.4
59	7.8	15.4	5.3	7.6	10.1	2.5
1960	12.3	18.7	10.2	6.4	8.5	2.1
61	6.0	9.9	4.7	3.9	5.2	1.3
62	3.7	7.9	2.2	4.2	5.7	1.5
63	3.2	9.9	0.6	6.7	9.3	2.6
64	8.6	10.5	7.9	1.9	2.6	0.7
1965	5.4	8.7	4.0	3.3	4.7	1.4
66	0.7	4.6	−1.0	3.9	5.6	1.7
67	−3.0	1.7	−3.6	4.7	5.3	0.6
68	9.0	14.8	6.4	5.8	8.4	2.6
69	12.7	15.5	11.3	2.8	4.2	1.4
1970	6.2	9.7	4.4	3.5	5.3	1.8
71	1.6	3.1	0.8	1.5	2.3	0.8
72	3.2	5.5	2.0	2.3	3.5	1.2
73	6.5	11.0	3.9	4.5	7.1	2.6
74	−2.0	−2.2	−1.9	−0.2	−0.3	−0.1
1975	−6.8	−6.6	−6.9	0.2	0.3	0.1
76	8.8	12.8	6.4	4.0	6.4	2.4
77	2.3	4.6	0.9	2.3	3.7	1.4

NOTES: The annual growth rates are weighted with the relative contribution to total production.
Column 1: Total industry (48 branches of manufacturing and mining).
Column 2: Innovation industries (weighted average growth rate of chemicals, petroleum refining, automobiles, aircraft construction, electrical equipment, and plastics manufacturing).
Column 3: Total industry excluding innovation industries.
SOURCE: Krengel *et al.* (1978, pp. 6, 8), and authors' own calculations.

1930s and 40s are the branches with fastest growth during the prosperity phases after the war. And the slowdown of this growth in the 1960s and 70s we attribute to the fading of the innovation impetus.

This fading and slowdown in recent years, is, we think, coupled to an imbalanced type of structural change which has created a state of structural instability in the economy, which in turn provides the preconditions for another spurt of basic innovations in the years to come.

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PART TWO

NATIONAL INNOVATION POLICY IN DIFFERENT COUNTRIES

INTRODUCTION

Jennifer Robinson

Assume that you are a national policy maker and that you believe that technological innovation is an integral part of economic growth and of adaptation to changing circumstances. What do you do? How do you decide what measures to employ? What effect do these measures have?

Obviously, your choice is affected by the economic system within which you operate, by your national needs and resources, by your ideology, by what you know about technology, and by how you and your political constituency react to all of these factors.

This section includes papers describing policy responses to the questions of managing technological innovation in different countries. There is considerable variety among the papers it contains.

In centrally planned economies technological innovation policy is tightly interwoven with existing planning procedures, and is much more goal oriented than in market economies. Thus the three papers from planned economies in this section, those by Pokrovski and by Glagolev, both from the USSR, and by Szanto from Hungary, all deal with planned innovation, discussing topics such as fitting innovation into socioeconomic development plans, making the innovation process function well within existing institutional frameworks, and keeping innovation goal directed. The paper by Glagolev provides a clear, brief overview of the decision making hierarchy through which science and technology policy is worked out in the USSR. Pokrovski's paper covers much of the same ground as Glagolev's but puts less emphasis on the framework and more on the activities taking place within the framework. The paper by Szanto is considerably more conceptual and philosophical than the two Soviet contributions; the first part of the paper sets forth a theory of innovation and planned innovation. Only the second half pertains specifically to Hungary.

In the market economies relatively little concern is shown for coordination of innovation policy with overall development plans, for the obvious reason that central plans do not exist. Instead, innovation policy is oriented toward stimulating (or not blocking) innovation and directing it toward fulfillment of societal needs in a context of technological laissez faire. Approaches to the subject, like this collection of papers, vary from piecemeal and ad hoc measures to fairly comprehensive planning.

We divide the market economy papers into two groups: those looking at specific, partial measures and those aimed at more comprehensive development of national policy. In the first group come papers by Jörgensen and by Schwarzkopf which describe specific programs. Jörgensen and Schwarzkopf describe respectively Swedish and US programs to assist inventors; the Swedish program is intended as an aid to inventors; the US program is ostensibly conducted to gain information on the process of invention and how it can be promoted. These are followed by a paper by Burkhardt which describes the use of public procurement as a means of stimulating innovation in the Federal Republic of Germany.

In the second group are papers by de Graaf and Tindemans, by Chaloupek, and by Eto which describe recent evolution of more comprehensive national innovation policies. Two of the countries described, Holland and Austria, have not, at least until recently, taken much public action to stimulate innovation. The third, Japan, has a somewhat longer tradition of government involvement in technological development. Chaloupek's paper on Austria largely reports events and statistics with only occasional interpretation or philosophizing; the de Graaf and Tindemans paper on Holland's innovation policy deals much more with the conceptualization behind the recently announced Dutch innovation policy. Eto describes historical and cultural factors, seeking in them an answer to the question of why Japanese industry has largely contributed improvement (as opposed to basic) innovations.

PLANNING THE DEVELOPMENT OF SCIENCE AND TECHNOLOGY IN THE USSR

Vladimir Glagolev

The USSR was the first country in the world to recognize the necessity of formulating science and technology policy and implementing it on the basis of a system of plans. The first steps in this area were taken in the first years of the Soviet system. National industrialization on the basis of electrification was the main core of economic, science, and technology policies. In 1920, 3 years after the revolution, the first long-term plan (10 years) of Russian electrification (the GOERLO plan) was worked out and successfully completed ahead of schedule. It was the core of an all-round expansion of the economy on the basis of mechanization. On the basis of the GOERLO commission the State Planning Committee was later established. It is interesting to note that 56 years later, a similar body was established in the USA: the Energy Research and Development Administration (US Congress 1974), with objectives that sound like GOERLO objectives.

Understandably, the methods of drafting the GOERLO plan were far from perfect, there being no experience of nationwide planning at that time. There is now a comprehensive planning system for the development of science and technology in the USSR, which is the basis for the implementation of science and technology policy. It includes the following hierarchical levels:

- long-term forecasts for the development of science and technology; a comprehensive program for scientific and technical progress and its social and economic effects (draft);
- programs to resolve key scientific and technical problems;
- state 5-year and annual plans for science and technology;

- economic branch 5-year and annual plans for science and technology;
- union republic 5-year and annual plans for science and technology;
- associations, organizations, and enterprises 5-year and annual plans for scientific and technical progress.

Let us have a closer look at the upper levels of this system.

Long-term forecasts for the development of science and technology include retrospective analysis and the prediction of development trends. Forecasting is the initial stage of planning, which is based on the detailed study of factors affecting the development of science and technology in the past and the present as well as in the future. Forecasts give some possible variants of how the stated task might be performed, depending on conditions.

From the planning process point of view, a long-term forecast for the development of science and technology requires the following:

- prediction of the main probable developments in the future with estimates of the earliest and latest that a forecast event may take place
- evaluation of the areas in which predicted developments may be useful and the determination of the volume of resources (raw materials, labor, energy, finance, etc.) needed for their implementation
- assessment of the social and economic effects of forecast developments in order to take them into account in long-term plans and to coordinate them with other forecasts.

The Presidium of the USSR Academy of Sciences provides guidance for the work on drawing up forecasts. The State Committee for Science and Technology provides guidance on the application of science and technology.

The comprehensive program for scientific and technical progress and its social and economic effects is presently in draft form. Academic institutes, jointly with ministries, departments, and planning bodies, continue the work on the improvement of this program. This program is becoming an integral part of the planning system for the development of science and technology, connecting 5-year plans with forecasts.

Programs to resolve key scientific and technical problems are worked out on the basis of forecasts and the Comprehensive Program for Scientific and Technical Progress and Its Social and Economic Effects. This program cover projects of an applied nature which have a fairly high probability of achieving their intended results. Most such programs have a multidisciplinary and intersectoral character, which means their solution requires a whole complex of work to be carried out from research stage to their application and production.

Examples of such programs (Dzhavadov 1978, Kosygin 1976) are the following:

- developing the production base of nuclear power generation;
- creation of large power block units for thermal generating stations;
- mechanizing manual and arduous labour in the national economy;
- protection of the environment.

Programs to resolve key scientific and technical problems occupy a special position in the planning system for the development of science and technology. From the point of view of the time horizon they jointly, with the Comprehensive Program for Scientific and Technical Progress, serve to link 5-year planning with long-term forecasting. From the point of view of planning process organization they establish the main scientific and technological targets in the 5-year plan, especially in the section entitled "Solving the Main Scientific and Technical Problems." Elaboration of programs must be carried out prior to the drafting of the 5-year plan as program tasks are included in the 5-year plan.

The main purposes of the programs are the following:

- formulation of the aims and targets of work at each stage of the program;
- ensuring continuity of the innovation process and consistency in the fulfillment of the work;
- coordination of activities among scientific research, project design organization, and industrial enterprises participating in the solution of a specific problem;
- securing the necessary resources for program targets.

Completion dates are fixed for each program, the organizations responsible for the work and the financing organizations are named, and the cost confirmed. Up to 50 ministries and departments of the USSR participate in the fulfillment of some programs. In some cases as many as 500 scientific research and design organizations and industrial enterprises become involved in program execution (Dzhavadov 1978).

Program drafts are elaborated by the main ministries (departments) responsible for the solution of the corresponding problems as a whole, with the cooperation of ministries and departments whose involvement is necessary for the fulfillment of these plans. All disagreements or conflicts which arise are resolved by the State Committee for Science and Technology. This committee considers and approves programs, introducing appropriate changes where necessary. After that, programs become directive documents and the tasks they set forth are obligatory for all ministries and departments.

The main form of state planning for the development of science and technology, as for the whole national economy, is the 5-year plan. It is elaborated on the basis of a long-term forecast, the Comprehensive Program for Scientific and Technical Progress and Its Social and Economic Effects, Programs to Resolve the Key Scientific and Technical Problems.

The principle of combining centralized planning from "above" with proposals from "below" is broadly used in the course of plan elaboration.

At the present time the Five Year Plan for Science and Technology consists of the following sections:

- solving the main scientific and technical problems
- starting new methods of industrial production
- mechanization and automation of production processes and introduction of advanced technology
- selling of Soviet licenses abroad and buying of foreign licenses
- application of computers in the economy
- state standardization and metrological servicing of the economy
- improvement of management and labor organizations
- main indices of the technical and economic level of production processes and output
- financing of scientific research works
- training of scientific personnel.

The contents and designation of each section are as follows.

1. Starting New Methods of Industrial Production

This is concerned with products being developed for the first time in the USSR or essentially modified. An average of approximately 4000 new types of machinery, equipment, apparatus, instruments, and automation means have been developed and initiated per year over the last 10-year period. But a yearly average of only 1170 in the period 1966–1970, 3300 in 1971–1975, and 3400 in 1976–1978 have achieved the stage of batch production (Statistical Yearbook 1978). Special attention is paid to improvement of the technical and economic characteristics of machinery and productivity and reducing material intensiveness.

2. Production Process Mechanization and Automation and Introduction of Advanced Technology

This is concerned with measures for supplying and equipping branches of the national economy with advanced machinery based on the use of high speeds, pressures, and temperatures.

At the present time particular attention is being paid to technical re-equipping of the national economy by transferring to the production and wide-scale use of highly productive systems of machinery, equipment, instruments, and technologies, ensuring comprehensive mechanization and automation of entire technological production processes, including auxiliary, transport, and warehousing operations, replacing individual machines and technological operations. Such systems of machinery have higher technical, economic, and other indices of performance than individual machines. Special attention is paid to the production of machinery and equipment for labor-intensive processes and industries in which mechanization could release large numbers of workers for other employment.

This section also contains the tasks for raising the level of mechanization and automation. As shown by the data in Table 1, in USSR industry both the proportion of workers controlling or monitoring machinery and their total number has consistently increased. In 1975 more than 45% of all workers were engaged in controlling or monitoring machinery. The fraction of workers feeding and unloading machines and performing manual tasks not using machinery decreased in the period 1959–1975 by about 13 percent. Further mechanization and automation of labor is one of the main social and economic tasks for science and technology development (see Table 1).

TABLE 1 Statistics describing labor mechanization and automation in industry, 1959–1975.

Task	Percentage of total, by year				
	1959	1965	1969	1972	1975
Controlling or monitoring machines	35.8	40.3	42.4	44.3	45.5
Feeding and unloading machines	9.3	7.9	7.3	7.1	7.3
Manual tasks not using machinery	45.4	40.6	38.2	36.0	34.6
Repair and maintenance of machines	9.5	11.2	12.1	12.6	12.6
TOTAL	100	100	100	100	100

SOURCE: Glagolev (1975).

3. Application of Computers in the National Economy

This section establishes tasks with respect to the creation of computer-aided control systems (automated systems of management in Russian terms) for managing enterprises, production associations, scientific organizations, and regional bodies, and for controlling technological production processes. In the first 3 years of the tenth 5-year plan (1976–1978) more than 1100 computer-aided systems were brought into operation at various levels of management of the national economy (Table 2). Performance indices indicate that computer-aided systems for production enterprises and associations are effective in mechanical engineering; for example, they have led to a 5–6% increase in labor productivity, a 2–4% reduction in the need for raw material inputs, and a reduction in the stocks of material and made-up components of optimum dimensions.

4. State Standardization and Metrological Servicing of the Economy

A whole set of measures is envisaged in this section concerning the standardization of raw materials, industrial supplies, and tools and other items whose quality has a decisive influence on the productivity, reliability, and durability of machinery and other capital goods. This section also deals with the functional properties of consumer goods.

The main task of this section is planning for improvement of product quality. A set of generalized and differentiated indicators is used for this purpose. Procedures for certifying the quality of manufactured goods on the basis of three categories of quality have been established in each branch of the economy. Coefficients increasing contributions to the

TABLE 2 The development of computer-aided control systems in the USSR.

	1966–1978	1971–1975	1976–1978
Number of computer-aided control systems	3,885	2,309	1,162
Management information systems (MIS) in use in enterprises	1,207	838	218
Automatic production process control systems	1,329	564	595
MIS in ministries and departments	239	168	52
MIS in regional organizations	922	631	230
Automated systems for processing information	188	108	67

SOURCE: Statistical Yearbook (1978).

bonus funds from profits made through increased sales of top quality goods are established, while coefficients that lower the standard rate are applied to output of category 2 (out-of-date) goods.

5. Training of Scientific and Scientific-Pedagogical Personnel

This section of the plan stipulates the number of postgraduate students to be accepted in universities and scientific research institutions and the different scientific specialities in which they will graduate. One of the main tasks of this section is to foresee in good time the change of scientific personnel structure and to establish new specialities in accordance with the needs of scientific, technological, and national economic development.

CONCLUSIONS

In order to speed up the innovative capacity of the national economy a further improvement of planning systems and of economic incentives is necessary. Soviet planners and scientists are presently working on the problems of the improvement of coordination for plans of various time horizons, the choice of the system of planning indicators for plans of various time horizon, and on methodological problems of working out scientific and technical programs, including improvement of the system of financing and economic incentives for work on the programs.

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GOALS, DIRECTIONS, AND PROBLEMS OF INNOVATION POLICY IN THE USSR

V.A. Pokrovski

INTRODUCTION

Technological progress under Socialism is directed toward promoting the personal development, material welfare, and intellectual needs of working people. Scientific and technological policy is central to the development of the Soviet state. Since 1917 the USSR has developed significant scientific and technological capacity. Research and development is carried out in thousands of scientific institutions, in hundreds of higher educational establishments, in over 200 R&D and production amalgamations, and in tens of thousands of design and development organizations and departments within amalgamations and enterprises. The science and technology sphere employs more than 4 million people including 1.3 million researchers and teaching staff.

We take pride in the accomplishments of our own scientific and technological work force, including:

- a high average percentage of annually introduced new product lines (from 3–4 percent some 25 years ago to 8–9 percent at present);
- economic growth through assimilation of new technology: the GNP has expanded from 12.3 billion rubles during the ninth 5-year plan period (1970–1975) to 20 billion rubles planned for the current period;
- increased release of labor from labor-intensive industries through technological advance: in the ninth 5-year plan period 9 million people were so released and in the tenth, 11.85 million (as planned).

Conscious, goal-oriented guidance of social development, including the scientific and technological development, is a cornerstone of Marxism. Centralized management of science and technology in the USSR is based on the premise of public ownership of the means of production. The need for centralized management and direction of science is increasing owing to the increasingly complex nature of scientific research. Development of stronger ties between science and the branches of the national economy plays a critical part in this process and serves to enhance the effectiveness of the interbranch management of science.

An essential feature of the Soviet science and technology policy is its long-range nature and orientation toward restructuring the entire technical base of the national economy. Accordingly, ever-increasing emphasis is placed on the development of long-term technological forecasts. A good example of how long-range policy is being used to bring about unified technological and social advance is provided by the Comprehensive Program of Scientific and Technological Advance. This program was elaborated on the basis of technological, social, and demographic forecasts prepared by tens of thousands of scientists and leading specialists of this country.

The State Committee of the USSR for Science and Technology (GKNT) is responsible for pursuing a unified national policy on innovation and the application of technological achievements in the national economy, the identification of major trends in science and technology in the USSR, and organization of activities aimed at the solution of interbranch technological problems through program planning and supervision of the major technological programs.

The USSR Academy of Sciences, which includes the country's most prominent scientists, is responsible for coordinating research; the Academy initiates major research programs based on fundamental discoveries of great scientific and national economic significance. For instance, the Academy's 1976-1980 plans envisage more than 500 fundamental research programs and 84 research directions. Work on these problems will provide new tools for managing natural and social processes and advancing production technologies. To speed up the practical application of research discoveries, problems are jointly tackled by a multitude of industrial research institutions, design establishments, and factory laboratories.

Research and development has an economic effect only when its results are introduced into practice. Thus one Article of the Constitution of the USSR reads "In accordance with society's needs the State provides for the introduction of the results of research in the economy and other spheres of life." This implies that government action results in an accelerated application of innovations. The national policy of innovations in the USSR contains three major elements: planning, organization, and incentives. Let us consider each of the elements separately.

Planning

Planning of scientific and technological research is central to the entire system of managing the socioeconomic development of society. Science planning in the USSR takes place within the context of national 5-year plans. The 5-year plans contain a special section "Development of science and technology" broken down into subsections such as scientific and technological problems, assimilation of new product lines, introduction of advanced technology, mechanization and automation of production processes and computer-based management systems, financing of research and development, and training of scientific personnel and teaching staff.

This section identifies primary lines of research. It is oriented toward the satisfaction of the most pressing and long-range needs of the country's population.

As a complement to the assignment of priorities in the Comprehensive Program, prospective lines of research and development are continuously identified. This is the responsibility of scientists and specialists on the science boards of the Academy of Sciences of the USSR and the State Committee for Science and Technology and of temporary science and technology committees and expert groups set up by the latter.

A unified national innovation policy specifies for each 5-year plan period the direction of technological advance determining the prospects for long-range economic development. In the tenth 5-year plan period, for example, the directions for specific areas are as follows.

Implement production. Increased output per unit capacity of machinery and plants; shift of focus from development and introduction of individual implements to development and introduction of integrated production systems; mechanization and automation of labor-intensive types of production; supply of proper raw materials; technological process improvement; development of technology that is efficient in its use of basic materials, fuel, and materials, and protection of the environment.

Energy engineering. Rapid development of atomic powerengineering, construction of hydraulic power stations and super-high-capacity coal-fired power plants, development of large, more efficient turbogenerators, discovery and exploitation of new energy sources.

Construction materials. Increased production of high quality steels, especially by electroslag and vacuum remelting, greater mix of rolled steel, increased proportion of aluminum and titanium in the total output of construction materials, production of synthetic materials.

Particularly high and steady rates of development are noted in branches of industry that are vital and central to technological progress, such as electrical engineering, oil and gas production, chemistry and electronics, machine building, and production of automatic control facilities.

The unified policy of innovations covers the entire cycle from research to design to production to utilization. This permits accelerated introduction of top priority innovations. To improve further the planning of science and technology the USSR, starting from the present (tenth) 5-year plan, is elaborating programs to cope with the nation's most pressing scientific and technological problems. These programs should provide useful means of speeding technological advance as they concentrate resources on the attainment of specific results. Under these programs, most development of computer-based management systems and technological processes and materials is transferred to industry. The targets specified in the programs are supported by adequate resources and integrated with national plans for production, capital construction, and inventory.

A central issue in the formulation of goal-oriented technological programs is the selection of an operating subsystem. Technological achievements are applied more efficiently when an interdepartmental technological and economic assessment of finished projects is planned, the branches of the national economy extensively applying the innovations are predetermined, and the plans of respective ministries and agencies include the selected projects.

The program planning at the industrial level is managed through a system or orders in which organizations and enterprises producing resources needed in R&D are charged with filling R&D orders. Each such order outlines the R&D objectives, the performance characteristics of a newly developed technology, and the areas of its application; its resource requirements at different stages determines the project's aggregate costs, year-by-year financing requirements, and volume and source of bonuses.

On the basis of the unified technological policy, industrial science has moved from development and introduction of individual machines and processes to development, manufacture, and application of highly efficient systems on a large scale. For example, using the unified order system described above the Ministry of Electrical Engineering has developed and introduced a new unified type of asynchronous electric motor, A-4 type, in the remarkably short time of 5 years. By contrast, development of the preceding similar type A-2 took 12 years.

The development and introduction of innovations in the USSR is financed from the national budget and internal sources of ministries and departments. The national budget provides financial support primarily to the activities related to major technological problems and important fundamental scientific research. Most financing of science and technology is carried out in a centralized manner through the national plan.

Science financing plans specify total costs, including those associated with the most important technological problems, wages funds of research institutions, and sources of financing these expenditures. The amount and priority of funding for a scientific or technological venture is determined mostly by its economic feasibility and estimates confirming its socioeconomic effectiveness. In order to secure a bank of scientific ideas from which new discoveries can be drawn, a sizeable portion of the total science budget is allocated to fundamental and exploratory research.

In line with the Decree of July 12, 1979, of the Central Committee of the Communist Party of the Soviet Union (CPSU) and the USSR Council of Ministers on "Improvement of planning and increasing the effect of the economic mechanism on raising the efficiency of production and the quality of work," all industrial ministries and departments are establishing unified funds for scientific and technological development aimed at financing R&D and technological programs. These cover projects related to the development and introduction of new products and technological processes and scientifically based work standards as well as the financing of product quality programs and the payment of overheads during the initial years of the new product manufacture.

Centralized financing has the advantage of allowing goal-oriented commitment of resources to the development of science and technology, reallocation of resources between various branches, and tighter control over the efficiency of investments. Transition to a single multi-industrial source of innovation financing makes it possible to initiate goal-oriented planning of research and development and the introduction of new technology.

Organization

The organizational goals of national science and technology policy are primarily directed toward building closer relationships between science and industry.

The existing organizational structure of science and technology management involves three principal hierarchical levels: the national economic level, the branch level, and the level of industrial organizations. The growing scale of science development has necessitated deep qualitative changes, the most important and promising of which concern various forms of science and production integration at the national economic and industrial levels.

Science and production integration involves transformation of the way different R&D stages are integrated. This depends on the scope of the scientific activities the branch or subbranch conducts. Integration takes place within the following hierarchies:

- research laboratories, design bureaus, technological services directly at enterprises;
- research institutes within large-scale production amalgamations and enterprises;
- integrated research establishments containing, apart from research units, the design, technological organizations and pilot (experimental) production;
- R&D production amalgamations affiliating research institutes, design and development units, pilot production, centers of personnel training, and development of branches (subbranches) of industry and other organizations contributing to the "research-production" system with regard to specific features of a given branch (subbranch) of industry and amalgamation;

- academic, scientific, and technological complexes set up within the framework of the Academies of Sciences;
- research centers in large economic and administrative regions with a spread system of research establishments, design and development bureaus and pilot production.

The way the ties between science and industry should be strengthened was outlined in the 1973 Decree of the Central Committee of the CPSU and the Council of Ministers "On certain measures for further improvement of industrial management" which provided for transition to two- and three-level systems of industrial management as well as the establishment of various amalgamations. Consistent with the general schemes of industrial management the amalgamations have become the central link of industry. There are 3800 amalgamations (including over 200 R&D and production amalgamations) in the USSR, whose output accounts for about 50 percent of industrial produce.

The distinguishing feature of the current stage of the scientific and technological revolution is the combination of science and production and the coordination of planning, organization, and management of science and technology with production activities. This is most fully realized within the R&D and production amalgamations. The emergence of the latter reflects the elimination of overlapping and duplicating of activities in the "research-production" cycle. The major task of R&D and production amalgamations — acceleration of technological advance — is achieved through optimal organization of the "research-production" process, through greater contribution of science to production potential and through concentration of resources in specific sections of a branch (subbranch). For example, the "science-intensity" index of "plastpolymer" R&D and production amalgamation of the chemical industry is twenty times higher than the industrial average.

At present about two thirds of R&D and production amalgamations function within the All-Union industrial amalgamations, i.e. the middle management link, and the remaining ones report directly to ministries.

Coherent cross-cutting long-range plans covering all the links of the "research-production" cycle drastically reduce the lead time of new technology (1.5–2 times as intermediate "delivery-reception" stages compared to the same activities in industrial enterprises). Amalgamation of R&D and production yields high rates of efficiency, growth, returns on investment, circulation of current assets, etc. An analysis comparing a group of research establishments affiliated in 12 R&D and production amalgamations with similar organizations outside amalgamations indicated that the economic efficiency of the former is 1.5 times higher than that of the latter, the number of patents issued is twice as high, and the share of the most significant project is three times higher.

Emphasis on scientific and technological development increases the responsibility of the aforementioned amalgamations for the ultimate results of R&D. They exert great influence on the performance of branches (subbranches) of the national economy, speeding up the renovation of production facilities and the technical base. For example, the introduction of a technique developed at the "Sojuznauchplitprom" amalgamation which sharply increased the output of technological lines made it possible to more than double the design capacities in chip-board production. The fraction of the labor force engaged in such amalgamations in the development and rapid introduction of new technology has tended to increase. According to the data collected from over 30 amalgamations of this type, 17% of the employees are engaged in research activities, 22% in development, 4% in design, 2% in experiments, 2% in mounting and tooling, 48% in pilot production, and 5% in managerial and administrative activities.

Centralization of management is an important part of the overall strategy of science and technology development. Centralization provides for a unified technical and economic policy, brings closer the interests of different groups of employees, increases the concentration of efforts and means for most perspective research directions, reduces the managerial staff, and opens up broad opportunities for the application of computers and office equipment and the transition to computer-based management systems.

The progressive integration between science and industry originates from the Academy of Sciences. In particular, the Siberian branch of the USSR Academy of Sciences and the Ukrainian Academy of Sciences successfully work on joint long-term scientific and technological programs in collaboration with ministries (departments). The Ukrainian Academy of Sciences initiated a new form of scientific complexes, the Academic Scientific and Technological Associations, which affiliate research institutes, big design bureaus, pilot production, and plants. Such a system provides for the closed-cycle fundamental research, design, development, and testing. Such associations drastically reduce the length of the "science-production" cycle.

Regular evaluation of their scientific and technical activities undertaken by ministries and departments takes place once every 3–4 years. This serves in times of change as a flexible tool for growing scientific activities towards new topics of research. These evaluations help identify scientific and technical opportunities for R&D, to assess the research activities on scientific and technical effectiveness of research and its impact on economic indicators, to promote economic efficiency, and to evaluate social and ecological implications of practical application of the newly developed techniques. These evaluations provide a basis for decisions about further development (or abandonment) of both the scientific organizations and separate research directions. Such decisions are important input to the scientific and technological policy, as they provide feedback needed for organizational improvements and to make the nation adaptable in tackling its long-range R&D problems. The results of the evaluation are also used in decision-making concerning lines of research and development, rates of scientific personnel training, allocation of resources in the field of science, etc.

Incentives

Development, assimilation and introduction of new technology provides employment for a powerful work force. Rapid development and assimilation of innovations is an important lever for raising the efficiency of science and technology.

Practice shows that emphasis on more extensive and rapid application of R&D results in a gradual transition of research organizations, amalgamations to a system of planning, financing, and economic incentives oriented toward the development, assimilation, and introduction of new technology. At present this system is operative in 15 branches of industry. In line with the recent (June 12, 1979) Decree of the Central Committee of the CPSU and the USSR Council of Ministers, this system is to be introduced throughout the industrial ministries and departments.

The procedure envisaged for the establishment of economic incentives is the creation of three economic incentive funds in scientific organizations — one each for material encouragement, a welfare and housing construction fund, and organization development. These will be used to a greater measure than ever before, as incentives to increase the interest of scientific organizations' personnel in the results of their activities. This interest is supported by the changes in the fund-forming indicators. The major ones are an actual (guaranteed) effect of introduction and the scientific and technical level of the ultimate result of a development. The principal behind the use of these funds is that workers have a right to share the profits which they have helped to make.

Previously the bonus for a new technology was paid out automatically irrespective of the wages fund. Now, the encouragement funds are created mostly from the money inflows from the enterprises after a new technology has been developed and introduced in production. The positive effect of the economic stimulation and material encouragement system is reflected in a greater R&D payback, and increased quantity of newly introduced products.

The branches of industry that pay serious attention to improving their organization for development and introduction of new products show higher R&D efficiency: for example, the Ministry of Electrical Engineering, which 10 years ago shifted to a special system of planning, financing, and economic incentives for new technology development and carried out a set of measures aimed at bringing science closer to production. In electrical engineering the economic effect of one ruble of investment committed to the development of science and technology is 2–2.5 times higher than that in other industrial ministries and departments. The aggregate annual economic contribution from application in the national economy of new technology developed by the scientific establishments and enterprises of the Ministry of Electrical Engineering are more than sixfold since the introduction of the new system of incentives.

More efficient use of a scientific and technological potential is noted also in other industrial ministries that have switched to this system. It is due to that fact that the aforementioned Decree of the CPSU and the USSR Council of Ministers made provisions for transferring all the industrial branches of the national economy to this system by the end of 1980.

Most new technology resulting from R&D is handed over for assimilation and introduction to industrial enterprises. However, both the indicators currently used for assessing the economic activities of enterprises and the standing procedure of pricing provide poor economic incentives for the industrial assimilation of new technologies. This is because the period of the new product assimilation, accompanied by the reduced output of established and highly profitable products, is characterized by the lower profitability of the enterprise as a whole and the volume of output in value terms.

A set of measures was instituted in 1979 that markedly raised the interest of industry in rapid introduction of innovations.

It is worth noting that a new indicator is introduced in the 5-year plans of industrial ministries, amalgamations and enterprises, namely "an economic effect of scientific and technological undertakings." Use of this indicator in planning decisions along with the targets on the share of higher grade products, stimulates the amalgamations (enterprises) to much faster utilization of innovations.

Until recently industry has had little interest in reducing the material intensity of its products, particularly of the newly developed ones, as frequently this resulted in lower production indices of amalgamations and enterprises. Hence a positive alteration was introduced both into the system of production indices (transition to pure product) and into the system of accounting products. Now, the wholesale prices of new, less material-intensive products are not reduced in a way that reduces the enterprise's profits until the end of a 5-year plan period. Consequently, enterprises (amalgamations) introducing material-saving changes do not face a reduction in profits, respectively, in the incentives fund.

To make industry more interested in the introduction of new technologies and in increasing output, it is desirable to reinforce the aforementioned measures with the following. Firstly, when planning the application of new technology in amalgamations, enterprises, and organizations, the ministries should not reduce the volume of economic incentive funds during the period of assimilation and introduction of the new technology. Secondly, it must be made a standing practice to invite the people from industrial enterprises to participate, from the early stages, in the development of new technologies that will eventually be used in their enterprises. Thirdly, to stimulate the industrial enterprises and amalgamations to renew and modernize the product mix promptly, the price of the new technology should depend mostly on the degree of improvement of its characteristics. Also, the prices for the assimilated products and those being assimilated must be established in a stepwise manner with regard to increased output and reduced production costs made possible by improvements in technological processes. Fourthly, the formation and utilization of the incentives fund, within the limits allocated to the enterprise, should to a greater measure depend on the rates of introduction of scientific and technological achievements.

In conditions of an ever-increasing "science intensity" of new products, the maximum realization of the potential economic effect of R&D is possible only through a whole set of planned, organizational, and incentives measures.

PLANNED INNOVATION IN THEORY AND PRACTICE: THE CASE OF HUNGARY

Borisz Szanto

WHY DEAL WITH INNOVATION?

The modernization of the industrial product structure is a current task of industrial policy in both the industrialized and the developing countries. This is so not only because if you do not modernize you will fall behind, but also because rapid scientific and technological development has forced reevaluation of the means of industrial policy. Consequently, new ideas, knowhow and inventions have been upgraded and the development of adaptive capacity and the factor of the organization has acquired more importance. Planned innovation has become one of the most significant means of scientific policy in the development of technology.

What does technology mean here? Technology equals:

- Tools and materials
- Knowhow
- Knowledge
- Experience
- Culture

Innovations may have different purposes, as for example:

(a) economic, profit-oriented innovation;

(b) economic, non-profit-oriented innovation;

(c) specific innovation (military, environmental protection, etc.);

(d) "l'art pour l'art" innovation.

THE THEORY OF INNOVATION IN ECONOMIC POLICY

Policy of Structural Modernization

No country's industrial policy can afford to ignore the minimal requirements of keeping up with the "today's" technological level. Selectively developing industry to narrow the excessively wide and scattered production list can work for this end by permitting us to concentrate our efforts and utilize increased international cooperation to gain access to the articles we no longer make.

The selective development of industry means that technology, too, concentrates its attacks on fewer and narrower fields. This is done in all the countries of the world, each being compelled to make selections when determining development goals. At present only the USA and the USSR can afford to engage in every branch of science and every area of development.

By selecting a few effective technologies that can be realized relatively fast and seem to offer large profits, even countries with poorer opportunities can remain close to the technological forefront.

Consequently, structural modernization policy is based on the selection of effective technologies, each resulting in the market realization of the largest amount of value added. This requires in turn that the product manufactured by the technology should have considerable price-forming power on the world market and, if possible, should not be very investment intensive.

In order to be capable of exercising a wider pull in industry, a technology must be new and original, and must have good market prospects. It is also important that the technology chosen should not be in contradiction of the socioeconomic principles of the society.

Novelty gives strength, because it is unexpected in the world market, but at the same time it creates problems for the industry and agriculture of an insufficiently developed country whose economic adaptive capacity* is not developed enough to handle it.

If, however, the new technology is really promising, the country should be able to achieve success despite its previously low level of technology. To do so, priority has to be given to institutes and companies of a higher than average technological level and adaptive capacity.

In the case of planned innovation we do not trust to chance: instead we try deliberately to discover and utilize the sources of innovation.

The strategy of production structure modernization relies on two principles:

(a) creation of the preconditions for a technological breakthrough by facilitating the discovery and utilization of resources for innovations that are strikingly new and are likely to affect pricing;

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*Adaptation readiness is the readiness and inclination of management to utilize the newest achievements of science. The adaptive capacity is determined by the firm's product (technology) market and intellectual potential.

(b) facilitating the increase of the general technological level.

Principle (a) is aimed at generating the effectiveness, the forward driving force of the innovation, and (b) at the improvement of the industrial and agricultural basis needed by the first. For (a) we need original invention and research results of our own; (b) is most efficiently realized through the purchase of licenses and knowhow. A relatively small and not highly developed country has a rather limited area in which technology can be brought to current standards by relying largely on domestic research and development. Such a country's research and development resources should be used to lay the foundations for forward-driving technologies and to make the most of these technologies. It is so much the better if the licenses purchased can be further developed at home by own results; this may then produce a pulling force as well.

Sources of Innovation

Strikingly original inventions are usually a matter of chance, but certain incentives may promote their emergence. Although individually made inventions cannot be neglected, the national research network is to be regarded as the main source of the active innovation in any given country.

From an innovation-centered point of view the range of action of the research network can be described as follows:

0. Widening the limits of our knowledge
1. Exploratory Research: "the study of new phenomena and relationships"
2. Research for Social Use: "the creation of innovation sources"
3. Technological Research: "Development, Experimental Production and Preparation of Production"
4. Selection of the most suitable technology when licenses are purchased
5. Facilitating adaptation after license purchase
6. Examination of the expediency of further research on development after the purchase of the license
7. Organizational work connected with innovation's realization.

Group A (definitions 1 to 3 as suggested by Balazs 1977) includes the classical activities of research institutes. The activities 0 and 1 represent basic research. These activities cannot be planned to result in innovation, for results depend on the research team and not on prefixed targets. In phase 1, however, researchers deliberately look for what is new and technologically exploitable.

In relation to Group A and Group B activities it should be noted that organizational work can be critical. In many instances public neglect has greatly increased the time required for an invention to progress to development. This is not to say that scientists should take up on organizational responsibility for the useful application of their invention occasionally. This does happen, but usually the inventor is the least suitable person to do this. The research institute, however, could have well-trained experts for the solution of the problems of technology transfer, meaning not the mere handing over of the documentation, but active organizational work to promote the innovation. This holds especially for research institutes that are organizationally separated from the production sphere.

Permanent Innovation

Chain reaction of innovations

The relationship between innovation and society has a positive feedback mechanism built into it. Basic innovation strongly influences society, and society creates the possibility of basic innovations being made. According to this thesis, innovation is a self-stimulating process: it is itself accelerating scientific and technological progress.

The more instances of basic innovation occur, the higher is the technological level; and conversely, a higher level of technology results in more innovation. Basic, improvement and pseudo-innovations evolve as if by a chain reaction started by a basic innovation as shown in Figures 1 and 2. The accelerating scientific-technological development is propelled by this process, a kind of chain reaction.

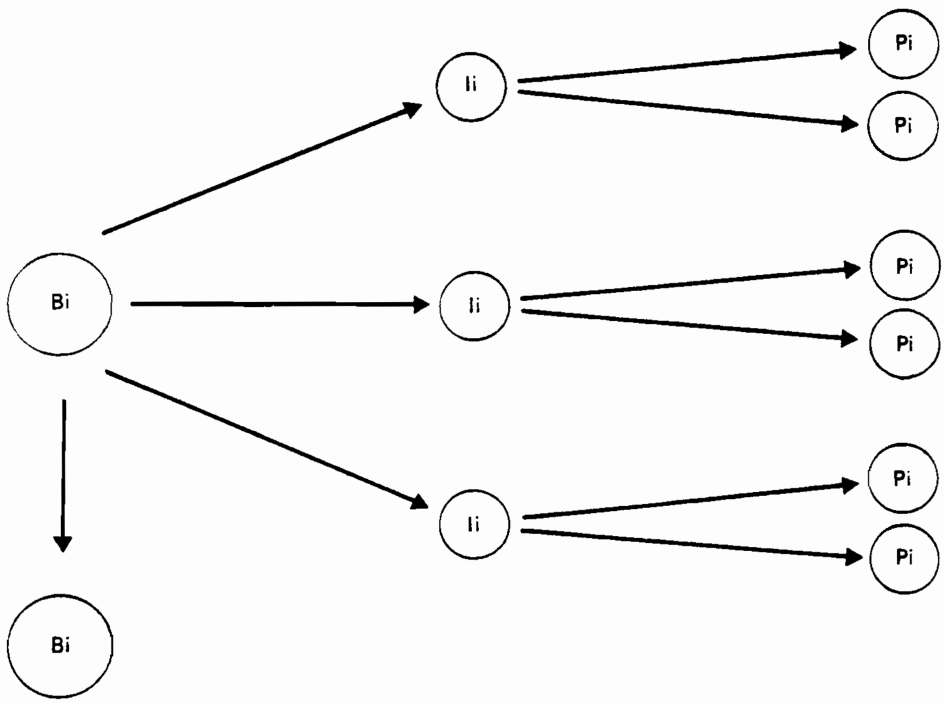

FIGURE 1 Chain reaction of innovations: Bi, basic innovation; Ii, improvement innovation; Pi, pseudoinnovation.

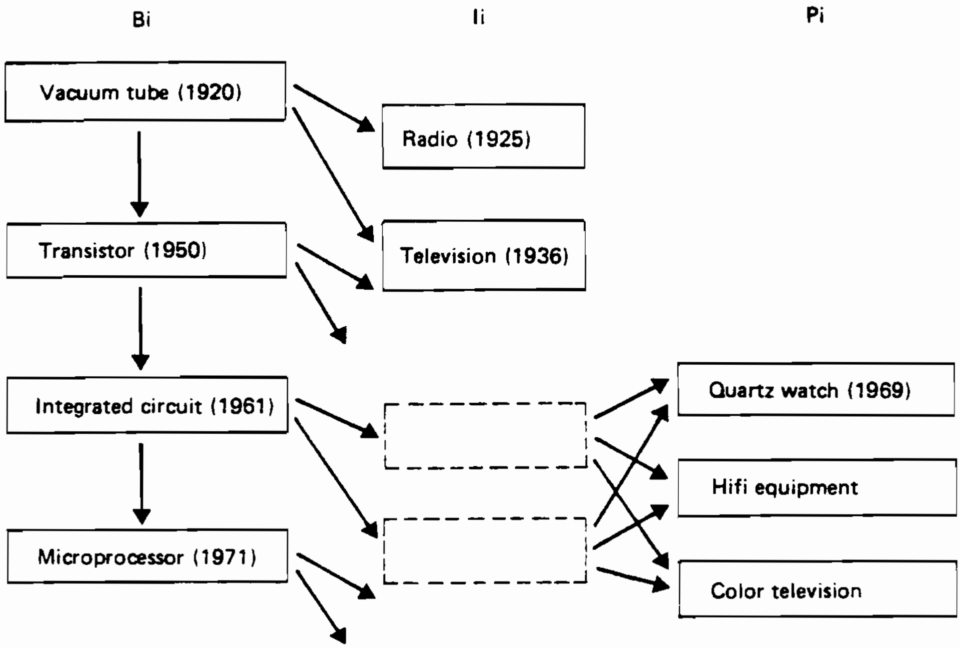

FIGURE 2 Chain reaction of innovations in consumer electronics.

Projecting the direct relationship of "innovation technological level" to the company sphere, we conclude that mostly the technically advanced companies are to be relied on for planned innovation. This theoretical reasoning is supported by practical experience; the companies that succeed in carrying out innovation have generally a higher than average technological level and a more developed infrastructure. Innovations are too expensive and require too much additional investment for weaker companies which lack the infrastructure, internal resources, and high technological culture required for operating new technology.

The commercial realization of an innovation can be shown as a curve by plotting variation of technological level or economic effects against time (see Figure 3). Essentially this curve is a product life curve, where $0-t_1$ is the period of the product's introduction and marketing, t_1-t_2 is the period of effective production and beyond t_2 the period of aging (Bucsy 1976). The rise of technological level to T_{max} symbolizes the accumulation of human knowledge.

An economy that is realizing planned innovation has to reckon with the phenomenon that after a certain time (t_2) an innovation loses its economic effectiveness. In other words, a single, technologically isolated innovation extinguishes itself; autogeneration stops. If, however, further development of old technology or the starting of a new innovation is ensured by internal or external factors, conditions for continual and accelerating scientific technical development are created.

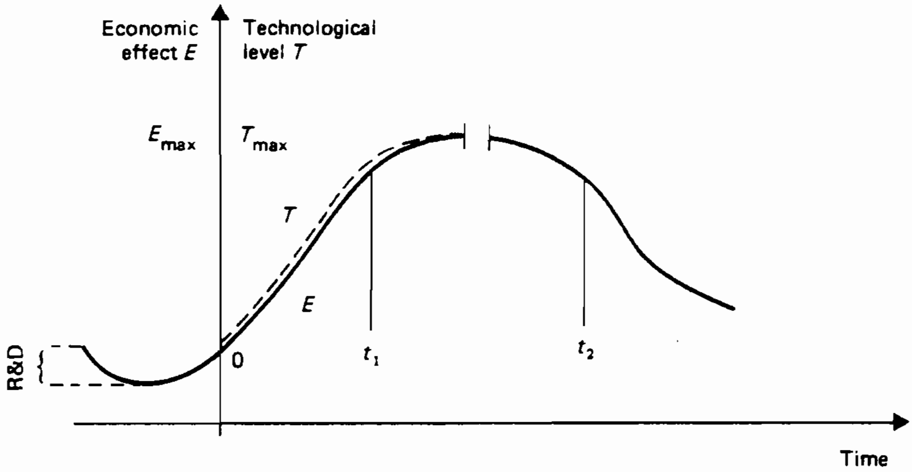

FIGURE 3 The lifespan of an innovation-based product.

This means that when an economic unit has achieved a certain success, it has to think of the time after t_1 and to prepare a new innovation. New R&D should be started before current technology saturates its innovation potential (Figure 4).

If new R&D leads to an innovation that does not significantly change the technological level, the company is able to maintain its favorable economic position (covering curve A) but if it scores significant R&D results then both the technological level and market results show significant increase (covering curve B).

It means that the first innovation in a chosen system of coordinates should be regarded as Basic, the following one with significant increase of technological level, Improvement, and the one with economic effect but without significant change of the original technological level, Pseudo-innovation. What innovation is regarded as Basic depends on where we place our system of coordinates. Thus a licensed technology can be a basis for development by a chain of improvement innovations produced by our own R&D activity.

Permanent innovation activity organized to ensure continual development and timing of R&D activity to bring about new innovation sources as they are needed are strategic necessities for an economic unit operating with an innovation plan.

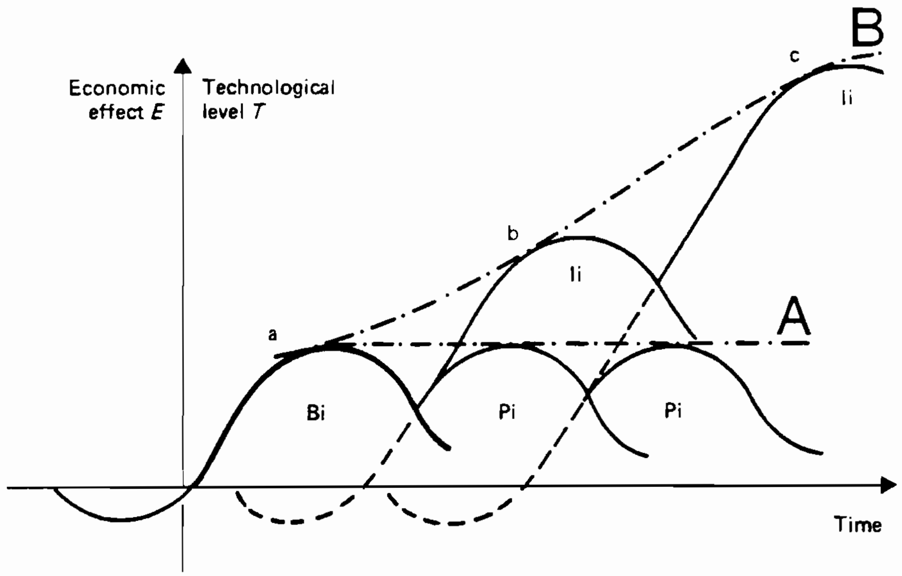

FIGURE 4 Permanent innovation.

INFORMATION PROCESSING IN THE COURSE OF INNOVATION

The Closed Circle of Innovation

An economically oriented innovation process starts with the creation of an innovation source and finishes with market realization. The main steps of the innovation process are represented in Figure 5. Information and feedback flow in a closed circle from marketing to research to development to production and back to sales and marketing.

When the innovation process operates smoothly and all these elements are functioning, the closed innovation circuit separates itself from its environment and acquires a relatively independent life and a development capability of its own. Drawing a parallel with cybernetics, one can say that an automatically controlled closed system of negative feedback has developed.

In reality the closed circle of innovation runs through administrative managerial organization and/or across systems of connected organizations (firms). The elements around the circle represent points at which information is processed and transferred. Their continual interaction requires both the feedback mechanism of marketing research, and the two-way information flows between research and production, production and sales, and so on.

Information coming back to research from experimental production, from production and marketing, is a basis for continued research and further development.

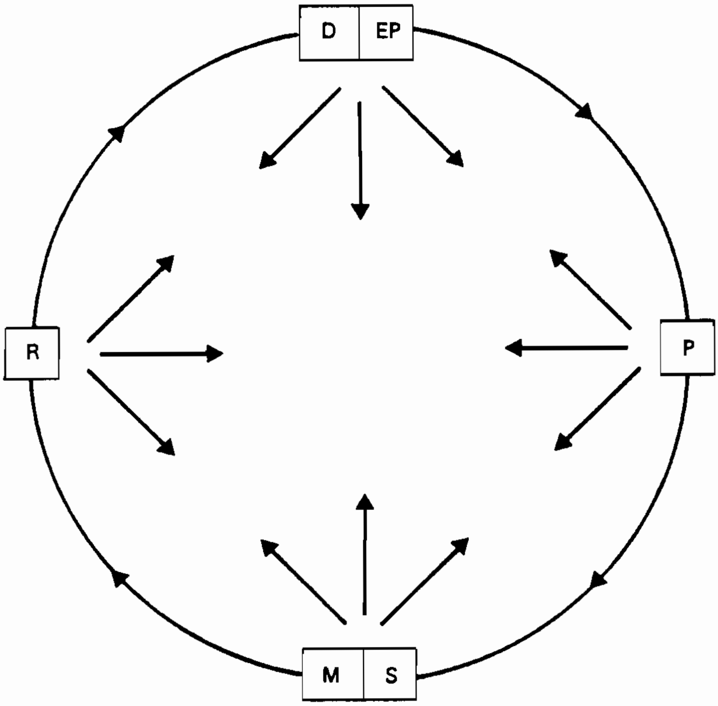

FIGURE 5 The closed circle of innovation. Abbreviations: R, research or the creation of something new; D, development; EP, experimental production; P, production; M, marketing; S, sales.

The idealized closed circle of innovation presented here is an oversimplified view of complex multivariate processes and systems, but it may be helpful for identifying the system's main relationships. It may also be useful as a model or guide for designing programs to insure fulfillment of permanent innovation criteria.

The closed, self-renewing nature of the circle of innovation may lead to problems of self-contained technocratic development and endless reproduction of the innovation, something that is not necessarily in harmony with the goals of society. Therefore external, centralized (e.g., governmental) intervention is needed to determine the main directions of innovation and to control innovation policy (Trapeznikov 1978).

Planned Innovation

Planned innovation presumes not only local goal-oriented planning but also the coordination of this planning with more comprehensive socioeconomic plans, such as the national governmental development plan.

The full circle means division of labor between its main points, regardless of whether these points each represent a single enterprise or several companies. In this context both keeping an innovation circle within a firm and distributing the cycle through many organizations have advantages and disadvantages. An innovation circle established within the framework of one firm can be regarded as a partial solution of the innovation linkage system. The single firm approach has the advantage that it is easier to establish a full innovation cycle within the framework of a single company; the linkage system is relatively easy to manage and external disturbances have relatively little effect.

On the other hand, a change in the general line of innovations within the framework of the company is made almost impossible by the rigid organizational forms. That is why a number of Western authors insist on the thesis "new innovation, new company" (Malmstrom 1978).

By contrast an innovation system organized for a given innovation from administratively separate elements acts expediently in the interest of the given innovation. It can be a system of bilateral contracts between companies, a joint venture, an association, or a loose alliance based on shared or coincidental interests. If the innovation target is modified, the system comes apart without major shock, and its parts enter new linkage systems, other innovation circles, for the sake of other innovations.

I do not dispute the proposition that a new innovation means a new undertaking. It may be that under capitalist circumstances new ventures can generally be undertaken by creating new companies. Under socialist conditions, however, an undertaking, a closed innovation circle, can be organized through the association of the research institute and the production and trading companies concerned.

The Control of the Innovation Circle

Incentives

The closed circle relationship implies a predominance of direct face-to-face contacts. Therefore it is extremely important that people, groups, companies, etc., constituting an innovation circle should be united by common interest in the innovation's success. Thus, it should be established during the planning stage how and with what incentives the participating companies and key figures of the undertaking can be stimulated to do good work. Personally, I consider moral acknowledgement of the inventor and of the realizers of the innovation by society as the most significant stimulating factor.

The functions and units of control

Establishment of a closed innovation circle requires a source of innovation, flexible and enterprising companies, excellent personal relationships between the participants, market opportunities, and a suitable infrastructural and financial environment.

The source of innovation is generally an invention. The inventor is to be regarded as the core of the closed innovation system.

The information processed within the circle is partly technical data and requirements pertaining to products and production processes and partly managerial information concerning cooperation. The innovation system must therefore have a "think tank" that examines technical scientific problems and a manager who has an overview of the entire linkage system. Both of them are responsible for the preparation for decision making. Decisions are to be made by an organ, e.g. a board of directors, which represents the components of the circle.

It takes a person of exceptional ability to be a successful innovation manager. A good manager needs to be an expert in the field, a good organizer and economist, and a man possessed. Ideas are new and original because they differ from ingrained customs, opinions, and practice. Resistance and occasionally even hostile reactions in the face of new ideas should be reckoned with and considered objectively.

This kind of resistance can only be subdued by a man who combines interest with optimism, persistency and great activity, a man who sees the potential market perspectives of the invention and is ready to fight for their realization. In the absence of such a manager the inventor himself often tries to manage his own invention, and since in most cases he is unsuitable for this role and he harms his brainchild and himself in the process.

Innovation is usually an enormous financial risk for the entrepreneurs that can only be bridged by external aid. Therefore financing, credit or loans from banks, and active assistance from organizations representing state interests may be a decisive factor.

INNOVATION PRACTICE IN HUNGARY

Level of Technological Development

Hungary is a relatively small country at a medium level of industrial development, without significant mineral resources. About 28 to 30 percent of its manufactured goods were exported in 1977 and its import volume was almost the same. About 50 percent of its GNP is realized through foreign trade.

In the classification scale used by Nyilas (1977) and shown in Table 1, Hungary has partly the technology of today and partly that of yesterday. A medium level of development is accompanied by a medium technological level. From the point of view of innovation, it should be pointed out that the technological level in terms of hardware and software is unevenly developed in Hungarian industry and agriculture.

The technological level at research institutes and a relatively small number of industrial companies can be rated as that of today, or, in a few cases, of tomorrow. However, most industrial companies and the services in general stand at the level of yesterday. Their machinery is outdated, and professional skills and managerial practice are at best mediocre. This relatively low development has repercussions on the economic infrastructure (production of component parts, communication, etc.) which

TABLE 1 The technological days: a schematic classification of technological development.

Technological development		
	1. *"The day after the day after tomorrow"*. Military and space R&D of the USSR and the USA	
	2. *"The day after tomorrow"*. The latest military and space technology of the USSR and the USA	
	3. *"Tomorrow"*. The nonsecret military technology of the USSR and the USA	
	4. *"Today"*. Western Europe in general, CMEA countries in part	Hungary
	5. *"Yesterday"*. CMEA in general, capitalist countries in part	
	6. *"The day before yesterday"*. The developing world	

more developed companies have to live with.

The engineering and consulting services needed today for sophisticated technological activity are still underdeveloped and sporadic, and their organization is mediocre. The greatest problem, however, is caused by the insufficient cultural level of the labor force and in the consequent lower adaptive capacity.

This conditions calls for active innovation planning, but at the same time hinders the implementation of plans.

Factors Hindering Innovation

The economic control and regulation system related to inventions and innovations is an organic inseparable part of the general economic control system.

Our present system of material and moral incentives is antithetical to innovation at several crucial points. The rewards to persons directly and actively participating in an innovation are not significantly higher than those to the others; companies strive for stability and are more interested in increasing output than in improving efficiency and profitability; a large number of managers authorized to make decisions are reluctant to take risks, to accept change, or to introduce new methods.

These factors hinder innovation activity, but do not make it impossible. A reform currently under way to reevaluate the system of economic regulators is expected to create stronger incentives for innovative behavior.

Also detrimental to innovation is the undesirably large number of companies. True, closed innovation circles may be more easily established and controlled in the framework of these large companies, but they tend to be unadaptive and inflexible to changing market conditions.

More than 38,000 scientists and lecturers work in Hungary's 126 research institutes. In 1978, as much as 19,200 million forints (about US$77 million), 3 percent of the GNP, was devoted to research and development. Thirty-seven of the research institutes work under the authority of the Hungarian Academy of Sciences; more than 20 are under the aegis of the industrial ministries; 14 belong to large industrial companies, and 30 operate in agriculture. Research capacity may be said to be high, but the research institutes and laboratories are not optimally concentrated and are often inadequately equipped.

Detachment from the problems of the industry and consequent sluggish integration of research, production, and sales is the worst drawback of a high concentration of research capacity. The relatively low technological level of industrial companies creates a situation in which the unit making a discovery is often left with the responsibility of promoting it as well. Companies are not eagerly watching research institutes for new discoveries and research institutes are forced to seek out the companies likely to need and apply a result. Moreover, the product development plans of industrial companies are aimed at products that have become known during marketing and leave no room for including the new products that may emerge from original research. The improvement of organization is the least expensive means to promote innovation.

However, organizational improvement is needed most in companies with a lower technological level as this is where the labor culture of the employees is the lowest and the organization least receptive to change.

The importance of innovation in industrial policy and in the economy in general has still not been recognized widely enough. This also hinders innovation.

New Innovation Policy Measures

Ten years ago the Central Committee of the Hungarian Socialist Workers' Party (HSWP) formulated the directives of scientific policy, stressing that priority was to be given to research problems connected with development projects which are likely to promote the attainment of excellence in some field and to contribute to the solution of some complex problems in a way to benefit society.

In 1977, after evaluating the experience with the realization of past scientific policy directives, the HSWP Central Committee considered it timely to set up associations for carrying out individual research programs. The members of such associations would realize common interests, take mutual risks in the application of research results, and could ensure the unity of the control process from research to the application of the results in practice.

The 11th Congress of the HSWP stressed the importance of improving the methods and system of planning.

The October 1977 resolution of the HSWP Central Committee decided to encourage more self-reliant companies. "Central decision can only deal with the most important comprehensive development goals. Matters of product structure are, however, in most cases within the competence of the company. Implementation is to be based on the self-reliance of the companies and on a socialist spirit of enterprise together with the simultaneous enforcement of the responsibilities of the directing organs. The companies should consider market requirements in every aspect of their foreign trade activity, in order to create, develop and render effective the new forms of contact which extend to the functions of development, production and sale."

A number of government resolutions treated the need for improving legal protection in industry in order to encourage company innovation. The problems of associations comprising all the participants of the innovation chain were also dealt with. Ministerial measures were taken for the sake of spreading organizational culture, and large sums are spent to draw on the services of management consultants. The modernization of the economic control and regulation system is also under way.

The Technical Development Fund (along with the budget) serves for financing the development and utilization of inventions. Currently the Technical Development Fund allocates money to companies in fixed proportion to their total production value, with the proportional allocation depending on the individual industrial branch. From 1981 onwards, technical development funds will be allocated on the basis of value added and not the total production value, and will be extended to agriculture. From 1980 onwards, new loan constructions and promoting organizations will be established to facilitate innovation activities. The innovation loan created at the National Bank of Hungary can be used by any economic unit for financing the development of a product idea into a marketable commodity. An organization established within the bank's framework will assist the innovation, and contribute to its realization of the innovation through sharing in the risks.

Foreign trade companies play an increasing role in the organization and promotion of innovation, but even more could be done. This is especially true where the chosen development starts with the purchase of a foreign license and goes on with its further development, thus realizing permanent innovation.

Many linkage systems along the lines of closed innovation circles have been established in Hungary, but this number is still smaller than expected, and planning has not always been at the required level. The Institute of Energy Management, with its own 10 to 15 patents a year, is the host and control center of a number of innovation systems: to mention just two, the air condensation cooling system of Heller and Forgo, and the seawater desalinization process. Another example: the Taurus Rubber Factory has worked out development conceptions for 40 product groups on the basis of criteria of newness and market position. Individual product groups have been evaluated according to 17 characteristics in relation to similar products ranking highly internationally. A computer model is used for the evaluation, continuously following the change of characteristics and the position of the products in the income of the company. The deep drilling rubber hose of Taurus is a good example of successful risk taking, for the creation of a forward-driving technology based on an original invention.

The Chinoin Factory is realizing permanent innovation using an industrialized closed corn production system developed under an American license. The system has since been introduced at more than 200 farms, covering nearly 350,000 hectares, and it is already sold abroad as a system and as knowhow. This activity has served as an example for other agricultural innovation. The corn and industrial plant production system of Nadudvar and the swine breeding systems have brought something that is technologically new to internal and external markets.

Innovation can flourish only under a socially beneficial climate. Hungary's innovation climate is fast improving. Our reserves for the practical application of innovations have not yet been exploited at all. There is good reason for further developing innovation theory and for continuing with analysis of its economic, organizational, and sociological aspects.

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SWEDISH GOVERNMENT SUPPORT FOR PRIVATE INVENTORS

Peter Jörgensen

The National Swedish Board for Technical Development (STU) is the main, and virtually the only, source of government support for private inventors in Sweden. STU both gives advice and financial support and assists in technology marketing.

GENERAL INFORMATION ABOUT STU

STU's task is to encourage technical development and to promote technical research. Some of its programs are tailored specifically for development projects; within this scope advice and financial support are provided at the initial project stage. Thus STU covers the development phases from the basic idea stage to the stage of working prototype; it does not fund pilot production, investment in production equipment, or marketing to the end user. Financing for these latter stages is provided by other organizations, such as Sweden's 24 Regional Development Funds with whom STU cooperates closely, the Swedish Investment Bank, or commercial banks.

Financial project support provided by the STU is given as a grant or loan which may be used for the development, demonstration, and evaluation of ideas behind new products, methods, and processes. STU is expected to finance risk-bearing projects and to assist projects in areas where expected social benefits are greater than benefits to the entrepreneurial firm (e.g., aids to disabled persons, environmental conservation, and factory safety equipment). Financial support may be given with conditional repayment, meaning that STU will demand a refund if the project succeeds. For projects conducted by companies STU normally provides only half the project cost. Private inventors and small firms are normally provided with 100 percent of the project costs.

STU also assists the Regional Development Funds in evaluation of new inventions and product development ideas presented to them. Here again the result can be that both STU and the fund find reason to support the project.

Other innovation support is available through the liaison officers at the universities, who have certain funds for the investigation of new ideas. Service to inventors is also given by the Swedish Inventors Association in agreement with the conditions stipulated by the STU. However, both these sources are quite limited in nature.

SUPPORT TO PRIVATE INVENTORS AS PART OF THE INNOVATION POLICY

The support to private inventors is a small but important part of the Swedish innovation policy. Until 1979 it was a special program at STU but recently it has been integrated into several other programs at STU.

The reasons for establishing STU were partly historical. STU was formed in 1968 through the merger of a special agency for support to inventors with several other agencies that supported research. Another reason, also historical, is the great respect Swedes have for inventors. Men like Gustaf Dahlen and Alfred Nobel helped to create that respect, and deservedly so: during the first half of the present century a very large part of Swedish industry was both created and started by inventors such as Dahlen and Nobel.

A more rational reason for the present program is the fact that many of the radically new innovations do in fact come from private inventors and small companies (prominent US examples are the techniques marketed under the trademarks Xerox and Polaroid). Another reason is that an organization or program designed to assist private inventors and an organization funding research need rather different characteristics.

Since 1979 the new program has been fully integrated with other programs at STU. Special efforts have been made so as not to decrease the quality or quantity of the support given through the earlier program. Thus the government has stipulated a minimum amount that STU must reserve for project assistance to inventors. For the fiscal year 1979–1980 this amount is 25 million Swedish kroner (about US$6 million). Project applications by private and small industry inventors are screened by technical officers with special experience in the field and who also have industrial experience.

HOW STU CONSIDERS AN APPLICATION

STU receives about 1000 applications from inventors every year. In the application the inventor normally describes the use and operation of his invention and how he intends to exploit it commercially. Of these 1000 applications about 20 percent are rejected after a brief examination.

The remaining 800 applications are considered in greater depth. Points such as evidence of technical progress and possibility for commercial exploitation are carefully considered. This consideration involves estimation of factors such as estimated production cost, buyer's risk factor, potential market, what commercial interest has been shown, potential domestic market, and compatibility of the product with existing or changing regulations. The result of this examination is a rather vague estimation of the project's potential value: the more radical or unusual the project is, the less definite the estimation can be.

When considering the possibility of exploiting the project, patent considerations and availability of potential licensees are also studied. The invention is investigated to see if it is patentable and if patenting will provide sound protection from competitors. Answering these questions requires an investigation that is normally more thorough than the examination made by the patent authorities. Our assessment also depends on the number of possible licensees within the country. In our experience, exporting nonproven technology is difficult; therefore, to ensure a reasonable chance of success the licensee has to be found in Sweden. Some projects could lead to the start of a new company, many say. This is true, but it is not something that can be counted on.

Finally, we evaluate the applicant's competence. This is extremely difficult, especially for applicants with no previous record of having invented something or for persons without formal technical training. It is also difficult to assess an inventor with some failures behind him: he might have learned enough to succeed the next time.

It may be of interest to know how STU handles an application from an inventor. Generally the process is as follows:

- the application is registered and classified as secret
- the application is judged and if found to be of very low standard a rapid negative reply is given
- the project is discussed with the inventor and necessary information is acquired from specialists in consent with the applicant
- contact with the applicable Regional Development Fund is made if further support is anticipated
- a decision is taken by a group on the basis of the information presented
- a grant or loan is issued together with applicable conditions for repayment, etc.

Normally about 25 percent of the proposed projects are supported. The evaluation takes about 3 months. External experts are sometimes consulted. The average grant is about SwKr50,000 (US$12,000). Support is given with conditional repayment as mentioned earlier. The inventor has all rights to the project and the patents providing he makes such conditional repayments as are applicable.

During project execution STU may assist the inventor in different ways, especially establishing contact; for example, STU officers often help inventors to find good workshops where they can have their prototype produced and tested. Sometimes university professors or consultants are contacted to assist with calculations, marketing estimations, and feasibility studies.

At some phase of the project's development marketing must start. STU can assist both in finding and negotiating with suitable partners and with the actual writing of contracts. These activities are sometimes carried out under a special program by the Technology Marketing Department. This support is given with a conditional repayment clause covering STU manpower costs.

RESULTS

In the beginning of 1976 a major study was completed covering all projects supported in 1960-1975. A special part of the study covered 67 inventions supported in the first 3 years of this period.

These 67 projects proved to have managed rather well with regard to both production and marketing, although a small number of the projects generate a large percentage of the sales. Through STU grants of about SwKr1.6 million, 15 of the projects (22 percent) reach a combined sales figure of SwKr29 million in 1975. Three years after the inventors had received the STU grants, the actual sales generated by these inventions was 9.7 times as great as the initial STU grants. After 4 years the factor had risen to 16.3 (not taking account of inflation). The remaining 78 percent of the projects had not reached the production stage.

A more recent survey showed that STU spent SwKr18.8 million (about US$4.5 million) between 1968–75 on projects from innovators. The sales generated from these projects amounted to SwKr100 million (about US$24 million). When studying these figures one should notice that the STU grant only covers the development costs and not production and marketing costs. However, the projects with the highest sales were licensed, and production and marketing investment were therefore probably not prohibitive.

Unfortunately, it has only been possible to study sales. It would have been interesting also to examine net profits and return on invested capital. The accounting procedures of the companies concerned are so different, however, that such analyses would have been unreliable.

Some more findings from the study made in the beginning of 1976 may be of interest.

- Of the inventors who received grants from STU, 25 percent had previously succeeded in exploiting at least one invention without support from STU. Just over 5 percent had exploited more than five inventions.
- Approximately 59 percent of all the grant recipients were working in the manufacturing, building, or mining industries (only 40 percent of the employed population is engaged in these branches). The engineering industry was particularly well represented, accounting for 25 percent of the beneficiaries but only 6 percent of Sweden's employed population. Industries which were poorly represented included foodstuffs, clothing,

wood products and furniture, pulp and paper, and the graphics industry.

- The grants were awarded to "spare time inventors" in 54 percent of the cases, and to owners of companies in about 25 percent.
- In many cases the development of the invention has involved a change in the employment status of the person seeking the grant. In about 45 cases companies were subsequently formed. In a number of other cases the inventor became part owner of the new company.
- Design and manufacture of prototypes was normally undertaken by the inventor himself.
- According to the inventors, the main problems encountered in the course of the development work were in financing and in assessing the sales potential and market conditions.
- According to the inventors, insufficient financial resources was the biggest problem both in manufacturing and in marketing and sales of the inventions.

DEVELOPMENT OF THE SUPPORT

We are now investigating new ways to support inventors. One approach being investigated is locating the industries that are interested in defining and presenting actual problems to inventors. Different ways to exploit this concept are being examined. Courses concerning patenting strategy and licensing negotiations have also been tried.

NATIONAL SCIENCE FOUNDATION EXPERIMENTS IN INDUSTRIAL INNOVATION

Alex Schwarzkopf

INTRODUCTION

Technological and industrial innovation is a major factor in the economic well-being of nations. Innovations provide new areas for economic growth and generally raise overall productivity. The apparent decline in the rate of innovation in the United States in recent years has heightened the importance of innovation and has resulted in more studies of the innovation process and the means by which innovation might be stimulated. The Domestic Policy Review Report released by the US President is an example of these concerns. The purpose of this paper is to describe the experiments being conducted by the National Science Foundation (NSF) Industry Program that are designed to study and accelerate the innovation process in the US.

The Industry Program traces its origin to the Experimental R&D Incentives Program started in 1972. Over the ensuing years, it has become the Industry Program and is now part of the Engineering and Applied Science Directorate within the NSF (one of the seven directorates comprising the NSF). The charter for the Industry Program has remained essentially unchanged since its inception. It calls for the program to "provide a focus in the Federal structure for testing various means of accelerating the rate of technological innovation in the private and public sectors of the economy. The Program supports: (1) background studies to identify and understand barriers and blockages to the technical innovation process; (2) experiments designed to investigate incentives intended to overcome these blockages. Each experiment supports tests on the effect a specific incentive mechanism has on a barrier to the innovation process." The Industry Program, as shown in Table 1, is divided

TABLE 1 Organization of the NSF industry program.

I University–industry coupling
- A. Centers
  - 1. For scientific excellence
  - 2. For high technology business starts
- B. Technology innovation projects

II Small business innovation research

between studies of university–industry coupling and small business innovation research. University–industry coupling experiments are further subdivided into centers (of two types) and technology innovation projects (TIPS). Centers differ from TIPS in that their experiments attempt to build self-sustaining institutions, while TIPS are experiments with specific finite lifetime projects. In the following text each of the subdivisions of the Industry Program is described in turn accompanied by one or two examples of how its program operates.

UNIVERSITY–INDUSTRY COUPLING

The Industry Program performs experiments with different university–industry coupling arrangements designed to improve our understanding of how such couplings contribute to innovation. Thus, while we desire experiments which produce successful university–industry linkages, we are more interested in the knowledge gained through our experiments about underlying relationships and institutional structures necessary for productive university–industry couplings.

Coupling experiments are directed to areas in which it is felt that external benefits from research are high; that is to areas in which total benefits from research are greater than benefits to individual companies conducting research. Areas of high external benefit have been identified using the following model.

When a successful product is introduced in highly fragmented industries, such as the construction material industry, where the majority of firms are too small to undertake research and development, the ratio of total to individual returns is high owing to the large number of firms available to adopt it (see Table 2). If individual returns are plotted against the ratio of individual to total returns a scatter suggesting a hyperbolic form, as shown in Figure 1, results. On the far left of this curve, where the ratio of total to individual return is high, the public benefit of such innovations warrants financial assistance by the public sector. Besides construction materials, other examples are subway systems, fire trucks, military aircraft, dams, etc. This area is characterized

TABLE 2 Total and individual rates of return from investment in 17 innovations.

Innovation	Rate of return (%)		
	Total	Individual	Total/individual
Primary metals innovation	17	18	0.9
Machine tool innovation	83	35	2.4
Component for control system	29	7	4.1
Construction material	96	9	10.7
Drilling material	54	16	3.4
Drafting innovation	92	47	2.0
Paper innovation	82	42	2.0
Thread innovation	307	27	11.4
Door control innovation	27	37	0.7
New electronic device	Negative	Negative	–
Chemical product innovation	71	9	7.9
Chemical process innovation	32	25	1.3
Chemical process innovation	13	4	3.2
Major chemical process innovation	56	31	1.8
Household cleaning device	209	214	1.0
Stain remover	116	4	29.0
Dishwashing liquid	45	46	1.0
MEDIAN	56	25	2.2

SOURCE: **Mansfield** *et al.* (1977).

by a strong public need, fragmented industries, and the lack of private capital.

There is a transition region on the curve with good to moderate returns from innovation to both the public and private sectors. For example, machine tool innovation shows an individual corporate return of 35 percent with a total return of 83 percent. But, responsibility in this region among State and local governments, the Federal Government, and industry is not always clearly defined and innovations that fall in these regions may be ignored by both sectors. It is in this area that we feel the greatest opportunities for the Industry Program lie.

UNIVERSITY–INDUSTRY CENTERS

University-Industry Research Centers are institutional experiments designed to produce a coupling that becomes self-sustaining over the long term; i.e., industry ultimately supports the entire center on a continuing basis. These experiments focus on two types of centers: centers of scientific excellence, which have both industry and scientific-discipline-specific and technology-specific orientations; and centers for high technology business starts which are directed toward educating and developing innovative and entrepreneurial skills that could lead to high technology business starts. The business services of these latter centers provide

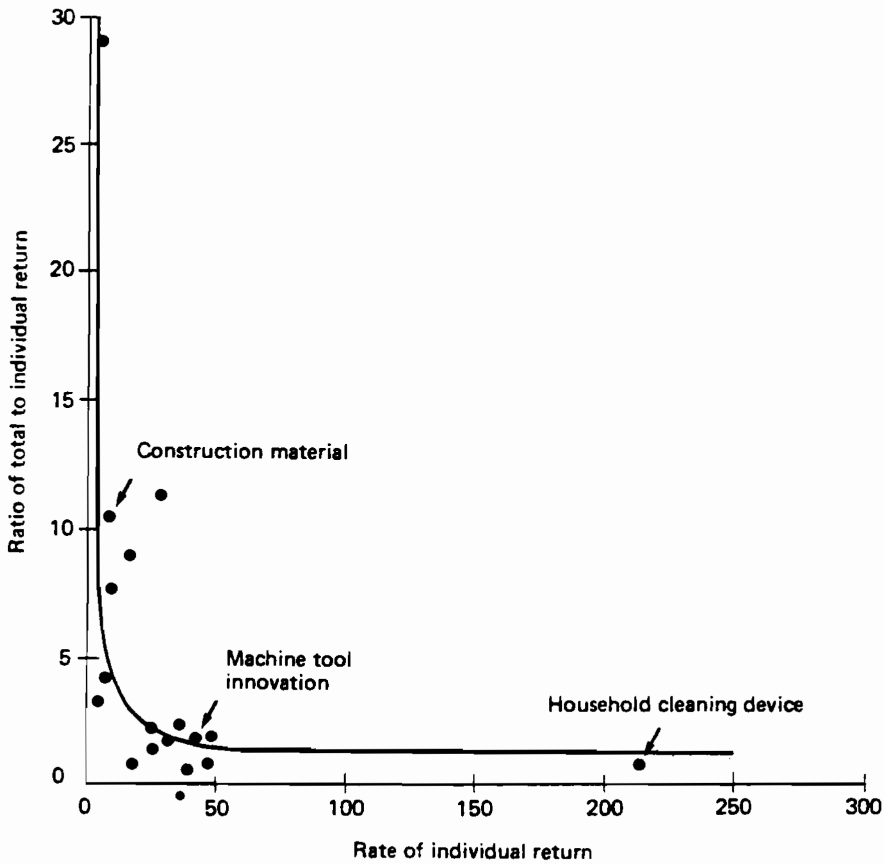

FIGURE 1 Rates of total and individual return from seventeen innovations. Source: Mansfield *et al.* (1977).

supplemental funds for continued center operation. In both types of centers one of our objectives is to study the variables that produce successful centers.

The Industry Program restricts funding for the initiation of centers for research to areas in which there is reason to belief funding will result in innovations which are able to justify private investment. However, because the US Government is committed to a market economy, it may be reluctant to fund centers that do not become self-sufficient. This means that the class and quantity of innovations resulting from research activities at a center must have a rate of individual return sufficient to justify the company's continued support of the center. Because a center aggregates company research funds, the cost per innovation is reduced for each participant. In effect, we are causing a given innovation to move to the right along the curve in Figure 1. Centers that generate a class of innovations sufficient in numbers to maintain company participation and continued financial support result in successful centers.

The MIT Polymer Processing Center: a Center of Scientific Excellence

The Massachusetts Institute of Technology Polymer Processing Center has directed its research activities in the areas shown in Table 3. The operating mode of the center, which was started in 1973, is focused around the Director. The three major functions in the operation of the center are administration, research, and the interactions with participating industries. Administration is accomplished by the Director with the advice and consultation of the Industrial Advisory Council and with institutional support from MIT. The Industrial Advisory Council consists of senior representatives of the industrial participants, the MIT Vice President for Research, the Director, and a senior representative for MIT's Center for Policy Alternatives. Research is performed primarily by participating graduate students supervised by the Director with participation and supervision by other faculty and staff. Industry interactions are focused on quarterly Technical Review Meetings attended by 30 to 40 people who are equally divided between MIT program staff personnel and representatives of the industrial participants.

TABLE 3 MIT Polymer Research Center projects 1974–1978.

Electric field mixing
Accelerated testing
Friction and wear of polymers
Graphitization
Adhesive tape
Impingement mixing
Rubber mixing
Electrostatic powder mixing
Mixing viscous reacting liquids
Rapid processing of thermo plastics
Asbestos reinforced phenolics
Fiber reinforced phenolics

At these meetings, the research program is reviewed by the Director, and the graduate students and the participating faculty members give reports on their active research projects. Considerable interaction ensues between the program staff and industrial representatives — vice presidents and managers of research and operational entities. The operational structure has been highly successful, but it places a heavy burden on the Director for leadership.

NSF provided some US$450,000 over a 5-year period with the support declining in the last 2 years of the experiment. During this period, the center built up industrial support to where it now receives over US$500,000 annually from twelve companies. NSF financial support ceased in July 1978.

Evaluation of MIT polymer center experiment

Analysis of the subjective assessments, obtained from meetings of participants, has indicated that industrial participants have become progressively more involved with the center, have found the projects to be increasingly more useful, perceived the research as being of high quality, and have respect for the abilities of the student researchers. We believe the center is successful because it is creating a sufficient number of process breakthroughs to maintain company support. It has also reduced the cost of these innovations to each participating company. In effect, the center has increased the rate of individual return from innovation. This corresponds to a movement along the line to the right on the innovation-return curve shown in Figure 1

The NCSU Furniture R&D Applications Institute: a Center of Excellence

Another example of a university–industry center is the North Carolina State University Furniture R&D Applications Institute. This center has directed its research activities in the areas shown in Table 4.

TABLE 4 North Carolina State University Furniture Research Center projects 1974–1978.

Clark chair frame
Finger-jointing
Lumber yield
Robots – spraying/wiping
Material handling
Dowel joints
Production control
Workshops
Reinforcement device for furniture construction

This center, also initiated in 1973, was structured to operate with a strong Director reporting to a board. (In this instance the strong Director plan was not realized.) The board of Directors consisted of Deans from the various schools of the university, with the Dean of Research as chairman.

This board was assisted by an Advisory Board consisting of appointed representatives of sponsoring companies. The research agenda of the Institute was to be based primarily on needs perceived by industry sponsors, although suggestions could be accepted from any source. The Director, with the assistance of a Technical Committee, would screen the suggested projects and obtain proposals from competent researchers for those projects which appeared to have a high industry impact. These proposals would be screened by the Board of Directors and Advisory Board, and the approved projects would be implemented.

For this center, NSF provided over US$700,000 during a 5-year period, again with the support declining in the last years. Targeted industrial support was to reach over US$500,000 annually but only US$60,000 per year was achieved. An effort was made to increase industry participation through sponsorship by an industry association. This did not materialize and the university has entered a retrenchment mode since at least US$300,000 annually was needed to continue the full operation of the center.

Evaluation of NCSU furniture R&D applications institute

The structure of the furniture industry and the nature of its product indicate that substantial continuing government financial participation would be required to continue this center. Even though a number of technological developments were created by this center, they were not sufficient in number to build and maintain industrial support. In this case, there were not enough firms aggregated to lower the supporting center.

Centers for High Technology Business Starts

Another of the university–industry coupling efforts of the Industry Program is the initiation of Centers for High Technology Business Starts. This effort began in 1973 as innovation center experiments. Four centers are in operation. Each is a unique experiment but all combine elements of entrepreneurial education, business, and innovation exposure for students, and research and private business/inventor assistance in stimulating innovations and entrepreneurship. The uniqueness of each center derives from the various institutional settings and the perceptions of the center Directors. One such center is described here.

The Utah Innovation Center

The Utah Innovation Center began operations in the fall of 1978. The objectives of this center include increasing the number of technological entrepreneurs emerging from the university; establishing an atmosphere in which innovation occurs; increasing the use and commercial exploitation of new technology developed at the University and in the community; encouraging the development of Utah-based companies; and increasing the success rate of small technologically oriented businesses.

Activities include educational programs, product development assistance and the creation, for the first time, of lines of communication among innovators, entrepreneurs, venture capital organizations, new product-oriented companies, and interested educators and organizations.

The center provides straightforward, low-cost evaluations of ideas for University students, faculty and staff, and community inventors. If an evaluation is sufficiently favorable, the inventor may be asked to submit a brief application containing a summary of goals, plans for development, and a description of the assistance sought. At this point, the inventor would be introduced to the formal requirements of the center and encouraged to enroll in an individualized study program at the University to pursue the idea in more detail.

The center may, for especially promising concepts, negotiate arrangements to provide specialized services such as laboratory studies, machine shop services, computer time, and hiring of consultants needed to enhance the development of the product toward eventual commercialization.

In many instances, the best business strategy for the technological innovator is licensing of the new product to existing industry. The Innovation Center, through its wide-ranging contacts with individual firms, can assist the innovator to locate specific firms likely to be interested in the project. New technology executives in such firms, when dealing with a project recommended by the center, can be assured that the idea is sound and that thorough business planning has been undertaken.

Experience indicates that there are many problems in need of innovative solutions within established firms. In such cases, the Innovation Center can conduct structured problem-solving sessions with respect to the proprietary interests of the sponsoring firm and bring together highly creative talent not otherwise available to the firm. Technological product and process needs common to an industry group can be approached through the joint effort of the center and an industrial association.

Evaluation of innovation centers

These centers are planned to become self-sufficient over a 5-year period. Self-sufficiency depends on their development of income from royalties, industrial sponsorship, and government contracts and on university support.

Only in the case of the center at MIT has sufficient funding been generated to continue without NSF support. The results to date indicate that the following are necessary for a successful innovation center: (1) strong leadership during and after the NSF grant; (2) sufficient annual funding of approximately US$250,000 during the start-up period to obtain both dedicated space and personnel and adequate visibility within the university; (3) qualification of the courses developed and the laboratory investigations for full recognition and support as part of the university's curricula; (4) faculty participation other than the center staff; (5) the support of suppliers, distributors, and bankers; (6) a continued flow of new ideas into the center from outside and within the university; and (7) a plan for licenses, royalties, equity, or other income necessary for the economic viability of the center at the end of the 5 years of NSF support.

The impact of this activity is evidenced by the great interest expressed by many educational institutions and governments both in the United States and elsewhere.

Technology Innovation Projects

The next group of university–industry coupling experiments is in technology innovation projects. These projects do not attempt to build an institution or center that extends beyond the project itself. Instead, they are designed to test how to accelerate the application of the results of university research supported by the National Science Foundation to industrial applications and provide data for policies in this area. These projects typically involve research programs that are unsuitable for a single firm to undertake without assistance. They typically involve innovations that have a high total rate of return but one that cannot be entirely captured by any single company. These projects generally link a company (or companies) with a university (or universities) to make the firm familiar with current applicable research results. This permits the firm to identify and work with the university to resolve the remaining research gaps blocking the implementation and testing of an innovation.

It should also be noted that, no matter how successful a Technology Innovation Project experiment, the companies and universities party to it always believed they had gained a valuable experience. Companies cooperated fully with the universities, often committing more funds than initially agreed upon. At the same time they learned about the ongoing research at universities so that they could consider possible subsequent applications. Universities learned about the types of data companies needed to make decisions and could identify future areas of research that would probably be significant. Finally, while the success of the experiment is important, the knowledge gained on the factors of the successful interaction is of primary significance to us.

The Westinghouse TIP

A current project will provide one example of an experiment. This project, "Programmable Assembly Research Technology Transfer to Industry," builds upon many research results already generated by NSF's Production Research and Technology Program. If these research results could be implemented in a timely fashion by manufacturers using batch assembly operations, the research results could have a significant impact on productivity.

In the first phase of the project at Westinghouse, their Research and Development Center worked with the University of Massachusetts, Stanford Research Institute (SRI), and the Charles Stark Draper Laboratory, Inc., to analyze all the available research results on programmable automation to determine which were ready for application in batch manufacturing assembly operations. Among the results of this phase of the project was a conceptual design of an experimental Adaptable Programmable Assembly System for fractional horsepower electric motors. The proposed system synthesized those research results ready for application with the latest state of the art in industry. Economic studies indicated the proposed system would be cost effective if subsequent research could fill in the remaining information gaps and the adoption of the research results to assembly line conditions were successful.

Funding has been provided for Westinghouse Research and Development Center to work with universities in filling in the current phase of the project. A binary imaging processing system is evolving from SRI research results and SRI is currently developing visual serving systems for final assembly operations. Programmable part presentation systems are evolving from work at the University of Massachusetts. Compliance and force sensing systems are evolving from the Charles Stark Draper Laboratories initial research breakthroughs.

If the current research is successful, the next phase of this project will be to build an experimental system for the assembly of the end bells for small electric motors and test the system under simulated production operations for 3 months. In the last phase the experimental system for final use in assembly lines will be built and tested. The Westinghouse data on these tests should provide the vital information necessary to minimize the risk in adoption of an adaptable programmable assembly system by US manufacturers having batch assembly operations.

Technology Innovation Projects generally have a cost-sharing arrangement. This one will cost approximately 1.8 million dollars over a 39-month period with Westinghouse contributing 25%.

SMALL BUSINESS INNOVATION RESEARCH

The last major activity of the Industry Program is that involved with small high technology business firms. Studies have shown that small businesses support scientists and engineers at half the cost of large firms and each scientist and engineer produces twice to three times the number of patents as do those in large firms. Because the total rate of return for investment in research by small business appears to be high, the United States Congress directed that a percentage of the Engineering and Applied Science Directorate's budget be used for small business research. This fiscal year, approximately US$8 million is targeted to use small business as a resource for the reasons listed in Table 5.

TABLE 5 Small business as a resource.

Many have strong science/technology capabilities
Produce more innovations per scientist than large firms
Receive only 3.5% of Federal R&D expenditures (OFPP 1976)
Ideal coupling to technological innovation and utilization

Small businesses can participate in this program by either of two mechanisms. One is through an unsolicited proposal which is the standard mechanism to request NSF support. Unsolicited small business proposals compete with all other unsolicited proposals received. The other mechanism is by responding to the Small Business Innovation Research Solicitation. The solicitation is a three-phase competition designed exclusively for small, profit-making businesses. In this program, small businesses do not have to cost share. In the first phase, small businesses respond to the solicitation with a simple proposal of no more than 20 pages. These proposals compete for approximately fifty awards of US$25,000 each of 6 months duration. During the 6-month period, the necessary research needs to be performed to obtain the data base and then a detailed research plan to attain the proposed objectives is prepared. The research accomplished during this first phase also establishes the feasibility of the project and tests the capability of the small business firm to perform research. Phase 1 winners only can then submit a phase II proposal. Phase II performs the research deemed feasible in phase I. It carries awards averaging a total of US$200,000 for up to a 2-year period. Small businesses that successfully complete phase II are expected to be funded in phase III by previously identified private venture capital sources to pursue commercialization. While the solicitation involves research in all areas of applied science in the Engineering and Applied Science Directorate, the Industry Program plays a major role in coordinating all the phase I proposal processing.

Over 100 awards have been made to date to companies with up to five hundred employees. Many have been small businesses with only one or two people. An example of one such firm may be useful.

The Ionomet Company

The Ionomet Company started as a one-man firm that competed in the Small Business Innovation Research solicitation.

The Ionomet Company proposed to study a process that would significantly increase the sensitivity and reliability of photoplates for mass spectrometers. Ionomet competed successfully and showed that the objectives of the project were feasible. When Ionomet decided to submit a proposal for phase II funding, it had difficulty identifying a venture capital source interested in underwriting the proposed process for photoplates. Identification of follow-on venture capital interest is one item considered by the National Science Foundation in evaluating phase II proposals. In discussions with Ionomet, the NSF program manager suggested that the electronics industry might be interested in the research because the proposed photoplate process had a very high resolution that might be useful in microcircuitry. Ionomet then discussed this possibility with a university, which saw merit in the approach and suggested relevant companies. A number of the companies contacted agreed the process could result in an important innovation and committed themselves to a venture capital follow-on if the proposed phase II objectives in the ongoing research were met. The growing industrial interest and potential applications have resulted in the Ionomet Company expanding to a staff of four professionals.

The NSF Industry Program is performing experiments that contribute to a better understanding of innovation and ways to stimulate it. The experiments we perform must be within the Charter of the National Science Foundation so they address only a limited area of the innovation process. Within this area, we have learned that leadership, organization, university resources and attitudes, and industry structure are key elements required in the melding of a successful university industry experiment.

Our effort is only one of many that the United States is undertaking to create a broad base of knowledge. The unquestioned need for innovation and its related benefits make these studies increasingly important to all policy makers.

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PUBLIC PROCUREMENT AND TECHNICAL INNOVATION: THE EXPERIENCE OF THE FEDERAL REPUBLIC OF GERMANY

Dietrich Burkhardt

THE PROBLEM AND THE PRESENT SITUATION

Technological policy in highly industrialized countries has long been concerned with the direct and indirect funding of R&D in industry, universities and other research establishments, and with facilitating and accelerating the transfer of the results of R&D into economic use, generally known as promotion. The various measures and instruments used for these two activities are well known and their effects have been adequately analyzed and discussed.

However, the question of how far innovation can be promoted through the demand side has so far been given little attention There is increasing evidence that government has very great leverage for promoting innovation through the demand side (Allen 1978), both through legal regulations and through procurement transactions which influence the market chances of new products. Just as there is no doubt that government spending helps to ensure full employment, its use for stimulating innovation may equally well become a matter of course in the near future.

Reflection on technological and innovative stagnation in the industrial nations of the West leads to the conclusion that state purchases may be concentrated in areas where potential for innovation is high. Provision of private consumer goods, which government does not buy in great quantities, has reached a high level, both quantitatively and qualitatively. So-called basic innovations are seemingly absent in consumer goods industries and these industries do not appear ready to support large scale innovation in the near future. On the other hand, there is an increasing need for services which are traditionally provided by various government departments, such as health services, environmental protection, public security, municipal waste disposal and utilities, transport, and communications. In all these sectors the state is an important procurer of installations and equipment for provision of the corresponding services. Whether and to what extent technical novelties can establish themselves on these markets will be greatly affected by the readiness of the State to procure new products (Overmeer and Prakke 1978).

It is also noteworthy that the sectors mentioned are characterized by a large share of the direct national R&D expenditure since they are given a high social priority. Thus, in the end, the State's willingness to buy new products also determines the effectiveness of direct state R&D expenditures. This is not to be confused with a policy of "buy German," but it is immediately clear, particularly in these areas, that insufficient enthusiasm for innovation on the part of the state can be very obstructive to technical development.

The following aims should be kept in view when using public procurement as a means of stimulating innovation: firstly, optimum provision of public services should be maintained and the general criteria of economic production and maximum resource allocation should be observed; and secondly, technological standards should be raised, thereby increasing the vitality of the economy and improving its competitiveness on international markets.

When speaking of "new products" here, no distinction is made between the initial innovation phase and the diffusion phase: Public demand can operate in both phases as a support and incentive, although when dealing with products that are already selling well the diffusion phase may well prove a more favorable starting point for public procurement.

In the context of this paper "the state" is taken to mean all institutions for which the German contract regulations (VOL and VOB) are binding, i.e. the Ministries of the Federal State and the "Länder," with their subordinate authorities, the local authorities, and the Special Funds of the German Federal Railway and Post Office.

GENERAL REMARKS ON THE APPLICABILITY OF THE INSTRUMENT

In discussing and examining the utility of procurement as an instrument for innovation promotion, it is necessary to consider questions of legal framework, probable effectiveness, and competition regulations.

Legal Framework

The legal framework within which public contracts are placed is mainly codified in the contract regulations (VOL and VOB), the Federal State and "Länder" budget regulations (BHO and LHO) and the German constitutional budgetary law (HGrG).

Numerous single regulations in these sources are or could be relevant in the present context. To cite four examples:

(1) There are important forms of offering for tender, public invitation, limited invitation, and private contract. Of these, public invitation is most likely to provide an opportunity for companies with new products to participate in making offers.

(2) It is stipulated that the "most economic offer" should obtain the contract. This must not be taken rigidly, i.e., it should not be limited solely to the investment cost. Maintenance and operating costs must be taken into account. The criterion "lifecycle costs" is being increasingly applied, e.g. in American provisions. The overall economic aspects can be equally important, as in the preliminary regulations for BHO, for example, which stipulate that cost benefit analyses are to be carried out in order to assess the financial importance and suitability of public measures (Vorl.VV BHO 1973).

(3) In the VOL amendments the "design" specification is replaced by one which determines "performance" in conformity with the European Economic Community regulations. Although problems are more open to solution under the performance specification than under the design one, proof of performance standard can prove very costly for the procurement agency. For this reason experience with the performance specification in the US has not been entirely positive.

(4) Restrictive adherence to technical norms can impede market entry for new products.

Of course, legal regulations can be altered. However, practically speaking, activities strengthening the innovation aspect of procurement must work within the scope of the present legal framework.

Probable Effectiveness

The impact of the instrument of public demand on innovation policy is largely dependent on how far it improves the market chances for new products; in other words, how far it reduces or eliminates existing competitive disadvantages. This can be achieved, for example, through government contracts which secure production on a sufficiently large scale to enable calculation of a competitive price.

In addition, the government can establish the technical quality of the product by so called demonstration projects, so providing the product with a competitive advantage. This can also be important with regard to opening up foreign markets.

Whether or not the effects mentioned actually come into operation depends, among other things, on the magnitude of the government demand, the structure of the market, and the behavior of the market "partners."

In principle, government demand is a more powerful force where: (1) government demand is large in relation to the overall demand on the market; (2) the supply side is intensively competitive; and (3) the procuring agency or decision maker has a positive attitude toward innovation.

It should also be noted that the potential use of demand for stimulating an innovation always remains weak for commodity cases, where the main consideration is the most economic use of budget funds.

Magnitude of Demand

Table 1 gives an analysis of capital procurement spending on public contracts for 1974. It can be seen that 28 out of DM55 billion, a good half, is spent by the local authorities.

TABLE 1 Public expenditures on investive procurement in 1974 (in billion deutsche marks).

Item	Expenditure
Federal Republic, Equalization Fund	6.68
Federal Railways	3.95
Federal Postal Administration	8.00
Länder	8.26
Local Authorities, municipalities	28.38
TOTAL	55.27

However, bearing in mind that the municipal demand is itself widely dispersed, one may conclude that the quantitative effect is slight. This impression is further strengthened by the figures in Table 2 which show that only in the steel, carmaking, and building sectors does the state demand appreciably exceed 5 percent of the overall turnover of the industry. The proportional state demand for all industries is 6 percent.

Competitive Structure

However, a purely quantitative assessment would lead to wrong conclusions. A supplementary analysis of the competitive structure of the individual markets is absolutely necessary here.

Where, for example, the suppliers are mainly small and medium-sized companies, a relatively small public demand can be sufficient to pull production of an innovative product over the "break-even point" and so to provide the initial incentive for market success. For this reason the Federal Government has emphasized the possible suitability of this instrument for the particular marketing and managerial conditions in small and medium-sized firms (Federal Ministry of Science and Technology and Federal Ministry of Economics 1978).

The theory of competition emphasizes that an oligopolistic structure has a favorable influence on innovative behavior on both supply and demand sides of the market. Since the state in its role of supplier of public services is only seldom in competition with other vendors, there is no immediate pressure on the procurement agencies to achieve a competitive advantage among the public services offered by purchasing new, qualitatively superior and/or more economic products. For this reason, motivating the public agencies concerned toward a greater readiness to

TABLE 2 The importance of public purchases of capital goods in the economy of the Federal Republic of Germany in 1973.

	Research and development statistics			Supply of capital goods to territorial authorities		
	R&D expenditures (in million DM)	R&D expenditures (as a percentage of total sales)	State grants[a] for R&D expenditure (as a percentage)	In million DM	As a percentage of total public purchases	As a percentage of total sales
Chemicals	2,894	4.4	4.0	338	1.0	0.5
Oil refining	59	0.2	8.5	–	–	–
Machinery	1,364	3.1	22.0	1,009	3.1	1.5
Road and air transport equipment	2,432	4.9	36.4	386	1.2	0.7
Electrical goods	2,936	5.8	21.0	1,218	3.7	1.5
Precision mechanics and optics	232	5.0	9.1	239	0.7	3.3
Iron, tin and metal goods	32	0.9	8.4	335	1.0	1.3
Leather, textiles, and clothing	38	0.8	13.2	71	0.1	0.1
Nonferrous metals	75	0.8	–	338	1.0	2.8
Steel and rolling stock		–	–	950	2.9	6.9
Plastics, rubber, and asbestos	142	3.2	2.8	89	0.3	0.4
Stone and clay, ceramics, glass	66	0.9	10.6	634	1.9	2.2
Building trade	20	0.2	25.0	23,447	71.4	30.3
Transportation and communication	144	0.4	–	171	0.5	–
ALL INDUSTRY	11,179	2.6	20.9	32,850	100.0	6.0

[a] Federal grants including Defense Ministry.

SOURCE: Stiftverband für die Deutsche Wissenschaft; Rheinisch-Westfälisches Institut für Wirtschaftsforschung; Statistisches Bundesamt; Faktenbericht 1977 zum Bundesbericht Forschung (hrsg. vom BVFT).

innovate represents an important task for technology policy.

Although the quantitative aspect of public demand should not be overestimated, there is always a "break-even point" which must be reached before there can be any stimulating effect on firms' readiness to innovate. Therefore, in special cases, it may prove necessary to coordinate the demand of various government offices. Long-term delivery contracts or concentration of single orders at the same time can also be advantageous.

This procedure can create general problems of organization and specific difficulties with antitrust law and Federal competition policy. Whether and to what extent this kind of measure produces a detrimental effect on competition can only be judged in individual cases, taking into account the specific structures and competition on the market in question. The possibility of conflicts arising between the objectives of technology policy on the one hand and competition policy on the other cannot be excluded. In these cases, a political decision must be made, taking into consideration social priorities and the interests of those concerned.

THE FEDERAL MINISTRY OF RESEARCH AND TECHNOLOGY RESEARCH PROJECT

The economic and technological situation in the Western industrial nations has caused some countries to evaluate its possible effects and to develop measures for reducing potential obstacles.

The US government's Experimental Technology Incentive Program (ETIP) carried out by the National Bureau of Standards (NBS) in the US Department of Commerce must be regarded as the forerunner of most of these programs. The first activity started as early as 1973.

Innovation by US government purchasing was implemented in two ways:

(1) Innovative products were purchased in cooperation with a procurement agency, whereby both partners made a financial contribution.

(2) Demonstration projects were financed with the purpose of establishing the technical and economic suitability of new products and so promoting acceptance with other buyers, private buyers included.

The examples were selected from sectors which were of overall social importance, had a technological backlog demand and could nevertheless be presumed to have an innovative potential.

In 1978 a working conference was held in Dublin in connection with the "Six Countries Programme on Aspects of Government Policies towards Technological Innovation in Industry" at which the different countries gave reports on current programs and activities on the theme "Procurement and Innovation" (Overmeer and Prakke 1979). At this gathering the representative of the US Department of Commerce (Wolek 1978) undertook a critical assessment of ETIP's achievement so far. In this the following reasons, among others, were given for the as yet not always encouraging results of the experimental purchases (noiseless lawnmowers and energy-saving air conditioning are well known examples):

- underestimation of the ability of government agencies to insist on the traditional purchasing procedure and also of the special connections between technical advisers and purchasers;
- lack of agreement between overall social interests and the concrete purchasing aims of a public institution;
- insufficient emphasis on specific products in demonstration purchasing.

Against this, the introduction of the concepts of lifecycle costs and functional performance specification in US government regulations was mentioned as a positive result of ETIP.

In the Federal Republic the most positive experience of other countries with comparable programs led the BMFT in consultation with the BMWi to instigate an investigation of the possible uses of public procurement policy for promoting technological transfer and technical innovation with special reference to political, legal, and economic conditions. The study was intended to bring to light obstacles and mechanisms that might arise in innovation promotion through the demand side and to work out draft measures which could serve as a basis for the development of a promotion instrument.

Problems were examined by taking case studies from five separate sectors. In each case procurement activities had already been completed. Sectors were chosen keeping in mind social or political interests (e.g., promotion of R&D through public funds), innovative potential (patent statistics were included in the criteria applied here), and composition of the overall demand, both public and private (in other words, the state should not be regarded as the sole purchaser of the product in question).

In choosing case studies care was taken that wherever possible they showed a typical range of problems occurring in innovative procurement and that examples of both central procurement, e.g., Federal Army (Bundeswehr) and Post, and decentralized purchasing, mainly local authorities, were represented. The case studies have shown that only under favorable conditions can innovative procurement be carried out without additional incentives. The problems encountered can be summarized as follows:

- low motivation of the procurer to undertake the risks associated with purchasing new products
- insufficient information about new products
- inadequate planning process; introduction of new products frequently calls for a more extensive and complex systems analysis with its associated costs
- limitation of options by restrictive conditions and norms

-- small orders, where the impact on the product is difficult to assess
-- incomplete decision criteria, e.g. in the choice of the "most economic offer"
-- insufficient public funds to allow preference to be given to a product with high initial but low maintenance costs rather than to one which is initially cheaper but more expensive to operate.

The problems described were used as a basis for developing possible measures aimed at helping to stimulate innovative procurement. Table 3

TABLE 3 Draft of measures.

Motivation	1	Innovation consulting
	2	Premium system (purchaser)
	3	Removal of regression fear
	4	Adoption of positive attitude to innovation
Information	5	Publications
	6	Trade fairs, etc.
	7	Information systems
	8	Product information
	9	Local purchaser newspaper
	10	Extension of tenders
Planning	11	New planning methods
	12	State subsidies of planning costs
Means	13	Innovation promotion in the diffusion phase
	14	Financing pool
	15	Subsidy systems
Demand	16	Coordination of demand
	17	Longterm contracts
Norms	18	Modification of technical norms
	19	Elimination of market introduction difficulties
	20	Removal of restrictive specifications (VOL/VOB)
Decision	21	Methods of cost-effectiveness calculation
	22	Modification of guarantee requirements
Supporting measures	23	Consumer publications
	24	Requisition criteria and testing norms
	25	Premium systems (manufacturers)
	26	Purchase of prototypes

shows the measures in the individual problem areas. Further investigation is needed concerning the effectiveness and financial impacts of these measures as well as their compatibility with the existing legal and administrational structures and their feasibility from the organizational and institutional points of view.

CONCLUSIONS AND OUTLOOK

Analysis of case studies has not only shown the problem areas and possible obstacles which may arise in promoting innovation through the demand side, but it has also brought to light the following positive effects of successful innovation procurement:

- First introduction or utilization of new products by public authorities can have a positive technological influence on the whole market.
- Public procurement can in fact stimulate development of new, more economic products or effect a considerable improvement in existing products.
- Adoption of new products by public authorities can achieve a multiplier effect in the diffusion phase.

These findings, which are supported by similar investigations in other countries, provide a stimulus to examine the practicability, effectiveness and profitability of the suggested measures by means of so-called procurement models.

In such a model, procurement would be accompanied and supported by expert advice on planning, organization, and financing. The aim of a procurement model is to remove obstacles, to foster an innovative attitude and to ensure that in future dealings with commodity coverage the procurer is better informed about new products, more open to offers, and more ready to purchase new products. Care must be taken not to repeat mistakes made in other countries' programs. However, at the present stage of discussion it can be concluded that public authorities, through their demand for products and services, can provide an increasingly valuable stimulus for innovation.

The success of this kind of innovation promotion depends on the extent to which market mechanisms remain undisturbed, how far competition acts as an incentive, and the amount of public money employed for this purpose.

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NATIONAL INNOVATION POLICY AND STRATEGY IN THE NETHERLANDS

P. de Graaf and P. Tindemans

In September 1978 the government of the Netherlands published a white paper on sectoral policy in which a new, formal innovation policy was announced. This paper describes some of the features of that policy and the thinking behind it.

Under the new policy, total government spending on R&D will increase by 10 percent, thereby increasing the government contribution to industrial R&D from a mere 5 percent of total R&D expenditures to about 10-15 percent, which comes close to the average in industrialized nations. An extensive reorientation of the R&D and innovation infrastructure will accompany this increase, and government spending on "general improvement of knowledge" via universities etc. (now more than 50% of government R&D spending) will continue, but with new attention to the applicability of the results in the manufacturing and service sectors.

Like many such policies, the above is a compromise between political points of view, long-term thinking, and theoretical studies. Here effective policy decisions are hindered by the complete lack of methods to make good quantitative estimates and evaluations (in economic and social terms) of the effect of government measures. This problem is formidable. Unless a complete input-output model is used, microeconomic studies on innovation policy end up in the booby trap of counting R&D spending; and I think most readers will agree that R&D spending is a very poor yardstick for judging an innovation policy, whether on a macro-, meso- or microlevel.

In the absence of hard data, the Dutch innovation policy was based on a mixture of qualitative results of various studies, national and international, and discussions with representatives of several groups in society. Institutional factors were taken into account, and policy design attempted to make society profit as much as possible from the dynamic "hop, skip, and jump" character of technological change.

Two main methodological questions remain to be solved: how to monitor the effects of government innovation policy and what methods to employ in selecting the directions in which government will encourage innovation. In selecting directions it should be noted that Dutch policy mostly aims to create a set of conditions within which industry (and the service sector) can unfold their creativity, knowing the market forces, etc. That part of the innovations program was not too difficult to develop: A "cost reduction scheme" and a "risk reduction scheme" were created for that goal. Where difficulty arose was in formulation of the "selection" theme, which is part of most measures of the so-called "infrastructural line."

To act effectively, government needs a clear picture of the various factors affecting the process of innovation in industry and the way in which it can influence these factors. The framework of the Dutch innovation policy is based on two theoretical conceptions. Firstly, the interaction between natural technological trajectories, and the selection environment in which the innovative process within a firm will take place. By technological trajectories are meant scientific and technical trends which predominate for a given period, somewhat like the ones proposed by Nelson and Winter. Examples are the increase in the scale of production; the substitution of natural materials by artificial ones; miniaturization; and some successful product designs. The term selection environment covers the acceptance or rejection of an innovation by the market, and other background factors (such as the social and economic climate, government policy etc.). It is important to realize that there is an interaction between technological and background factors. In many cases there is no sharp distinction between the technological supply angle and the market angle, as sometimes suggested by the use of concepts such as technology push and demand pull.

Secondly, the Dutch policy is based on the conception of appropriate firm strategy. In this conception firm strategy should be developed in the area where the technological trajectories and the selection environment interact, taking account of the firm's strong and weak points. It is of the utmost importance to select a segment of the market which corresponds to the size of the firm. Small and medium-sized firms in particular often have difficulty in developing strategies appropriate to technological trajectories and environment; often they will need to call in outside experts. Also important are the internal organization of the firm and the question of finance. Owing to the multiple aspects of innovation, the firm's internal organization should be able to cope with the demands it places on coordination and planning. Chief among these is interaction and exchange of information between individuals and groups involved in innovation. The worst problems with regard to finance are the high cost of R&D work and the limited availability of venture capital: innovation is a time-consuming affair and investments do not bring in good returns for some considerable time.

Policy in the Netherlands also recognizes the key role of people; creativity, good education, opportunities for retraining and refresher courses, and mobility are very important in stimulating and maintaining an innovative society. Integration of these two points leads to a scheme as presented in Figure 1.

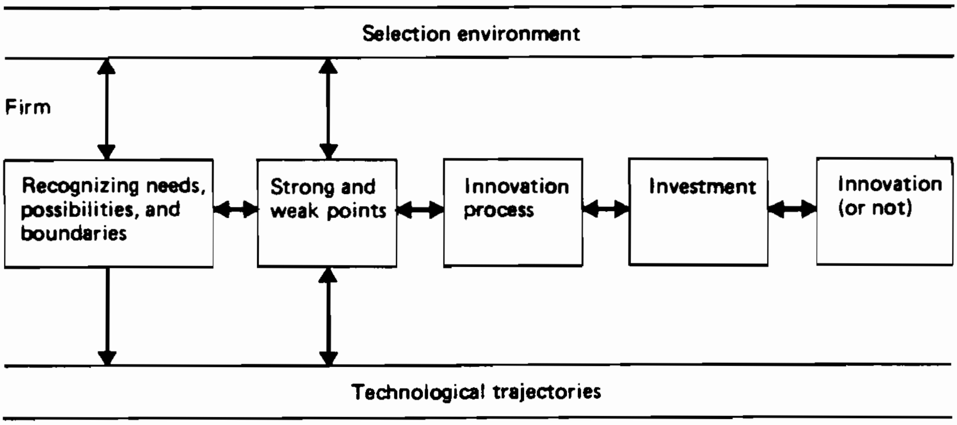

FIGURE 1 Scheme of factors in innovation policy in the Netherlands.

In developing Dutch innovation policy we devised the above scheme to show how the innovative firm with its weak and strong points is influenced by technological trajectories and selection environment. This proved to be a nice way to reconcile theory and practice of innovation. This was mainly because:

- it avoids the still too often presented view of demand pull versus technology push;
- various specialized institutions active in the innovative domain fit naturally into the scheme; and last but not least
- it represents both government policies on a level of high abstraction and those aimed at individual projects.

In this context I would like to register a complaint against the directions taken by study of the innovation process. We found it necessary to construct the above scheme because we could not find anything in the literature that met our needs. Moreover, we found a great void in the literature concerning the mixture of macro-, meso-, and microinstruments. In our experience this is an important policy question and it deserves research. Admittedly, innovation takes place only on the microlevel; however, the government in the Netherlands or in any other country is not apt to deal with the individual projects of all innovative firms. Moreover, not every firm really needs and appreciates this individual attention; therefore policy mix deserves greater emphasis both in research and in practice.

In recognition of the importance of mesolevel policy measures, the Government White Paper on sectoral policy published last September allowed for a collective, sectorwise approach which permits new sectors to be created through designation of key areas. On the macrolevel, the Dutch government mostly uses a nonspecific approach to innovation, although certain topics like regulation, procurement policy, attention to environmental questions, energy, raw materials, and international division of labor, must sometimes be tackled on a project specific basis. The new innovation policy also created possibilities for technical universities, research institutions (like TNO), and other members of the research infrastructure to tune in on firm's needs on all three levels.

The big question to be answered in the coming years is, of course, whether these policy measures really influence the innovation rate in the Netherlands. We in the policy community would welcome suggestions of practical ways of measuring this.

The rest of this paper is about the mainframe of the Dutch innovation policy in relation to which I have just discussed a few theoretical points.

First, however, a possible answer to the obvious questions "why innovations policy?" and "why now?" Certainly not because innovation is something new: one of the main characteristics of modern history has been the rapid rate of innovation in agriculture, industrial manufacturing — both products and processes — and in the service sectors. However, the innovative capacity in the Western industrialized world has come in recent years under pressures of various kinds. Competitive pressure is obvious, and needs no further mention other than to say that all countries are under pressure to "keep up with the neighbors." Apart from that aspect, however, important factors are as follows.

- Shifts are occurring in the international division of labor. In comparison with other industrialized countries the Netherlands is heavily engaged in processing raw materials and manufacturing intermediate products. Developing countries will certainly concentrate on these sectors in the coming decades, in which the developed countries will concentrate on sophisticated, skill-intensive goods and services. The high wage levels and social security costs in the Netherlands place us in a relatively weak competitive position in comparison to other highly industrialized countries.
- There has been a reduced willingness in industrial companies to take the risks associated with innovative programs: there is a tendency to concentrate on short-term survival.
- Technological innovations have important implications in policy areas such as energy supply, environmental policy, regional development etc. It is necessary to anticipate these effects of technological change and to develop policies to cope with them. The objections of selective growth policy can provide stimuli for industry to find answers by way of technological innovations to the problems posed by the new scarcities.

- The ever-increasing demand to employ technology to satisfy public needs (health care, public transportation, communication services, etc.) increases the need to anticipate technological change. Here satisfaction of public needs and encouragement of industrial innovation should be able to go hand in hand.
- The rate of technological change is an essential structural factor in present socioeconomic problems. While the relationship is not easy to define, let alone to quantify, it is essential for favorable social and economic development that industry and society are in a position to absorb and apply the results of science and technology.
- The division (not the total amount) of government R&D spending in the Netherlands has been quite different from the mean for industrialized countries.

Turning now to innovation policy as formulated in the recent White Paper, I should first of all mention a few underlying principles. In a market-oriented economy like ours, industry itself is primarily responsible for its innovation. The government, however, can and should create conditions for the stimulation of new activities. It also influences the orientation of innovative actions either by regulations or by supporting programs in areas which are considered to be of national interest, like energy-saving technology, health care, and others. Such programs, when successful, result in new industrial activities. Of course, any policy aiming at technological innovation must take into account the restrictions and limitations set by other policy goals.

The innovations program announced by the Netherlands' government centers around four nuclei. Firstly we will concentrate upon increasing the innovative capacity of industry itself. Individual firms are in the best position to react to the demand that manifests itself in the market. In view of the great diversity in demand and scope for goods and services and in production facilities, the basic policy is to maintain and develop a balanced mix of large, medium-sized and small firms complementing one another. In the case of large firms, which account for about 90 percent of industry's R&D spending in our country, government can help to maintain innovative capacity by reducing R&D costs and may enhance it by sharing the risk involved in larger innovative projects.

Medium and small-sized firms require and receive special attention. We are impressed by the recent results of the group of Professor Birch of MIT in relation to the important contribution of smaller firms to the net creation of new jobs.

The aim of policy in the Netherlands is to ensure that small and medium-sized firms make the best use of their specific advantages, such as their inherent flexibility. Our intention is to stimulate the innovative capacity of industry itself along two lines. The first is a cost reduction scheme of about 150 million guilders to cover part of the wage costs associated with R&D. Medium and small-sized firms will be granted a higher percentage than large firms. The second line is a risk reduction scheme. There will be a substantial increase in the budget for development credits.

The second nucleus in the Dutch program centers around attempts to increase the effectiveness of R&D institutions in supporting technological innovation. The efforts will be directed both at more effective utilization of existing knowledge and at producing new results that can be exploited. There are two important policy objectives. The first is to identify areas of technology which are likely to have a strong impact on industry and to stimulate R&D in these areas. The second is to design practical procedures to promote the more effective use of the available expertise for innovation, e.g. by reprogramming the R&D efforts financed from public money and by encouraging cooperation between (semi-) governmental R&D institutions and industry and within industry itself.

A few example of joint actions of the government and R&D institutions are as follows:

- reorganization of TNO to strengthen its user orientation and to improve its potential for solving multidisciplinary problems facing government, industry, and society as a whole
- introduction of innovation-oriented background research programs with participation of universities, (semi-) governmental R&D organizations and industry
- support of small and medium-sized firms in applying electronics; in order to do this, cooperation between scientific institutions (and where possible with industry) will be encouraged
- opportunities for retraining and refresher courses will be extended as an integral part of employment policy.

The third nucleus in the Dutch program centers on support through consultancy and information. Most firms can increase their innovative capacity by increasing their use of knowhow available from outside the firm. This applies in particular to small and medium-sized firms. Management requires knowledge and information of various kinds: technological, organizational, financial, and on markets and national and international regulations. The support of firms by providing them with innovation-oriented information takes different forms, including (a) the removal of obstacles which prevent firms from obtaining available information, and (b) assistance, either general or specific, in the effective utilization of such information (e.g., assistance to inventors).

The fourth (and last) nucleus of the program centers on intensifying the use of technological innovation to satisfy public needs and extending the government's potential role in voicing these needs. This can be an important source of industrial innovation.

The Netherlands is very densely populated and is highly vulnerable to the new resource scarcities. It is hardly surprising, therefore, that we should aim at a selective growth in which the objective of economic growth is balanced against the objectives of national policies concerning energy, the environment, regional planning, natural resources, and the international economic order. This policy is clearly formulated in the government memorandum on selective growth, published in 1976. Procurement policies are important in this respect, though not as important as in large countries. Regulations, developed to serve public needs, may also result in new processes and products.

I have tried to give some impression of the efforts in the Netherlands to give a new momentum to our industrial policy. A more detailed English language summary of the policy in this respect in the Netherlands will be available.

The process of industrial innovation is very complicated and requires a variety of skill and actions. As a consequence a policy to encourage innovation should work, in our opinion, from many angles. Whether we have chosen the right ones only the future can tell. (And without proper evaluation instruments even the future will not tell.)

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RESEARCH AND DEVELOPMENT IN A SMALL COUNTRY: THE CASE OF AUSTRIA

G.K. Chaloupek

RESEARCH AND DEVELOPMENT IN AUSTRIA IN THE EARLY 1960s

From the early 1950s onwards expenditure on research and development (R&D) in the industrialized countries has been rising considerably faster than industrial production or GNP. In Austria, however, it was not until the middle of the 1960s that the importance of R&D in relation to overall economic growth and the international competitiveness of the country's industry was realized.

The basic conclusion of the first comprehensive study on R&D in Austria undertaken by the economic research department of the Chamber of Labor was that the R&D efforts of the Austrian economy lagged far behind most Western industrialized nations (Prager 1963). Despite its well-established tradition of high standards and achievements in research and academic education in various fields of science and technology, Austria's economy had failed to recognize and utilize the enormous potential of these human resources. In the postwar period a substantial number of scientists and technicians with a high international reputation were forced into emigration for lack of opportunities. For a considerable proportion of the qualified technical personnel turned out by the institutions of technological education it had proved impossible to find jobs corresponding to the training they had received. The total nongovernmental expenditure on R&D in 1963 was estimated at around AS500 million, about 0.25 percent of GNP (Prager 1963, p.39). This was far below the corresponding figures for most other OECD countries except for the lesser developed southern European states.

The comparative neglect of R&D in the first two decades of Austria's postwar economic development should not —as Josef Steindl convincingly argues — be considered an altogether irrational policy. Austria's economic development up to the mid-1960s was characterized by high growth rates and great prosperity. The obvious contrast between this quite impressive record of economic growth and low R&D effort can easily be explained by looking at "the state of technology which Austria inherited from the interwar period." This technology was backward and did not embody methods which had already become fairly commonplace in the USA some time ago (for example, the broad strip mill, large paper machines, the catalytic cracking process, modern kilns, efficient methods of internal transport, etc.). These methods were then introduced in a comparatively short time (assisted, in part, by Marshall aid), and the technology was lifted abruptly to a higher level.

Thus a process of catching up with other countries took place and over the period 1957–1969 Austrian labor productivity in manufacturing industry rose by 5% per annum while that of the United States rose only by 2.7%. We have absorbed technology faster than it can be currently produced, drawing it, as it were, from a stock of "accumulated knowledge" (Steindl 1977, p.211).

This effortless technological success has created a mentality of not bothering with the high risk and cost of R&D but of relying instead on the readily available stock of knowhow accumulated elsewhere. This lazy attitude toward technological progress presently poses a far greater danger to future Austrian economic development than does its past and current low expenditure on R&D. Hence, the commonplace question of whether Austria can afford more R&D should be put the other way around: can Austria afford not to increase substantially its R&D effort (Prager 1963, p.9)?

THE RECORD OF THE 1970s

Since the 1960s there have been successful efforts to increase the Austrian public and the business community's interest in R&D. In 1968 two special funds for the promotion of research were set up, one of which was devoted to the furtherance of industrial research ("Forschungsforderungsfonds der gewerblichen Wirtschaft"). Its purpose is to assist the R&D efforts of Austrian industry by giving subsidies and subsidized loans for specific projects.

In 1970, a separate Ministry for Science and Research was formed which, since then, has been in charge of the science and research policy of the federal government. The Science and Research ministry is required to report to Parliament each year on matters of R&D. An "Austrian Research Conception" was worked out by a group of experts and adopted by the ministry (Bundesministerium für Wissenschaft und Forschung 1972).

This increasing government concern with R&D was paralleled by a substantial rise of private business expenditure on R&D (see Tables 1 and 2). The number of firms reporting R&D activities of their own increased from 382 in 1966 to 652 in 1975. This increase appears unduly great, as the coverage of surveys has been extended continuously and the number of small firms included in the survey was higher in 1975 than in 1966. Total R&D personnel more than doubled in a decade, rising from 3,560 in 1966 to 8,433 in 1975. The number of scientists involved in R&D increased roughly in proportion to the total personnel while the number of technicians more than tripled.

TABLE 1 Research personnel and R&D expenditure, 1966–1975.

	1966	1969	1972	1975	Increase 1966–1975 (%)
Scientists	790	1,423	1,703	1,911	141.9
Engineers	1,130	2,511	2,537	3,570	215.9
Others	1,640	1,919	2,982	2,952	80.0
TOTAL	3,560	5,843	7,222	8,433	136.9
Expenditure (million schillings)	950.4[a]	1,224.3	2,255.8	3,551.4	273.7

[a]Excluding small-scale industry.
SOURCE: Federal Economic Chamber.

The R&D coefficient (R&D in relation to total turnover) of the firms covered in the survey rose from 1.13 percent in 1969 to 1.7 percent in 1975; the proportion of personnel engaged in R&D was 1.92 percent in 1969 and 2.3 percent in 1975.

There was little change in the structure of the R&D expenditure between 1969 and 1975 (Table 3). The seven most R&D-intensive branches accounted for 87% of total expenditure in 1969 and for 88.5% in 1975. In this period the oil industry increased its share from 4.2% to 19.9%, which can be largely attributed to the intensification of exploration after 1973.

Most of the R&D is undertaken in large firms (Table 4), which account for more than 80% of total R&D, leaving less than 20% for the small and medium-sized firms.

The share of the state owned-industry in total R&D expenditure declined from over 40% in 1969 to 35% in 1977. The R&D expenditure of the business sector was almost totally financed by current proceeds of the firms in 1975. The contribution of public subsidies to private R&D amounted to only 4% of the total as compared to 1.3% in 1969.

The share of R&D expenditure in GNP has increased substantially in the 1970s. R&D in the business sector amounted to 0.58% of GNP in 1978 as compared with 0.37% in 1969. Since the public R&D expenditure has also been very dynamic in the 1970s the share of total R&D (business and government) rose from 0.93% in 1970 to 1.25% in 1978. This is all the more remarkable as the corresponding figures have declined in this period in most Western countries (see the interesting article "Die Schweizerische Forschung im Internationalen Vergleich" 1979, in Der Monat, No. 9). Thus, Austria has been able to catch up considerably in comparison to other countries; however, there is still some leeway for improvement.

TABLE 2 **R&D expenditure 1970–1979, in million schillings.**

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979[a]
Total R&D expenditure	3,492.0	4,012.1	4,830.3	5,658.5	6,891.4	7,860.5	8,952.1	9,536.7	10,589.7	11,510.3
Federal government	1,355.3	1,599.8	2,046.4	2,325.1	2,829.9	3,403.9	3,798.5	3,758.9	4,210.4	4,595.1
Provincial governments	385.7	457.8	551.1	690.4	853.5	1,029.9	1,099.6	1,200.8	1,417.3	1,540.2
Business sectors	1,711.0	1,909.5	2,182.8	2,588.0	3,148.0	3,361.7	3,984.0	4,502.0	4,882.0	5,290.0
Other	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0
Gross domestic product (GDP) at current prices, in billion schillings	375.7	418.8	476.2	535.7	613.1	656.3	727.6	792.5	844.0	900.0
R&D expenditure as a percentage of GDP	0.93	0.96	1.01	1.06	1.12	1.20	1.23	1.20	1.25	1.28

[a] Forecast.

SOURCE: Forschungsbericht der Bundesregierung 1979. (Governmental Report on R&D, 1979.)

TABLE 3 R&D expenditure, by branch of industry.

	1969	1975
Mining and iron production	18.3	14.2
Oil	4.2	19.9
Quarrying	2.5	1.5
Glass	0	0.8
Chemical industry	24.6	20.8
Paper	1.8	1.1
Wood processing	1.3	1.3
Food, drinks, and tobacco	3.4	1.7
Leather	0.8	0.8
Foundries	1.9	2.1
Mechanical engineering	10.7	8.8
Transportation	6.8	5.6
Iron and metalworking	5.8	5.1
Electrical industry	16.6	14.1
Textiles and clothing	1.3	2.4
TOTAL	100	100

SOURCE: Federal Economic Chamber.

TABLE 4 Distribution of R&D expenditure, by firm size.

Number of employees of the firm	1966	1969	1975
<100	2.7	4.8	4.3
101–500	10.9	18.2	14.2
>500	86.4	77.0	81.5
TOTAL	100	100	100

SOURCE: Federal Economic Chamber.

LOOKING BEHIND THE FIGURES: SOME PROBLEMS OF AUSTRIAN R&D POLICY

So far I have only presented the conventional R&D statistics which must be interpreted with a good deal of caution. R&D statistics are basically input data. They permit the conclusion that R&D activities have been substantially intensified in the 1970s. But the question remains open to what extent these increased activities have been successful: whether and how far they have materialized in specific products and processes of industry.

For one thing it must be said that Austrian technological research in the 1970s has produced nothing that could be termed a "major breakthrough" like the so-called "L-D process" in steel production in the late forties and early fifties. This kind of innovation now almost seems to be beyond the reach of any Austrian industrial enterprise. But there were some remarkable achievements in various fields as can be illustrated by the following examples:

- hard metals (Planseewerk Reutte): special parts for machines, implanting material for medical purposes
- steel production: increases in efficiency in certain energy-intensive processes
- powder metals: polishing of wheels
- transport: light Diesel engines, cross-country vehicles
- mechanical engineering: automatic spinning machines (at present the most prominent example of innovation by a medium-sized firm), reactor units (Vöest-Andritz), track-laying machinery, branch exchange systems
- pharmaceutical industry: especially antibiotics.

In the Austrian case one question is of particular relevance: How much does the Austrian economy benefit from its R&D expenditure? The question arises from the fact that foreign-owned companies dominate a large and growing share of Austrian industry. Two of the most research-intensive branches — the electrical and the pharmaceutical industries — are overwhelmingly dominated by multinational companies (i.e., Siemens, Philips, ITT, Sandoz, Ciba-Geigy-Hoffmann, Höchst, Böhringer-Bender) (Grünwald and Lacina 1979). According to a cautious estimate (Table 5) in 1975 about one third of the total R&D of the business sector was undertaken in foreign-owned enterprises, some 40 percent in the state-owned industry, and roughly a quarter in privately owned Austrian firms.

TABLE 5 Breakdown of business R&D expenditure by ownership in 1975.

	Million schillings	Percent
State-owned industry	1,355	40
Multinational companies	1,100	33
TOTAL	2,455	
TOTAL INDUSTRY	3,362	
Difference (i.e., private Austrian-owned industry)	908	27

SOURCES: ÖIAG (state-owned industry); Federal Economic Chamber; own estimates (multinational companies).

In some cases the outcome of R&D efforts of foreign-owned enterprises formed the basis for new industrial activities in this country. The most recent example of this is the videotape recorder factory of Philips which is located in Vienna because the Austrian branch of the firm has provided the knowhow. On the other hand, there are multinational firms of the electrical and pharmaceutical industries with research establishments in Austria which are not linked to their respective production units in this country but directly tied to the mother company abroad. Thus, a significant proportion of R&D undertaken in Austria may and will not be passed on to the country's industry. And there are no Austrian counterparts abroad to transfer R&D results obtained abroad to this country.

The privately owned Austrian firms are in a rather unfavorable position with respect to R&D, a position which arises basically from their restricted size. Small and medium-sized firms are usually not in a position to commit sufficient funds to risky research projects. Nevertheless they are often forced to do so and the outcome may be unsatisfactory. A medium-sized firm can usually afford only one project. If this fails the firm may be driven close to bankruptcy, but if it succeeds the firm is liable to be bought out.

The size structure of firms shifts the burden of basic research almost entirely to the government. This and the high share of state-owned industry in the R&D of the business sector places an extraordinarily high burden of responsibility on the public sector.

In recent years there has been growing concern with the impact of recent technological developments such as the microprocessor on Austria's industrial structure. Austria will only be able to maintain her competitiveness on international markets if she can manage the required structural adjustments. The need has been emphasized to give proper incentives for industry (Advisory Board on Economic and Social Questions 1978). This could be done by shifting some of the incentives now given for investment generally to R&D efforts in the manufacturing sector.

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THE RELATIONSHIP BETWEEN BASIC AND IMPROVEMENT INNOVATIONS: THE DEVELOPMENT OF INNOVATION POLICY IN JAPAN

Hajime Eto

INTRODUCTION

Basic innovation has traditionally been considered more valuable than improvement innovation. However, the history of Japanese technology indicates that a thriving technological base can exist based mainly on improvement innovation. This paper first discusses these historical lessons of Japan. Secondly, it examines reasons why improvement innovation is so dominant over basic innovation in Japan.

THE DEVELOPMENT STAGE OF INNOVATION

The Development of Japanese Technology Policy

Development and changes in Japanese science and technology policy over the past decades are reflected in the titles of Science and Technology White Papers reported by the Science and Technology Agency of the Prime Minister's Office (Table 1). The need for R&D itself was stressed at the end of the 1960s. In the first half of the 1970s the titles made no explicit reference to R&D itself and were concerned rather with guidance and the assessment of a technology's development course. In the second half of the 1970s the titles resume emphasis on the need and urgency for R&D itself.

At the end of the 1960s Japanese technology caught up with Western technology, and the Western countries became reluctant to export technology to Japan. Accordingly, technology policy focus shifted to replacing technology imports with technology self-development and to promotion of

TABLE 1 The titles of Science and Technology White Papers of Japan.

Year	Title
1967	Status Quo of R&D
1968	Science & Technology in Economic Society
1969	Promotion of Selfdeveloped Technology
1970	Science and Technology for a Wealthy Society
1971	New Needs for Technology Innovation
1972	Response to the Age of Change
1973	For a Society of Hope
1974	Response to the Age of Change
1975	For New Needs of Stable Development
1976	For Technology Innovation in Social Development
1977	Facing the Ordeal of Technology Development
1978	The Increasing Importance of Governmental R&D Activity
1979	Improvement in the Efficiency of R&D Activities

technological self-reliance. Emphasis was also put on high quality technology which was expected to bring a high income and a wealthy life.

In the first half of the 1970s rapid economic growth enabled Japanese firms to increase R&D resources. Hence the government was optimistic about technology development itself and was concerned with guiding and assessing it on the criterion of the new value system. The titles in that period refer explicitly to the goal of social development, implying that technology development was a requisite for this.

In the second half of the 1970s to the present, continuing economic recession has discouraged R&D investment and the uncertainty over social structure makes R&D managers less confident of the orientation of technology development. This results in stagnation of technological innovation. The Science and Technology White Paper in 1978 discusses the necessity for governmental intervention in R&D through an increase in the governmental research activity and grants to the private sector's R&D. The latest White Paper in 1979 discusses the necessity of improving the effectiveness and efficiency of R&D investment for its limited amount.

The 1979 White Paper indicates a need for reform in the organization of R&D activities. The effect of investment on R&D effectiveness is saturated today, and the economic resources for it are limited by the anticipation of a low rate of economic growth. The key factor for R&D promotion is shifting from increase of input to improvement of efficiency.

Innovation for Excellency in Technical Performance

Japanese industry shifted from light industry (in particular the textile industry) to heavy industry in the 1930s. This was preceded by successes in pure sciences such as theoretical physics and mathematics. Most research was done in universities, and R&D in the private sector was negligible. R&D for defense (shipbuilding and aircraft) dominated R&D for industry.

Around 1940 Japanese technology developed the world's best navy aircraft. For example, the Zero Fighter, a ship plane designed for taking off from aircraft carriers, was the best in speed and range with the heaviest arms in the world. With it Japan believed it could control the Pacific Ocean.

The Japanese aircraft industry, however, had the following weakness which negated its excellent technical performance: (i) inefficient production processes which hindered mass production; (ii) low reliability due to lack of quality control; (iii) poor delivery system for parts in the production process; and (iv) a poor inventory system for repair parts on the front which resulted in poor operation on the front.

Similar things happened with iron and steel technology. Japanese physicists developed high quality steel in the interwar period. But the Japanese production process for iron and steel was inefficient for mass production, and lack of quality control resulted in big variance of quality which reduced the theoretically calculated high quality. The basic innovation founded on important physical discoveries was found useless without suitable production technology.

A third example is radar. A Japanese scientist discovered the fundamental law for radar and invented its major parts in the 1930s, but Japanese communications technology failed to put it quickly into production. When Japan started its production, the Japanese airforce was already powerless in terms of number of aircraft.

Innovation For Efficiency in Production Technology

Having learned from the war experience that technology for mass production with quality control and inventory control was decisive, Japanese technology began R&D to attain this goal.

In the postwar period the Japanese aircraft industry was converted into the automobile industry. The automobile industry found that progress in the technical performance of the car was already saturated. Hence higher priority was given to innovation in production technology, reliability, and service systems in the delivery of parts than to innovation in speed and power. As a result Japanese cars attained a good reputation on international markets though their technical performance was no better than American and European cars.

Similar things happened in the iron and steel industry. A great deal of effort was put into automation technology development rather than into improvement in the quality of iron and steel itself.

Figure 1 shows that the Japanese iron and steel industry is less R&D intensive than the average of the total industry, while automation-related industries (the electrical machinery industry and the precision instrument industry) are the most R&D intensive. A similar thing is seen with the Japanese transport equipment industry which includes Japan's major export industries: automobiles and shipbuilding. Figure 2 shows that the Japanese transport industry is less R&D intensive than that of other industrialized countries.

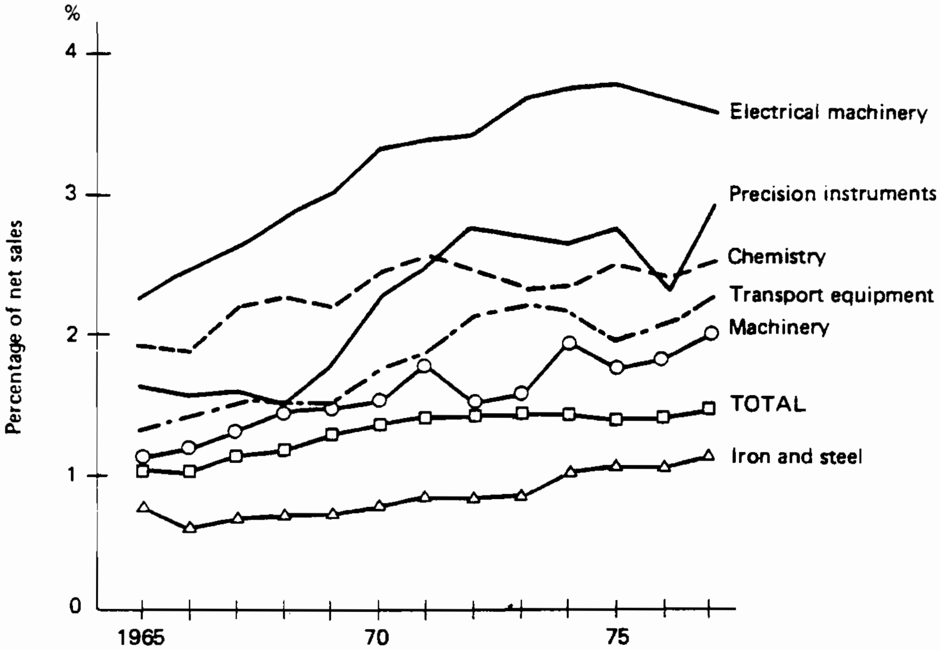

FIGURE 1 R&D expenditure as a percentage of net sales, by sector. Source: Science and Technology White Paper of Japan (1979).

The prerequisite for an efficient production system is a balanced system of technology in diverse fields rather than highly excellent technology in a particular field. Accordingly, manpower training and personnel management systems are often more important than scientific discoveries. Japan learned this lesson from history and put it into practice successfully between 1945 and 1965.

Innovation for Need-Oriented Technology

At the end of the 1960s Japanese society began to shift its major goal from economic growth to welfare. This was naturally accompanied by a need for new technology which was called welfare technology. Welfare technology was characterized as a proper combination of the existing technologies to satisfy social needs or to solve social problems. On the one hand it was stimulated by the success of space technology which was a typical example of a combination of existing technologies. On the other hand it responded to the criticism of space technology as being noncontributive to welfare.

Systems analysis, policy science, or sociotechnology has been assigned a central role in systematically combining existing technology to solve social or political problems. The Ministry of Education established new departments and graduate schools in these fields in the state universities. The Science and Technology Agency has bestowed upon these fields, collectively, the name "soft science," meaning the system of knowhow needed to exploit the existing hardware technology for problem

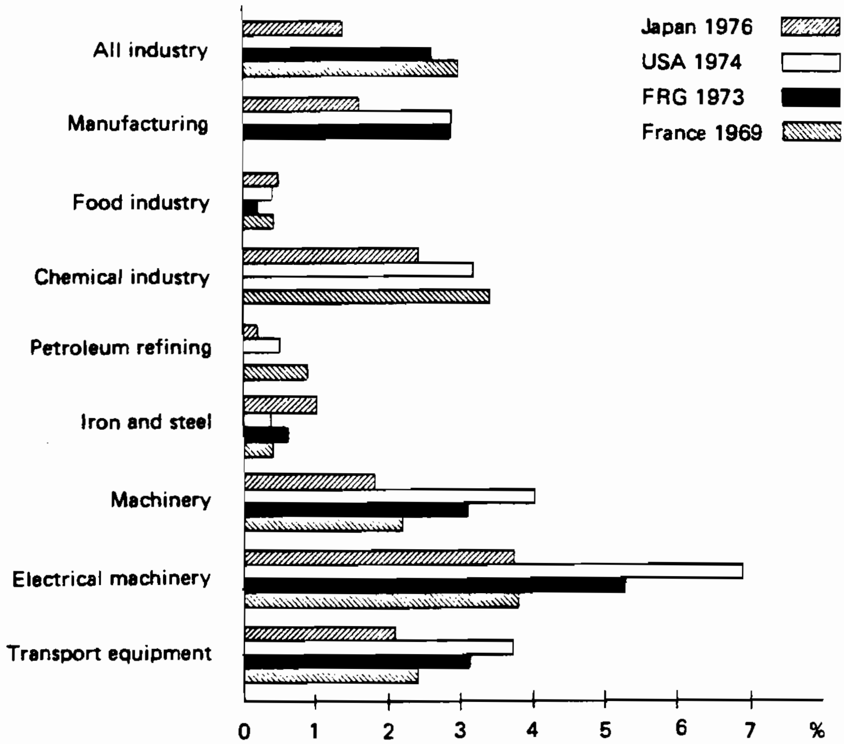

FIGURE 2 R&D expenditure as a percentage of net sales by sectors. Source: Indicators of the Science and Technology Society of Japan (1978).

solving. The naming of a new science on a national policy level implied promotion of soft science as an innovation to be used in steering society toward achievement of national goals. This met with the silent resistance of R&D organizations, especially universities.

Innovation for Seed-Oriented Technology

"Soft science" was expected to contribute a great deal to solving the problems but its progress has been much slower than expected. This gap caused policy emphasis to return from need-oriented technology to seed-oriented technology. Figure 3 shows that private industry, particularly the electric machinery industry, is losing interest in need-oriented technology and is increasingly interested in seed-oriented technology in every sector. But this fact does not imply that the weight is shifting from improvement innovation to epoch-making or macroscopic innovation. Figure 4 shows that every sector expects improvement innovation as the most realistic and likely innovation. Even the electrical machinery industry, which considers its innovation seeds to be bright prospects, expects little epoch-making innovation.

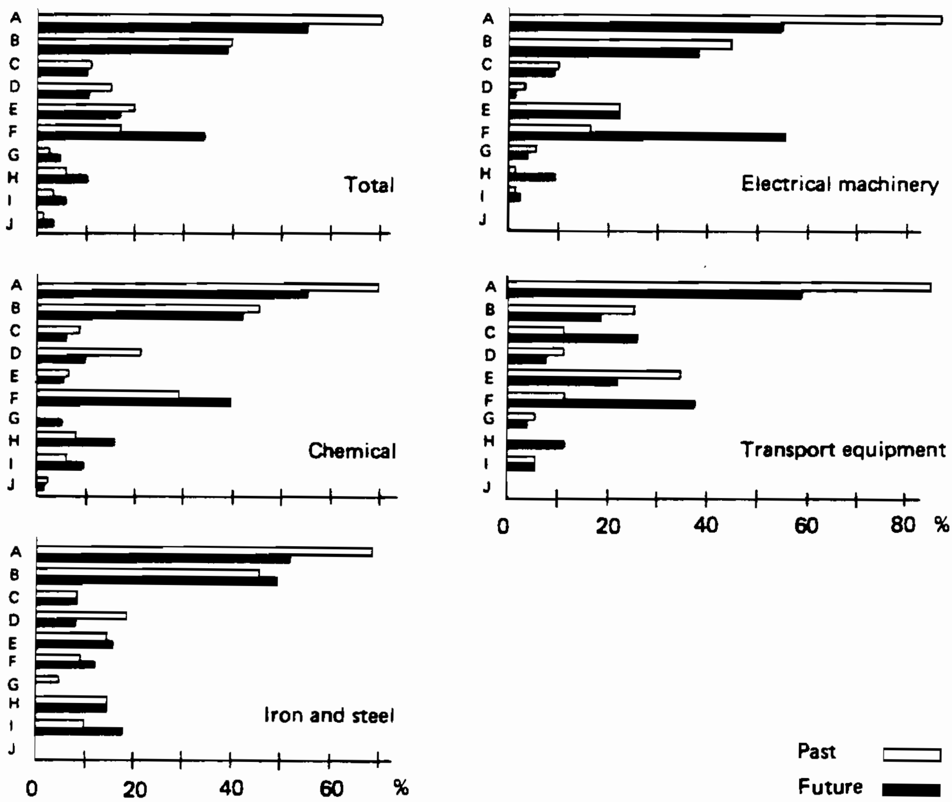

FIGURE 3 Priorities of R&D in the past and future. Source: Science and Technology White Paper of Japan (1979). A, need-oriented new products in the same field; B, higher quality in the same field; C, energy saving in the same field; D, resource saving in the same field; E, labor saving in the same field; F, seed-oriented new products in the same field; G, more basic R&D in a related field; H, more applied R&D in a related field; I, R&D in different fields; J, others.

Innovation seeds are growing steadily, especially in the material science field (the materials revolution). Without a policy direction settled by systems analysis or policy science it is hardly expected to generate a drastic and profound effect on industry. In this sense basic and epoch-making innovation is hardly expected to result from it.

In the electronics field the materials revolution took the form of innovation in the production process of electronic circuits and resulted in mass production of cheap microcomputers. This innovation is mostly aimed at cost reduction; it has permitted continued expansion of microcomputer markets in all fields despite economic recession. In an age of diversified social value systems, innovation by small steps is the most acceptable to society, while epoch-making innovation is hardly put into practice owing to the absence of strong leadership. Thus microscopic or improvement innovation is likely to follow from the present seed-oriented innovation policy. In fact the series of "The State of the Art and the

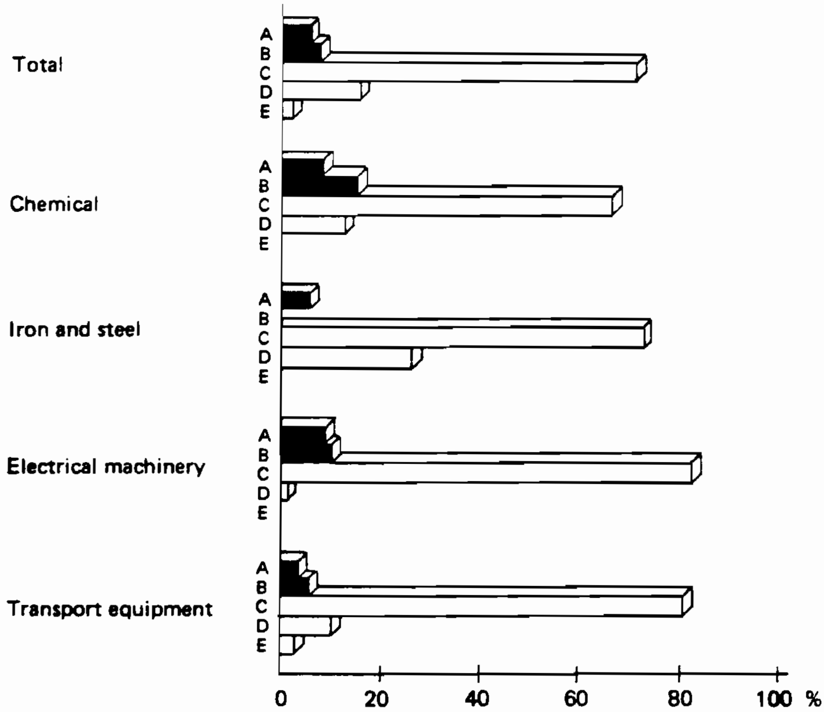

FIGURE 4 Expectations of innovation. Source: Science and Technology White Paper of Japan (1979). A, epoch-making innovation in 5 years; B, epoch-making innovation in 10 years; C, improvement innovation in 5 years; D, improvement innovation in 10 years; E, no significant innovation in 10 years.

Future of Materials Technology" which has been published annually by the Science and Technology Agency since 1973 is focusing on process technology of new materials for the purpose of industrial practicability.

MANAGERIAL BACKGROUND OF IMPROVEMENT-ORIENTED INNOVATION

Absence of Strategic Mobilization

Mr. Alan Williams, then the UK Minister of Industry, after his visit to Japan, told the House of Commons select Committee on Science and Technology that the most impressive feature of Japanese R&D behavior was the continued priority being given to R&D. In other words drastic mobilization of R&D resources for a particular subject is common. National unity or consensus is the key factor in Japanese policy formation. This principle tends to lead to conservatism. Policies continue over many years despite environmental change, until the majority begins to demand a new policy. In an extremely uncertain field like innovation, decision makers tend to choose conservative courses for safety's sake and to allocate R&D resources according to precedent. This makes epoch-making or basic innovation highly unlikely.

The consensus-seeking principle also implies that, in the absence of a strong majority, policy will be broadly based with equal allocation of the R&D resources to every innovation item. This results in infinitesimal improvement in every field, yielding a balanced technology system. Such a system works favorably for mass production with high quality as well as for commodity exports and economic growth.

Quick and Slow Responses at Tactical and Strategic Decision Levels

Mr. Williams stated that the second most impressive feature of Japanese R&D behavior was the rapid absorption of technological change and that the third was systematic search for up-to-date knowhow. These observations are true at a tactical or operational level but the contrary holds true at a strategic level. In Japanese management systems the most important responsibilities lie at the lower decision level (the bottom-up decision system) and lower-level decision makers are earnest in quick responses to technological innovation. In a similar way trade unions are quite cooperative in absorption of up-to-date technology. In contrast, many top managers want to avoid the possibility of drastic organizational changes caused by new technology systems and therefore prefer improvement innovation within the frame of the existing technology system to basic innovation. Such a resistance of the "top managers' union" is a strong obstacle to basic innovation.

Mr. Alan Williams stated that the fourth most impressive feature of Japanese R&D behavior was the separation between and coordination of R&D for the near future and that for the distant future. There are various reasons for this. The most decisive one may be attributed to the homogeneity principle of Japanese management, which separates the whole into homogeneous units and cuts off influence between them. This management principle leads to poor channels between basic research and development and makes basic innovation through cooperation between basic research and development very slow.

Slow strategic innovation becomes a problem when firms in a certain field meet with saturation of innovation potential in their field and are forced to convert to another field. In such situations Japanese top managers tend to postpone strategic conversion until they reach a critical point. For example, shipbuilding corporations are now slowly converting their technology into the plant field while their profitability is quickly declining.

Risk Averseness in Innovation

The stagnation or relative decrease of R&D investment in the second half of the 1970s is not so much due to economic depression as to risk-averse behavior in R&D investment. Figure 5 shows that the R&D managers in private industry decline to invest in R&D mainly to avoid risks.

The same survey also revealed that R&D managers consider the risk averseness inherent in Japan's many small-scale firms to be the major cause (52.5%) of the inferiority of Japanese R&D. However, this explanation is not convincing. The scale of Japanese firms is indeed smaller than that of American firms but not smaller than that of European firms.

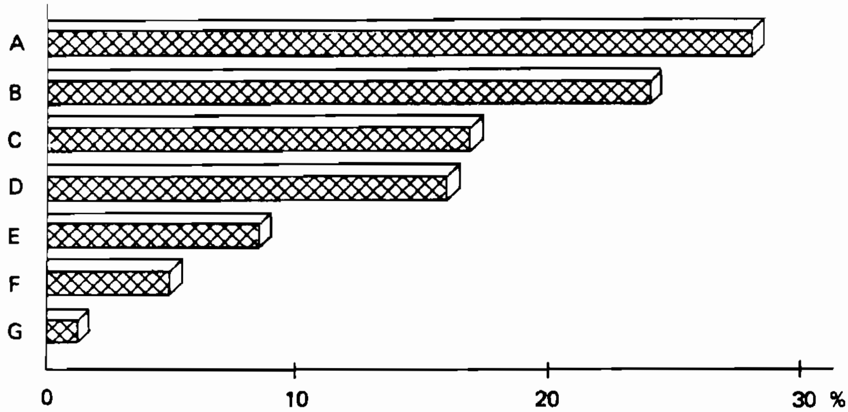

FIGURE 5 Major reasons for the decline of R&D in the private sector. Source: Survey of R&D in Private Industry (1978). A, increasing risk due to increasing R&D expenditure; B, less seed owing to stagnation of basic research; C, less stimulus owing to global trend of stagnation of innovation; D, decreasing originator's profit owing to speed up of technology advance; E, diversity of needs due to variety of values; F, reduced acceptability of new technology to public; G, miscellaneous.

Unmanageability of Multiple-Goal Technology

As is shown in Figure 5, a fifth reason for the decline in R&D investment is the increasing difficulty of R&D management owing to diversification of R&D goals. As the national value system is diversified, so are needs for innovation (Figure 6). This makes R&D management so difficult that many R&D managers and engineers tend to avoid need-oriented innovation and return to traditional seed-oriented innovation.

Seed-oriented innovation is easily manageable under traditional R&D management systems which give researchers disciplinary autonomy. This system leads to diffused allocation of R&D resources lacking strategic cross-disciplinary decision making and therefore to infinitesimal innovation in many fields. This further increases the dominance of improvement innovation in Japan.

Inefficiency in Basic Research Organizations

The advance of Japanese technology over the past decades has been due to a significant increase in R&D investment. Now, with continuing economic depression inhibiting investment, improvement of R&D efficiency is the key factor for the promotion of innovation.

The share of universities in basic research was 64.3% in the 1977 budget year. In this sense universities are largely responsible for the inactivity of basic research in Japan. Japanese private industry does not trust the basic research activity in universities and obtains seed mainly

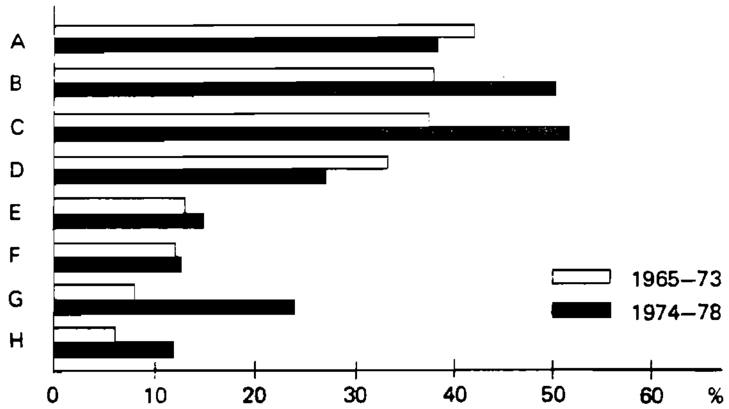

FIGURE 6 Goals of technology. Source: Science and Technology White Paper of Japan (1979). A, higher quality; B, greater convenience; C, labor saving; D, mass production; E, safety; F, resource saving; G, environmental protection; H, energy saving.

from other firms (Figure 7) with only 3.4% from Japanese universities.

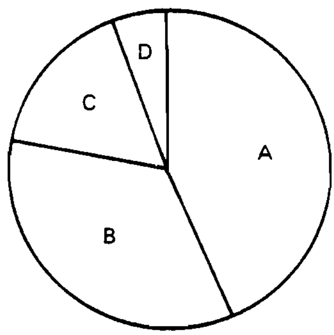

FIGURE 7 Source of seed. Source: Science and Technology White Paper of Japan (1979). A, other Japanese firms in different fields; B, other Japanese firms in the same field; C, foreign firms; D, Japanese universities.

The Science and Technology White Paper in 1979 mentioned, though only implicitly, the inefficiency of universities for the first time in the White Papers series. The government has long been in conflict with the teachers' union of the elementary and middle school education system but has traditionally cooperated with universities. Thus it is significant that the 1979 White Paper quoted private industry's criticism of the inefficiency and ineffectiveness of universities.

The University of Tokyo and the University of Tsukuba have the greatest budgets among Japan's hundreds of universities and colleges. In the following we explore the efficiency and effectiveness of Japan's universities by looking at these two largest universities.

The University of Tokyo was founded about 100 years ago. At that time each of its departments focused on the most up-to-date research topic. The department of physics chose mathematical systematization of classical physics and the department of philosophy chose neo-Kantian philosophy. When the department of economics was added after the Russian revolution, it chose Marxist economic theory. Departments have stuck to their original research topics and ignored the emergence of new subjects. The department of physics overlooked relativity and quantum theories: the department of philosophy paid little attention to modern philosophy after the neo-Kantian school, and the department of economics was long behind in econometrics. This tradition continues even today in the University of Tokyo. In fact it has rejected proposals to start new departments such as environmental science.

The University of Tsukuba combines a traditional university (Tokyo University of Arts and Sciences), which was excellent in the traditional disciplines such as physics, mathematics, and history, with a completely new university which was designed to promote interdisciplinary research and education in modern fields. It is organized in matrix fashion, coupling the faculty's disciplinary research institutes with the student's interdisciplinary education schools. Within a few years of its start its interdisciplinary education schools ceased to allow students the freedom of choosing interdisciplinary programs, and its matrix structure became a diagonal matrix by making a one-to-one correspondence between the faculty's institutes and the student's schools. Now the University of Tsukuba has lost its organizational appropriateness for new interdisciplinary basic research.

History shows that great steps in science are often made in new organizations, but the anticipated low rate of economic growth makes it difficult to start new universities and research institutes. Thus it is unlikely that Japan will make epoch-making innovations based on basic scientific discoveries in the near future.

Balance-Seeking Behavior and Appropriate Technology

Japan's top leaders are often said to be of colorless personality. Indeed a colorful personality is never an advantage in getting a top position in Japan. Instead a balance-seeking personality poised between extremes is the norm for top leadership. This results in conservatism among researchers and R&D managers which in turn generates a social situation favorable for improvement innovation.

In addition Japan is a closed culture, isolated from other advanced countries. Specifically in the technology field Japan needs a closed system of technology wherein every field is balanced. Therefore deficiencies in every field must be filled and, for this purpose, improvements must be made in every field. Hence improvement innovation is emphasized more than basic innovation.

This balanced system of technology is unsuitable for technology export. In fact Japan imports technology much more than she exports because the balanced system lacks the sort of local excellence that is needed for export. On the other hand it is quite appropriate for improving the national welfare (Eto 1980). Japanese society is, therefore, quite satisfied with its balanced, closed, and appropriate system of technology. Indeed the majority of faculties in the University of Tokyo and the University of Tsukuba enjoy their conservatism in management philosophy.

CONCLUSIONS

The history of Japanese innovation has been reviewed in the light of the categories of basic and improvement innovations. Japanese innovation in 1945–1965 can be characterized as a shift from a basic innovation orientation to an improvement innovation orientation. The innovation process in the last decade was characterized as an oscillation from need-oriented innovation to seed-oriented innovation; the recent emphasis on need-oriented innovation was shown to lead to predominance of improvement innovations .

The reasons why improvement innovation is constantly dominant in Japan despite the rapid change in many fields were examined in the context of R&D organization and management. The implicit principle of conservatism in the Japanese way of management in R&D organizations was shown to be responsible for ineffectiveness and inefficiency in basic innovation and effectiveness and efficiency in improvement innovation.

Improvement innovation made simultaneously in many fields has given Japan a balanced and extensively comprehensive system of technology. In this sense it is quite desirable as a means of developing an appropriate and welfare-oriented technology system. At the same time it might damage Japan's potential energy for basic innovation as welfare in general might do that. The choice or mixture between basic and improvement innovations is a matter to be decided upon the basis of the national value system.

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PART THREE

COMPANY STRATEGIES: THE EXPERIENCE IN DIFFERENT BRANCHES OF INDUSTRY

INTRODUCTION

Jennifer Robinson

The phrase "technological innovation" encompasses everything from use of lasers in laser surgery, to enhanced petroleum recovery techniques, to continuous casting of steel, to office automation, to biosynthesis of complex organic chemicals. The physical basis of innovations ranges, in the cases mentioned, from human biology and laser physics, to geology and petroleum chemistry, to metallurgy, to cell chemistry and genetics. The social and economic organizations involved range from individual medical practitioners dealing with individual patients, to established multinational corporations and state-owned conglomerates, to the fluid, opportunistic structures typical in microelectronics industries.

There is no reason to believe, because we have grouped all these factors under the label "technological innovations," that they are alike. The products involved do very different things, fill different needs, compete on different markets and have different scopes for further technical development and innovation. Therefore it seems natural that they would be affected differently by different firm strategies and policy measures.

For example, biosynthesis is just beginning to see commercial application, and appears to have an enormous potential for further industrial application. The constraints placed on recombinant DNA research may be the determining factor in its future development. On the other hand, laser surgery appears to have a limited market which is subject to multiple regulations, to fashions in the medical community, and to medical research funding. Oil politics and OPEC pricing may be determining in the case of enhanced oil recovery, and relatively pure economics may be determining in the case of steel. The microelectronics industry seems to be in a position of an Aladdin who has discovered a powerful but peculiar genie and is trying to find ways of employing his powers to develop products no one has ever seen before. Imagination, and how to hold and channel creativity within a corporate structure, appear to be more critical in microelectronics than regulation, politics, or economics.

The heterogeneity of technological innovation makes it difficult to formulate generalizations about technological innovation as a whole except in very broad terms. However, if one looks at the specific branches (or sectors) one finds a much higher degree of homogeneity, and hence can develop much richer descriptions of the mechanisms involved, and hence of what strategies and policies are useful for stimulating innovation.

Accordingly, the present section looks at the question of innovation and firm strategy in different branches. It contains six papers, which are presented in order of increasing generality. Thus the opening paper by Vedin presents findings on organizational structure and firm strategy in specific firms as a function of their lines of business, while the closing paper by Krejs presents an overview on the subject of strategic planning and firm strategy with relation to technological innovation. Between these two extremes are three papers on specific branches within specific nations (Vecsenyi's paper on Hungarian pharmaceuticals, Okada on the Japanese steel industry, Harman on the US electronics sector) and a paper by Richter on the strategic function of combinats in the promotion of innovations in GDR industry.

Vedin's paper has two distinct parts. The first is based on observations of six firms that have gone from media work, such as publishing or film production, into the production of innovative goods. The observations center on the question of whether media industries, whose business deals heavily with the management of creativity, can effectively transform that creativity into production of new and innovative goods. Vedin's research suggests an answer in the affirmative. In particular, he finds that media industries have a capability for *ad hoc* organization.

The second part of Vedin's paper contains observations of eight large electronics companies, all of which are active in microelectronics, computers, and other lines of electronics where technological change is extraordinarily fast and has been for around three decades. The central question in this section of text is "How, institutionally, do companies organize for rapid change?" Or, to put it differently, "What marks does rapid technological change leave on the electronics industry firms that have survived on the forefront of change?" In answer to these questions, Vedin notes four syndromes that appear to be common in innovative electronics firms and relates these syndromes to a certain style of managerial climate that is typical in electronics.

The paper by Vecsenyi deals with the problem of organizing for innovation in a planned economy. The Hungarian pharmaceutical industry, historically, has been innovative. Hungarian planners would like to see its innovativeness increase in order to make it more effective in competition on the highly competitive international pharmaceutical markets. To increase the industry's innovativeness they planned for a large scale innovation project, instituted within the Central Development Program (CDP) in 1981.

The key strategic problem for the CDP is how to coordinate the work of many decentralized institutions involved in the Hungarian pharmaceutical industry in a way that will increase their competitiveness on international markets. This comes down to questions such as: How best should the work of the five manufacturing firms be coordinated with that of the foreign trade company which markets their products and with the various industrial companies, research institutes, clinics and university departments involved in pharmaceutical R&D? How should economic and fiscal responsibilities be shared among the organizations? What legal form should be used to accomplish the desired organizational structure?

Vecsenyi was a member of the systems analysis team responsible for drafting plans for the CDP. Much of his paper is devoted to description of the analytic and procedural approach his team used in working out their designs. Thus the paper can be read either for information on the organization of the Hungarian pharmaceutical industry or as description of analytic methodology for institutional redesign.

The paper by Okada can be considered a paper on the Japanese experience in development, as seen in the steel industry. The Japanese steel industry leads the world in terms of labor productivity and cost and energy efficiency. Okada briefly discusses the history of the Japanese steel industry and then examines both technological factors and human factors that have contributed to the excellent performance of the Japanese steel industry.

On the technical side, the Japanese steel industry has a high proportion of large-scale, coastal, integrated plants. These are very up to date and utilize highly efficient techniques, such as computerized control, continuous casting, continuous annealing and improved LD conversion processes. On the human side, Okada ascribes the ability of the Japanese steel industry to reach a state of technical excellence to cooperation between labor and management in reaching corporate goals and to the high motivation of the Japanese workforce.

The US electronics sector has been particularly successful at technological innovation since the 1940s. Harman's paper addresses governmental policies that influence the process of technological innovation, drawing on aspects of the history of the electronics sector. Three topics receive particular attention: (1) uncertainties, ideas, and imperfect appropriability; (2) returns on R&D-associated investments; (3) competition and selection environments. As a foundation for this discussion, several conceptual frameworks are briefly described and some classifications for innovations are explored, i.e. by importance (basic/improvement), by locus of change (process/product), by area of application (peaceful/dangerous), by locus of choice (private/public), and by value (worthwhile/not worthwhile). The discussion is underscored by the observation that better links between conceptual understanding and policy formulation are needed in order to convert practical insights into useful actions. One specific policy recommendation is tendered: an income tax credit on earnings of all employees (including salaried staff and managers) of R&D-intensive firms.

The paper by Richter describes the main strategic problems faced by industry in the German Democratic Republic and the way in which they are dealt with within the structure of the combinats. After describing the basic problems faced by GDR industry, he goes on to elaborate how combinats are structured, how they fit into the governmental and economic structures of the GDR and how the combinat structure serves a strategic function in overcoming problems and attaining national goals. He covers such aspects as the way combinat structures support long-term strategic activities such as are necessary for technological innovation, what combinat strategy comprises (production strategy, product strategy, resource strategy, and social strategy, etc.), and how it is formulated. He closes with two recommendations for ways in which strategic management of combinats could be made better for dealing with technological innovation: through extension of the top-down management system used in production activities to include the mastery of the innovation process, and alertness and careful consideration of the behavioral and psychological aspects of the managers themselves.

INVASION OF ELECTRONICS INNOVATION: DEFENSIVE AND OFFENSIVE CORPORATE STRATEGIES

Bengt-Arne Vedin

This is a report on companies representing extremes in the spectrum of innovation. The report builds on the findings of two projects where different efforts to achieve radical innovation have been monitored.

One extreme is represented by the so-called media industry: publishers, advertising agencies, movie makers, etc. The six companies scrutinized see creativity as one of their major production factors and assets, and thus they have developed methods for the management of what is regarded to be media creativity. In the instances under study these six media companies have left their main line of business, venturing into technical research, development, and production, and even into marketing of goods, in some instances with spectacular success. Thus excellence in the management of creativity may in some instances, e.g., if the idea is good enough, compensate for lack of experience in the production of goods.

Another extreme is represented by the electronics industry. If one studies the list of leading companies in this industry over a couple of decades, one observes that companies appear and vanish from the top list frequently. The reason is that a company has to stay innovative to survive and that companies failing on this issue vanish (additional qualities may be needed, but innovativeness is one prerequisite).

This project contains an in-depth study of eight large (annual revenue range of US$400 to 800 million) electronics companies which have succeeded in staying innovative. Their organizational structure and other features are dissected.

This report is a summary of these two investigations They are given full accounts elsewhere. Here we attempt to summarize the main findings, and to extract some questions having bearings on both company and national policies.

MEDIA INDUSTRY CREATIVITY MANAGEMENT APPLIED TO TECHNOLOGY

Analysis

The six cases were selected from a range of media industries including publishing (books, newspapers, educational, and magazines) advertising, and audiovisual program producers (TV, music, and movie). Half were Scandinavian, half Anglo-Saxon. They were followed by the author personally for between 4 and 8 years using sources including official statements, press reports, books, memoirs, internal memos, and interviews with persons inside and outside the companies involved. For confidential reasons all companies are given fictitious names in this report.

My object is to identify reasons for the success and failure of media companies in innovation. This is not a simple task. The projects themselves were risky and may have failed apart from management questions. Where failure occurred my problem is to conclude whether the idea as such was good but the project was inappropriately managed, or whether the project was managed appropriately but in vain, because of the inherent weakness of the idea.

To identify reasons for success or failure I present, in tabular form, some of the organizational features suggested as being critical for the six projects for both the idea generation and the development stages. Therefore I examine characteristics that successful (or unsuccessful) projects have in common.

The tables convey the essence of the cases in a simplified form. For example, utilization in an *ad hoc* organization is noted by a simple "yes" or "no," which means that within each yes/no category there may exist a certain latitude and a variety of finer characteristics. Such a variety is described by the different methods and inputs related in the idea generation column.

In general, comparisons with the technically based projects in the same vein indicate that the media corporations were efficient, not least when looking upon development time schedules.

Stage 1: Idea Generation

Idea generation is the stage where ideas are generated and sifted through. Presumably it is the point at which media industry creativity will operate to greatest advantage. Table 1 records how the idea originated, whether it had top management authority, whether the technical idea was clearly defined, and the absence or presence of inventor freedom, *ad hoc* organization, and comprehension of the whole development process.

TABLE 1 Idea generation characteristics of the six companies.

Case	Idea generation	Top management authority	Definition	Inventor freedom	*Ad hoc* organization	Development comprehension
Enco	Software/hardware relation plus technology analogy	Yes	No	Yes	Yes	No
Devco	General electronics challenge	Yes	Yes, per project	Yes	Yes	Yes
Hinesyte/Pelerol	Internal customer plus diversification plus inventor	Yes	No	Yes	Yes	No
Lank/Obs	Technical audit for resources	Yes	Yes	Yes	Yes	Yes
Sovcom	General electronics challenge	Yes	Yes, usually per project	Yes	Yes	No
Ziz	(Specific) electronics challenge audit	Yes	Yes	Yes	Yes	Yes

TABLE 2 Development characteristics of the six companies.

Case	Top management authority	Top management patience	Inventor freedom	*Ad hoc* organization	Comprehension of total process	Culture
Enco	Dithering	No	Yes	Yes	No	Mixed
Devco	Yes	Yes	No	Yes	Yes, mostly	No
Hinesyte/Pelerol	Yes/no (yes for spending, no for control)	Yes	Yes	Yes	No	No
Lank/Obs	Yes	Yes	No	Yes	Yes	Competent
Sovcom	Mixed	--	No	Yes	Mostly	Mixed, sometimes confused
Ziz	Yes	Yes	No	Yes	Yes	Competent

In the first column we see that in two cases general technical audit for resources, not least ideas, was the starting point for idea generation. We also see that the electronics challenge has served as a stimulus in three cases. The severe effects of television upon, first of all, the movie industry, but also upon point media, has created an "electronics revolution syndrome" that is taken very seriously in these industries. Auditing for the effects of "the next electronics revolution" is rather common. The next threat should be transformed into business opportunity Few companies pick up other opportunities, generated by this process — who could blame them? Now that electronics invades many industries, they may have something to learn from the media industries' experiences. Still another reason for searching for new opportunities is to find new outlets for existing software, i.e., broadening the market for existing products.

In the other columns we see that all cases had top management authority, inventor freedom and *ad hoc* team organization. All projects except Enco which eventually failed, and Pelerol, which nearly failed, display both definition and comprehension of the whole development process.

To get the very best starting point for further development, freedom for the inventor is important in idea generation. In product development, however, inventor freedom must be constrained.

Finally, we might compare the tabulation with results. Enco was a failure. Pelerol was a failure that finally became successful in a new context. Ziz and Obs represent successes; Devco and Sovcom gave birth to a number of successful projects, even if the companies themselves were deprived of them to favor their mother companies.

Stage 2: Development

Once the idea has been defined, the development process starts. While idea generation is divergent — creativity in all directions is encouraged — development is convergent: creativity is employed to advance the design of the product towards the defined idea, essentially a business idea.

Again, I have tried to establish a table noting the different features, suggested as being critical to the development process. Some of these are common to the previous step, whereas others are new.

One question is whether management is patient enough. Media industries are often geared toward shorter development periods and less costly projects than when technical development is involved. Is top management continuing to extend authority? Inventor freedom should now be more restrained, the divergent idea generation being substituted by convergent processes. A new feature under scrutiny is the company culture, i.e. to what extent the corporation has gained some earlier, more profound experience of such a project (see Table 2).

Again, the two failure (near-failure) projects single themselves out, this time on account of their too-large freedom for continuing inventor divergence. Management authority is now sliding, however, and the same holds for Sovcom as an entity on its own; authority is instead extended to transfer promising projects from Sovcom to the particular owners. Comprehension is still lacking in these three instances. The three successes display the opposite features, including a company culture that provides, and to some extent is developed to provide, competence for technical development.

The lack of comprehension of the whole process and the lack of definition contributed to the failure of Enco's Woms system. The lack of comprehensive planning caused too late the formation of a group of companies that was too heterogeneous. The Woms partnership stage, a third stage, might be characterized by sometimes no authority, sometimes a confused — nearly erratic — one. Some partners also had less patience than others. Instead of relying on the best resources of the partners, the culture became mixed, and the advantageous *ad hoc* team was disbanded. Comprehension was sought when it came to expertise, but not when it came to the whole product launch process.

The Pelerol project was saved in its third stage, which meant a new regime, extending authority, for the first time giving the project definition and control, and quenching the anarchistic inventor freedom. The new environment offered a good climate and culture, and the new managers were careful in planning and execution. The cases of Sovcom and Enco (at the collaborative stage) indicate that media industries would tend to look for partners in new, risky areas. But do all partners agree on the same project definition? Such partnerships tend to risk aversion, dithering, and politicking, because of different or competing interests and priorities, lack of authority and patience. These are general problems with joint ventures, but in the formation of development companies such as those described, extra care is recommended.

It would seem to be beneficial to set up a development unit —"*ad hoc* group" — outside all existing organizational structures. Such a unit should give those working on a project the opportunity to concentrate fully on that task only. The individuals should be hand-picked for their creative gifts, but also for their thorough knowledge and expertise.

High level commitment and interest are vitally important. They provide authority and impetus, and also funds, for the project. The commitment must be permanent and comprehensive, and not represent a temporary mood. But commitment and patience, freedom to spend, and trust in the inventive individual must be balanced by positive control, by comprehensive planning not only of technical development but also of production and marketing, albeit conditionally, right from the outset.

This control element serves to guarantee that the inventive mind has the full understanding of the managerial, economic, and other consequences of the adopted development program. Top management must have, or acquire, technical expertise for the technical auditing of the plans and the results of the innovation work, as they arrive.

It is important to preserve the *ad hoc* approach. This provides flexibility during different phases and contingencies including project failure. The drawbacks are superseded by advantages. A temporary setting allows for changing team composition whenever new skills are required or when unproductive ideas should be abandoned.

When entering into major development efforts it seems important to review current company culture as well. As seen in the Enco story, "old history" may lead to some superficial analogies and too loose control. In other cases, prejudices or lack of knowledge may cause unnecessary or wrong concerns. Reading, training, and discussions with professionals in this field, not to mention the Ziz idea of hiring a former top executive, would add substantially to climate and culture. (Some companies achieve this, for example, by establishing an externally based scientific council.)

Success should not come as a surprise. Already when entering the project, top management should call for a complete appraisal of actions to be taken, should the project reach the stage of commercialization. Several of our case companies neglected this advice, losing time and momentum and presumably the best deal with the best partners.

Such an initial analysis also reveals the need for supporting technology at an early stage, while the late discovery of such a need may threaten the whole project. A late discovery may add substantially to costs and cause detrimental delays.

True innovation in the media industry seems to take place when one top man believes in one basic idea. When the development sidetracks, the top man should be careful to hold to definition. If redefinition takes place, a complete reappraisal should also be made. And if another possible money-maker spins off, the solution is to spin off another team or another company, too.

We have seen examples of how an inventive organization, outside the normal company setting, may spur a number of new ideas, which are then implanted in the normal company as developed ideas (notably in the Devco case). This saves the ideas from being killed in infancy. We have also seen that such groups may gain other benefits from their development companies.

But again, care must be taken that the genuine business idea is not confused. This "genuine idea" could certainly be adjusted and changed with time. The Devco example shows how a Devco II was established because Devco had got deeply involved in one specific promising area.

The six cases reviewed would seem to corroborate most earlier innovation studies. Interestingly enough, though, the centralization so typical of the media industry is beneficial to innovation — in contradiction to other findings, based upon other types of industries.

It would be interesting to compare the results compiled here with results from other industries, which share some media industry characteristics. Fashion and styling, for example, is characterized by factory production and intuition and "fashion" in styling.

Construction companies and construction consultancies, as well as other consultancies, display an *ad hoc* organization of a kind (c.f. advertising agencies, e.g., Hinesyte). Especially in construction, technical competence and culture obviously are present. A preliminary collection of data from this field indicates excellent creativity, and problems with definition, control, and comprehensive project management.

Agencies representing foreign supplies of equipment, often find that they have to develop turnkey solutions to customer problems. Again, an *ad hoc* organization may be the solution — and innovation might be the result.

Conclusions

Staying within one's competence is a basic managerial rule. The companies studied have crossed into a field where they have no competence — the production of goods — and they have proved that this can be done successfully. Their pathway to success entails transporting competence in one field, handling creativity, into a very different field, production and marketing of goods. In the past, companies have relied upon one specific competence to invade markets and fields new to them. It would seem as if the media industry's skill in managing creativity might form a basis for invading new fields, where the management of creativity is an important condition for success.

If successful, this creativity management is characterized by several factors:

- the notion of creativity as a production factor (the main production factor) is central: company climate is conducive to to the creative act, and to the creative individual
- the creative individual is in focus: freedom and resources are supplied, not reluctantly, but purposely
- *ad hoc* teams, tailored to the specific project task, are easily established and disbanded; not least psychological traits are accounted for in establishing the team
- top management is keen both on project content and management
- decision making is centralized, autocratic, and authoritative
- intuition is acknowledged as being the last resort in decision making: it is pointless to analyze high risk ventures to the last decimal (or even to put it into precise figures)
- methods for idea generation are powerful tools in generating successful businesses: these methods have been tried and refined.

In project management, two "rules" are eminently important: arriving at a working definition of the new business idea, and comprehension in planning and performing the development project. The intuitive nature of the project makes it all the more important to get a clear definition that may be communicated along the line and serve as a basis for comprehensive planning.

On the negative side, lack of company culture where R&D is an integrated part might create random inputs and imbalances in project management, and lack of definition and of comprehension.

There may also be a serious shortage of patience, understanding, and management expertise. On the other hand, few "not invented here," "vested interests" or "already tried" barriers exist.

Goods-producing industries may learn from media industries' experiences in establishing *ad hoc* groups and in managing creativity in general. These *ad hoc* teams are concentrating on one task at a time. They are formed to solve this single task in an efficient way, which brings costs and development time down. They are also formed to obtain a working team, efficient in relation to its particular task.

The lack of internal competence may be offset by external consultants, etc., to a surprisingly high degree. This is an important conclusion, since it indicates that "knowhow" might be restricted to "know how to manage."

The idea generation processes may contribute some new ideas. One such successful approach might be termed technology auditing. This may take two forms: the search for unrecognized ideas within the ranks of the company, and the assessment of the risks created by new technologies, in the case of media electronics and optics. "Innovation by invasion" is a threat that may itself trigger other innovations. The hardware–software relationship, giving impetus to searches for new software outlets, may also be reversed, in that searches for these new software outlets create new hardware inventions, offering completely new software opportunities. New developments in electronics and optics have caused media companies to look for risks, and to identify opportunities. One might speculate whether numerous goods-producing companies would not meet similar "electronic challenges" in the near future – and whether they might learn from the media.

Finally, a word of warning might be issued. Media industries often lack capital to undertake all the costs associated with the innovation process – especially if the project is successful, markets may turn out to be unpleasantly large, since huge production and marketing investments then will have to precede selling and revenues. Without comprehensive planning well in advance, too large a success may cause unbearable strains to the developing company trying to exploit the success. The warning, then, concerns many schemes for collaboration. The idea to establish an organization backed by companies complementing each other may very well lead to downfall later on. Complementing companies will not only complement each other, but also display diverging interests and priorities.

Sometimes, development, innovation, and ideas take their own ways. Rather than moulding them into one given form they must develop their own shape. But this shape must sooner or later become stable, by definition. And practical solutions must be in agreement with policy and individual aspirations.

Costs for establishing odd but dedicated innovative *ad hoc* organizations seem to be offset by the advantages with the same approach: care for the individual, and for freedom with skilled control. Competence must be assured; if necessary, acquired. Definition and the whole production–marketing structure should be analyzed comprehensively from the outset, when the idea concept is taking shape.

INNOVATION IN ELECTRONICS: SURVIVAL OF THE INNOVATION

Introduction

Organizing and managing a company always involves conflicts and compromises. Taking into account all the different considerations listed as conducive to innovation, and complying with marketing, production, and capital market needs, as well as government, employment, and other social pressures, do not create one single formula for "one best" company organization, and for its development as it grows and responds to new challenges and threats. Rather, in the light of the main business idea, and on the background and experiences of the managers of the company — mostly top executives or "founding fathers" — certain main patterns and guideposts are outlined. These include the general experiences of the industry; one might at times be tempted to call it a lore of the electronics industry.

Such experiences are almost archetypical, representing traumata of some companies. Actually, they tend to aggregate several of the points that we have mentioned as pertaining to successful innovation, and sometimes to management in other respects. Thus, such a "collective experience" summarizes several of the explanatory points made earlier, giving them varying weights, however, and making them operational in linking them with business ideas and organizational and managerial implications. I have called these experiences and guideposts "syndromes," and tried to describe them in background, characteristics, and implications. We have seen these experiences and guideposts developing in the interviews.

Innovation in the electronics industry takes place at a prodigious rate. Large computer companies may introduce a new product every week or two, and a semiconductor firm may be turning out a new circuit every day or two. The number of functions attainable per dollar in semiconductor products has been doubling about every 18 months, while computation speed and circuit capacity have been doubling every 3 years. Such rates of change have been maintained in the semiconductor industries since transistors began to be commercially produced in the early 1950s.

One would expect that survival, amidst such tumultuous conditions, would require management and organizational structures quite different from those found in more settled industry. I have conducted in-depth studies of eight companies, three mainly in the computer business, four mainly in semiconductors and one a general electronics company, to develop a sense of how companies organize to survive amidst the rapid change in the electronics industry. The companies studied were between 10 and 60 years old, all had more than 10,000 employees and four had annual revenues of between US$400 and 800 million.

I discovered that four patterns of organization, "syndromes," affected all these companies and seem, in general, to characterize the rapidly innovating segments of the electronics industry. In the following I first describe the four syndromes and the ways in which companies typically deal with them. Then I describe some factors, related to the syndromes, that appear to exert strong influence on the innovativeness and organizational structure of the companies under scrutiny. This leads to specific treatment of the syndromes as manifested in the eight companies and finally to concluding remarks on the special characteristics of the electronics industry.

This way of describing important features of the industry, of course, lends many characteristics from much recent action research. Since the syndromes are aggregates of different phenomena, given different weights, they will show some overlaps on some of the phenomena.

One might ask whether or not this list of "syndromes" is something that the author has constructed to fit the data. The answer is that these explanations were suggested by the interviewed executives themselves. Very often they used almost exactly the same phrases, and though their characterizations of the syndromes and the conclusions drawn from them were not identical, they showed a high degree of coincidence. The names of the syndromes are my own, however, though in most instances they have been suggested by those interviewed or by the trade press.

The Syndromes

Carothers' syndrome

According to legend, around 1930 Du Pont gave a very outstanding polymer scientist, Carothers, a free hand, saying: "Build your own laboratory, do something you believe in, we won't intervene, we just hope for some profitable results in the long run." And one of the results, of course, was nylon. This is somewhat of an exaggeration. Still, it is descriptive of an innovation form found in the electronics industry. In this form a creative individual, given freedom and adequate resources, attains long-term results. To apply this strategy successfully a company must: (1) look out for contributors of Carothers's quality; (2) provide freedom and resources; and (3) apply a little more control than in the myth: define the area or the goal.

Fairchild syndrome

Shockley left Bell to found Shockley Transistor, but soon some key people left to start Fairchild Semiconductor. Partly the same people left Fairchild a decade later to form Intel. Meanwhile hundreds of start-up companies were started by people leaving the then leading semiconductor companies to be on their own. As a result much of the semiconductor industry can be charted, family tree style, in lines of descent from the Shockley and Fairchild groups.

Because to a large extent people are the key to success in the semiconductor industry, Fairchild, when in trouble in the middle of the 60s, lured away the whole management team of Motorola Semiconductor. Likewise Inmos, a company sponsored by the British government, which was started on the same basis of individual excellence, has found it a prime management concern to develop schemes and methods to keep their key personnel.

The Fairchild Syndrome — people leaving parent companies to start new ventures — happens in part because it is an established pattern in the electronics industry. People are motivated to leave because they have ideas not being developed; they would like a share in the company's growth; they would like to have the freedom to do it their way; they would like to run their own shop; and they find large organizations too stifling.

The electronics industry attempts to keep their creative people and to defend themselves against the Fairchild Syndrome by giving generous stock options, generous rewards, and high status to contributors of ideas. They also find it useful to maintain informality, to have a Chief Executive Officer (CEO) active in idea searching, and short circuiting bureaucracy, and to provide multiple ways for ideas to emerge, freedom on the job to choose tasks, a challenging atmosphere, challenging career paths, job rotation, and establishment of new subsidiaries and divisions.

The next technology family syndrome

Both the semiconductor industry and the computer industry have been characterized by distinct generation changes. These have followed upon the development and implementation of new technologies. The companies who have dragged their feet, or otherwise not been prepared for the inherent drastic changes, have suffered, even to the point of bankruptcy. To see this demonstrated over and over again causes fears and prompts recipes for avoiding such a sinister fate.

Adoption into new technology families is often inhibited because existing investments/commitments prevent adoption of the new technology, because many management cultures put up "not invented here" barriers, because existing marketing organization and company structure are not suited to the innovation, or because managers are blind to new combinations (e.g., integration, collaboration). Attempts to adopt new technology families often fail owing to wrong timing, failures to recognize new markets, and blindness to new combinations.

Measures that may effectively be used to protect against the new technology family syndrome include technical and idea auditing, technological forecasting, multiple paths for ideas, CEO concern with new technology families, use of outside consultants, invention of new families and creation of new combinations, and differentiation and integration (in the Lawrence and Lorsch sense).

The integration syndrome

There is in the electronics industry a strong trend to integrate backwards, forwards, and horizontally. Companies integrate forward because components and systems will merge and companies find that the forward enterprises are where the future is, where the profits are, and where the needs and the design inputs are. In sum, they find that forward integration is essential to future competence.

They integrate backwards because their production inputs shape their futures and are often profitable lines of business. Backward integration puts greater control of a company's environment and links it to a region where further innovations may emerge.

They integrate horizontally because it is a good business concept and might work in new markets.

Forward integration is directed into areas with low barriers to entry, into areas where earlier customers might not be disturbed, and into areas where the customers have a need for a higher system level. Backward integration often occurs to make specific custom-designed integrated circuits, to make innovative contributions, or to get a "window" to the development. Horizontal integration occurs by using auxiliary ideas and by using existing marketing capabilities.

Factors Related to Innovativeness

Two unanticipated factors seemed to have an important influence on the innovativeness and the organizational structure of the companies under scrutiny: company climate or culture, and industry culture (the syndromes). A third, expected, factor also turned out to be of primary importance: business ideas, closely and explicitly linked to innovation strategy (again, the syndromes form a background). In the following, I will make a summary of the findings, grouping them together under different headings of interest.

The greenhouse atmosphere

In some companies one is astonished by the strong impression of a coherent climate, permeating not only different departments but also different locations. On discussing the electronics industry company climate, several industry leaders emphasized the "heat," the greenhouse atmosphere existing south of San Francisco and at some other places in the US. Five of our eight companies are located mainly in such Silicon Valley(s).

It is, of course, an exaggeration to say that Silicon Valley, Santa Clara County, Palo Alto, Mountain View, Cupertino, etc., is where all the action takes place. There are other areas, e.g. Arizona and Texas, in which the same kind of greenhouse atmosphere exists, with the latest knowledge and physical resources, experience, and suppliers easily at hand. But there is a general concern outside the US and also within the country that "a window to the Valley" is a must. Thus, for example, European companies such as Philips and Siemens have acquired Signetics and Advanced Micro Devices respectively. The simple conclusion that companies have drawn from this is that you have to have a plant in Santa Clara County to benefit from the atmosphere there, to inject it into the company all over.

The "atmosphere" in Silicon Valley serves to underline the importance of the Fairchild Syndrome. Through job rotation and other means of communication the spirit of the Valley also pervades company departments in most other locations.

Organization features

Electronics companies need organizational forms that can deal with the high degree of forward, backward, and horizontal integration in the industry, which are conducive to rapid change and creative product development, and which can handle a high degree of product diversification.

To meet these requirements electronics companies typically utilize pluralistic structures using multiple approaches to problem solving and idea generation. Pluralism is often achieved through simultaneously pursuing alternate strategic approaches. For example, a company might simultaneously approach the same product development goal using a marketing and a technological approach, a hardware and a software approach, a large and a small systems approach, or a centralized and a decentralized approach.

It is a perception shared in at least seven of the eight companies that multiplicity in development undertakings, properly managed, is contrary to wasteful: it allows for many more odd ideas to emerge instead of being killed. Several executives bring up the question of dedication: "if you have good people, they set out to prove they are right, even if they are wrong, and in the end the product is right." In other words, the competitive spirit will give birth to a number of serendipitous proofs that those projects were worthwhile.

Organizing development groups *ad hoc* is a standard feature in this industry. Most companies are open to external and internal ideas, but only A,D, and E, the largest companies in the group, have formalized and developed the means for doing so. Every company claims to have more ideas than they can take care of, but some also say that they lack the "golden eggs" — which means the new telephones, transistors, or Xerox inventions. (One might add that Western Union rejected Bell, the transistor was too odd to deserve space in conference proceedings in 1949, and that several large companies turned the Xerox process down. Would you recognize a breakthrough when you saw it?)

The atmosphere in electronics companies is sufficiently positive to create a lot of ideas within the ordinary, multiple structure. Several managers talk about using creative methods, suggestion boxes, and external capacities — but the internal ideas are felt to be sufficient, especially when growth causes so many other problems.

Methods

With a technology and an industry that is changing as rapidly as the electronics industry, forecasting is both a necessity and an impossibility. The results of "institutionalized" forecasting are part of the established framework, the industry culture. A tendency to stagnation, to a halt in the rapid change, would actually be felt as a major change.

On the other hand, such forecasting just shows gross development, not which applications, market niches, and new business opportunities will develop. If we regard a 100 per cent change as "one generation," such a step is taken every second year or so. Forecasting won't help for much more than such a period.

Thus technological forecasting is a framework, a substrate to work from, but not much more. Creativity in shaping and inventing the future is needed — and supplied.

As discussed in the previous section, electronics companies generally have an abundance of ideas. Methods for generating even more ideas are not felt to be needed. The most frequent method to trace new opportunities is auditing, taking the following forms:

- technology auditing, i.e. analyzing the consequences for the company (and especially its markets) of a new or envisaged technology (family)
- idea auditing, i.e. "vacuum cleaning" the organization for new ideas
- market auditing, i.e. the systematic questioning of and feedback from the market regarding new requirements or important problem areas.

In general, the methods applied for evaluating new projects are not very sophisticated. The reasons for this are linked to the rapid change in the industry:

- new technology families mean a 50 per cent or better change in important features, so finely tuned analysis is both unnecessary and impossible
- technology push makes many market estimates conjectural; personal thrust and marketing twists may be significant contributors in the final attempt
- projects are risky but not necessarily too costly, allowing for a "statistical" approach.

The business idea

The business idea is extremely well integrated with technology and innovation in companies C, D, and E. This integration is high also in A, B, and F. It is equally high for technology in G, with its concentration on trailing, but consequently not with original innovation here.

Top management

The executive team consists — wholly or partially — of engineers and scientists in companies B, C, D, E, F, and H. There is no question, however, that the chief executives of A and G are also highly concerned with innovation. In all companies, the CEO is involved in strategic decisions on innovations; in D and H, he is himself the last "innovation ombudsman" to be called freely upon should an idea get stifled; and in companies C and E he even involves himself directly in challenging projects. The risky and intuitive nature of innovative projects is recognized by all management teams of the eight companies. That this is not a lip service has been demonstrated by the substantial losses on high risk ventures, not least for A, C, D, and F, which during the same period display growth and profit even exceeding that of the other four.

Top management has been most concerned with the process of innovation in company A (with its elaborate structure), C, D, E, and F.

Individual incentives

As mentioned previously, the electronics industry generates more ideas than it can develop or even evaluate. Clearly, this has been one reason for the Fairchildren phenomenon: people insist on getting their pet ideas afoot, and venture capital is available at the smell of Silicon Valley. In an industry where the key resource is people, and where companies are constantly recruiting new personnel because of rapid growth, it is imperative to keep the best, those with the entrepreneurial spirit to start on their own. One reason for applying an ombudsman or a "pluralistic" approach is that this makes it easier for ideas to get a foothold, however odd they may seem at the outset. Another important factor is freedom, including opportunities to choose one's own projects and to try new jobs, and different ways of opening such opportunities have also been instituted. As we have seen, some companies give a long-term total freedom (Carothers's syndrome — especially company A), some offer a creative career path (especially B).

Another reason for starting a company on one's own would be to get a share in the growth of its assets. This same effect may, in principle, be achieved through stock options. In large and more mature companies this may not offer the same incentives as in a boom-rocketing new corporation. Offering substantial rewards is an alternative way, though it has also been argued that too large rewards may in fact be counterproductive in that they prevent an open exchange of ideas. A third way is different status-creating activities.

Most psychological accounts of innovativeness make a distinction between the personality traits of an inventor and of an entrepreneur. Relatively speaking, the former is more of a dreamer, the latter more of a doer. For example, in the Swedish innovation debate it is discussed how to get these two to find each other, and to work well together. In the US, this distinction is not accepted to the same extent. The attitude is rather to train the inventor to double as an entrepreneur. This is actually done successfully, not in training courses but rather through trial and error: if the first attempt to build a company fails, try again, with that experience as a background. One role of the venture capitalist is often to be, if not the teacher, the counsel and the sparring partner.

Again and again the Silicon Valley environment as a major factor in creating an entrepreneurial pattern was stressed. This has two sides. The environment is conducive to innovation within the company — but also to leaving it for a new start-up.

The syndromes

Here we review briefly the extent to which the eight companies (A–H) have manifested the four syndromes.

(1) Carothers' Syndrome. I found that one company, A, has followed the recipe for the Carothers syndrome systematically and to the last letter with good results. Companies B, D, and E also display the Carothers' syndrome, but for various reasons, sometimes linked to other commitments and limited resources, their programs and especially time horizons are more limited. Companies C, F, G, and H attempted to apply Carothers-like schemes, but for various reasons could not. All were unhappy about this failure.

(2) The Integration Syndrome. All four companies with a base in semiconductors have integrated or are integrating forward; two successfully, two with less success. The latter seem to have had too vague ideas about marketing, also regarding the type of unique contributions or sales proposals they were offering.

Some 4 years ago, a handful of systems-producing companies had integrated backward —today, the number approaches 40. Of our systems producers, most belong to the former group. This majority was intrigued by the innovative aspects; else the approach is more defensive. One company mentions profit generation as a subsidiary requirement. A regular request for outside competing bids secures this. "Since our plant delivers internally only, we save the sales costs."

Horizontal integration does not form a regular pattern. One pitfall is lacking insights into market and marketing requirements — but several examples of successful "diversification" may also be quoted.

In some instances, experiences with integration —especially horizontal —will lead to an antisyndrome: stay with your expertise.

At least three of the companies under scrutiny are managed by people who are themselves "Fairchildren." In one way or the other, all eight have experienced their syndrome themselves, in some instances with very substantial repercussions.

We might now list in a matrix what policies are implemented (see Tables 3 and 4).

TABLE 3 Syndromes impacting different companies.

Syndrome	Company							
	A	B	C	D	E	F	G	H
Carothers	x	x	–	x	x	–	–	–
Integration	x	x	x	x	x	–	–	–
Fairchildren[a]	See Table 4							
New Technology Family	x	x	x	x	x	x	–	x

[a]See Table 4.

TABLE 4 Fairchildren prevention policies.

Company	Multiplicity	Rewards			Chief Executive Officer		Informality, challenging atmosphere	Freedom	New career, subsidiaries
		Stock options	Monetary	Status	Short circuiting	On workshop floor			
A	x	–	x	x	–	–	–	o	–
B	x	–	–	o	o	o	o	x	o
C	o	x	o	o	x	–	x	x	–
D	x	x	–	o	x	x	x	x	–
E	o	x	–	–	x	x	x	o	o
F	x	x	o	x	x	–	x	x	x
G	–	x	–	o	–	–	o	–	–
H	x	o	x	x	x	–	o	o	o

NOTES: – = no; o = to some extent; x = fully fledged.

(3) The Next Technology Family Syndrome. All but one of the companies in our sample have the expressed objective of being leaders in inventing the new technologies. All companies utilize technological (and market) forecasting.

Company A applies most of these measures listed, possibly with the exception of "CEO concern." Companies C and D exclude the auditing and outside consultants actions, but implement the other measures. Company C shows a very high CEO concern and involvement in "generation shifts."

Company E displays the unique feature of integrating development and production. Timing is certainly one of this company's strongest sales proposals. Internal "not invented here" barriers, of course, never build up. The CEO is directly involved, multiple paths exist, as in all eight companies.

Company F applies the whole recipe package.

Company G is the one company, not primarily aiming to be a leader, but rather to have a full hand. It has the least developed structure for not being bypassed by new technologies, but on the other hand its strategy of trailing in everything worthwhile makes it generally susceptible to buying licenses to everything new that has proved to be promising.

Company H, finally, originated from a "generation shift" and has survived later shifts. The awareness of this phenomenon is very high, the measures being some auditing and forecasting, CEO involvement, and multiplicity in approach.

Syndrome summary

The syndrome discussion is summarized in Table 5.

Conclusions

The electronics industry is in a seemingly permanent stage of rapid growth and rapid change. Clearly, this would not be the case if there were no new markets opening up. But these markets are to a large extent being created.

The growth seems perpetual in that in a climate of boom, a climate of change sustains itself. This climate has been characterized here as a series of syndromes. If one looks at, for example, the most typical "climatological" factor, Silicon Valley, the question would be how to reproduce something like that. Clearly, climate, tax laws, the availability of land, and the presence of an outstanding university in the neighborhood are all important factors.

One might wonder whether this climate would also permeate other industries. It seems as if "electronics" is a notion that is growing wider and wider, but the aerospace industry in the same geographical area, for example, does not seem to prosper in the same way. On the other hand, the next would-be boom industry, "genetic engineering," seems to be enhanced in much the same way and by the same climate as the electronics industry. One might venture the idea that there is a relation between the "culture" of an industry, and the size of the projects, risks, and

TABLE 5 Features of electronics companies, related to innovativeness.

Company	Company objectives	Top management concern	Organizational multiplicity	Differentiation–integration (D&I) combination	Methods[a]	Individual incentive	Backward/forward integration
A	Growth Market share Profit	Yes	6	Extremely high D&I	All	Money Freedom	All directions
B	Market share Dividends Growth	Yes	6	High D&I	TF	Freedom Promotion	Backward and horizontally
C	Growth Independence	Yes, very much	3	High D&I	TF	Stock options Freedom	Backward and horizontally (the latter with mixed success)
D	Growth Independence Work satisfaction	Yes, very much	3	Extremely high D, high I	TF and others	Stock options	All directions
E	Freedom Fun to work Growth	Yes, very much	3	Extremely high I, moderate D	TF	Stock options New companies	Somewhat; more in future
F	Growth Profits	Yes	4	Extremely high D, high I	All	Stock options	All directions
G	Growth Independence Profits		2	Extremely high D, moderate I	TF	Stock options	Yes, forward though with mixed success
H	Profits Market share Dividends	Yes	3	High D, moderate I	All	Money Awards Promotion	Yes, forward though with mixed success

[a]TF = technological forecasting.

investments. Actually, venture organizations such as Exxon Enterprises seem to have drawn this conclusion in establishing such investment criteria as:

- fast-growing markets (allows for learning by doing, offers a place for the newcomer)
- developing technology
- low to moderate initial investments
- possible future synergistic effects between different ventures.

The next important conclusion is that there is not only a very tangible culture in the industry but also a very distinct subculture developed, haphazardly or consciously, in each company. This may be more or less distinct, and it may be more or less consciously developed. It would seem as it had a direct relation to the objectives and the performance of the company. In other words, companies should be concerned with how they create and sustain a company climate coherent with their objectives. In a fast-growing business, new personnel may make up 20-50 percent of the total each year, creating no small problems in sustaining the climate aimed for.

Certainly, a more developed methodology for probing, creating, and sustaining company climates might be called for.

The next conclusion is that company objectives and business ideas could and should be firmly tied to innovative strategies. Company D has succeeded in letting its trial-and-error-and-success strategy permeate the whole company, all over the globe, linked as it is to the objectives of the company. Company E has a firm and demonstrably well proved belief that timing is a key factor to success, consequently concentrated on eliminating internal communications barriers, and ended up on a far from optimal production process should production be static, but with a wonderfully rapid fire innovation process. Company A has taken into account all the lessons from the innovation and management literature and tried out a complex scheme, fitting its size, growth, environment, and objectives. The same can be said of company F, which has complemented the normal functional and geographical differentiation with one along the time dimension, a temporal differentiation, thus linking innovation and organizational change, creating the social (in this case organizational) carrier of technology simultaneously with the new technology itself. Company B also applies a temporal differentiation, but with another twist, and company C has a unique market-oriented approach to its product design that creates very definite guidelines for innovation.

There would seem to be a whole universe of different approaches combining objectives, business ideas, and innovation strategy. But each organization has to develop one coherent pattern. This might be changed with time, environment, growth, and technological change, not to speak of creative resources, and it has to comply with resources, size, and available capital — but it is of utmost importance that such a combination be developed. The examples given by several of the eight companies demonstrate that this is a highly creative undertaking.

That such a volatile and highly innovative industry as electronics would require extensive top management involvement in innovation, in recruiting creative and entrepreneurial managers, in managing the innovation process, in strategic decisions, and even in specific projects, is not too surprising a conclusion. Nor is it surprising that these creative and entrepreneurial individuals form the key resource and must be treated accordingly. Incentives include opportunities to get odd ideas tried and launched, personal freedom, stock as a share of the corporate growth that might be one result of creative contribution, substantial monetary rewards, career opportunities, and status. To further the creative process, different types of assistance to the project manager are developed; for example, the resource of a listener or sparring partner.

All companies stress the benefits of slack resources. But this slack should be located so as to be accessible to the people who have new ideas, to allow for "under-the-bench" experiments. Such slack is built into most of the eight companies' budgets and organizations.

This is but one way to create multiple paths for an idea to get its fair chance. The point with this multiplicity is that it should never get standardized, should never attempt to cover everything, and should be changed from time to time. This pluralism would aim at differentiation and integration in new dimensions, at centralization with one measure, at decentralization with another. It is hoped that this report would give the reader new inputs for the creation of multiple idea paths.

Multiple paths also point to the fact that far from being afraid of internal competition, electronics companies inspire it and organize to create it. Again, the different approaches that competing departments will have create a successful result in the end —and several opportunities for sharp criticism and evaluation as well as for beneficial combinations on the way there. The NIH (not invented here) phenomenon has been converted into a contributing force.

The findings of Lawrence and Lorsch on the necessity of combining differentiation and integration —which is confirmed here, but just a stepping stone —led them to formulating a contingency theory of corporate organization. The results of this report would also indicate that in an industry such as electronics, moving even faster than the plastics industry, a number of additional factors must be taken into account, apart from the integration/ differentiation pair.

Thus, we may draw the following conclusions.

(1) One "ombudsman for innovation" is not enough; several are needed. Purposeful slack resources and internal competition are but two opportunities. A pluralistic approach should be applied.

(2) Organizational change should be built in —the organization must contain strong anticipative elements. Decentralization may take place not only along dimensions such as function, geography, or product, but also through time.

(3) Integration, though risky, may be the best way to secure innovative inputs, from subsidiary technologies or from end markets. It must be balanced against the danger of falling into the traps of obsolescence and protected climate, however.

(4) The strong interdependence between basic business ideas, strategies to achieve these ideas, and production, marketing, servicing, and innovation policies, etc., must be realized and clear-cut conclusions must be drawn and implemented.

(5) The company climate as such is an important production factor, linked to business ideas and strategy, and also a factor that may be affected to make the company more dedicated, efficient, and successful.

(6) The industry culture is an important substrate for any company climate. To a certain extent this can be simulated and some of the characteristics of a "greenhouse industry" copied in companies outside that industry.

(7) Individual incentives are important. They should preferably be linked to company climate, i.e. to enhance loyalty. Among the means are personal freedom, job rotation, the maintaining of small units, stock options, monetary and symbol rewards, and top management involvement.

As semiconductor technology families, or computer generations, prosper and then suddenly die, so may paradigms. Electronics industry managers who are highly successful in one era might be unlucky during the next period —and such an era may last just 5 years.

But an era might be sufficiently long for the manager to get promoted, perhaps to another industry, before his adaptability been put on trial. I believe that in the future we will see an increasing flux of top managers in all industries hired over from success in electronics. Thus the spirit of Silicon Valley will spread to other branches of the economy.

But at one point or another we will also see a major breakthrough, a new innovation — social or technological — a new syndrome, that will shake the foundations of the industry. That trend shift might well make one or all of the syndromes obsolete. Actually, the "Integration Syndrome" contains something of an anticipated trend shift, with some virtues of a self-fulfilling prophecy. And we have seen the need for a coherent company climate dominating over the need to prevent "Fairchildren" from spinning off.

Such a trend shift would not only shake the foundations of the electronics industry but also add new and important contingencies to the conclusions brought forward in this report.

Policy Questions

The findings reported give rise to numerous questions such as:

-- How can we give more than lip service to real creativity?

-- How can we create a framework for real *ad hoc* understandings?

-- How may we recruit development teams on the basis of "psychological fit?"

-- How can we manage the creative process better?

-- How may media (and other "artistic") corporations collaborate with goods-producing corporations?

-- What is the role of "risk/opportunity auditing" in creating innovative ideas?

-- How do we manage to comprehend the whole innovation process?

-- How do we manage to get from "divergent" creativity to "convergent" creativity?

-- How do we develop the close links between business ideas and innovation strategy?

-- How can we simulate an innovative greenhouse of rapid change?

-- How may we translate into the economy the lessons learned from the role played by small companies becoming large?

-- How do we develop pluralistic organizations, providing slack and multiple paths for ideas?

-- What involvement do we need from top executives and how should they be trained?

ORGANIZATIONAL ASPECTS OF LARGE-SCALE TECHNOLOGICAL INNOVATION PROGRAMS: A CASE STUDY OF INNOVATION IN THE HUNGARIAN PHARMACEUTICAL INDUSTRY

Janos Vecsenyi

INTRODUCTION

According to the field marshal Montecuccoli, three basic things are needed for waging war: MONEY, MONEY, and MONEY. A large-scale innovation program, too, is based on three things: OBJECTIVES, INFORMATION, and MONEY. Without money, outstanding researchers cannot be employed, nor can new equipment be obtained; but lacking objectives, it is not clear what researchers are to do or where equipment is to be used. Therefore planning of large-scale innovation programs requires technological, economic, and organizational analyses. The latter are needed to determine how objectives based on technological—economic analyses can be achieved. This study describes such an organizational analysis.

The need for clearly establishing both ends and means has become more pronounced in planning large-scale innovation programs (LSIP). Various approaches exist. Approaches based on computer software, such as networking and experimental technique, are familiar, though much remains to be learned about the integration of individual innovation activities and about the sorts of management systems that will best promote cooperation among different organizations and their branches in pursuit of established goals.

Project management methods, especially matrix organization techniques, are well known from the literature (e.g., Cleland and King 1975), although reports on use of matrix techniques are largely confined to study of company practices. Less information is available on organizational methods appropriate to managing LSIPs involving several organizations. In Hungary, we are confronted with the problem of how best to organize what are called Central Development Programs (CDP), LSIPs selected and subsidized by the government, most of which require cooperation between several organizations. One such CDP is to begin in the pharmaceutical industry in 1981.

Given the need for better understanding of multiple organization LSIPs, our agency, the Bureau for Systems Analysis of the Hungarian State Committee for Technological Development, has welcomed the tasks of (1) performing a functional analysis of the innovation system which will be involved in the pharmaceutical industry CDP, and (2) writing a proposal relating to organizational development for this CDP. The task is novel and challenging; it involves working out ways to bring about the fruitful cooperation of more than one hundred organizations.

A SHORT SURVEY OF THE HUNGARIAN PHARMACEUTICAL INDUSTRY

The Hungarian pharmaceutical industry is about 100 years old. It has a respectable record in research, development, manufacturing, and sales. On the basis of its 1978 turnover it ranked 27th in the world.

Increased international competition, the exportability of pharmaceutical products, and an improvement in Hungarian market positions have provided an impetus to innovation activities designed to produce better results. On these grounds the government decided to launch a CDP for intensive development of the pharmaceutical industry.

The general purpose of the program was to make the pharmaceutical industry more export oriented by giving a larger share to new products. The concrete objectives of the program were determined by a series of analyzing and planning activities.

Hungary's pharmaceutical industry is organizationally decentralized. Manufacturing takes place at five separate companies. Industrial companies, research institutes, clinics, and university departments are involved in R&D. Foreign sales are handled by a foreign trade company. The manufacturers and one of the largest research institutes have signed a cooperation and merger contract, and a partnership contract was concluded between the trade association and the foreign trade company in order to improve coordination of R&D activities and to align economic and fiscal responsibilities. These efforts merely defined the framework of interorganizational cooperation; they did not provide a design for the management system and means of cooperation.

THE PROCESS OF SYSTEMS ANALYSIS

Figure 1 shows the steps we followed in conducting our work. In the following, the steps are described in sequence.

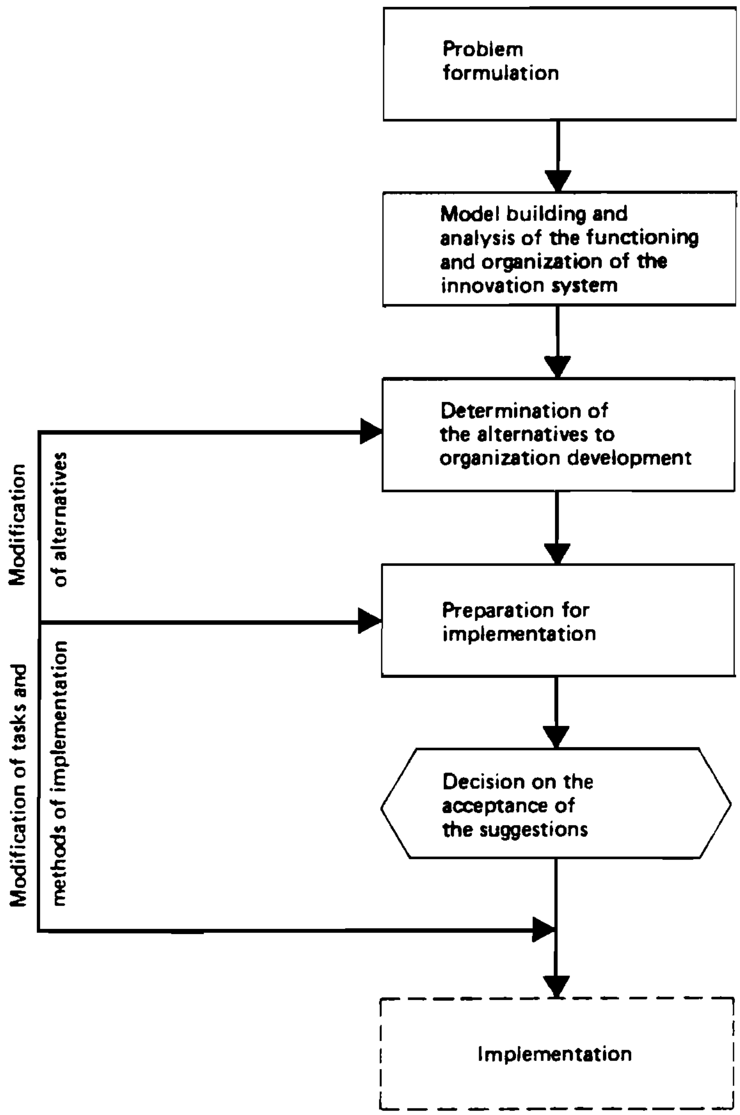

FIGURE 1 The process of systems analysis.

Problem Formulation

Problem formulation activities included clarifying the origin of the problem, understanding its situational context, planning the analytical work, and organization of the problem solving teams.

Problem origins

The pharmaceutical CDP was jointly initiated by the pharmaceutical companies and by their respective supervisory body, the Ministry of Heavy Industry. In 1978, the State Committee for Planning accepted the proposed program and issued a decision binding the ministries and other government organs involved to prepare a detailed plan so that the program might begin in 1981. The decree also prescribed that the detailed plan should include a proposal on the development of a suitable management system for the program. This was an innovation on the State Committee's part. Plans for previous CDPs had not provided for systems or organizational analyses.

Situational context

In looking at the situational context we aimed to understand our clients' natures, interests and achievement criteria as well as environment factors impinging on the CDP.

Our situational context was complex. Our project was initiated by the State Committee for Science Policy. Responsibility for making decisions on organizational matters was divided; some decision makers were in the State apparatus while others were in various enterprises. It was difficult to determine decision makers' aims and interests because interviews with high level representatives could not be obtained. Therefore analysis of important government and political documents was undertaken to infer their aims and objectives. Interviews were conducted with some top managers of the respective companies, thus giving us direct information on their aims and interests.

The most important environmental factors were found to be the economic circumstances that made the development program necessary in the first place, the interests motivating the development of the pharmaceutical industry, and the state of and the changes in the international market. The economic incentive system, financing possibilities, and laws and regulations were found to be important factors in the problem solving climate.

Planning for problem solving and setting up teams

Available resources were assessed, personnel requirements were determined according to professional and organizational specifications, and a preliminary budget for the analysis was made. Our work plan had to take into account the fact that we had only 6 months to complete the analysis.

On the basis of these plans two teams were organized, a systems analysis team and a team of pharmaceutical experts. The systems analysis team included an economist, a sociologist, a lawyer, a management consultant, and a research organizer. No one on the team had previous professional contact with the pharmaceutical industry. The expert team was composed of top-level research managers, medium-level managers from the companies and the foreign trade company, and representatives from the Hungarian Drug Commission and the Ministry of Heavy Industry. Shortness of time and the novelty of the project task resulted, in practice, in these two teams merging into a single fourteen-member team.

Model Building and Analysis of the Operation and Organization of the Innovation System

In this phase the CDP's objectives were identified, the general requirements for an organization implementing a large-scale innovation program were drawn up, a model of the functions of such an organization was constructed, and a survey of the present state of the pharmaceutical innovation system was made.

Definition of objectives

The activities and organizations appropriate for achieving program objectives cannot be specified without knowing what these objectives are. Two important objectives appear to motivate: (1) development of products serving medical treatment; (2) increased profits through sales of drugs on the world market.

Figure 2 illustrates the ways of manufacturing products that can serve the needs of medical treatment. Available and potential compounds are denoted by set A, biological effects by set B, medical treatment by set C. An element of set C is a well diagnosed case of medical treatment and its needs. Applying these symbols, the area of intersection ABC is the set of biologically active compounds used in medical treatment. This may be done either by seeking biologically active compounds with the required effect for a specific medical treatment, or by seeking an appropriate area for the application of a biologically active compound with known properties.

Figure 3 illustrates possible objectives of product marketing strategies on the world market. Set M stands for the need for medical treatment using chemicals. The elements of set N stand for the drugs and related research results (e.g., semifinished drugs) produced by multinational firms, and those of set L stand for the analogous elements produced by nonmultinational firms.

The objective of the innovation organization and its marketing subsystem is to meet one or more requirements of medical treatment by utilizing a product or research result in order to achieve an adequate profit margin. This means, while using the symbols as given in Figure 3, that the elements of set L (i.e., Hungarian produced pharmaceuticals) should be moved into set M (i.e., made to serve medical needs). In planning product development strategy, the CDP must choose between

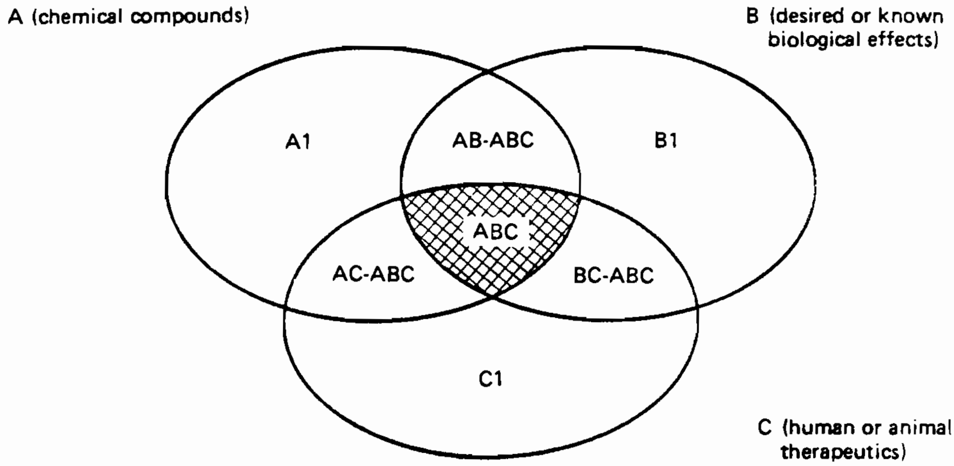

FIGURE 2 Model for interpreting the objectives of R&D. Interpretation of sets: AB, biologically active chemicals; AC, chemicals in therapeutics; BC, biological effects in therapeutics; ABC, biologically active chemicals in therapeutics; AB-ABC, biologically active compounds not yet used in therapeutics; AC-ABC, biologically inactive compounds in therapeutics; BC-ABC, biological effects in therapeutics without chemicals; A1, biologically inactive compounds; B1, nontherapeutic biological effects; C1, therapeutics not using chemicals.

developing wholly new products that operate on new markets (M1), moving into market spheres where there is competition with multinational and other firms (MNL), or moving into market areas where only multinationals are active (MN-MNL) or where only nonmultinational firms are active (ML-MNL). In all regions except M1, only those drugs whose medical properties or price make them capable of ousting products already on the market are economically viable. As for new drugs (M1), time is crucial. The greatest profits go to the firm which is the first on the market.

General requirements for target program organization

Following Churchman (1968) and Szabo (1970), we recognized five groups of requirements for successful target-oriented program organization.

(1) *Objectives:* The organization should be suitable for the following: (1) meeting government-set scientific, technological, economic, and time objectives; (2) planning, selecting, organizing, modifying, and directing projects through to their completion; (3) supporting and stimulating individual, free, but program-oriented research and —in cases of success —transforming the same into projects; and (4) the organization should possess the authority and the scientific, information, financial, and organizational means to incorporate its goals and tasks into the plans, and the functioning and organizational whole of the participating organizations.

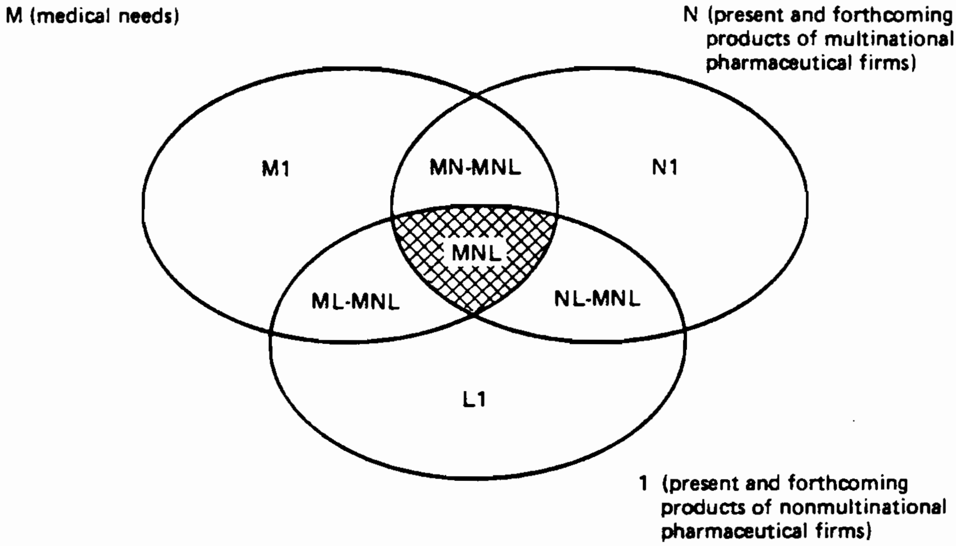

FIGURE 3 Model for interpreting the objective of the program and the task of the marketing subsystem. Interpretation of sets: MN, multinational firms on the market sphere; ML, nonmultinational firms on the market sphere; NL, mutual spheres of interest in research and sales; MNL, drugs meeting demands; NL-MNL, sphere of mutual research interest; ML-MNL, drugs meeting demands: nonmultinational firms; MN-MNL, drugs meeting demands: multinational firms; M1, medical needs not met by drugs; N1, research results of multinational firms; L1, research results of nonmultinational firms.

(2) *Environment:* The organization should be capable of embracing all the involved companies and institutions. It should be able to recognize changes in market positions, macroeconomic policy, and administration, and to promote the participants' adjustment to the same.

(3) *Resources:* The organization should possess adequate personnel, equipment and financial resources for the program, and within this, for the various individual projects and researches.

(4) *Components:* The organization should be capable of continuous learning, self-development and self-regulation, and of facilitating creativity. The content and the relationship of managing and operating subsystems should be adequately planned and the executors well trained; and it should provide adequate structure for subsystems, processes, and projects.

(5) *Management:* The management of the program organization and of all participating organizations should be capable of directing an innovative program or project.

Modeling the innovation system

In analyzing the activities of the innovation system of the pharmaceutical industry, we found it useful to differentiate between well-distinguishable subsystems. These included, for example, R&D subsystems, different kinds of managing subsystems, and further components in the innovation chain. After several iterations our analysis settled on the model of the innovation system containing three managing and six operating subsystems, shown in Figure 4.

In this model the functions of the individual subsystems are as follows.

The strategic managing subsystem establishes the main research, development, manufacturing, and marketing objectives and approaches, project criteria, and the complex plans of the program. In so doing it oversees the whole innovation system.

The operative managing subsystem collects and processes data and provides decision aids for the strategic managing subsystem. This subsystem thus links the strategic subsystem with the project management subsystem. A separate project managing subsystem is needed for each project. Each project managing subsystem is responsible for detailed planning and coordination of activities and organizations involved in production and marketing of new products.

The marketing subsystem serves for: (1) acquiring market information for strategic planning and product development activities; (2) organizing the prerequisites to actual marketing; (3) marketing products or knowhow; (4) maintaining markets.

The research (chemical, biological, and human) subsystem produces medical knowhow, i.e., scientific documentation on the application of a new drug. The quality and quantity of its investigations basically determine whether the project succeeds in introducing a new product which fulfills project objectives.

The technological development subsystem produces the technological know-how and appropriate documentation of the developed drug. This kind of activity is associated with domestically developed or license-based products. Technological development activities link pharmaceutical R&D with manufacturing. The form of the drug itself and its packaging, the profitability of the manufacturing technology, and the volume are all influenced by market information and economic analysis.

The manufacturing subsystem produces both old and new products. In this subsystem it is revealed whether or not our products fulfill medical and technological requirements and the criteria set by the international GMP (good manufacturing products) standards.

The industrial patent legislation subsystem is responsible for patenting R&D achievements, and for obtaining information from patent documentation. It is treated as a separate subsystem because owing to heavy competition and constant product development, industrial patent legislation significantly influences the acquisition and maintenance of market positions and the profitability of sales in the pharmaceutical industry. It is important that the patent legislation subsystem should coordinate

Figure 4 goes here

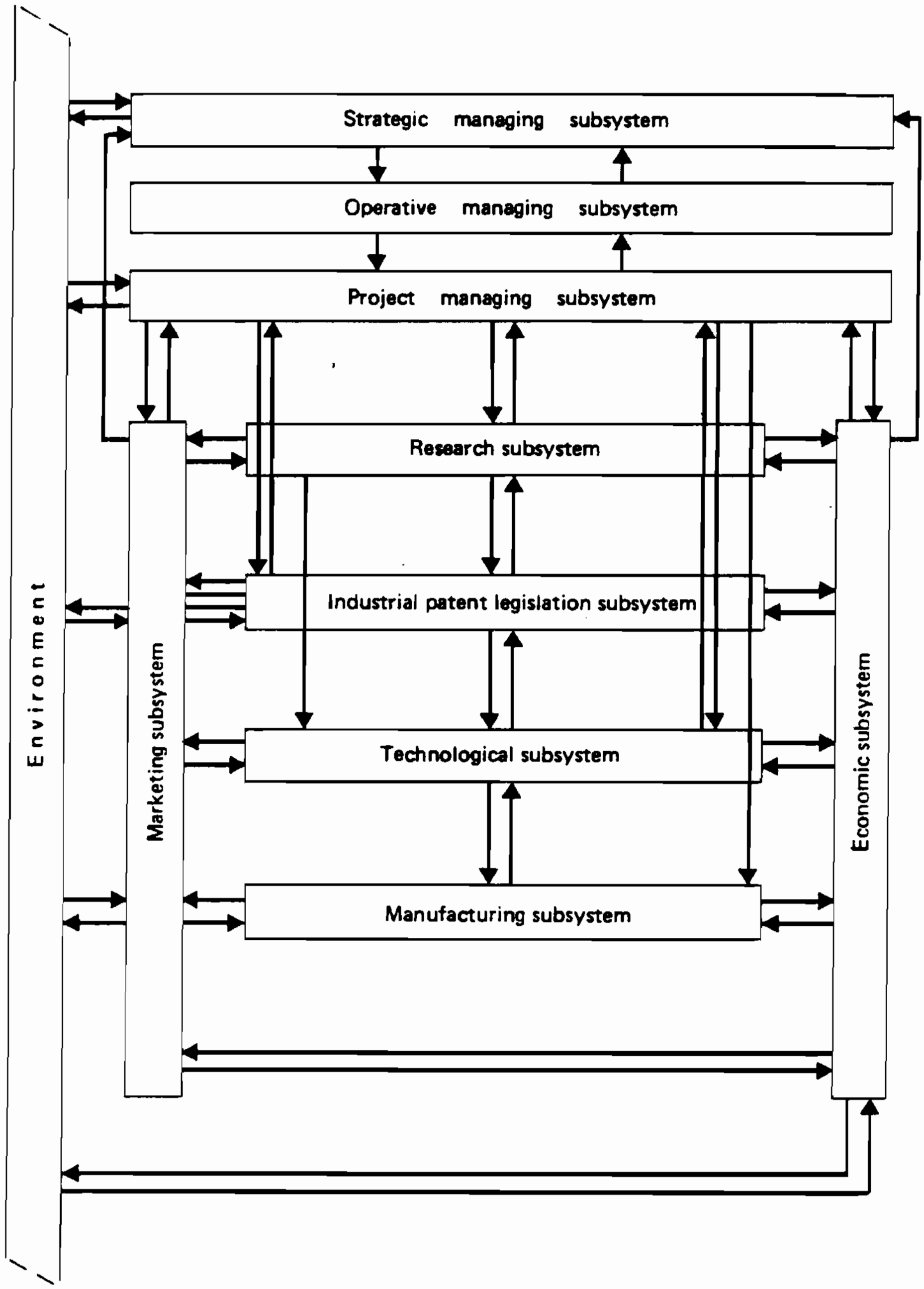

FIGURE 4 The model for the pharmaceutical innovation system.

research, marketing, and technological activities to serve a deliberately adopted offensive and defensive industrial patent legislation policy.

The economic–fiscal–investment subsystem investigates, analyzes, and makes arrangements for the innovation system's economic requirements. This involves analysis of resource utilization efficiencies as well as preparation and organization of the investments needed for the realization of the innovation. The economic subsystem results are utilized by the project managing and operating subsystems as well as by the strategic managing subsystem. The economic success of the program can be judged on the basis of analyses made of this subsystem. Economic success is judged from both a technical and a sales point of view. Criteria include return on investment and other factors, such as increase in the volume of traditional production.

The dynamic model shown in Figure 4 has been reformulated as a system definition matrix (Nadler and Thesen, in Delp *et al.* 1977) in order to show purposes, inputs, outputs, sequences, environment, physical and information catalysts, and human agents. One part of this matrix is shown in Table 1. We have also developed dynamic schema and flow charts of sequences which show the functioning of the subsystems of innovation and the logical linkages between them. The dynamic scheme represents the main group of activities (Figure 5). The flow charts show the detailed activities, decision inputs and outputs, in order as a basis for making networks, planning resource allocation, and defining the criteria of decision situations.

Analyzing the present state and organization of the innovation system

The analysis revealed that the present objectives were fundamentally different from the earlier objectives of pharmaceutical organizations. This suggested that considerable changes are needed in the dynamics and structure of the pharmaceutical innovation system. The realization of new objectives requires considerably closer cooperation between companies, research institutes, university research laboratories and clinics, as well as a more concentrated allocation of resources.

The analysis showed that the organizations involved lacked a uniform strategy. The purposeful allocation of resources has still not been achieved, projects are often disorganized, and intrasystem interfaces between marketing and R&D are inadequate. On the positive side the analysis showed that the R&D results achieved demonstrate a strong tradition of innovation in the pharmaceutical industry and offer a good intellectual basis for further development.

Determination of Organization Development Alternatives

By organization development we mean goal-directed activities aimed at establishing or improving organizational dynamics and structure. Organization development may be called for by new objectives, by changes in the organizational environment, or by shortcomings in the existing organizational system.

TABLE 1 System definition matrix. Strategic managing subsystem (detail).

PURPOSE	Determination and modification of main objectives, approaches and plans of research, development, manufacturing, and marketing
INPUT	Scientific prognosis Therapeutic demand forecast Suggestions for new R&D trends Suggestions for sales and production plans Information on the size and composition of available resources Indication for modifying strategies or plans Survey and results Need for strategic decision Operative plans
INFORMATION CATALYSTS	Information on international price policy Market reports Contracts Earlier research and strategic plans Information on current worldwide R&D standards Information on the number and qualifications of the research personnel
SEQUENCE	Determination of marketing concept Determination of scientific concept Developing strategies Preparation of detailed strategic plans Supervision and control Modification of plans and strategies Strategic decision making
OUTPUT	Scientific concept Selected strategy Complex plan Modification of strategies and plans Strategic decisions
ENVIRONMENT	Requirements of macroeconomic plans National and international economic and legal regulations Domestic and foreign political situation Interests World economic and market developments Competition Changes in therapeutic needs
PHYSICAL CATALYSTS	Financial assets (capital) Office space and equipment Management information system
HUMAN CATALYSTS	Board of top managers Marketing body R&D body

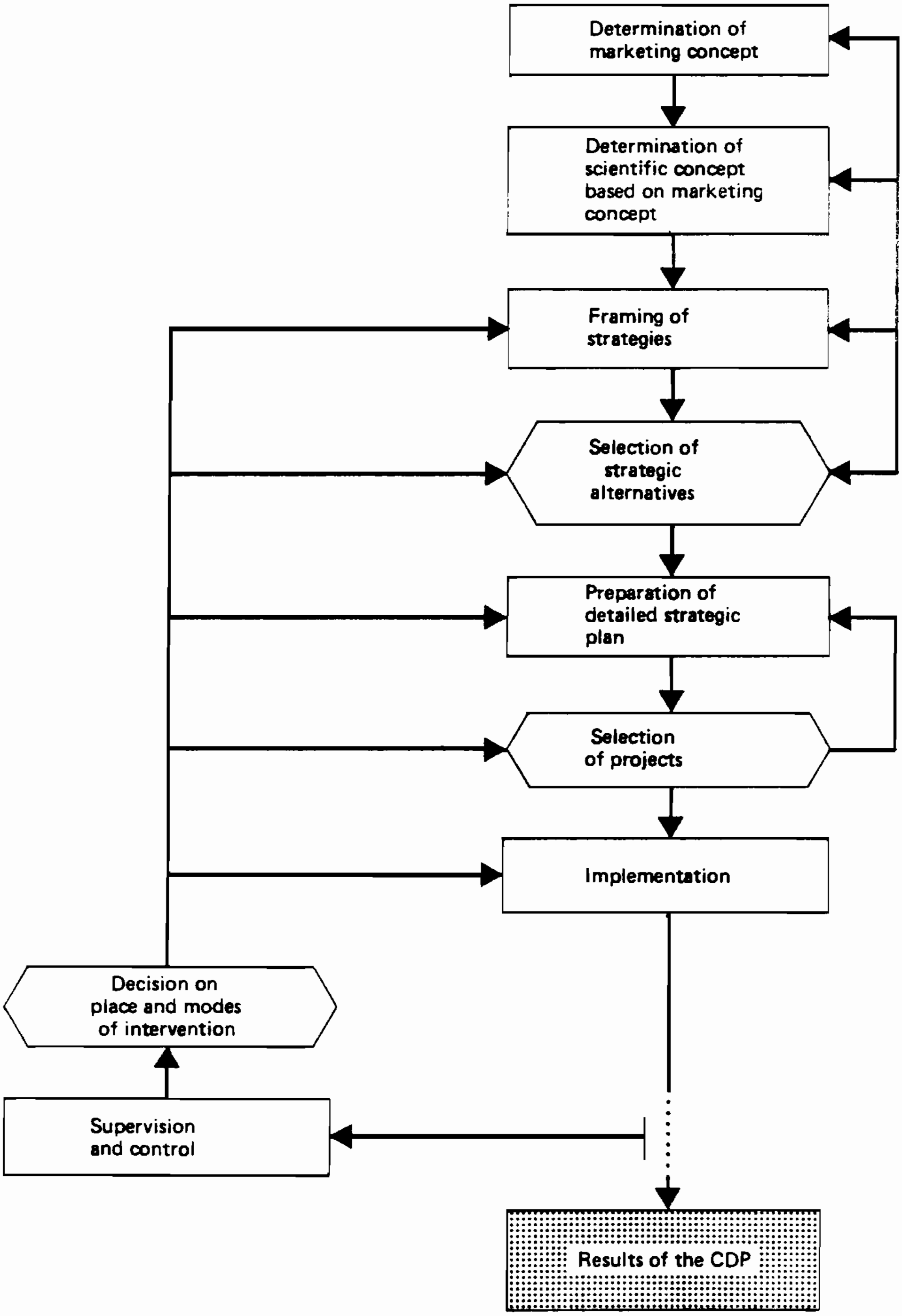

FIGURE 5 Dynamic scheme of the strategic managing subsystem.

Our analysis of the pharmaceutical industry innovation system clearly indicated a need for change. In working out organizational alternatives we first examined various strategic possibilities, tasks, and limitations, and then worked out the details for two alternatives. Finally, to evaluate these we listed the advantages, disadvantages, and the conditions of implementation for each alternative.

Strategies for organization development

Based on the analysis of objectives of the CDP and the dynamics of the innovation system we established the following two strategies:

(1) *Goal–oriented system:* Development of innovative methods and flexible organization capable of realizing the program's objectives —of changing program and industry objectives on the basis of observed results and changes in environment and of formulating and realizing new objectives.

(2) *"Green light" project systems:* Organization of project systems suitable for accelerating the process of producing original drugs from potential compounds for the market.

These strategies can be alternatives, or the second can be a part of the first. In the latter case, a goal-oriented innovation system is organized including the research, development, manufacturing, and marketing of new products as a series of projects. However, it could also happen that we fail to establish a goal-oriented innovation system covering the entire Hungarian pharmaceutical industry. In that case, individual companies will have to develop the necessary system to achieve their goals. As a result, the CDP may be realized as sets of uncoordinated projects.

The adoption of Strategy 1 leads to the organization of an innovation system capable of comprehensive, long-term development of the Hungarian pharmaceutical industry. Strategy 2 by itself can only provide a solution for the duration of the program (i.e., 10 years), although without comprehensive strategic direction it is doubtful whether strategy 2 would bring about realization of the CDP objectives.

All things considered, the systems analyzing team decided to propose the adoption of Strategy 1 combined with Strategy 2.

Tasks and limits in organizational development

Systematic organizing is required to make an existing organization work better or to set up a new organization. In designing the "goal-oriented innovation system," the following tasks of organization development were considered necessary:

(1) Adding institutions for strategic, operative and project management to the existing structure.

(2) Increasing the efficiency of operational subsystems and processes, paying special attention to the relationship between R&D, marketing, and the management information system.

(3) Establishing project organizations comprising staff members from industrial and foreign trade companies, research institutes and laboratories, and other organizations for the selection, development, and management of projects.

(4) Working out program-oriented personnel training plans, organization of training courses, and adoption of a personnel management system.

In the course of planning we had to consider some limitations. The new organization had to complement the existing one and at the same time meet the requirements of the program organization; it should also minimize modification of the present organizational structure and minimize money and time requirements.

Organization structure alternatives

Legally, new organizational forms can be developed either by state administration, or by companies and other organizations based on civil contracts. The former seems to provide the most effective structure for centralized strategic management. The latter has the advantage of being more firmly based on the autonomy and interests of the participants, but it requires more time and coordination. The choice of legal form is strongly influenced, but not determined, by the program's channel of financing. If subsidy has a major role in financing the program, the state administration solution is preferred; when the program is mostly financed by the companies, the contract form is given preference.

We identified six specific legal forms under which organizational development might take place. Four of these were rejected by planners. This left two options: the central program board and the trade association. The central program board is a specific collaboration for business administration that is set up by a government decision. As a legal entity, the central program board exercises decision rights on behalf of the appointed companies and other organizations over a list of specific questions. In this case company autonomy is restricted only in decisions relating to the program of innovation. The trade association is a voluntary partnership contract of companies and other organizations; it may be used for coordinating the strategies and activities related to the program.

The fundamental decisions under both alternatives are determination of strategies, selection and termination of projects, appointment of organizations to be in charge of the project, financing (resource allocation), determination of investment demand, evaluation of the achievements of operational subsystems, and modification of strategies and plans.

Essential differences between the two are as follows:

(1) In trade associations, the purposes of the companies are generally similar. This may not be true of the central program board.

(2) In trade associations, financial resources are mostly provided by the companies, which transfer a part of their own resources into a common pool. In the central program board, financing is mostly subsidized.

(3) The central program board has the right of disposing of the subsidy without restrictions. Trade associations may acquire the right to use part of the subsidy by transfer, with some restrictions, from external financing authorities such as ministries and state committees.

(4) In trade associations, fundamental decisions are based on the consensus of all members of a board of directors representing all member organizations. The central program board and its President have the authority to delegate matters pertaining to the companies involved.

In evaluating the organization alternatives we could not agree upon a single set of criteria. Therefore we used nominal group technique (Delbecq and Van de Ven, in Delp *et al.* 1977) to determine the advantages and disadvantages of the alternatives and the necessary prerequisites for the realization of their advantages. The list compiled, partly shown in Table 2, provides the necessary information for the decision makers.

TABLE 2 Advantages, conditions, and disadvantages in the case of Trade Associations and the Central Program Board.

Trade Association	Central Program Board
Advantages	
Voluntary; company interest is recognizable in realizing the innovation program	Good basis for realizing the innovation program's central strategy
Encourages cooperation between the organizations involved	Authority and centralized resources
Conditions	
The companies should pool resources for financing projects	Disposal of subsidy resources needed for the whole innovation
Mutual interest of the companies	Right to issue directives to companies
Disadvantages	
Does not necessarily lead to realization of the program objectives	Restricted freedom of decision making
	Establishes a parallel management system
Stops functioning under permanent and conflicting interests	

Preparation for Implementation

Convincing the decision makers

Without the participation and agreement of the decision makers no essential changes can be accomplished. Therefore we sought discussions with identifiable decision makers. Before submitting the final suggestions, we met with some of the decision makers at the state administration level and, at another time, with company decision makers. These discussions revealed that most of these decision makers prefer the trade association alternative to the central program board. This was partially due to the fact that there already exists a Hungarian Trade Association of the Pharmaceutical Industry. It was founded by companies and research institutes, and decision makers believed it could be transformed into a target-oriented organization. The final suggestions resulting from these discussions became part of the submitted program plan.

This plan will be the basis for the final decisions of the State Committee for Planning in 1980.

Determination of the implementation tasks

The analysis has made it obvious that the operational method and organization structure for realizing the new objectives could not be created overnight. We had to define what to do in the 1-year period between the Government approval of the objectives of technological, economic, and organization plans of the CDP and the starting of the program. These organizational tasks were divided into two groups:

(1) selection of the most important projects;

(2) development of a goal-oriented innovation organization.

In our view, projects need to be organized as quickly as possible in order to expedite research, development, manufacturing, and marketing of compounds already known that may be made into drugs. In other words, a "green light" was called for. Therefore, we defined activities, methods, and an organization for project selection and organization.

For establishing a new organization, or (more likely) for transforming the present organization, the launching of an organization project was suggested.

Documentation of systems analysis

Our analysis was documented in two volumes. The first volume contains the summary suggestions of economic and organizational requirements, the dynamic model of the innovation system, the analysis of the present state of the pharmaceutical industry, the alternatives of organization development, and the main tasks of implementation.

The second volume supports and complements the conclusions contained in the first volume in a series of appendices. It shows in detail the different models of the innovation system, summarizing the more important conclusions of content analysis. It lists and groups over one hundred organizations involved in the innovation system, discusses in detail the present state of the pharmaceutical industry, and explains the alternatives of organization development.

SOME CONCLUSIONS ON THE BASIS OF SYSTEMS ANALYSIS

Our conclusions can be summarized in two groups: one relates to the innovation system, and the other to the methodology of systems analysis.

Conclusions concerning the innovation system

Historically, the Hungarian pharmaceutical industry has proved its innovative capability. However, in order to cope with the present sharp competition on the international market, considerable changes are needed in objectives, operation, and organizational structure. In a market dominated by multinational firms, only organizations which possess both adequate capital and the organizational characteristics of such large companies are competitive. Without such organization, companies cannot produce marketable new drugs at the right time and place. For multiple organizations with different interests to cooperate in competition on international markets they must have mutual interests and objectives and their participants must possess adequate information. Cooperation can be stimulated by the sound allocation of capital. Consequently, money becomes an effective factor if it is used strategically to attain goals.

Conclusions concerning methodology

In our experience no available methodology of systems analysis can provide clear guidelines for decisions serving organization development. Organizational theory offers several approaches, but appropriate systems-analytic techniques are lacking. We have used a methodology combining general principles and methods of systems and organization analyses. The models we developed were based on a generalization of the experiences of team members. We used figures, schemes and group creative techniques, such as brainstorming and nominal group technique, to generate ideas. These were combined in accordance with the principles of the PROVISORG methodology (Szabo 1971). We did not find an opportunity to employ usefully formal mathematical modeling techniques.

The systems analysis committee has become an interdisciplinary team. In selecting committee members, a heterogeneous professional composition was attempted. This provided only a possibility for an actually goal-oriented teamwork in which members were really concerned with and accepted the points of view of professionals in other fields. Efficient collective work was brought about by communication between the team members during the series of team meetings held to establish a common scheme of reference. An aspect of this was the familiarization of the participants with excerpts from the relevant project management literature.

The exercise of conducting a systems analysis would have been a good management training course. It led participants to develop a complex set of concepts and a knowledge of group creative methods that would have been very useful for managing a large-scale innovation program. If such activities could be supplemented with new methods, for example, development of simulated competitive activities (i.e., war games in which territory is defended or gained by innovative activities), participation on a system analysis team could be an excellent device for managerial training.

The very short period of only 6 to 8 months was not sufficient for team members to achieve full agreement of the details of the proposal. An investigation showed the agreement to be 79 percent. This suggests a need for further investigation on decisions by those who are involved in the preparatory stages as well.

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BACKGROUND TO TECHNOLOGICAL ADVANCE IN THE JAPANESE STEEL INDUSTRY

H. Okada

INTRODUCTION

Since the Meiji restoration in 1868, Japan has energetically promoted the development of a strong domestic steel industry. The history of the Japanese steel industry, although short by European standards, now spans more than one hundred years. Only since the end of World War Two, however, has the Japanese steel industry made the dramatic progress in both quality and quantity for which it is renowned. The growth of the Japanese steel industry since 1868 is illustrated in Figure 1. Before 1945, a steel production peak of 7.65 million tons was reached in 1943. After the war, steel output peaked at 119 million tons in 1973. From that time annual steel output has remained around the 100 million ton level.

The reasons for the progress made by the Japanese steel industry after the Second World War are manifold. One of the external reasons is the rapid increase in domestic steel, automotive, shipbuilding, electrical appliance, and machinery industries after the War. In my presentation, I would like to limit my analysis to the internal reasons. The following two internal reasons seem to me to be the most outstanding reasons for the development of the Japanese steel industry.

Firstly, Japan's heavy dependence on foreign countries for fuel and raw material supplies has compelled Japanese steelmakers to make every effort to cut costs and improve quality. Their success in keeping costs down while at the same time improving quality is the major factor behind the international competitiveness of the Japanese steel industry.

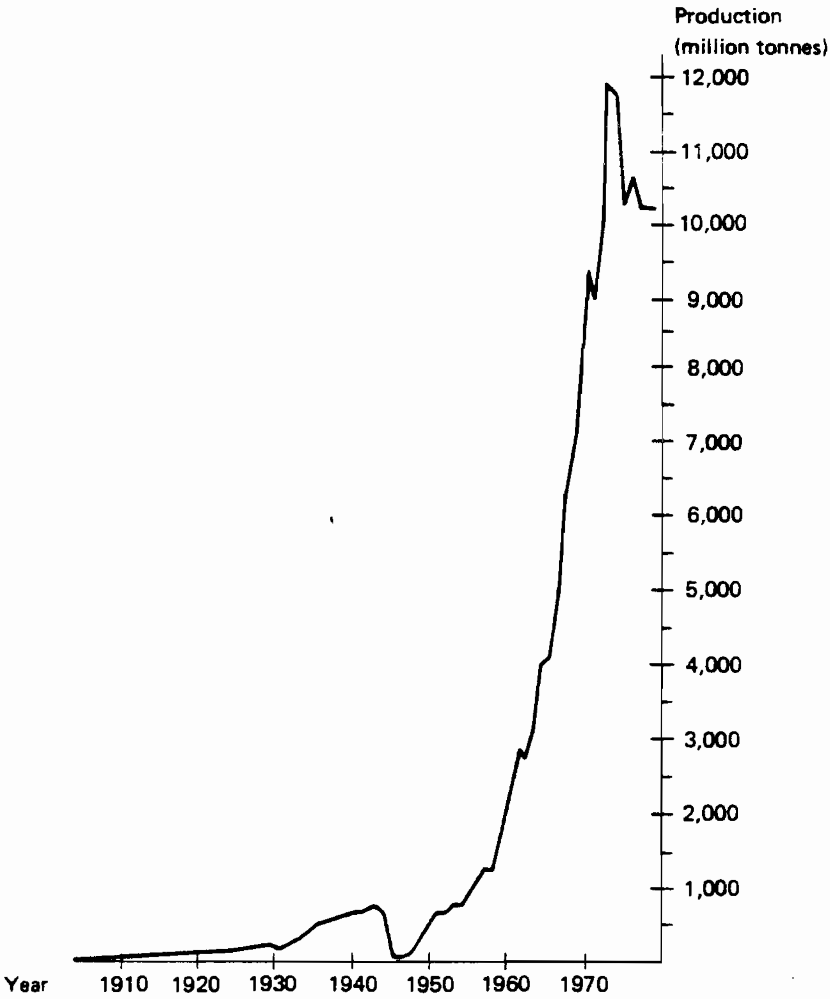

FIGURE 1 Crude steel production in Japan. Source: Japan Iron and Steel Federation.

Secondly, these industrial successes were attainable because labor and management worked together to realize corporate goals. This cooperation is a reflection of the feeling of commitment that highly motivated Japanese employees have toward their companies.

This paper describes these two outstanding factors which contributed to the technological progress made by the Japanese steel industry.

1. IMPROVEMENT IN INTERNATIONAL COMPETITIVENESS

1.1. Construction of Coastal Integrated Steelworks

What has the Japanese steel industry achieved since the end of World War Two to make itself internationally competitive — cost-wise and quality-wise — despite Japan's resource-poor condition? In a nutshell, the competitiveness of the Japanese steel industry is the result of: (1) the construction of many large integrated steelworks that employ the most efficient and most up-to-date system of technology available; and (2) the fact that these large-scale modern steelworks have been built at ocean front sites. This facilitates the handling of raw materials which are for the most part imported by means of large carriers developed by Japanese shipbuilders. Between 1953 and 1972, thirteen giant steel mills were built in coastal areas, as shown in Table 1 and Figure 2. This period also witnessed a number of technical innovations and improvements which together established the current system of integrated steel mill technology, which employs large-volume blast furnaces, large-scale basic oxygen furnaces, continuous casters, and high speed rolling mills.

TABLE 1 Steelworks constructed since 1945.

Steelworks	Date of blow-in of no. 1 blast furnace
Chiba: Kawasaki Steel	June 1953
Kobe: Kobe Steel	January 1959
Tobata: Nippon Steel (YAWATA)	September 1959
Wakayama: Sumitomo Metal Industries	March 1961
Mizue: Nippon Kokan	November 1962
Nagoya: Nippon Steel (Fuji)	September 1964
Sakai: Nippon Steel (YAWATA)	June 1965
Fukuyama: Nippon Kokan	August 1966
Mizushima: Kawasaki Steel	April 1967
Kimitsu: Nippon Steel (YAWATA)	July 1967
Kakogawa: Kobe Steel (YAWATA)	August 1970
Kashima: Sumitomo Metal Industries	January 1971
Oita: Nippon Steel	January 1972

This adoption of the most modern steel production technology means not only the use of large equipment to exploit economies of scale but also using more efficient and higher quality operating techniques to complement physical economies of scale. For example, computers and a variety of other instrumental techniques have been applied to process control and systems management; vacuum technology has been adopted to improve steel quality; and new civil engineering and construction techniques have been introduced in steel plant construction. Today, an integrated Japanese steelworks is not merely a combination of metallurgical and mechanical engineering skills but represents an all-inclusive technological system in which a myriad of techniques from many different areas are systematically combined. As a result, the Japanese steel industry is far more efficient than any of its counterparts in the world. As shown in Figure 3, the Japanese steel industry, as a whole, is more energy-efficient than its counterparts in other developed market economies. As shown in Figure 4, part of Japan's energy efficiency is due to the low fuel ratios (e.g. fuel/pig ton output) in Japanese blast furnaces. Japan also leads the world in production yield and labor productivity.

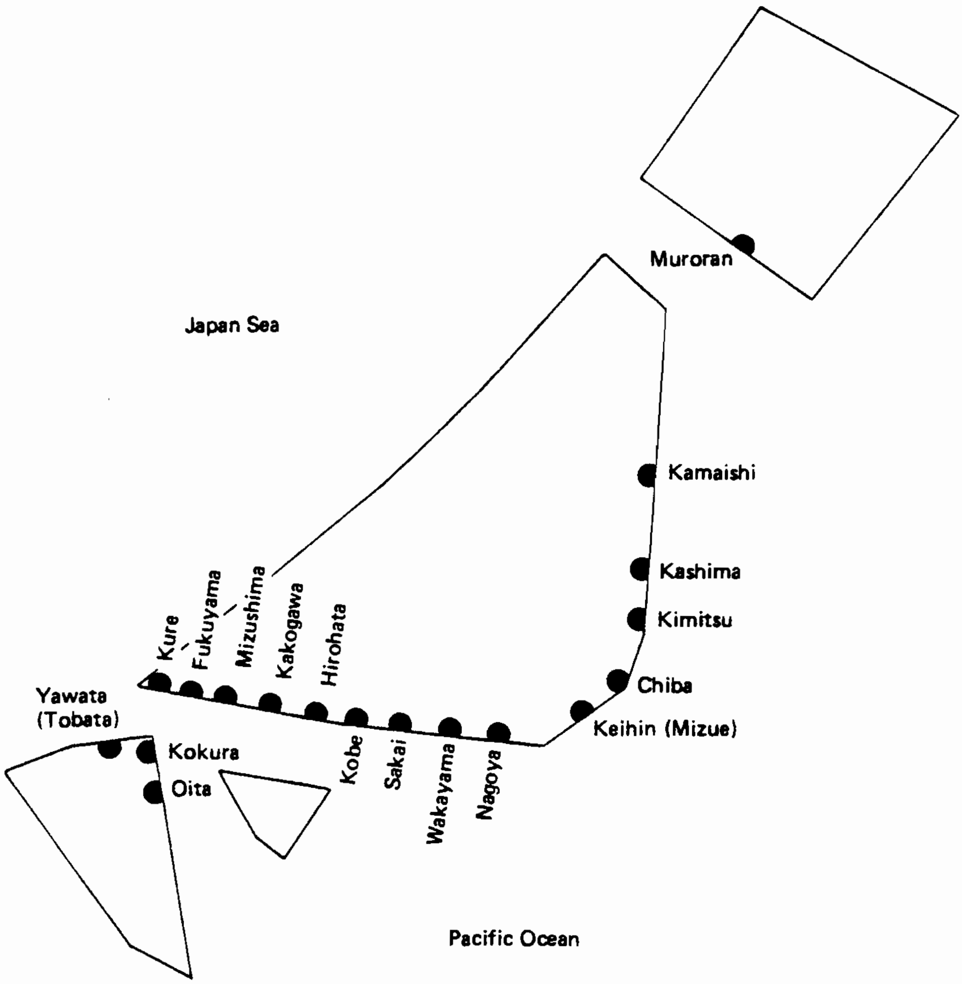

FIGURE 2 Location of coastal integrated steel works in Japan.

What are then some of the major technological innovations which made the building of these efficient steel plants possible?

1.2. Conspicuous Technical Developments

Perhaps the components of integrated iron- and steel-making technology which most typify the high level of technical sophistication of the Japanese steel industry are: the LD process, the continuous casting process, and the continuous annealing and processing techniques.

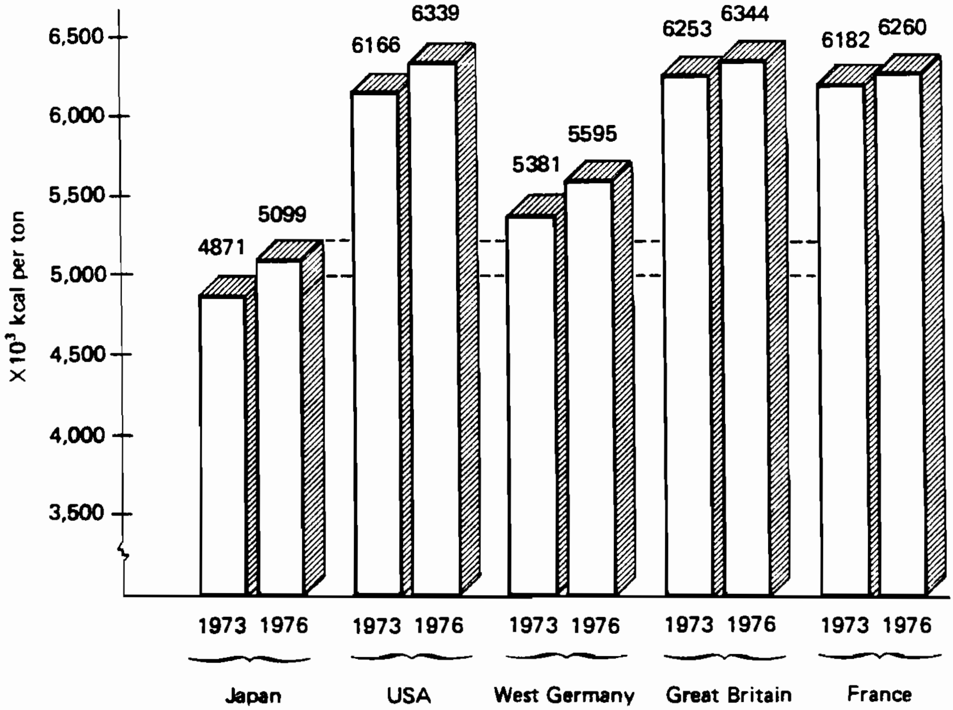

FIGURE 3 Energy consumption per ton of crude steel. Source: International Iron and Steel Institute.

LD converter steelmaking and continuous casting are two techniques which Japan imported from abroad and then made major improvements upon, whereas the continuous annealing and processing technique is an example of a technique which was independently developed by Japanese steelmakers.

1.2.1. LD converters

Immediately after World War Two most of the world's steelmakers used the open hearth process. Beginning in 1949, Japanese steelmakers developed a technique whereby oxygen was introduced into open hearth furnaces. This greatly improved the efficiency of open hearth furnace operations and drastically reduced fuel consumption. In the years after 1949, Japan led the world in large-sized oxygen plant construction and oxygen utilization techniques.

In 1952, Voest and Oemag, two Austrian steel manufacturers in Linz and Donawitz, announced the successful industrial application of a steelmaking process in which oxygen was top-blown into a refractory-lined converter containing molten iron. This process is known as the LD process. This new steelmaking process attracted the attention of Japanese steelmakers, who were then plagued by the high cost of scrap. Their experience with the use of earlier converters, as well as with the development of the previously-mentioned oxygen utilization technique for open

Figure 4 goes here

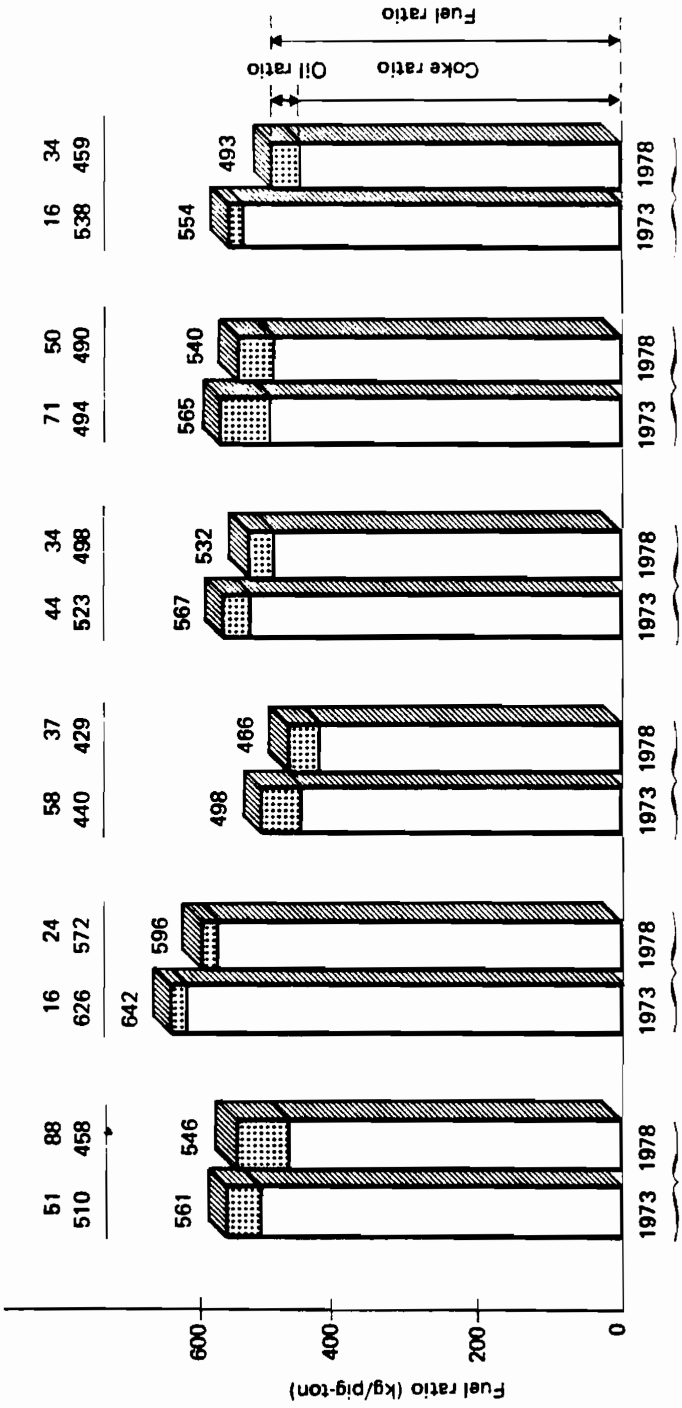

FIGURE 4 Trend of fuel ratio used in blast furnaces in various countries. Source: International Iron and Steel Institute.

hearth furnace operations, encouraged Japanese steel manufacturers to consider introducing this LD steelmaking process. In 1957 an LD converter was put on-line for the first time in Japan. Soon, enough operating experience was gained to prove the superiority of the LD converter process to the open hearth furnace. As is evident from Table 2, with the introduction of the LD converter process productivity increased approximately tenfold and construction costs per ton of steel capacity decreased

TABLE 2 Comparison of LD converter, electric furnace, and open-hearth furnace performance.

	Open hearth furnace	LD converter	Electric furnace
Capacity of furnace (ton/charge)	100–200	200–300	60–100
Number of charges/day	4–6	30–40	8–13
Output/day	400–1,200	6,000–10,000	400–1,000
Scrap ratio (%)	30–100	0–30	100
Fuels	Fuel oil, COG	Oxygen[a]	Electric power
Fuel consumption (kcal/ton)	600,000	90,000	1,600,000
Plant/equipment construction cost multiple	1	0.5	0.25
Steelmaking productivity (ton/hour)	15	245	13
Sound ingot yield[b] (%)	85.5	91.9	89.4

[a]Oxygen is not a direct fuel of the LD converter. Heat from the oxygen reaction with carbon, silicon, and other elements in the molten iron is used.
[b]Sound ingot yield = sound ingot/(hot metal + steel scrap).
SOURCES: Nippon Steel and Japan Iron and Steel Federation.

50 to 70 percent. Owing to the obvious superiority of the new process, all green field projects from 1960 onwards were for construction of LD converters to the exclusion of its predecessor. It then became possible to establish and diffuse a highly efficient mass-production system which effectively combined imported fuel and raw materials, large blast furnaces, and LD converters. Figure 5 shows the percentage distribution of crude steel output by different steelmaking furnaces since 1957. As early as 1963, LD converter steel output exceeded open hearth steel output. By the end of 1977 open hearth steel production ceased altogether in Japan.

The success of the LD process in Japan may be attributed to the development of multihole lances, the development of an optimum furnace profile, and other improvements to converters; however, the evolution of vital peripheral techniques has been equally or more important. These include:

(1) progress in refractory and repairing techniques in the hot state, which has extended the life of converters and greatly reduced the specific consumption of refractories

(2) use of computer control, which has improved the exactness of the chemical composition of steels and stabilized converter operations (an LD converter may take as little as 15 minutes to refine steel; this makes it essential to introduce and develop an exclusive process computer system), and

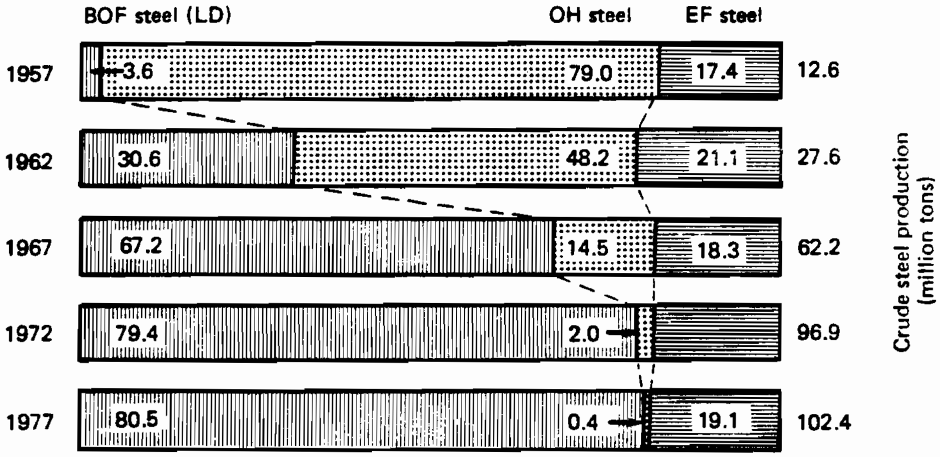

FIGURE 5 Crude steel output by production process (methods) for Japan. Source: Japan Iron and Steel Federation. LD, LD convertor; OH, open hearth; EF, electric furnace.

(3) the combination of the LD converter with vacuum degassing equipment, which has enabled LD converters to produce clean steels of quality as high as that attainable by electric furnaces. (Nowadays any steel grade except special high alloy steels can be made in the LD converter process.)

An account of the LD steelmaking process is not complete without mention of the basic oxygen furnace gas cooling and clearing system, commonly shortened to the OG process. This unique Japanese-developed converter gas recovery system not only contributes to heat recovery but also helps to protect the environment. To date, more than 100 OG units have been sold, both at home and abroad, under technology licensing agreements. This has marked a turning point for the engineering activities of the Japanese steel industry.

1.2.2. Continuous casting

Flanked on one side by a large, highly efficient LD converter shop and, on the other, by wide continuous hot strip mills, the ingot making and slabbing mill shops of the early 1960s were continually pressed to achieve technological innovations to match the capacity of preceding and succeeding processes. Conventional ingot making was clearly inefficient and slabbing mills had low yields. What was worse, the working conditions at ingot making shops were disagreeable and rigorous. To solve these problems, the use of the continuous casting process had long been viewed with interest. The continuous casting process, however, was not without its own problems. At that time, productivity, equipment costs, and product quality had yet to be improved. By the end of the 1960s, however, the continuous casting method began to be tried at various steel companies throughout the world, particularly in areas where the merits of improved yields under the new process were extraordinarily great.

The CONCAST continuous casting process was introduced to Japan from Switzerland between 1955 and 1960. It took several years, however, before the first practical model of Japanese make was commissioned in 1965. As Figure 6 shows, the continuous casting process produces considerable benefits in the areas of energy conservation, yield improvement and labor savings. By making constant improvements in continuous casting equipment, the cost effectiveness of the process grew. Not surprisingly, in the 1970s steelmakers rushed to introduce large continuous casters and apply them to carbon steel production. In 1972 the Oita Works of Nippon Steel became operational. At this works, ingot making completely gave way to continuous casting.

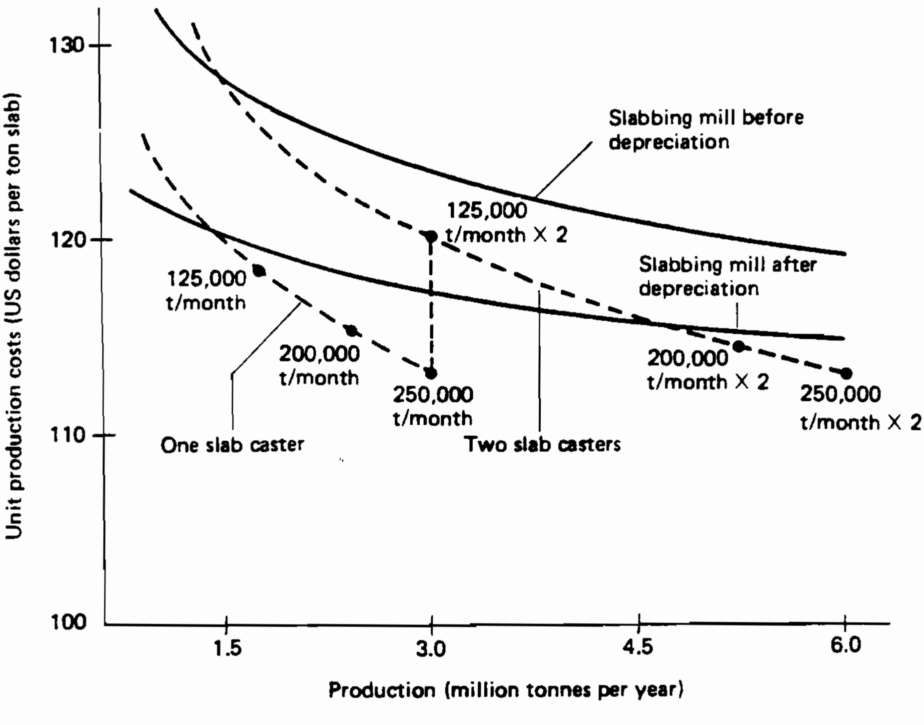

FIGURE 6 Relationship between productivity and production cost of slabbing mills and continuous slab casters. Source: International Iron and Steel Institute.

Nevertheless, in the first half of the 1970s, the continuous casting process still had many unsolved problems involving product quality. Its productivity was also lower than that for the slabbing process. These productivity problems were tackled by introducing the continuous-continuous casting process, by increasing the casting speed, by using variable width molds and by taking other productivity-oriented measures. It will not be long before a one-to-one correspondence is established between large LD converters and large continuous casters.

To improve the quality of continuously cast steels a number of steps have been taken. The homogeneity of cast steel has been improved by electromagnetic induction stirring. Refractories have been upgraded. Molten steel has been kept out of contact with air by inert gas sealing. The amount of inclusions has been reduced by using degassing apparatus. Through these measures the quality of continuously cast steels has now improved to the point where they are practically as good as ingot cast steels.

Because of the increased emphasis on energy saving since the oil price increase in 1973, slabbing mills are rapidly being replaced by continuous casting equipment. Figure 7 shows the growing ratio of continuous casting in the Japanese steel industry. The figure also shows a comparison of the continuous casting ratios in Japan and other countries. In all probability, Japan's CC ratio, i.e., the ratio of continuous casting to total steel production, will rise to 75 percent in 5 years time.

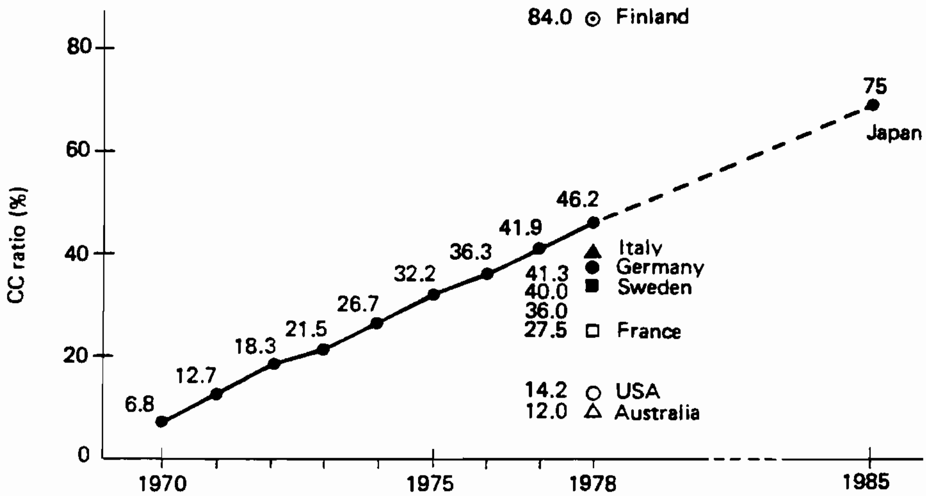

FIGURE 7 Trend of continuous casting ratio in Japan, compared with the 1978 ratio in other countries. Sources: Japan Iron and Steel Federation and International Iron and Steel Institute.

The continuous casting process is an emerging technology with much room for further improvement. In any event, continuous casting is sure to assume a central role in the future progress of steelmaking technology.

1.2.3. Continuous annealing and processing line

One of the technological innovations worthy of note in the rolling sector of the Japanese steel industry is the continuous annealing and processing technique. This process is used in the production of cold-rolled steels intended for further fabrication. As shown in Figure 8, cold rolling activities comprise five distinct processes: electrolytic cleaning, annealing, cooling, skin-pass rolling, and inspection and finishing. For many years, steel engineers dreamed that some day these five processes could be combined into one continuous process. A commonly held view at the time was that it was "industrially infeasible."

Challenged by the promise of savings such a combined process would offer, Japanese steel engineers initiated research and development projects in this field in the last half of the 1960s. Using the results of past basic research on pure iron, a breakthrough was made in controlling the level of impurities in steel at the end of 1969. In early 1970, a practical continuous annealing line was finally brought onstream. The time it takes for this new annealing equipment to continuously anneal a certain amount of steel has been reduced to a mere 10 minutes from the 1 week it took the conventional batch-type annealing equipment. The continuous annealing and processing line provides uniform product quality and excellent surface properties. The benefits of the new line in yield improvement and energy conservation are great and it has thus contributed much to reducing production costs.

The Japanese-developed continuous annealing and processing line has undergone continual improvement. Today it is attracting worldwide attention as a technique for producing cold-rolled, high strength, low-alloy steel sheet, which meets the low-weight requirements for car body steels. The continuous annealing and processing technology is expected to be widely used by steelmakers in the future.

1.2.4. Product development

After World War Two, Japanese steel companies marketed steel products which had been developed in Europe or the United States and whose qualities were therefore well suited to market demand. This might account for the greater emphasis which the Japanese steelmakers attached to cost-reducing process developments. In spite of this, many new steel products have emerged from Japanese laboratories. Japanese products include ORIENTCORE.HI-B (grain-oriented electrical sheet steels with exceedingly low core loss value), high tensile steels, high strength line pipe materials, tin-free steel, and a substitute for tinplate. In addition, many other new products are now being marketed or developed. These product development efforts have made an immense contribution to the accumulation of a wide range of steelmaking techniques in Japan.

Figure 8 goes here

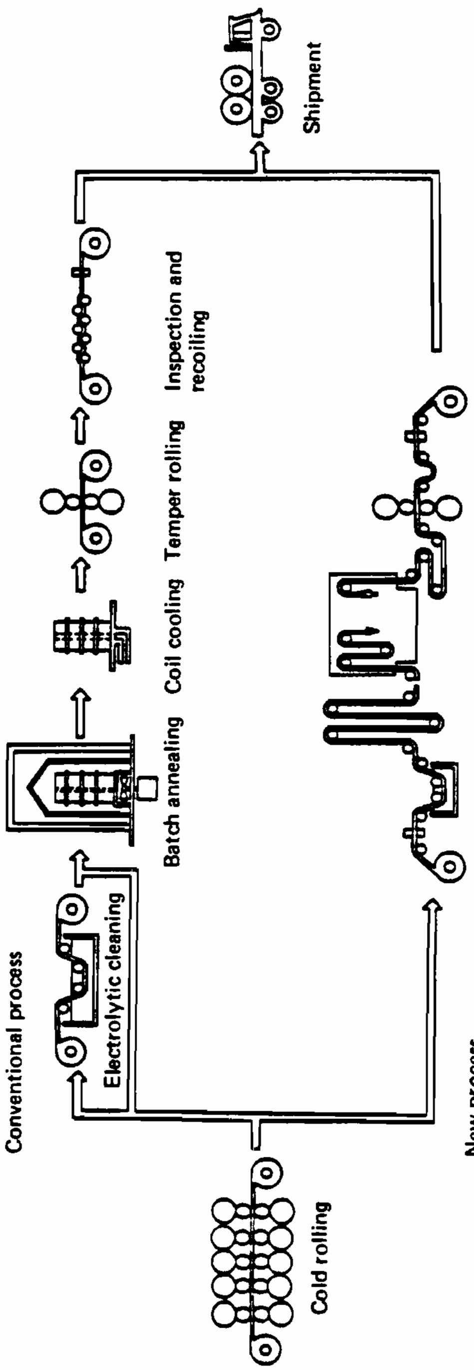

FIGURE 8 Continuous annealing and processing line technology. Source: Nippon Steel Corporation.

2. HUMAN FACTORS IN THE DEVELOPMENT OF TECHNOLOGY

For a period right after World War Two, the Japanese steel industry was given preferential treatment by the Japanese government in its reconstruction efforts. However, as is evident from the foregoing discussions, the spectacular advances which the Japanese steel industry made after that period can justly be ascribed to the persistent efforts of civilian employees working at steel companies.

What then is the secret that accounts for the contributions that Japanese workers make to the successive development of technology? In my belief, it is the strong sense of attachment which a majority of Japanese employees feel for their companies. In other words, it is the awareness of workers that they contribute to the advance of the enterprises to which they belong. In this next section I will dwell on this peculiarity of the Japanese in general and discuss the way in which research and development activities should proceed in the future.

2.1. Japanese Employees and Their Feeling of Commitment to the Company

Before World War Two, the Japanese people had "something" to live for in the form of the nation, or the Emperor. This something formed the background against which their lives existed. Defeat in the war brought about a collapse of that old system and with it that special something by which most Japanese had oriented their lives vanished. For some years that followed, Japanese minds swayed right and left in search of something else worth living for. At length they came to find that new something — an entity which is less national than private. This private entity in many cases came to be the private enterprise or company for which they worked. Far from taking the individualistic route as in Europe or America, the Japanese found purpose in a distinctly Japanese "collectivism." They could identify themselves with and commit themselves to the corporate cause. Hence the following of a peculiar Japanese groupism or collectivism centered around the business corporation.

It may seem unusual that in Japan after World War Two, while democracy was growing rapidly, at the same time a groupism based on loyalty to a business enterprise was spreading steadily throughout the nation. Of course, this loyalty is different in nature from the prewar loyalty to the nation which had been fostered through years of feudalism. The Japanese groupism is apparently based on the Japanese way of thinking, or ideology, in which Japanese place greater importance on the group than on the individual. When conflicts arise between what is good for the individual and what is good for the group, the group prevails. The Japanese gain satisfaction within themselves by following this way of thinking.

In the absence of an understanding of the above, it may be hard to appreciate the loyalty most Japanese have for their own company. This fidelity to the enterprise forms the foundations of the ever-advancing Japanese industry. This notion of loyalty was not built in a day but has been built up in the mind of the Japanese people over the past four centuries — ever since the start of the Edo era in Japan. Only since the Second

World War has the object of Japanese loyalty changed from Emperor-centered to company-centered life — to put it succinctly for ease of understanding by those who are not familiar with the Japanese way of life. Accordingly, in any Japanese business enterprise, whether an employee is on the management or labor side, you will find that at the bottom of his heart is an undoubted sense of attachment to his company, even though the degree of that sentiment may vary from person to person. Viewed in this light, you may well understand why Japanese labor unions generally cooperate with management.

Under the new post-war order the aristocracy was abolished. This, coupled with agrarian reform and other democratization policies, helped reduce class consciousness among the Japanese. Furthermore, the heavy dependence of Japanese enterprises upon external loans put a practical end to the existence of capitalists, a fact which helped the development of a labor-management cooperation. For example, in the construction of a green field integrated steel mill on the coast, a considerable number of employees can be smoothly moved from the old to the new steelworks, all because these people are loyal and their trade union is cooperative. Also, the technological innovations described earlier entailed the smooth transfer of employees from shop to shop or from one works to another. Without the willing cooperation of employees and unions, the Japanese steel industry could not have realized the rapid progress of the past three decades.

Thus a business corporation in Japan is a community bound together by common interests, in which labor and management cooperate in profit making and in the improvement of the workers' standards of living. Similarly, it is a community knitted together by a common fate. Bankruptcy means deprivation of the means to earn a living for labor and management alike. The desire of employees to contribute and be loyal to their firm is accordingly enhanced. Undoubtedly, this positive attitude of employees toward their company forms the cornerstone of the successful development of technology in the steel industry.

This may be best illustrated with reference to the Jishu-Kanri (J-K) activities of mill-floor workers. J-K is a "voluntary" movement involving small groups of workers (normally a foreman and six or seven workers) in the same workshop. The purpose of the groups is to improve production efficiency and the work environment. The objective of improving efficiency, for example, includes such tasks as eliminating errors, improving machinery and equipment design, reducing input consumption, and improving product quality.

The proposals of these J-K groups are reported at plant, company, and national meetings, and a great number of them have been put into practice.

In this regard, it may be worthwhile to touch on the Japanese employment system, under which the feeling of commitment to one's own company has been cultivated. In short, the Japanese employment system features lifetime employment and a seniority based wage system. Lifetime employment means that employees serve only one company throughout life from their graduation from school until retirement. Under the seniority wage system, workers' wages and positions rise mainly with their length of service in the company. To add to this, employees are favored with housing opportunities, welfare facilities and other amenities. It is against this backdrop that the Japanese have so far been able to offer faithful service to their company with confidence and a sense of security.

2.2. Tasks Before the Japanese in Areas of Technological Development

As mentioned earlier, the Japanese tend to identify themselves with their we-group. They may, therefore, be very critical but are sometimes lacking in pioneering spirit. In fact, a careful look into the history of Japanese steel technology reveals that except for those techniques genuinely Japanese in origin, many of the technical developments supposedly achieved in Japan are merely extensions of what has been introduced from overseas. In other words, in the presence of a technique A, the Japanese would compare it with techniques B and C and invest large sums in the safest of them all. This approach may be successful when importing technology, but it is not conducive to initiative or invention.

Admittedly, employee loyalty, which is based on the groupism unique to Japan, has been a success in Japan's introduction of technology from overseas with the intention of improving on it. But it is a different story when it comes to technological innovation which presupposes originality and creativity. Here, "we-groupist" loyalty is not enough but must be coupled with something that appears to be missing in the Japanese way of life. I am convinced that this missing something is the self-reliance which springs from European and American individualism. I believe it is necessary to cultivate in the minds of the Japanese the pioneering spirit evident in the individualistic approach of those who are bent on what they have initiated on their own. It is my understanding, that if a certain European or American person (or an enterprise) has developed technique A, he is likely to try technique B. This contrasts with the Japanese who might be content with technique A or A'. If a Westerner finds technique B to be better than A, these individualistic Europeans or Americans go on to examine technique C, unlike the Japanese who may settle for B or B' as an improvement. This may account for the ease with which original inventions are far more often made in those autonomous, individualistic societies.

What is needed for the future of the Japanese industry is not the negation of its collective loyalty. On the contrary, it must combine this cultural heritage with a self-reliant, pioneering spirit, so that the range of human cultivation may be further extended. I firmly believe that in the final analysis, this enlarged scope of human orientation will allow uniquely Japanese technology to blossom in the not so distant future.

INDUSTRIAL INNOVATION AND GOVERNMENT POLICY: A REVIEW AND PROPOSAL BASED ON OBSERVATION OF THE US ELECTRONICS SECTOR

Alvin Jay Harman

1. INTRODUCTION

The US electronics sector has been particularly successful at technological innovation since the 1940s. This paper addresses governmental policies that influence the process of technological innovation, drawing on aspects of the history of the electronics sector. Three topics receive particular attention: (1) uncertainties, ideas, and imperfect appropriability; (2) returns to R&D and associated investments; and (3) competition and selection environments. As a foundation for this discussion, several conceptual frameworks are briefly described and some classifications for innovation are explored, i.e., by importance (basic/improvement), by locus of change (process/product), by area of application (peaceful/dangerous), by locus of choice (private/public), and by value (worthwhile/not worthwhile). The discussion is underscored by the observation that better links between conceptual understanding and policy formulation are needed in order to convert practical insights into useful actions. One specific policy recommendation is tendered: an income tax credit on earnings of all employees (including salaried staff and managers) of R&D-intensive firms. Such a policy would be appropriate from the standpoint of the topics outlined above (i.e., uncertainties, returns to R&D, and competition); the policy would also delegate responsibility for effective use of the subsidy to the employees and firms affected, and would directly acknowledge and reward the contributions of individuals — whether in R&D, production, marketing, or support areas —

to the innovative capabilities of their firms and the society at large.

2. PERSPECTIVES ON THE "REAL WORLD"*

When economists leave their theoretical models aside, they often refer to circumstances in the "real world." This reality is, of course, much more complex than the economists' theoretical formulations, but it is precisely the simplifying assumptions that allow the theorist to analyze fundamental influences conceptually and to verify them empirically.

Like theory development, policy formulation and implementation also depend on abstractions from the "real world." In April of 1978 President Carter initiated a "Domestic Policy Review of Industrial Innovation" for the United States. The Secretary of Commerce was charged with leading the review to answer the question, "What actions should the Federal Government take to encourage technological innovation?" Suggestions were sought from business, labor, and consumer groups as well as from "experts." The observations, analyses, and opinions rendered during this process had to be interpreted in the light of broader economic and political considerations before the President's "Industrial Innovation Initiatives" were formulated and promulgated (Carter 1979).

The legislative branch has also been active. Staffers have sought information and drafted position papers, hearings have been held,** and specific pieces of legislation have been formulated.

Meanwhile the "real world" continues to evolve: new products are announced, new companies are formed, and some of the existing companies "disappear" through merger or bankruptcy. The "real world" is changing and new problems are arising. The policy formulation process resulting directly from the Domestic Policy Review will continue for several years, during which time legislative and other action will be taken. Policy action will often take several more years to be fully implemented. Some implementation steps will be undertaken by individuals with limited understanding of the "subtle and intricate process" (Carter 1979, p.5) that they will be charged with influencing. Thus the policy process can produce errors in governmental action affecting technological innovation as easily as the simplifying assumptions of the theorist can produce errors of insight about the innovation process.

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**See Industrial Technology (1978), which provides the record of a hearing on governmental policy and innovation in the semiconductor and computer industries, together with a summary of several previous hearings on industrial technology; see also Gilpin (1975).

In short, conceptual formulations attempt to interpret reality and policy initiatives attempt to influence reality. Like the two fists of a boxer, it would be highly desirable if the two approaches were coordinated and directed at identifying and ameliorating or removing real problems, each approach sensitive to the many subtleties and limitations of the other. Even then there would be value issues to resolve — e.g. the choice of "targets" for policy actions. But too often theoretical models and policy initiatives are developed independently of one another, are often uncoordinated — more analogous to the claws of a lobster than the fists of a boxer — and can produce unforeseen interference as well as progress.

In this paper I will — in the context of the US electronics sector — both briefly sketch a few of the competing conceptual formulations for understanding technological innovation at the firm and industry level of aggregation, and discuss some of the policy actions that have been considered (or taken) in the past. In the course of these observations, I will comment on the need for further research and policy initiatives.

Although the principal objective of this paper is to foster discussion, a specific policy recommendation is tendered. To simulate technological innovation while delegating to the firm the responsibility of choice among options, I have suggested a personal income tax credit on earnings of all employees and salaried staff and managers of R&D-intensive firms. This would become, to some extent, an indirect subsidy to the firms: one that could be used for a range of options such as further R&D, new hiring, capital investment, etc. This policy would be relatively more favorable to smaller and more labor-intensive firms; it would also avoid some of the inherent biases favoring high income tax brackets as found in many capital gains tax proposals. The fiscal impact of the policy would have to be coordinated with broader fiscal policy objectives, and perhaps enacted in conjunction with encouragement of new investment and/or greater venture capital availability. One of the main objectives of such an income tax credit would be to acknowledge directly and reward the contribution of individuals — whether in R&D, production, marketing, or support areas — to the innovative capabilities and economic vitality of their firms and the society at large.

3. CONCEPTUAL APPROACHES TO TECHNOLOGICAL INNOVATION

3.1. The Innovation Process

If we view "technological innovation" as the introduction of a new or significantly improved product or process into the economy through the application of modern technology, then quality change and cost constitute the essence of such innovation. In recent decades, governments and firms have expended considerable energy and resources in attempts to organize the innovation process efficiently and to direct it toward useful* results.

*"Useful" here refers to the distinction between innovations which yield quality changes that are "worth" what they cost and those which are not.

Feedback from one stage of the research and development (R&D) process can help in formulation or reformulation at other stages; learning must take place so that an innovative concept can be confirmed to be both technically feasible and desired by the user. The qualitative nature of purely process innovations permits them to be measured relatively easily and quantitatively — in terms of cost reductions in the delivery of an identical end product. In contrast, the qualitative nature of product innovations is much more complicated, especially because the original objectives of the innovation may turn out to be secondary to other applications that are discovered after the innovation has become more widely diffused into an economy. For example, the demanding requirements for reliability and security of real-time applications of computers in the financial sector were hardly anticipated when the first computers were being introduced.

Serendipity plays an important role in the historical development of a branch of technology and its applications. The lines of descent of today's technological innovations can be studied, but it is much more difficult to anticipate the future directions of current trends. The antecedents of the US electronics sector can be traced back to the first prototype light bulb burned by Thomas Edison a hundred years ago. The earliest antecedents of the high volume production of much of today's electronics circuitry should include Eli Whitney's invention of rifles with interchangeable parts, as well as Henry Ford's mass production techniques. Opportunities to commercialize the results of these innovations were different; in the Whitney and Ford examples, a well-defined market opportunity existed. The needs of the ultimate user in terms of both product quality and price were critical to the success of all the innovations.

It is difficult to summarize succinctly the meaning of the phrase "anticipating the needs of the final user"*. In part this stems from the variety of potential final users for the vast array of goods and services available in an economy like that of the United States. Also, most of the goods and services are amenable to some form of technological innovation over time, so that either the characteristics of the product sought by the final user or the cost of production is susceptible to change. In Figure 1 a categorization scheme is suggested for distinguishing between choices of final goods and services by either private or public decision makers, as well as for considering the applicability of these choices to two broad categories of final goods and services — identified as "peaceful" or "dangerous." These distinctions are by no means clearcut; the categories "peaceful" and "dangerous" are descriptions of the extremes of a continuum of goods and services (hereafter referred to as "products") rather than mutually exclusive categories. Research and development can lead to technological innovations in either of these categories. Moreover, the earlier the stage of the R&D process (e.g. basic research), the less identifiable is the work with either of the extremes of this continuum (or any point in between). If we distinguish between technological innovations that are "basic"** and those that constitute "improvements," we should

*Also, the "needs" a firm deems worth satisfying may be different from the "needs" viewed as important by society at large.

**"Basic" innovations imply the opening up of a new field of product applications, or permit efficiency improvements through developing a new technology.

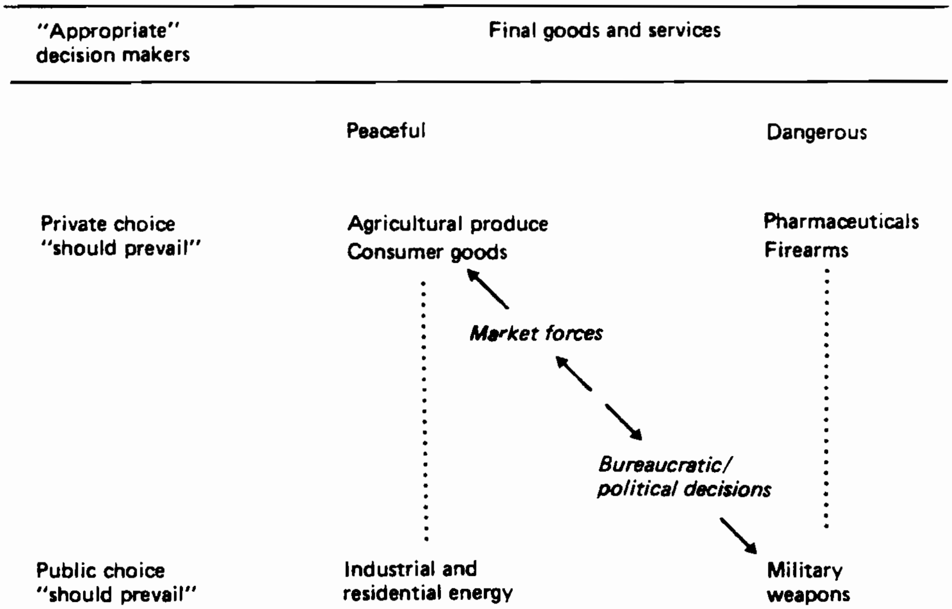

FIGURE 1 Microanalytic view of final goods and services, and private or public choice.

recognize that basic innovations can be motivated by end-uses at any point along the spectrum of final products. Innovations that led to the emergence of the English cotton textile industry in the late eighteenth century and the development of atomic energy in the mid-twentieth century illustrate this point.

"Improvement" innovations can have two different objectives; they can enhance products subsequent to the original application of a basic innovation (e.g., improvements in spinning and weaving machinery or in nuclear weapons design), or they can permit the application of a basic innovation for new end-uses, i.e., a movement on the continuum between peaceful and dangerous products. The directions of such innovations are motivated by the "needs" that are perceived to be worth satisfying.

Thus, consideration of decision making about uses of the final products reveals influences on technological innovation from sources other than technology. For final products that are not "dangerous" and for which private choices are most relevant, market forces have been demonstrated, both theoretically and empirically, to allocate scarce resources efficiently and to provide signals about the need for further technological innovation. The limited acceptance of the initial strains of high-yield rice produced in what has come to be called the "green revolution" occurred because the reduction in product quality (e.g. taste and texture) had unanticipated consequences for prices. "Improvement" innovations were needed to enhance the quality of the new strains, to make them more competitive with available alternatives. Such innovative activities can occur without deliberate public sector intervention.* In contrast, public choice is widely recognized as the relevant perspective for products relating to a nation's military capability, and market forces would provide inadequate guidance for technological innovation. Under such circumstances, reliance is placed on bureaucratic and political decisions.

It is important to consider these distinctions explicitly, for national security requirements, as perceived by national interests, govern a great deal of publicly supported R&D.** All countries rely to some degree on bureaucratic and political decision making in assessing the "needs" that determine allocation of publicly and privately supported R&D.

This discussion of the roles of market forces and bureaucratic/political decisions in clarifying the needs of the ultimate user — to whom successful technological innovation is directed — is applicable (to a greater or lesser extent) across the whole continuum of final products. For example, there are recognized and legitimate roles for government regulation of pharmaceuticals in the health care delivery field in the United States. There is also an expanding government role in determining appropriate rates of reimbursement for medical services, as well as activities by the courts in determining responsibility and damages for malpractice. It is striking that such public sector activities exist in an environment in which the medical profession has traditionally been relied upon to seek improvements in modes of medical intervention, in which the hospital sector has sought to attract physicians to its staff through nonprice competition (e.g., investments in the latest medical technologies), and in which the recipients of medical services are widely regarded as having incomplete information for choosing among medical services and few incentives for being "cost conscious" in such choices. Satisfaction of the "needs of the ultimate user" through further technological innovation in medical equipment and instrumentation involves responding to a very complex set of "market" incentives; in such circumstances, public policy initiatives can have quite unanticipated effects (Rettig and Harman 1979).

3.2. Economic Concepts

The activities of industrial enterprises (firms) undertaking technological innovation should be analyzed within a conceptual framework that captures the personal motivations of the participants, as well as more structured decision processes regarding product objectives. This framework should take consideration of both the context of market forces and the non-market environment. Despite a great deal of economic research on this topic, no consensus has been reached regarding such a conceptual framework. Thus, it seems desirable to use an eclectic approach as a guide to policy formulation.

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*The crucial ingredient, as Nancy Nimitz emphasizes, is the existence of cost-conscious and discriminating buyers. See also, Eads (1977) and Nelson *et al.* (1967).

**These "national interests" may be subject to a broad range of interpretation at a particular point in time, by leaders as different as Winston Churchill, Joseph Stalin, Franklin Delano Roosevelt, and Adolf Hitler.

Neoclassical theory has been receiving increasingly critical reviews in recent years. Still, it retains the advantage of being the most parsimonious description of the essential elements of a firm's economic motivations. Neoclassical theory ignores, however, the intrinsic uncertainties of the R&D process, treating them at best as an *a priori* known distribution of risky outcomes.*

Two other approaches to understanding firm behavior appear particularly intriguing. Nelson and Winter (1977) have argued for an evolutionary theory; it includes modeling of the intrinsic uncertainties of the innovative process with the aid of a set of conditional probabilistic outcomes of various R&D strategies. Nelson and Winter have also suggested that it may be important to recognize the role of institutional structures, in various economic sectors, in determining innovative outcomes. There may be a variety of "selection environments" that capture the competitive aspects of firm behavior and the needs of the ultimate user. These "selection environments" incorporate three elements: the determination of the "worth" (e.g. profit) of innovation activities by firms, the ways in which consumer and regulatory demands shape profitability, and the investment and imitation processes that are involved.

Nelson and Winter consider both market and nonmarket "selection environments." The principle distinction they propose is that in nonmarket sectors the interests of "firms" and "customers" are not as sharply defined as in the market sectors. They suggest that "natural trajectories" of technologies occur in which obvious weak spots in product designs or targets for improvement can be identified. Such natural trajectories can lead to rapid advancements in some economic sectors, while other sectors, lacking such natural trajectories, progress more slowly. The development of electronic components from vacuum tubes to very large-scale integrated (VLSI) circuitry seems to provide an example of a natural trajectory. The widely used S-shaped curve of technological advancement — i.e. initial rapid advancement in terms of quality enhancement of an end product's principal dimensions, and then a slowing — can be understood in terms of such trajectories and their underlying scientific and technological base.

In contrast, Klein suggests an explanation based on a dynamic theory:

> The principal reason why technologies come to be defined very narrowly and why the rate of progress eventually slows down is not because of a shortage of ideas, but rather because of a shortage of hidden foot feedback. Hidden foot feedback is the feedback a firm obtains from its rivals; and it is measured in terms of changes in market share.... In as much as what is a technological risk to one firm in an industry is a competitive risk to another, the more technological risk taking that is undertaken in developing products with nontrivial differences, the greater will be the changes in market shares... . Almost inevitably, the

*The author has used this approach in the past, with its many simplifying assumptions; see Harman 1971, Ch. 3.

> larger the advances that are sought, the wider will be the differences between more and less successful R&D projects, and the larger will be the change in market shares. (Klein 1979, pp.7-8).

Thus, Klein argues that intensive technological innovation and rapid rates of technological progress by firms are derived from the threat of a potentially successful rival. He further argues that the successful firm — one that grows and as a result becomes more bureaucratic — becomes susceptible to narrowing the range of investigation for resolving future uncertainties, and hence for coming up with further innovations. Klein argues that the rate of technological innovation for an individual firm may slow because of the tendency of such internal bureaucracy to establish routines and to preserve the status quo. The principal factor that determines whether or not the industry remains "dynamic" (i.e. continues with rapid introduction of new process or product innovations) is the ability of new firms to enter the industry (see also, Schumpeter 1934).

Finally, technological innovation in general has also been stimulated in important ways by the demands of a diverse and international marketplace.* The standard conception of international trade explains trade patterns according to a nation's comparative advantage for efficient production, based on the relative abundance of its resources, labor, and capital. An important extension of this theory, to the sphere of newly developed products, interprets international trade as being based on technology itself. The theory has also been extended to include the concept of a product lifecycle, in which the ability to produce certain products by firms in various countries changes over time.**

In early phases, few firms are innovators, and have the required production knowhow. As technology diffuses and imitation occurs, trade patterns are influenced more strongly by the traditional factors that determine comparative advantage. For example, standard electronic components that involve labor-intensive production will be cheaper for US producers and final consumers if they are imported from countries where labor is relatively cheaper than in the United States.

A firm can maintain its comparative advantage by continuing to evolve its product line in advance of its competitors (see Harman 1971, Ch. 3). This can occur, of course, only as long as a scientific and technological base exists to support such technological innovation and as long as the means of at least temporarily capturing the economic gains of the innovative activities are sustained. In other words, products will have periods of rapid growth and international marketing, followed by periods of consolidation. "Consolidation" may not mean a slowing of the potential for further technological advances; but the new products that could be developed may not be sufficiently valued by users to merit the price that would have to be charged for them in the national or international marketplace.

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* Is true for semiconductors and computers in particular.

**See, for example, Vernon (1967) and also Hufbauer (1970).

Thus, technologically determined trade patterns are intrinsically temporary, though they may last for a long time. The US advantage in computers and semiconductors has been fostered by a continuing stream of advances in technology. At the upper end of the computer lines, this advantage is still unchallenged internationally — no less than four US firms compete for customers. Some recent developments, such as the network-oriented computer, have been made possible in part by the new capabilities of the semiconductor industry. Such developments suggest that the American computer industry is continuing to be innovative. Participation in international markets not only affects the US balance of payments, but also provides opportunities for access to a wide spectrum of new ideas, so necessary to further product developments.

4. SOME OBSERVATIONS ON POLICY LEVERAGE*

4.1. Uncertainties, Ideas, and Imperfect Appropriability

A fitting place to begin the discussion of policy leverage on technological innovation is with the motivations of the individual. A wide spectrum of individuals is needed for successful technological innovation (or, alternatively, individuals with a wide spectrum of capabilities). Not only an "inventor" and "developer" is needed, but also a "product champion" who makes the case for backing a particular concept throughout its development process, a "gatekeeper" who helps with the flow of information within a large organization and between the organization and the outside world, a "production specialist" who keeps the concern for production efficiency prominent during the development process as well as during production, "salesmen" who distribute the end products and provide the organization with feedback regarding the unmet needs of various classes of users, and an "entrepreneur" (see, for example, Zaltman *et al.* 1973). A president of one of the US semiconductor firms describes the importance of these individuals as follows:

> For us to maintain technological leadership in a competitive world we must stimulate the total society to find its strength in its own members. Novelty comes from a self-confident personality. This entrepreneur will create innovations for the pure zest of achievement through the incentive of the well-being of himself, his loved ones, and his neighbors.

*This section draws upon the experience of the computer and semiconductor industries. Principal sources used include Industrial Technology (1978), Braun and MacDonald (1978), Phister (1974), Tilton (1971), and Harman (1971). The quotes from executives included in this section were taken from correspondence following a hearing before the US Senate Committee on Commerce, Science and Transportation (Industrial Technology 1978). In the preparation of earlier remarks (Harman 1978), on which this section is based, the author benefited greatly from exchanges of ideas with R. Anderson, A. Alexander, W. Baer, G. Eads, F.M. Fisher, D. Jaffee, E. Mansfield, R. Perry, R. Rettig, E. Thomas, J. Utterback, and W. Ware. The author is also indebted to Rand Graduate Institute students — and particularly to J.L. Burns, B.W. Don, L.B. Embry, and W.L. Schwabe — for stimulating discussions of some of these issues.

In essence, the process of successful technological innovation ultimately depends on one or more individuals coming up with good ideas. The exploration of good ideas — the difficult process of resolving uncertainties to achieve a successful new product or process — cannot be measured simply in terms of dollars expended. Some concepts for the new design of a piece of computer hardware may rely on readily available electronic components or technologies. In fact, the Amdahl line of computers used components for memories that were available "off-the-shelf" from more than one source. Novelty in the design came from efficiently packing the components, while maintaining competitive sources of supply.*

4.2. Direct Support of R&D

Government policies can affect the development of new ideas in a number of ways.** First of all, financial backing for basic research activities has been considered a legitimate role of government both theoretically and in practice. In recent times, privately funded basic research has been significantly curtailed (see Nason *et al.* 1978; Industrial Technology 1978, p.33; and Carter 1979, p.4). In the context of augmenting basic research support, it seems important to try to develop a closer link between industry and the universities. In this connection the view of another president of a semiconductor firm is relevant:

> We believe that closer links are very desirable. Our endorsement is based on our participation in and observation of the excellent links between Stanford and local industry. We are also aware that this came about through a vision and interest of a few individuals and is not generally experienced by most universities and their industrial neighbors.
>
> An approach that might be considered is to revise the federal income tax laws to provide a tax credit for corporate funds that are given to universities for research. Since this would supplement and not replace government research grants, the amounts would have to be limited. Perhaps two or three percent of a company's in-house R&D budget would be an appropriate ceiling. On a $25 billion base, two percent would generate a maximum of $500 million, which would represent about a ten percent increase in university research funds.

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*For further description of the design of this memory and the entire Amdahl computer, see Amdahl (1978), and Harman *et al.* (1977, pp. 37-41).

**For the purposes of this discussion the very important role that government actions can play in the rapid and low cost dissemination of information is left aside. One of President Carter's nine areas of initiatives included such actions — for example, increased monitoring of information on foreign R&D activities (Carter 1979, pp.2-3).

Government funding at a later stage of R&D has also been important. After World War Two the US government promoted considerable activity in both the computer and semiconductor fields through its defense programs and later through its space program (see Utterback and Murray 1977; and also Schnee 1978). More recently the Japanese government has used the direct subsidy route, with funding estimated to be on the order of $500 million or more. The British government also is investing in its semiconductor industry, to the order of 50 to 100 million pounds sterling. The French government has several activities in progress which involve investments in the French semiconductor industry, and the South Korean government is trying to establish a viable semiconductor industry committed to consumer goods applications (Corrigan 1978, pp.31-32). Thus, direct government support of R&D is a widespread mechanism for helping in the development of new ideas to sustain a country's technological innovations; the level of government resources committed to the support of technological innovation is one measure of the seriousness with which the government and the companies in a given country are pursuing new technologies. However, it is not necessarily a good measure of successful innovations.

4.2.1. Patent policies

The patent system is, of course, designed to encourage the development of new ideas: "flashes of creative genius." This is clearly an area in which policy implementation can have important repercussions. Note, for instance, the difficulties that were caused by the extreme delay in the granting of a patent, as in the case of ENIAC computer (see Harman 1978, pp.6,9; and Gilpin 1975). New challenges are being presented by the need to protect such intangibles as computer programs.

4.2.2. Toward a New Tax Policy for Innovation

The many individuals who contribute to the creation and practical development of new ideas collectively form the "labor" component of neoclassical production functions. In Harman 1980, pp. 34–35, a very simplified model of induced technological innovation is presented to illustrate that a firm's investment in enhancement of labor productivity is directly related to its total expenditure on labor and inversely proportional to the marginal cost of improving labor productivity. Fisher has observed that some labor skills may not receive the full "rents" due to them in the process of technological innovation.

> Even the case of special managerial skills need not result in rents being fully imputed to the factors of production with which they are properly associated. Particularly in large firms dealing with complicated and delicate technologies, it is perfectly possible for the added efficiency to accrue not to any small group of individuals but to the firm as a whole. If that is true, then while it would be possible for others to bid away any small group of individuals, managerial efficiencies would still rest in the organization, the whole being greater than the sum of its parts. In that circumstance there would still be unimputed rents... (Fisher 1978, p.27).

In the course of uncertainty resolution during a development process, teamwork among specialists can also lead to improved communication or other "group skills." The development of the transistor provides an example. It was preconditioned by certain scientific knowledge and simultaneous progress in several fields of investigation; this involved collaboration among an interdisciplinary team of physicists, chemists, metallurgists, and engineers (Braun and MacDonald 1978, Ch.4).* Technological development often requires the coordinated talents of a large number of highly specialized individuals. Such teamwork is also needed to carry out tasks outside the technical sphere.

It should be kept in mind that the transistor was developed during an era in which tax policies and the availability of venture capital were considerably different from what they are today (see also, Rothwell and Zegveld 1979). The above analysis suggests the need for a new tax policy initiative compatible with today's circumstances: it may be desirable to implement a personal income tax credit affecting all individuals employed by the most R&D-intensive firms. Such a personal income tax credit would serve several purposes. First, the initial impact would be to increase the take-home pay of all individuals employed in highly R&D-intensive firms. These could be firms with higher than the median expenditure on R&D, expressed as percentage of sales for the last 2 years; alternatively two levels of tax credit could be instituted for employees of firms with R&D expenditures greater than, say, 4% and 7% of sales, respectively. Since employment security in such firms is generally lower than in other sectors of the economy, this tax credit could be considered compensation for additional risks that may not be compensated at prevailing wage rates in current labor markets, especially in the case of smaller and newer R&D-intensive companies. Secondly, since labor markets may not compensate for such risks currently, there is little reason to believe that the full increase in take-home pay would remain with labor after the marketplace has a chance to adjust to this new tax initiative. Gradually the effective wage rate paid by the firms would be reduced. This would provide an incentive for firms to keep R&D commitments high enough to qualify their employees for the personal income tax credit. The tax credit's effect on wage rates paid might also encourage firms to invest in labor productivity enhancement, if the elasticity of substitution is sufficiently high. Of course, there would be attempts by firms to reclassify expenses as R&D in order to qualify their employees for the credit. Such problems require serious attention, but as Hufbauer has argued, they are not necessarily insuperable (Industrial Technology 1978, p.122).

Clearly, further research would be useful to verify the correctness of these observations and to determine the appropriate magnitude of such a tax credit. If this tax initiative were part of a larger tax revision package for technological innovation that encouraged greater availability of venture capital, such a proposal might be particularly beneficial to newer and smaller firms (which tend to be more labor-intensive). It would also

*Some team members eventually left and formed their own companies. Similarly, Control Data Corporation was formed in 1957 by a group that had been part of Sperry Rand's Univac Division (Harman 1971, p.19).

avoid the perverse distribution implications of many capital gains tax proposals, which tend to provide tax relief mainly in high income tax brackets (Musgrave 1978). The personal income tax credit proposed here is a possible way to encourage the "bearing of risk" that is widely recognized as an important element of technological innovation. As has been argued on a previous occasion, "When individuals (in management, in laboratories, in production, in sales, etc.) must operate in a world fraught with risk and uncertainty to achieve such innovation — especially when they must rely on their creative ideas to ensure the success of their enterprises — they must be allowed generous compensation for the activities that bring their ideas to fruition" (Industrial Technology 1978, p.15). (For further detailed discussion of this idea, see Harman 1981.)

4.3. Returns on R&D and Associated Investments

It is very difficult to acquire the detailed information necessary to make careful calculations of the returns on R&D or related investments required in the process of technological innovation. In an earlier study of the computer industry, it was possible to estimate econometrically the responsiveness of product quality change to investments in R&D by firms (Harman 1971). This analysis confirmed that some of the smaller and newer firms had quite effective R&D efforts. However, product quality is not a measure of profitability; in fact, success in the computer industry has often been attained by a shrewd choice of product design that avoided an ambitious push to the limits of technical feasibility (Harman 1971, Ch.4). On the average, one would expect that returns from this type of investment would be higher than the average for the industrial sector because of the risks inherent in R&D. The risks are well illustrated by General Electric and RCA, neither of which were able to participate profitably in the computer industry in the mid-1960s (Harman 1971, pp.16-17, 22-26). The process technology of transistors provides another example; it changed so rapidly that the original innovator — Philco — soon dropped out of the industry with a large, unprofitable capital investment in what rapidly became obsolete production equipment (Braun and MacDonald 1978, pp.142-3).

The recent research of Mansfield and his colleagues, in measuring not only the private but also the social rates of return from industrial innovations, sheds new light on this topic. However, their research involves a nonrandom sample of seventeen innovations that do not necessarily represent the results of activities in the electronics sector.*

Mansfield and his team found that the social rate of return from industrial innovation has been very high — the median is conservatively estimated to be over 50 percent. However, they also found that the private rates of return from these investments have been much lower. In nearly a third of their cases the private rate of return was so low that "no firm with the advantage of hindsight would have invested in the innovation, but the social rate of return from the innovation was so high that, from society's point of view, the investment was well worthwhile"

*The new electronic device is the only innovation that produced a negative rate of return both in private and social terms (Mansfield *et al.* 1977).

(Mansfield *et al.* 1977, p.235). These authors point out, however, that for a number of reasons such results have little bearing on whether there is an underinvestment in innovative activities.

4.3.1. Tax policies

Knowledge about the "real world" returns from investments in technological innovation is in very short supply. Representatives from the semiconductor industry have uniformly and fervently argued for a more favorable tax structure to encourage such investments. Heilmeier, for example, has pointed out specific sections of the tax statutes and regulations that he believes are either a disincentive to perform R&D or an encouragement to US firms to transfer more R&D to foreign countries. He further points out that "government agencies have no way of reviewing the regulations in the light of their impact on development of US technology and innovation" (Heilmeier 1978, p.21). Perkins points out the difficulty of hiring and retaining entrepreneurial managers subsequent to the removal of special tax treatment for the "qualified stock option." Without this form of stock option the manager recruited to a new enterprise must pay a capital gains tax on stock upon exercising this option, even if the gains he achieves are illiquid unless he sells his stock (Perkins 1978, p.43).

Although the Revenue Act of 1978 restored some of the capital gains tax incentives removed by the capital gains taxes of 1968 and subsequent years, industry can legitimately claim that the tax environment for venture capital availability and risky investments has deteriorated over the last decade. At the same time, the National Science Foundation has reported that nearly 40 percent of the R&D activity in private industry is financed by federal funds (some US$10 billion in 1977). Hufbauer has reported that "in addition, Section 174 of the Internal Revenue Code, which permits the immediate expensing of R&D outlays on salaries and expendable supplies (but not capital equipment), entails a modest incentive by comparison with the conceptual alternative of capitalizing and amortizing all R&D outlays. The value of this incentive in 1977 was about US$1.4 billion" (Hufbauer 1978, p.18). Kaplan and his colleagues summarize a set of studies of tax policies for R&D and technological innovation by noting that foreign countries often provide more generous tax incentives for R&D than does the United States; however, such problems as the difficulty of rewarding new R&D activities as opposed to simply subsidizing already existing ones, and undesirable distributional problems, suggest to them that "a program of direct government support of innovation is preferable to tax incentives. Of course, it must still be demonstrated that the government can devise a program of direct support that operates with as little red tape and delay as many tax incentive schemes" (Kaplan *et al.* 1976, p.18).

In the absence of strong empirical support for the claim that the market is failing to provide adequate incentives, the best evidence of the need for policy initiatives comes, perhaps, from the political decision to initiate the Domestic Policy Review on Innovation; further evidence may be derived from the fact that the results of the review led President Carter and his principal advisors to initiate some specific decisions and legislative recommendations that were expected to "have a significant impact" and to "provide a signal to the private sector that innovation is valued and that it is federal policy to preserve and promote it in the years ahead" (Carter 1979, p.1). The proposals were not widely regarded as significant (see Stanfield 1979), and all tax policy changes affecting industrial innovation were explicitly deferred, to be considered later in the context of broad fiscal policies.

4.3.2. Regulatory policies

In addition to strong support for a more favorable tax environment, firms in the electronics sector have been concerned about the expanding regulatory activities of the federal government. For example, a president of a semiconductor firm has stated:

> Desirable as favorable tax policies are, however, they would fail to stimulate innovation if they were hamstrung by the usual government demands for reports, studies, and impact statements. There is also some hazard that favorable treatment would be available only for "socially desirable" technologies, adding endless cost and complexity to defending technology proposals.

One of the President's nine areas for specific decisions regarding innovation is "improving our regulatory system." This includes greater emphasis on performance standards (rather than design or specification standards) for the Environmental Protection Agency, as well as the implementation of "innovation waivers." To help reduce regulatory uncertainties for industry, 5-year forecasts of their priorities and concerns are to be prepared by health and safety and environmental regulatory agencies. One of the latest (and perhaps most dubious) actions is the decision to have executive agencies develop and implement a system of priorities for expediting review of the safety and efficacy of products that "are most innovative and/or have exceptional social benefits." The problem with such attempts at forecasting or *a priori* assessments of the social desirability or undesirability of innovations is that there are long chains of sequences of impacts associated with basic innovations — from the development of "useful knowledge and science, to technological innovation, to growth in productivity, to changes in structure of production, to changes in other aspects of economic structure, to changes in political and social structure and beliefs, and back again to changed conditions of life and work..." (Kuznets 1971, p.349).

One of the characteristics of such long sequences is "the near impossibility of making a complete and relatively reliable prediction of the long-term consequences of a given major technological innovation ... to foresee not only the favorable or neutral, but also the adverse consequences" (Kuznets 1971, p.356). To illustrate the point, Kuznets poses the following question:

> Was it foreseen, or at the time predictable, that the spread of the motor car, by inducing migration of the middle and high income groups from the cities to the dormitory suburbs, would result in a breakdown of the urban tax base and lead to a near-collapse of effective municipal government — with all the ensuing problems with which major cities in the United States are presently struggling? ...If a prediction had suggested the problem to be created in two or three decades by traffic congestion in the cities, the impulse to an immediate counteracting policy would have been weakened by the argument that there's plenty of time and conditions may change. ...In view of the limited capacity of society to deal with the many problems needing solution, the lag in the attempt to avoid or inhibit the long-term undesirable structural change is almost inevitable. (Kuznets 1971, pp.352-353).

This is not to say that social costs of technological innovations are to be ignored! A recent example of the ability of the US government to take action in this regard was spurred by the growing concern over the computer information processing and storage capabilities and personal privacy. The Privacy Act of 1974 created the Privacy Protection Study Commission, which has held hearings on the major types of personal information and record systems that currently exist: research/statistical, employment, personnel, medical, insurance, depository, and credit. Some of the public policy issues uncovered by this review include: (1) Do we need a right-of-ownership status for personal information? (2) Does factual information need to be distinguished from subjective and conjectural information? (3) Should information collected to make a determination (and with no perceived future need) be distinguished from information needing to be kept? (See Ware 1976.)

4.4. Competition and Selection Environments

Competition plays a central role in all of the conceptual formulations of the innovation process discussed above. The term "competition" does not refer simply to price rivalry in a commercial marketplace. A fundamental form of competition in technological innovation concerns the ideas that are considered worth pursuing within a firm. Such competition involves both the technical and economic aspects of new design concepts, and is usually sustained well into the development process. For example, when a new system is under development at IBM, program managers for current lines are encouraged to look for ways to expand the capabilities of their products. Although limited development resources are devoted to such activities, IBM is careful not to cut off such competition. Current programs contending with new development efforts provide a type of insurance for the firm (Harman *et al.* 1977, p.36).

In the computer industry, there have been opportunities at many stages for choices among competing component technologies. The successful development of the transistor did not automatically lead to the replacement of vacuum tubes. Rather, it depended on the economics of production. The character of quality change of product-oriented technological innovation depends on the types of final users that are to be considered. For the development of the transistor, its capability and price relative to the vacuum tube were considered by computer developers and manufacturers: in contrast, performance capabilities (including reliability and ease of maintenance), as well as price are the principal dimensions for assessment by computer users — virtually regardless of the components used in the design. Still, the development of quantitative measures of user-oriented product quality dimensions that remain reliable over time is indeed a different undertaking.*

For other forms of competition, public policy plays a more prominent role. Let us consider the industry perspective. As Tilton (1971) implicitly points out, Klein's "hidden foot" rivalry has played a very important role in the semiconductor industry:

> The market structure of the semiconductor industry (in the United States, Britain, France, Germany, and Japan) ...is such that established firms are promptly disciplined or replaced when they fail to act quickly. (Tilton 1971, p.48; see also Klein 1977, pp.128-133; and Von Hippel 1977.)

In contrast, European countries have pursued consolidation policies within their computer industry and have fared much less successfully. Perhaps it is fortunate that Europe did not follow Servan-Schreiber's urging: "The logical policy for Europe would be to pool all the resources we can muster — probably from a British nucleus with immediate support from French, German and Dutch industry — into a unified effort, while blocking off some outlets for our own products. Only with a market of this size can we hope to compete with the Americans between now and 1980" (Servan-Schreiber 1968, Ch. XIV).

4.4.1. Antitrust policies**

For several reasons government antitrust policies have been effective in promoting rivalry among US firms. Through a consent decree ending the Justice Department's suit against IBM in 1956, IBM was required to sell its machines as well as to rent them. This led to greater competition in the sale of computer services and encouraged the development of this branch of the information processing industry (Harman 1971, p.13). Similarly, an antitrust suit against ATT initiated by the Justice Department in 1949 was finally settled by a consent decree in 1956 that led to a substantial shift in the dissemination of ATT controlled patents —all existing patents were to be licensed royalty free by Western Electric to any interested domestic firm (although Western Electric could ask for a cross-licensing provision) and all future patents were to be licensed for "reasonable royalties." On patents for semiconductors, royalties were

*For elaboration of this point, see Harman *et al.* (1977), and Linstone and Sahal (1976).

**The still-pending US Justice Department antitrust case against IBM is a matter that will not be dealt with in this paper.

generally set at no more than 2 percent of sales (Tilton 1971, pp.73,74,76). These new licensing policies — implemented by the firms under government pressure — set a standard that encouraged the diffusion of technology and "hidden foot" rivalry, which supported a continued rapid rate of technological innovation.

4.4.2. Procurement actions and new entry

For both the semiconductor and computer industries, the early development of the government market was an important stimulus for product innovation.* Tilton has discussed the link between qualitative improvements in semiconductors over time and the various end-users of the product; he attributes much of the stimulus for rapid innovative advances in product quality, as well as rapid diffusion of innovations throughout the US industry, to demanding government requirements. Utterback and Murray (1977) concluded that government procurement provided a more important stimulus to the civilian electronics industry than did direct support of R&D (although government procurement has since lost much of its significance for this sector).

Government procurement has also played a useful role in encouraging new firms to enter these industries, although there is little evidence that such a policy has been deliberate or has recognized the important role that entry or the threat of entry plays in stimulating technological innovation. (See, for example, Baumbusch and Harman 1977, pp.47-50, 53-56; and Baumbusch *et al.* 1978, pp.56-62.)

In a very pragmatic and insightful discussion of ways of diagnosing the existence of monopoly, Fisher concludes that the role of entry is particularly important. He states:

> whether considered as a phenomenon of new firms coming into the business or a phenomenon of older firms able to expand ... the analysis of entry conditions is the analysis of a central phenomenon which places or does not place constraints on the behavior of the alleged monopolist. It is therefore with some regret that I have to say that the analysis of barriers to entry is, in my view, the single most misunderstood topic in the analysis of competition and monopoly. (Fisher 1978, p.28.)

The availability of venture capital also helps to encourage the threat of new entry. In this regard, President Carter's Industrial Innovation Initiative (1979) — dealing with both fostering and development of small innovative firms and opening federal procurement to innovations — are small steps in the right direction. The income tax credit proposed in this paper would also be useful in this context, since new firms would have especially high R&D/sales ratios while initial sales are low. Further policy consideration of the role of new entries in stimulating technological innovation is warranted.

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*Tilton (1971, Ch.4); Harman (1971, Ch.2); see also the statements by Heilmeier and Corrigan in Industrial Technology (1978).

4.4.3. International economic policies

Finally, competition in the context of world markets merits some discussion. One issue concerns the protection of domestic markets from foreign competition through tariff or nontariff barriers. One does not have to follow the trade press very closely to know that the semiconductor industry has been unhappy with the recent situation. An executive in a semiconductor firm has described his concerns in the following terms:

> US companies can compete against any foreign manufacturer if we have free trade on an equal basis. This means that both tariff and nontariff barriers in Japan and Europe need to be removed or equalized. This is particularly true of Japan where import duties for US companies are considerably higher than US duties for Japanese products and nontariff barriers keep US semiconductor products from being used in certain markets such as Telecommunications; it is also going to be very important that two-tier pricing as employed by the Japanese (lower US prices than in their own markets) not be tolerated and a mechanism set up to quickly impose penalties on foreign semiconductor manufacturers (before the damage is done) who operate with a two tier price scheme.

Although such concerns are serious, the solution is not to establish retaliatory barriers; competition at many levels (even from foreign sources) fosters further technological innovation, and there is clearly room for further advances in semiconductor technology (see Sutherland *et al.* 1976). Although the Tokyo round of the General Agreement on Trade and Tariffs (GATT) has made some progress in the areas of tariff and nontariff barriers, the macroeconomic effects for the United States are likely to be very small.

The transfer of technology and limitations on direct ownership of foreign operations have been important in both the computer and semiconductor industries. Japan in particular has orchestrated a set of government policies that have proven very beneficial to their domestic industries. These issues have been treated elsewhere (Harman 1971; Tilton 1971), but may be useful topics for further consideration since they fall outside of the GATT framework. Similarly, it may be useful to consider more carefully the relationship between the parties to GATT and centrally planned economies.

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STRATEGIC FUNCTIONS OF COMBINATS IN GDR INDUSTRY AND PROMOTION OF INNOVATIONS

H. Richter

BACKGROUND

The German Democratic Republic (GDR) is a developed industrial country with intensive agriculture. In 1978, 66 percent of gross production was in industry. Industry is divided into four major sectors: machine- and vehicle-building, the chemical industry, the electrical industry, and light industry.

Between 1970 and 1978 labor productivity increased by 49 percent. The highest rates of increase were in the electrical and chemical industries. Increasing global resource scarcity, as affecting the GDR, has forced a thorough reappraisal of goals and plans for economic development. The GDR has limited domestic supplies of energy resources and raw materials. Therefore to maintain economic well-being she must use technological innovation to intensify the production process. In particular, innovation must be directed toward reducing inputs of energy and other raw materials (particularly imported inputs) per unit of output.

As it stands, production consumes too much. In 1978, 57 percent of gross product went toward purchase of material inputs. Amortization took an additional 5 percent, which left a net product of only 38 percent. To make things worse, in the eighties obligatory expansion and reconstruction investments in energy and raw material fields will require 60 percent of the total national investment fund. This leaves only 40 percent of potential investments available for measures that might raise labor productivity, such as expansion of manufacturing and processing industries, and investment in mechanization and automation.

In our opinion, inducing accelerated technoscientific progress and increasing productive efficiency through the combination of a fundamental constructive innovation policy and a corresponding firm strategy will become the key problem of industrial planning and management. This is made more important because the GDR industry is very export intensive: about 35 percent of total national income is realized through foreign trade.

Our latest experiences show that one important way to overcome these various problems and difficulties is establishment of economic potentials and corresponding organizational forms (called "combinats") with the ability to work out their own innovation strategies and concepts. It is important to note that combinats have a large degree of legal and economic independence. They are designed to realize and ensure two important preferences of an effective management:

(1) concentration and specialization of the production to increase productivity and efficiency; and
(2) ensuring and using the flexibility and mobility of relatively small plants within the combinats through maintaining the independence of the enterprises within the association of combinats.

The combinats characteristically include the following capacities:

- internal research and development
- project engineers
- human and physical capital for bringing about process plants for manufacture of finished products that are complimentary to the main product lines
- plants for custom manufacture of production equipment and specialized inputs
- internal marketing division for domestic and foreign marketing (until fairly recently all foreign marketing was undertaken by the state monopoly in foreign trade).

The combinats are specialized industrial branches. As a rule they are horizontally integrated. Some vertical integration has also taken place; but vertical integration introduces a trade-off of production. Through included stages of production the combinats have also a vertical structure of production. On one hand it is advantageous that essential suppliers belong to the combinats, for this gives producers greater control over input supplies. On the other hand vertical integration may reduce competitiveness, and generally undermines the principle of branch management. Further experience is required to estimate the relative advantages and disadvantages of vertical integration more exactly. The combinats are attached directly to the respective ministries. This avoids the complications of management and planning through an intermediate hierarchical level.

THE STRATEGIC TASKS OF THE COMBINATS IN THE NATIONAL ECONOMY

In the GDR we have learned by experience that middle- and short-term planning periods are unable to take into consideration the changes of needs and demands brought about by scientific and technological progress. We have also learned from experience that success requires both adequate development of technological specialities within each branch and appropriate technological and economic relationships between branches. The combinats play an important and ever-changing role in coordination of activities between the enterprises and the central authorities.

Combinats serve to elaborate long-term development plans and strategies in conformity with the central government's economic decisions and orientations. This activity takes the form of long-term strategic forecasts. For combinats to be effective in this role it is extremely important that accurate analyses and long-term forecasts be conducted to identify correctly the basic strategic problems and contradictions. In other words, before getting down to formulation of strategy it is necessary to come to a clear understanding of the dialectic forces bearing upon the problem and its solution. In particular, it is critical that strategies be formed on the basis of correct information on such factors as the following.

(1) The long-term development of the needs of the national and international market.

(2) The prospective development of scientific and technological progress.

(3) Development and structural distribution of funds in terms of fixed assets, material funds, and manpower potentials.

(4) Tendencies of the industrial division of labor. Structural development must be made responsive to international economic relations. This requires that combinats assist in actively adapting changes in the international state of affairs by increasing their output for export.

In sum one can say that the main strategic problem evolves in a dialectical manner, around the development of needs, resources, and technoscientific processes. Strategy must show the way to overcome expected future contradictions. Furthermore the main strategic problem comes out of the confrontation of social targets with international trends as well as from the specific conditions and possibilities of the combinats.

HOW COMBINAT STRATEGY IS FORMULATED

Investigation and experience show that in the course of elaborating an economic strategy, the following sequence of steps has to be observed:

(1) production strategy, sometimes called need or demand strategy

(2) product strategy, also called technological strategy or innovation strategy

(3) resources strategy, which relates to the use of materials and labor potential and to exploitation and development of the material–technological basis

(4) social strategy, which elaborates optimal social conditions (especially working conditions) and directs activity towards their achievement; social strategy serves to keep techno-scientific development in line with social needs and expectations

(5) export strategy (extremely important for combinats which export intensively)

(6) organizational strategy, which serves to determine the most useful future-oriented form of the combinats and their factories.

An important problem of national economical management is the balance between the strategy and planning. First, it must be noted that strategy does not yet equal a plan. The strategic work comes before the concrete planning process. In other words, strategy is the conceptual basis for long-term planning and 5-year plans. The national-economic balancing of the combinat's strategies within the planning system turns strategic targets into planning targets. This is a gradual iterative process in which overall national economic tasks are given priority. Therefore, in the process many combinats' strategies will have to be changed. It is quite clear that the strategy of a combinat is not always viable from the national economic point of view.

Management of the Innovation Process in the Combinats

The management of the innovation process is becoming a key problem in the intensive and efficient execution of the reproduction process. In the past it used to be possible to produce a given product for years without altering the method of production. Nowadays the frequency with which production methods must be changed has become so high that one can speak of innovation as a continuous managerial process. The innovation process has to be promoted in different ways, especially through subjective factors. The need for continuous changes in production has caused management theory and practice to give ever greater attention to the problem of optimal factor organization.

In GDR industry preference is generally given to developing an innovation-promoting organizational structure through modification of well-tested managerial structures. It is therefore extremely important for the managerial structures to be flexible and adaptable to whatever innovation processes are to be promoted. In the GDR a modified version of the product or object management called "order management" has been successfully applied. Concepts similar to the concepts of "planned organizational change" and "organizational development" which are frequently encountered in American management literature are also used in the GDR.

But it seems that the best solution would be if the existing top-down hierarchical management system were extended to the managerial mastery of the innovation process. Indeed, it is unavoidable that this happens because the management of innovation processes in the future will become the universal type of management.

We also consider the psychological and behavioral aspects of managers themselves to be of critical importance. These considerations extend to the creation of environmental conditions that are favorable to the people who suggest and introduce innovations.

According to sociological findings, a number of factors influence human creativity, including:

- personal attitude toward work, and toward innovations in particular
- level of education and qualification
- physical and psychological condition
- information system
- organizational level
- material and moral incentives
- human relationships and social climate
- manager's role.

The other seven factors all revolve around the manager's role. The manager not only directs the rest of the staff, he also establishes attitudes, physical and psychological conditions, employee qualifications, and all the other factors as well. Therefore it is critical that enterprises be run by suitable managers who are capable of initiating, organizing, and coordinating various sociological and psychological aspects of the teams they manage.

TECHNOLOGICAL LIFECYCLES AND STRATEGIC PLANNING

Franz Krejs

1. INTRODUCTION

For a technology-based firm, strategic planning is to a considerable extent planning in technologies and technological opportunities. At the outset of any meaningful strategic planning process the cardinal question has to be asked: "What business or set of businesses should we be in?" (e.g., Hofer and Schendel 1978, Steiner 1979). In the context of the technology-based firm, this entails the more specific question, "What technologies should we be in and what technological opportunities should we pursue?" These questions may be answered through a process of deliberate exploration and planning or in a considerably less systematic way, but whatever the answers, they will have strong implications for the firm's R&D efforts, its operations, its competitive position, and its ultimate well-being.

Research, and particularly a company's exploratory research effort, will be strongly influenced by these strategic decisions. Since, for a company, today's research largely determines tomorrow's products and production processes, and also because of the considerable time span it takes for an innovation to develop from the conception of the idea to the market introduction, the careful and deliberate establishment of an R&D strategy is of the utmost importance.

Over the past 10 to 15 years there has been a pervasive change in the United States with regard to the amount of control top management exerts over R&D strategy (Manners and Nason 1978). Following World War Two many companies built up large research centers which devoted a considerable amount of their resources to exploratory and basic research. Minimal direction was given by top management. The hope was that these laboratories would generate a substantial and continuous flow of technological innovation projects from which management could choose the most promising ones for further development. Elaborate project selection procedures have been devised to assist in this task (e.g., Allen 1969, Baker and Freeland 1975, Merrifield 1978, and Souder 1978). Yet in most cases this approach did not pay off as expected, and management became convinced of the need to provide direction to research in order to increase the fraction of usable and ultimately successful innovative proposals.

A variety of schemes has been advanced to direct research without stifling the creativity of scientists and engineers (e.g., Hampel 1979, Hanson 1978, Miller 1978). Yet beyond describing the organizational structures and procedures needed to direct the R&D effort, little has been written about the criteria and guidelines which may be used for actually selecting a broad technological arena or the technological thrust toward which a company's R&D efforts are to be directed.

In what follows we shall attempt to outline some of the considerations essential for a technology-based company in establishing its strategic course. We shall argue that it is important to be clear whether a company is primarily committed to the exploitation and application of a technology in which it holds a leading position or whether the commitment is predominantly to a certain type of product in which a particular technology is used. The importance of the distinction between these two orientations has recently also been emphasized by Fusfeld (1978). In the following sections we shall elaborate on the nature of the two different orientations and explore some implications for strategic management, particularly research policy.

2. UNITS OF ANALYSIS

In the recent past there has been a growing awareness of the need to integrate strategic planning to a fuller extent with other top management tasks. Thus the focus has been shifting from strategic planning as a largely independent function to strategic management which takes an integrated view of top management tasks of which strategic planning is but one, albeit important, part (e.g. Anshoff *et al.* 1976, Steiner 1979).

Parallel to the need to integrate top management tasks into strategic management there has been an effort to find the appropriate organizational entity and unit of analysis suitable for the purposes of strategic management and innovation. Coming from an innovation background Abernathy and Utterback (1975) made the step from the narrow marketing focus of the product lifecycle model to include production processes. They therefore defined what they call a productive unit consisting of a product or product line and its associated production facilities. By contrast in the realm of strategic planning the notion of the Strategic Business Unit (SBU) was introduced into the General Electric strategic planning effort and has become widely used. It denotes a firm or a division of a diversified company which operates within a clearly defined business with clearly identifiable competitors. For our purposes we prefer to somewhat more narrowly define a Strategic Product/Technology Unit which we take to comprise a product and its underlying technology, the associated production facilities, research and development which supports the product and technology, and the marketing and service function.

Since innovation is a complex process which over time involves the interaction of many different corporate functions, it can only be adequately studied and analyzed within such comprehensively defined units. This insight also underlies recent work by Maier and Haustein (1979) who associated a composite efficiency with a production unit. During the lifecycles of an innovation this efficiency then follows a characteristic pattern if compared to the average efficiency in the industry.

With regard to technological innovations there exists an age-old distinction between those which are "pulled" by the market and those which are "pushed" by technology. The former are are innovations for which a market or consumer need has been perceived and a technological means is sought to make possible the design and manufacture of a product which satisfies that need. By contrast, technology-plus innovations are driven by a technological capability which searches for an application that serves some useful consumer need. In this case, technology is the driving factor.

In order to appreciate the implications of these two kinds of innovation for a firm's strategic posture, it is helpful to put them into context by considering their development over time.

Since the two types of innovation are driven by different forces which dominate their development, one could reasonably expect that their respective lifecycles may be somewhat different and that they should be analyzed differently. These ideas for instance make it quite cogent for technology-driven innovations, not to consider the lifecycle of a product but rather to analyze the dynamic development and maturing of the generic technology which underlies it. This underlying generic technology may move in and out of a given product and may have applications in a variety of other products. Its development may be stimulated considerably by its application in a particular product, or this application may be rather peripheral without making a notable contribution to the development of the technology itself.

To analyze market-pulled innovations, it seems more appropriate to look at the product lifecycle and to analyze the development of a product concept and its associated product specifications and performance criteria. In fact in the course of the development of such a product concept different technologies may be used; in the late 1950s and early 1960s for example, transistor technology began to replace electron tube technology in computers.

Before pursuing these ideas further, we need to clarify such notions as generic technology or product concept. Technological innovation is ultimately based on the body of scientific and technological knowledge which expresses our scientific understanding of natural phenomena and the codification of this understanding in laws, theories, and procedures. For our purposes we shall call the utilization of scientific knowledge for a technical purpose or feasibility a generic technology. The utilization of the peculiar physical properties of semiconductors for amplification or current rectification purposes or the possibility of using the catalytic properties of surfaces to speed up the reaction rate and increase the yield of chemical reactions are examples of generic technologies.

By contrast, product concepts arise from a perceived market or consumer need which becomes translated into the idea of a contraption, gadget, or process which can satisfy this need. Essential elements of the product concept are performance dimensions and specifications, i.e., statements which characterize the need and the ways in which the product is to satisfy it. Performance specifications are crucial because it is these specifications which because of inherent limitations cannot be met by old technologies and thus call for new technological means. For instance, before the introduction of electronic computers, mechanical computers were available, but were totally incapable of meeting the specifications required to make computers a useful and significant tool in large scientific and defense-related calculations.

A "product" then is the combination of a product concept and one or more generic technologies which enable the product to perform as envisioned and to meet its performance requirements.

In what follows we shall describe two lifecycles: one for the development and maturing of generic technologies and, similarly, one for product concepts.

These two lifecycles characterize the two principal forces which govern technological innovation: market pull and technology push. It must be kept in mind, however, that a product is a true combination of a market need and a technological feasibility: product concept and technology interact closely. In fact a product can alternate between being pulled by the market and pushed by technology, as happened in the development of semiconductors. The interaction between technology and product concept can itself become a dynamic factor. Technology may change the product concept by making feasible features which originally were not contemplated. Conversely, as a market need becomes better understood and product specifications change accordingly, new demands may be imposed on technology which may stimulate further technological development.

3. LIFECYCLES

Before describing the development over time of generic technologies and product concepts a word should be said about the role and usefulness of lifecycle ideas in general. The well-known product lifecycle concept has been widely used, yet its benefit as a planning tool has repeatedly been called into question because literal adherence to the concept may simply make it a self-fulfilling prophesy (e.g., Dhalla and Yuseph 1976). In fact, neither the specific parameters of the lifecycle curve for a given product nor in many cases even the shape of the curve could be predicted with any reasonable degree of certainty. Furthermore the narrow focus on marketing makes it a very limited tool from the point of view of strategic management. Nevertheless it has been widely applied and has contributed to the understanding of the dynamics of the aging of a product.

Despite such reservations, lifecycle considerations can play a useful role. They identify and analyze a general pattern of development which allows one to put a company's situation in context. Identifying a technology's or product concept's state of development within a general pattern which is well understood allows the decision maker to gain a grasp and deeper contextual understanding of the situation at hand and at the same time gives a long-term perspective which is essential in the management of technological innovation.

The different phases of the generic technology as well as product concept lifecycles are summarized in Table 1.

TABLE 1 Life cycles.

Generic technology	Product concept
(1) *Formative stage* Body of scientific knowledge plus technical use Generic technology Feasibility investigations	(1) *Seed stage* Need identification and translation into product concept Identification or development of suitable technology
(2) *Exploration and validation* Establishment of applications criteria Identification of broad applications areas Research and development needs	(2) *Introductory stage* Intense learning Need/product concept Implementation technology Dominant design Clearer understanding of market potential
(3) *Technology development* Provide broad technological knowledge base Develop technology to point of application Specific opportunities are identified in the process	(3) *Established product stage* Competition Process innovation becomes more important R&D: Improve product Find new superior technologies to implement proven product concept
(4) *Introduction* Learning from actual use Efficient user–engineer feedback	(4) *Maturity* Technological "blind alley" Generation phenomenon
(5) *Maturity* Technology well understood Broad range of applications	

3.1. Development of Generic Technologies

In our description of the formation, development, and maturing of generic technologies we shall be brief and only indicate the salient features. Some characteristics of these stages have been described elsewhere (e.g., Haustein's opening paper in this volume; Abernathy and Utterback 1975, 1978; Hayes and Wheelwright 1979; Long 1976). Yet it is fair to say that important aspects such as organizational structure, management styles, information flows, etc. at the various stages as well as the transitions between stages have been insufficiently investigated so far. Empirical research into these questions will make a major contribution to the management of technological innovation.

One can readily distinguish five stages of development in the course of the lifetime of a generic technology (see Table 1).

3.1.1. Formative stage

A necessary precursor for the formation of a generic technology is the discovery and scientific understanding of physical phenomena which eventually can be put to a technical use. The gathering of scientific data and understanding can occur over long periods of time. It can happen with little regard for eventual technical usefulness — as is true of much research carried out in universities — or it can be done with eventual technical exploitation in mind, the nature of which is only broadly defined — as is the case of much exploratory research in industrial laboratories. And there is always the chance that significant discoveries are happened upon in totally unrelated work.

It is often very difficult and may require a flash of insight to associate the scientific knowledge about physical phenomena with a technical use to which it can be beneficially put. For this reason there may exist a significant time lag between scientific discovery and understanding and technological exploitation. Once such an identification of scientific knowledge and technical use has taken place, a new generic technology has been born.

Determining the feasibility of a generic technology requires additional and often significant research. This phase in the life of a generic technology takes place in a company's R&D laboratories and requires the allocation of adequate resources to this kind of research.

3.1.2. Exploration and validation

Once a new generic technology has been conceived, suitable application opportunities need to be identified. In other words, product (or process) concepts need to be found which will allow the use of the new technology in an advantageous way. This is by no means a straightforward process, as evidenced by the fact that rarely are the first applications of a new technology the most significant.

At this early stage the technology is in most cases not well enough understood to single out specific applications, but criteria and specifications for possible applications can be established. This then allows the definition of more or less broadly defined areas of possible application.

The most common pattern of introduction of a new technology is its utilization in existing products. In this case the new technology helps to perform traditional, well-understood and well-defined functions better, more cheaply, or more effectively. In most cases, only once the new technology is better understood and mastered and its broader potential more clearly recognized is it used to perform entirely new functions in product concepts which were stimulated by its very existence.

A number of attempts have been made to establish criteria for determining the suitability of generic technologies in the context of product concepts (e.g. White 1978). The identification of appropriate application areas is a task beyond the capabilities of the R&D department and requires substantial input from marketing and possibly also manufacturing. Furthermore the fit with existing strategic firm policies has to be kept in mind. Therefore this phase requires considerable interaction and coordination between various corporate functions. Once suitable areas have been identified, it becomes essential that management convinces itself that in these areas the established criteria can actually be met and the investment of funds for developing the technology can indeed be justified. How systematic and organized this process is varies widely, depending on a company's size, structure, and culture.

Furthermore, in this phase the problems which need to be solved and the tasks which need to be carried out to develop the new technology are identified and clarified. At this point decisions may be made to determine which parts of the development will be carried out in-house and which tasks, if any, will be contracted out or performed externally in some other fashion.

3.1.3. Technological development

A major commitment to the new technology having been made, a knowledge base needs to be built up which will allow the solution of problems and difficulties which stand in the way of application of the new technology. Building this foundation may require a considerable research effort. Not only is a solid scientific and technological knowledge base built, but in the course of the work specific applications opportunities may be identified. The body of scientific understanding and technological knowhow which is mastered during this phase also serves as a springboard for spinoff firms which may establish themselves and push the technology in new directions and applications. From the established knowledge base the product or process is then developed.

3.1.4. Introduction phase

A tremendous amount of learning takes place in the introductory phase of a new technology. Since application and use will uncover shortcomings and opportunities for improvement at a rapid rate — particularly in the early stages — it is essential that there should exist a direct and immediate link between those who use the new product or process and the R&D engineers. This phase is very similar to the introductory phase for market-driven innovations described in more detail in the next section.

At this stage the company needs to maintain a considerable degree of flexibility because the rapid learning of how the customer actually uses the new product or process and the learning about the technology itself make frequent changes in the product necessary. It is also during this phase that definite decisions between competing design options can be made.

3.1.5. Mature phase

By this time the new technology is well mastered and understood and has proven itself useful in one or more successful applications. It can subsequently be used in a potentially wide range of applications, and its integration into existing products may create new generations of these products. Alternatively, the technological potential which has been demonstrated and is now much better understood may stimulate the creation of product concepts which critically depend on the new technology. Research usually continues at a level somewhat reduced from the previous phase.

In this stage there is a sequence of applications of the new technology, some of which may stimulate new technological progress. The technology has become part of the general body of technological knowhow.

A company which has made a major commitment to a new technology is at this stage looking for new applications in product concepts where the new technology promises decisive advantages either by overcoming limitations of older technologies or by exploiting new and major synergies with embodiment technologies. Texas Instruments, strongly committed to semiconductor technology, found successful product concepts, e.g. in the pocket calculator and the electronic watch.

The development of new technology as we have just outlined is well illustrated by the development and introduction of laser processing by Western Electric in the 1960s (Long 1976).

When the laser was first discovered around 1960, its unusual and spectacular properties stimulated Western Electric to consider it for use as a no-contact, high-speed manufacturing tool. Given the increasing trend towards miniaturization in electronics, such a tool, which could treat small pieces with minimal danger of mechanical or heat damage, looked highly promising. In our terminology the use of the laser as no-contact, high-speed manufacturing tool constitutes a generic technology (formative stage).

Subsequently in what we called the exploration and validation phase, Western Electric management began to establish criteria for suitable applications which narrowed down the range of application possibilities. It was considered essential that the new technology effect increased economy wherever it replaced an existing process or that it would have to provide capabilities which existing techniques did not possess. Safety, reliability, and minimal maintenance requirements were additional considerations.

What in product innovation would be an appraisal of market acceptance and consumer psychology took here the form of consideration of whether the new manufacturing technology could be smoothly integrated, physically as well as psychologically, into existing manufacturing procedures without seriously disrupting them.

These considerations substantially narrowed down the acceptable areas of application and also led to the conviction that laser processing was a viable and potentially highly beneficial new manufacturing technology. It was concluded that the new technology warranted the allocation of considerable resources for development. This phase also provided clarification of needed efforts for the development of the technology.

The research carried out to establish the technological knowledge base in the technological development stage demonstrated a capability in both high and low energy applications.

The first industrial use of the laser took place in 1965 when it was used to drill holes in diamond dies used for wire drawing. Shortly thereafter it was used for material evaporation in resistor trimming. With laser processing entering the stage of technological maturity, the record of applications grew impressively:

1965	Diamond die drilling
1967	Resistor trimming
1968	Ceramic scribing
1969	Contact welding
1970	Integrated circuit repair, crystal adjustor
1971	Ceramic drilling
1972	Silicon scribing, silicon drilling
1973	Ceramic sawing, thin filter trimming

3.2. Product Concept Lifecycles

For products whose development is driven by a consumer need (market-pull) the evolution of the associated product concept which is designed to answer that need is of primary interest. In describing the development of such products we shall make use of Abernathy and Utterback's (1975, 1978) work. We shall identify four stages which are sufficiently different from each other to be clearly distinguishable.

The product or products which are based on a product concept are carried by a strategic product/technology unit as defined above. As a product concept matures, the character, activities, and tasks of the associated strategic product unit undergo significant changes, and it is important for management to understand the dynamics and characteristics of these changes to be able to adjust to them smoothly and in time. If a company, because of style, skills, and philosophy, does not want to make certain changes, important strategic questions arise, such as when to get out of certain products. The following outline of the development of products and the associated strategic product units should provide an understanding on the basis of which such questions can be more readily answered.

3.2.1. Seed stage

This phase begins with the identification of a need and its translation into a tentative product concept, which is the concept of a product which can meet the perceived need. Since at this early stage the need itself is usually only dimly understood, such a product concept can be at best tentative. The product concept spells out how the need is to be answered and identifies the relevant performance dimensions and performance specifications for the product. At this early stage this can only be done under considerable uncertainty.

Once the conclusion has been reached that a sufficient need exists and a tentative product concept has evolved, a technology must be found to implement it. Most probably, the development of a product concept and the choice of technology interact closely. It may be possible to adapt existing technology, or new technology may have to be developed. Chester Carlson's arduous search for appropriate technology to implement his product concept of a photocopier — which eventually resulted in xerography — is a case in point (Jewkes *et al.* 1958). Mature technologies, as described in the previous section, which are ready to be used in new applications are primary technological candidates.

After product or process development, the seed stage results in a product ready to be introduced into the market.

3.2.2. Introductory or start-up phase

The new product to be introduced is a first approximation under a variety of economic and possibly regulatory constraints of how a need that is still not definitely understood should be satisfied by means of a technology which never had been put to the particular use before. This situation, fraught with uncertainty, allows for a great deal of learning, namely with regard to a better understanding and definition of the market need and how it best can be satisfied and with regard to the use of the technology which underlies the product. The former leads to a clearer definition of the critical product performance dimensions and product specifications: in other words to a better-defined product concept. The increased understanding both of critical performance criteria and of the technological implementation may allow one to choose between competing designs. For example, in the 4 years preceding the introduction of the Model T, Ford developed, produced, and sold five different engines ranging from two to six cylinders. The experience gained with these different engines allowed a superior design to emerge, to which eventually about 15 million engines were built. Abernathy and Utterback have called this the "dominant design."

Since learning takes place at a rapid pace in this early phase, frequent changes are often required in the product. This requires very responsive engineering and flexible production facilities which can accommodate change readily. Production therefore is on a small scale with multipurpose equipment and a highly skilled labor force. Thus production at this point is quite inefficient and expensive. It has to be understood that the new product at this stage competes more on the basis of superior product performance and less on cost.

The company's R&D effort at this stage is very development intensive, and little research, especially of an exploratory nature, is carried out. Development needs to be flexible and responsive. Since these companies do little research themselves but often build on a sophisticated knowledge base, small companies which did not establish the knowledge base themselves often are located close to strong science-oriented universities or are spinoffs from larger companies which developed such a broad knowledge base. Abernathy and Utterback emphasize the dominance of product over manufacturing process innovation in this phase. The learning and the effort of this stage result in a clearly defined concept, i.e. an understanding of the actual need and the critical factors in satisfying it. Furthermore, a dominant design which uses technology in a superior way is answering that need. Beyond that and importantly, the experience gained should allow an estimation of the intensity of the need, or in other words the product's long-term market potential. This is crucial for allocating resources for further development.

3.2.3. Established product phase

The fact that a well-defined product concept exists and the market potential for it is much better understood gives rise to a number of developments.

Firstly, since considerable uncertainty about the product has been removed, competitors also have a better information base to assess their opportunities and will enter the field. This is likely to increase the importance of cost as a competitive factor and in consequence will lead to more efficient and productive manufacturing. Secondly, the period of rapid learning with respect to the product concept is over, and with a fairly stable product concept, less flexible yet more efficient manufacturing methods become possible. Therefore, part of manufacturing may become automated at this point. The focus of innovative activity is now shifting from product innovation to process innovation. Whereas it was essential to keep excellent communication between users and engineering in the introductory stage, the internal coordination of manufacturing, R&D, and process engineering gain increased importance in the present phase. This in turn has definite organizational implications.

The character of research also changes during this phase. As previously mentioned, considerable research will be devoted to process improvement. Since the value and future potential of the product concept has been established, it now also becomes worthwhile — indeed imperative for competitive reasons — to make major research commitments. The aim is not only to improve the technology which now implements the product concept, but also to look for entirely new technologies. By overcoming limitations of the current technology these may lead to superior product performance and may significantly enhance the product concept by making new performance features possible. If such technologies can be found or developed, an entirely new generation of products under the same product concept becomes possible. An excellent example is the introduction of transistors, which, by replacing electronic valves in computers, inaugurated the second computer generation. The magnitude of the research effort depends on the perceived strength and potential of the product concept and of course on competitive pressure.

Thus there is a considerable effort in exploratory and high risk research which takes place during this phase of a product concept's lifecycle.

3.2.4. Mature stage

The mature state of a product concept can take various forms, depending to a large extent on the dynamic interaction between need, product concept, and supporting technology.

It is possible that the product concept proves to be something like a technological blind alley. In this case a sufficient and apparently optimal technology has been found to implement the product concept. Neither profit potential, the nature of the product concept, nor competitive pressure —particularly from substitution products —can stimulate significant further technological development. The product enters what Abernathy and Utterback (1975, 1978) have called the specific stage in which few, and only incremental, product innovations take place, manufacturing becomes highly organized and automated, and cost becomes a dominant factor in competition. Innovation takes place mainly in manufacturing processes, but at a slow rate, because changes in highly automated production process are excessively costly.

On the other hand a product concept may lend itself to repeated radical technology improvements, by substitution of more limited technologies with more advanced ones. Furthermore, if there exists a sufficient market need the product concept may sustain a series of new generations of products. The concepts of the electronic computer, which began with electronic valve technology and experienced successive generations through the introduction of the transistor, integrated circuits, and very-large-scale integrated circuits, is an example par excellence of this type of development.

4. STRATEGIC MANAGEMENT IMPLICATIONS

The fact that generic technologies and product concepts follow a general pattern of development such as we have outlined above makes it possible to put a company's situation into a long-term context. It allows insight into the ways in which the problems, priorities, and preoccupations of a company change over time and further into the mechanisms and strategies by which a company can adjust.

From our brief description of the generic technology and product concept lifecycles it is obvious that the problems which a company faces change remarkably as the technology or product concept matures. And concurrently management, organizational structure, and the pattern of resource allocation all have to change.

More work needs to be done to understand better the characteristics of the various stages of the lifecycle, the predominant concerns, and the organizational structures and mechanisms which are most appropriate at these different stages. Some efforts have been made to describe and understand some of the relevant aspects in productive units —in particular with regard to production methods and marketing strategies —during the various stages of evolution, particularly in the work of Abernathy and Utterback (1975,1978), Hayes and Wheelwright (1979), and Haustein's opening paper in this volume.

The transition from one stage of the lifecycle to another is bound to be a difficult time because it involves major reorientation changes in management and organizational structure. If these changes are understood and to some extent anticipated as part of an ongoing evolutionary process, then they can be managed with greater insight. Furthermore, resistance to them and tenacious holding on to practices and structures which are no longer appropriate may be less difficult to overcome.

4.1. Implications for Strategic Planning

As was pointed out above, at the heart of any meaningful strategic planning effort lies the question: "What business are we and should we be in?" In the light of what has been said about technology and product concept lifecycles, this question gains an additional dimension. Specifically, it has to be clarified whether a company is primarily committed to the development and exploitation of one or more generic technologies, or whether it is committed to one or several product concepts which drive its development of appropriate technologies to implement them. The focus of the entire organization depends on the answer to this question.

Fusfeld (1978) recognized the importance of this basic orientation and proposed a product/generic technology matrix to analyze a company's position with regard to this crucial issue.

It should be noted, however, that whether a company is technology or product concept driven has nothing to do with the level of technological sophistication. IBM's computer division, for instance, which is driven by a most powerful product concept, is at the same time one of the most technologically sophisticated and advanced companies. Yet its technological developments are driven and motivated by their application within computers. Vice versa, technology-driven companies only make a profit by selling products and not simply by the fact that they have developed a superior technology. Some of the product concepts in which they apply their technology may be very powerful in their own right. Furthermore, technology and product concept closely interact. A product concept may stimulate a technological development which subsequently makes product features possible which could not have been conceived beforehand. Thus the product concept is augmented. Yet from the point of view of strategic planning the question of which factor drives a company's innovation efforts, technology or product concept, is of utmost importance.

The planning of an R&D strategy and portfolio management may serve as illustrations for the implications of this basic choice of orientation. In particular, in the following we shall consider the state of maturity for both generic technology and product concept.

4.2. Technology-Driven Company

At the mature stage a generic technology is fairly well understood and a company is looking for a range of applications opportunities to take advantage of and exploit the new generic technology. Being strongly committed to the technology in question will shape the company's R&D effort. The following orientation and emphasis in the different categories of R&D naturally emerges.

4.2.1. Exploratory research

The company is typically at the leading edge of the generic technology and is oriented toward maintaining an image of leadership. Much of exploratory research is thus devoted to advancing the state of the art and to keeping a leadership position. Nevertheless this effort will generally be less than what was required to build the fundamental knowledge base on which the applications of the generic technology rest (phase 3). If the company pursues a portfolio of technologies, then there will be a comparable effort with regard to each of them.

4.2.2. R&D in support of newly identified major applications

Since the company tries to exploit the technology in new and promising applications, work needs to be done;

- to adapt the generic technology to the new application and make necessary additions to the knowledge base
- to promote and develop the required embodiment technology.

Finally there is R&D to support the improvement of existing applications.

4.2.3. Portfolio management

Each new application of the generic technology starts a new product (or process) lifecycle with its own characteristic development. These applications are basically of two kinds:

- introduction of the new generic technology into existing product concepts which are well understood and where it replaces an older technology; in this connection it is worth nothing that radical innovations in an industry are frequently introduced from outside
- introduction into new product concepts which owe their very existence to the capabilities of the new technology.

Together these two span the range of application opportunities. Consideration for managing a portfolio of products comes in at two levels. The basic purpose of a product portfolio is to have a balanced mix of products at different stages of their respective lifecycles to ensure continuous profitability and growth.

At one level this implies a range of products which all use the basic generic technology which drives the strategic technology unit. The ongoing identification of new and promising applications of the generic technology assures a flow of new additions to the portfolio.

Yet it should be kept in mind that the applications potential of any given technology may not be inexhaustible, particularly if competing technologies emerge. Thus a generic technology may at some point begin to approach exhaustion of profitable applications opportunities. A case in point is cathode ray technology whose broad range of application was drastically reduced to the television tube by the advent of the transistor. If this happens, it then becomes imperative to diversify into alternative technologies and thus to arrive at a technology portfolio of two or more generic technologies. Major criteria for choosing such alternative technologies would include the applications potential, synergies with existing technologies or products, and the fit with existing research, management, and possibly production skills.

4.3. Product Concept Driven Company

For a company which is primarily committed to the development and exploitation of one or more product concepts, R&D for a strategic product unit depends strongly on an assessment of the long term market and technological innovation potential of the respective product concept. If these are considered sufficiently good and promising then a major investment may be made to develop new and better technologies to implement the product concept. Research, therefore, will be directed by the requirements and performance dimensions of the product concept. Work on magnetic bubble memories and charge-coupled devices are examples of the search of new technologies for a product concept whose performance requirements are well understood, namely computer memory. If alternative and better technologies can be found, a whole new generation of products under the same product concept may result, as happened, for example, when quartz technology replaced the older mechanisms in watches.

The introduction of a new technology into a product concept may make possible what one may call product concept augmentation. The capabilities of the new implementation technology may make possible new product features which could not be contemplated with the old technology. This may eventually lead to entirely new product concepts.

If market and innovation potential on the other hand are not deemed sufficiently attractive to warrant the expenditure of large research funds, then the company may decide to harvest the product, to prepare for Abernathy and Utterback's specific stage, or to get out.

Here, too, portfolio's management plays a role. Once the market and technological innovation potential are considered insufficient to support a new product generation the company will seriously have to consider phasing in new product concepts.

In closing we would like to remark on one further implication of the lifecycles as we described them in previous sections. As a product concept, and to a lesser extent a technology, moves through its lifecycle, basic skills requirements and organizational requirements also change. A company then has the option of growing with the product concept/technology and making the necessary organizational and skills changes. But it also may choose to maintain a certain range of skills and organizational structure and instead drop the product concept and phase in new ones. A clearer understanding of the lifecycles and the accompanying skill requirements and organizational options should thus prove helpful in the decision when to get in or out of technologies or product concepts.

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PART FOUR

ANALYTIC TOOLS

INTRODUCTION

Jennifer Robinson

The management of technology would be improved if policy makers had better information on basic questions such as: what technologies will come on line, when? What secondary and tertiary effects will they have? How do the instruments at my disposal affect technological innovation? Can basic problems be alleviated or solved by appropriately directed innovation? How, operationally, is innovation related to macroeconomic factors such as economic growth, inflation, and trade balances? Do the macroeconomic variables drive innovation, or are they driven by it, or are the two linked by some sort of complex feedback?

Indeed, from an outsider's perspective it may be alarming to realize that such questions are unanswered; this means that policy makers are forced to base virtually all decisions about how to manage innovation on poorly founded guesses to such fundamental questions. It would seem very desirable to develop a firmer basis for decision making concerning the management of innovation and to have some operationally useful tools to help decision makers manage innovation.

The papers in this section of text provide a sample of the approaches that systems analysis has to offer to decision makers concerned with the management of technology. It is arranged in the order of most general to most specific.

In the opening paper Harold Linstone first discusses what he calls structural modeling techniques — flexible analytic approaches that are appropriate for gaining insight on problem structure — and then comments on the shortcomings of structural models and proposes alternate system analytic techniques that may be useful in overcoming these shortcomings. Linstone's description of structural modeling is illustrated with description and comparison of eight computer software packages

(ISM, ELECTRE, SPIN, IMPACT, KSIM, XIMP, QSIM and SOPA) that are available for structural modeling and with three examples of problems to which such techniques have been applied.

Linstone proceeds to observe that most innovation policy questions have strong social/political/moral/organizational components, and that structural modeling techniques are ill-fitted to cope with such soft analytic factors. He then proposes, after Allison (1971), a set of three basic perspectives from which technology-related events may be viewed: the rational actor model (which is assumed by most structural models), the organizational process model, and the bureaucratic politics model. Examples are provided to show how different various technological events look depending on the perspective from which one looks at them.

The papers by Graham and Senge and by Bauerschmidt describe innovation in the light of two extremely different national economic models. The paper by Graham and Senge presents a strong, provocative conceptualization based on the MIT system dynamics model of the US economy. The salient feature of this model is that it tends to manifest strong economic cycles of approximately 50 years' duration. The behavior of these is highly reminiscent of the Kondratieff wave. Graham and Senge describe a set of mechanisms, centered around the accumulation of producer capital goods capital, which are responsible for this behavior. They then review historical evidence in support of the existence of such long waves. This leads to the observation that present economic indicators suggest that the US is now on the peak of a long wave (and about to enter a depression-like period).

In conclusion Graham and Senge argue that innovation policy measures framed without understanding of the long wave are likely to have no effect or to have effects quite contrary to what is intended. If we are on the crest of a long wave, and if physical capital has reached a point of peak volume and minimal flexibility, we are in circumstances inimical to innovation. Basic technical innovation, they predict, will not flourish until the overcapitalized state has depreciated away and the upswing of a new wave leads to major rebuilding. Meanwhile, they claim, social innovations may have greater utility and greater success than technological ones.

Bauerschmidt describes the economic submodel of a model of the FRG developed by himself and his coworkers at Hannover under the direction of Eduard Pestel. The core of the economic model is a 19-sector input–output matrix. This, coupled with demand and supply calculations to the year 2000, was used to identify areas in which unsatisfactory developments could be expected to appear and to describe the input–output characteristics that future technologies should have in order to alleviate anticipated problem conditions. The model shows definite problems arising with unemployment and energy demand and indicates possible long-term or indirect problems in materials and capital goods. Bauerschmidt recommends that energy and materials saving and labor intensive technologies should be encouraged.

Lu's paper is a good example of the application of econometric and empirical techniques to projecting productivity growth in a single sector, in this case agriculture. He begins with a brief overview of long-term historical trends in US agricultural productivity. He then proposes a simple model which is used to explain statistically the historical data as a distributed stage of production-oriented research and extension expenditures, educational attainment of farmers, and weather. This model, combined with a verbal description on probable emerging technologies in the agricultural sector, is then used to develop a set of scenarios concerning US agricultural productivity growth from 1979 to 2025 under five different levels of research and extension expenditure.

The paper by Haustein shifts from a macro- to a micro-level. It describes the application of a method for gaining insight into the factors promoting and inhibiting innovation within firms through development of factor profiles. Haustein begins by noting that previous analyses of innovations have been made in market economies and focused heavily on market variables. To make analysis more relevant to the needs of a planned economy (the GDR) he has reoriented the set of factors examined to include 26 problems commonly observed by would be innovators in the GDR and asked managers from 32 state-owned enterprises to evaluate for 32 successful innovations: (1) the degree of influence that these 26 factors have had in blocking the firm's innovative attempts; and (2) the extent to which the firms' own measures have been able to counteract the factors blocking innovation. The results of this investigation are described and displayed using several classification schemes. In the last section of the paper an approach of graphing the study results is developed and proposed as a useful tool for assessing the bottlenecks and opportunities for promotion of innovation within firms (or other units).

Finally, the paper by Geshka, Paul, and Storvik addresses the topic of how to identify customer needs — and market niches — into which to develop innovations. The paper begins by reviewing some empirical findings on the innovation process, all of which stress the importance of understanding the market in product innovations. This leads into a reporting of some of the tentative conclusions of the NAIB project (Needs Assessment and Information Behavior in the product innovation process), which at this time is a three-nation empirical study of the procedures actual firms use to assess user needs.

The findings take the form of a long list of types of measures and examples of how they are applied in practice. This leads to the general conclusions that needs assessment is important, that many approaches are used in practice, that little of the needs assessment taking place is done systematically, and that making market-related staff conscious of the need for needs assessment is essential to the needs assessment process.

THE ROLE OF STRUCTURAL MODELING IN DEVELOPING TECHNOLOGICAL INNOVATION POLICY

H.A. Linstone

1. INTRODUCTION

Technological forecasting in the United States, in its early years following World War Two, was largely concerned with extrapolations of technical capabilities. Needs analysis was soon recognized as an equally important aspect: what "ought to be" was seen to be as much a determinant as what "can be." In those early years the pioneering users were the military and high technology industries. By the mid-sixties lawmakers and public interest groups also became seriously concerned with technology, specifically with its impact. The "assessment" of technology was becoming as important as the forecast itself, public policy analysis as central as technological systems analysis. Today an innovator developing good and timely insight on the likely interactions with the setting into which the technology is to be introduced will be able to anticipate problems, facilitate implementation, and reduce chances of failure.

We are inevitably dealing with a very complex "system" and are thus naturally drawn to modeling.

Modeling has been a traditional tool contributing importantly to the success of science and engineering. Physical and mathematical modeling have been standard operating procedures for centuries. In view of the "future" and "social" nature of the environment of new technology, physical modeling has proven difficult. The usefulness of operations research (e.g., submarine search tactics in World War Two, inventory management in the 1950s) and systems analysis (e.g., design of complex weapon systems) and the development of the computer have made mathematical modeling increasingly popular outside the hard sciences. In fact, the concentration on quantitative modeling recalls Dostoyevski's comment (in "Notes from Underground"):

> Man is a frivolous and incongruous creature, and perhaps, like a chess player, loves the process of the game, not the end of it.

Three inherent characteristics of mathematically modeling should be particularly noted.

(1) Reductionism: a system is defined in terms of a set of elements with relations among them, i.e. the whole is studied in terms of the parts.

(2) Qualification: qualitative variables are either quantified or ignored.

(3) Objectivity: the modeler is seen as an external, unbiased observer of the system.

These properties are of little concern in traditional "hardware" (purely technological) systems, but they do raise serious problems in systems involving social or individual elements and subsystems. And these are precisely the types we deal with in technology assessment. It thus comes as no surprise that the three most widely used tools in this area are, in fact, not based on any kind of models. Trend extrapolation uses only data from the recent past, without demanding an explanatory model. Delphi is an iterative questioning of a panel which preserves anonymity (Linstone and Turoff 1975). Expert opinion similarly calls for no modeling. In the following section we will discuss structural modeling, another concept distinct from the usual mathematical modeling.

2. STRUCTURAL MODELS*

We define as "structural" those models which highlight the geometric, rather than algebraic, features of a system. They emphasize form and structure, rather than calculating or measuring quantitative output. They reflect Kane's assertion that structure is far more important than state for determination of the behavior of a complex system (Linstone and Turoff 1975, pp.380-381). Structural models (SM) provide a sense of the "geography" of a complex system, a rough map which can shed considerable light on the potential consequences of links between system elements. They fit the learning role of models as expressed by Holling and Goldberg (undated, pp.22,24):

*Sections 2 and 3 are based on the NSF-supported project, "The Use of Structural Modeling for Technology Assessment" (Linstone *et al.* 1978). Any opinions, findings, and conclusions or recommendations expressed in these sections are those of the project members and do not reflect the view of the National Science Foundation. Principal project participants included George Lendaris, Steven D. Rogers, Wayne Wakeland, and Mark Williams.

> We would rather be roughly right about a whole system than precisely right about a trivial part of that system... . A model that can be probed and explored in a simulated world...becomes an evolving device of self instruction. Its value is not so much to give answers as to generate better questions: not to define policy, but to expose some of the consequences of alternative policies.

A structural model is reductionist, but de-emphasizes quantification. A complex system is still defined as a set of elements with relations, nearly always assumed pairwise, linking some or all of them. The assumption of objectivity is also de-emphasized by the relative simplicity of structural models, which encourage multiple (subjective) perceptions of a reality to be displayed and compared.

In a structural model, elements are often graphically depicted by points (or nodes) and relations by connecting lines (or arcs); these define a graph. If an ordering or direction is specified for each connecting line, the graph becomes a directed graph or digraph. Weights and/or signs for the arcs may also be added. A graph or digraph may have two elements connected by more than one line (circuits or cycles, respectively) or one element connected by a loop to itself. Matrices are often used in place of digraphs (Figure 1). Although digraphs or matrices are often used as the initial input for computerized models, they can often be useful by themselves for gaining insight into the system.

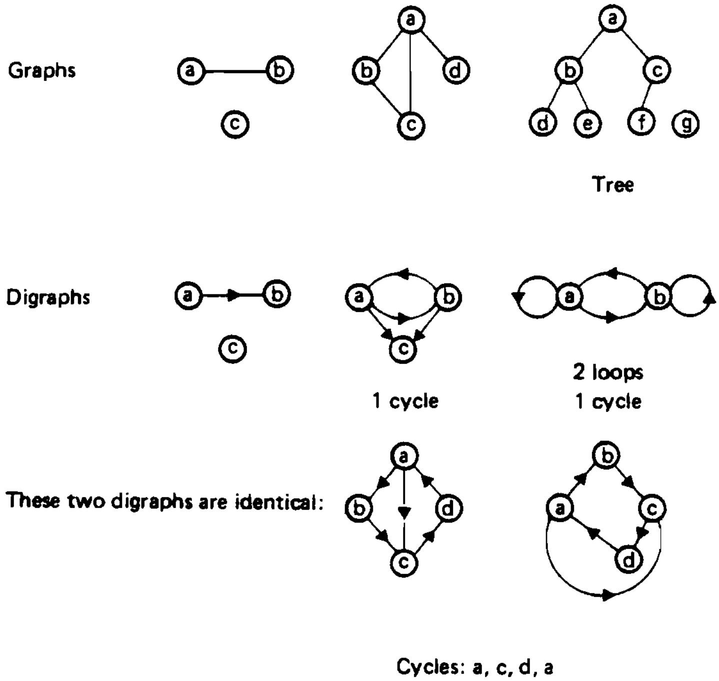
Signed digraphs may have two kinds of cycles: (1) those having an odd number of minus signs and known as negative (feedback), inhibiting, or deviation counteracting; and (2) those having an even number (or zero) minus signs and known as positive (feedback), augmenting, or deviation amplifying.

A preponderance of positive cycles is a clue to system instability. A complex system characteristically has many cycles, reflecting mutual, in contrast to unidirectional, causality (Linstone and Simmonds 1977, pp.140-142).

2.1. Attributes of Structural Model Techniques

Different SM techniques vary in attributes such as their assumptions about system structure, how they identify system elements, what kind of connections are possible, and how they treat time. These are discussed below.

Most structural models assume only pairwise relationships exist among the elements. The principle of superposition, or linearity, is also assumed. If the model is linear, it is sufficient to specify the interactions in terms of pairwise ones. However, if all the interactions are pairwise, it does not mean the model is linear. Finally transitivity of relationships is assumed.



$$\begin{array}{c c} & \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \end{array} & \begin{pmatrix} 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

FIGURE 1 Basic connections.

2.2. Generating Elements

Structural modeling begins with the identification of the elements comprising the system. Usually the choice is largely intuitive, based on individual or group perceptions and discussions. Lendaris (1979) surveyed procedures to generate the set of elements and found the following categories: techniques which emphasize an atmosphere for "free wheeling" thinking, and techniques which offer structure guidance using either semantics or geometry as vehicle. It should be noted that these techniques are not only useful as "generating tools" in the context of SM, but as creativity aids in the technological innovation process itself.

Interactions or connections between elements are generally of two types. Cumulative connections are long-term, the equation differential: $\dot{X} = AX$. Proportional connections are short-term, the equation algebraic: $\dot{X} = B\dot{X}$ (or $X = BX$). A connection may involve both, i.e. $\dot{X} = AX + B\dot{X}$. Each tool must be examined to determine the connections allowed by its algorithms.

Based on their treatment of time, four categories of structural models can be distinguished. Static models maintain invariance over time. Transient or pulse process models apply pulses to variables (or nodes), propagating in accordance with some rule. Uncalibrated dynamic models specify the rate of change of a variable over a time increment and then compute time histories for all variables. However, such trajectories must be interpreted qualitatively. Calibrated dynamic models plot simulated variable behavior against a meaningful time scale. This is the case in system dynamics models. One of the most serious criticisms of dynamic models is that they consider the variables as functions of time, but assume that the model structure is invariant over time.

The structural modeling project uncovered one hundred different techniques. Seven specific methods involving digraphs and/or matrices as input to computerized algorithms were selected for detailed evaluation. Criteria of selection included: low cost, application in days, easily understood procedure, and wide range of potential technology assessment applicability. A brief description of these seven tools follows.

ISM (Warfield 1973, 1974), Interpretive Structural Modeling, is a computerized algorithm for arranging a set of elements in an ordered sequence or hierarchy in accordance with a given ordering relationship. By assuming the connections are transitive and pairwise, the computer obviates the need to compare all possible pairs. It requests the minimum number of comparisons, uses the algorithm to calculate the remainder, and quickly determines the overall ranking of the elements. While the procedure seems unnecessary if the number of elements is small, it is very useful for a large set.

ELECTRE (Roy 1971; Roy and Bertier 1972) is a computerized algorithm for ranking a set of alternatives, when each has been rated on several criteria, or by several evaluators. The ELECTRE algorithm avoids some of the problems inherent in conventional multiplicative evaluation techniques. Comparisons among the alternatives (one pair at a time) are made for each criterion, and an index is calculated. The index is tested against three thresholds (which are set by the user) and the relationship between each pair of alternatives is determined as "strongly preferred to," "weakly preferred to," or "no preference." A ranking is developed from the preference matrix.

SPIN (McLean *et al.* 1976; Shepherd and McLean 1976; Linstone and Simmonds 1977). Building on work in France and on the work of Roberts and others, McLean *et al.* (1976) developed a computerized structuring tool called SPIN. In addition to allowing users to perform pulse analysis, matrix powering, and feedback loop analysis of digraphs, SPIN also allows users to perform clique analysis, ordering, and simplex analysis. These are useful for identifying subsystems and discovering patterns of relationships within a weighted digraph.

IMPACT (Roberts 1976; O'Leary 1975) is a structuring tool which computes the time behavior of a weighted digraph model. IMPACT uses an autonomous, continuous pulse process with bounded variables. Users develop a weighted digraph which is entered into the computer to estimate behavior and test alternatives.

KSIM (Linstone and Turoff 1975, pp. 369-382; Krusic 1974) focuses on the dynamic properties of a structure. It begins by asking expert groups or individuals to develop an interaction matrix (weighted digraph) and determine initial values of the elements. The values of the elements are projected over time, using a recursive formula applied to the initial values of the variables. The variables follow an S-shaped trajectory toward either the upper or the lower limit.

XIMP (Moll and Woodside 1976) is a slightly modified version of KSIM. It features an interactive implementation that has built-in structural analysis capabilities. The impact of an element at a point in time is proportional to the difference between its value at that time and its base values. The structural analysis includes stability and sensitivity analysis, parameter identification, and tracking optimization.

QSIM (Wakeland 1976a,b; Wakeland and Solley 1977) is also similar to KSIM, but more elaborate. Variables are not automatically bounded, the coefficients need not be constant, and the equations need not be linear. Users first develop an unsigned, unweighted adjacency matrix for the elements (Figure 1). Then each binary connection is elaborated by an interaction plot, portraying the rate of change of one element as a function of another element (see Figure 1).

2.3. Comparative Evaluation

These seven tools could be applied in a matter of days and are relatively inexpensive, but require a specialist if proper use is to be assured. Some tools are very versatile, because the elements and connections can have almost any conceivable meaning, others are limited, because the elements and connections have specific meanings. ISM and ELECTRE are static. SPIN and IMPACT are transient. SIMP and KSIM are uncalibrated dynamic. QSIM is calibrated dynamic.

By specifying desirable values for various characteristics in a TA context (Table 1), we finally classified the seven tools into three categories (Table 2).

TABLE 1 Characteristics most relevant in a TA context.

Very important	Important
Handle many elements	Nonpairwise connections
Qualitative emphasis	Delayed connections
Ease of use and communicability	Cumulative and proportional variables
	Explicit group process for subjective judgment
	Provide dynamic behavior

3. APPLICATIONS OF STRUCTURAL MODELS TO NEW TECHNOLOGY AND ITS ASSESSMENT

Two views of the role of structural modeling in the assessment of a technology (TA) are sketched in Figures 2 and 3. Figure 2 shows that structural models may be useful in any phase of an assessment. However, this should not be interpreted as a recommendation that they be used. Critical evaluation of a completed technology assessment indicates that explicit step by step methodologies have had a meager payoff. A striking common feature of the more effective analyses is an effort to fit methodology to the problem rather than to fit the given problem to an *a priori*

TABLE 2 Classification of tools.

Useful	Potentially useful	Problematic
ISM	QSIM	XIMP
KSIM	IMPACT	
SPIN	ELECTRE	

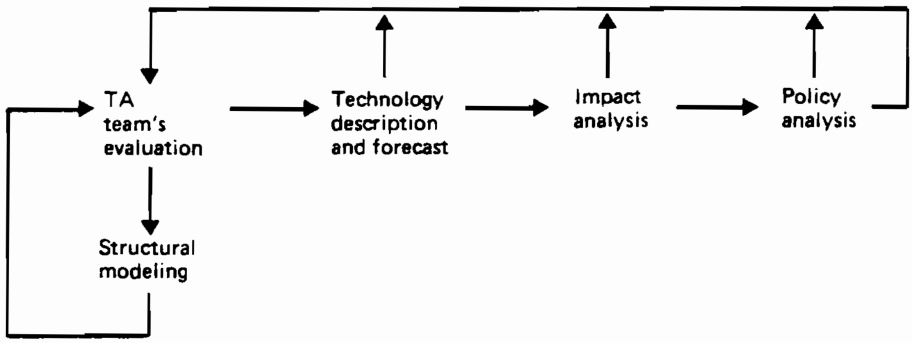


FIGURE 2 One view of the role of SM in technology assessment.

methodology. These studies are characterized by a deep embedding or "immersion" of the team in the problem. This suggests at once that the development of a single structural model for the assessment process might prove counterproductive, tying the innovation team to a Procrustean bed.

Figure 3 clearly exhibits the limitations of the digraph/matrix-oriented structural modeling tools in the technology–society context.

The proper use of SM in TA is not a trivial concern. The skilled analyst can use SM very effectively to lead the client through a complex chain of consequences resulting from the introduction of a technology; the unskilled analyst, with the same set of tools, utterly confuses the client. The able analyst might use SM to develop a meaningful roadmap for the TA; the mediocre one might unwittingly construct a map which misleads the user more than would the latter's own intuition. No amount of improvement in the tools can eliminate this concern. In fact the relative simplicity of SM is a mixed blessing: easy use and easy misuse.

The following are some guidelines which may prove helpful:

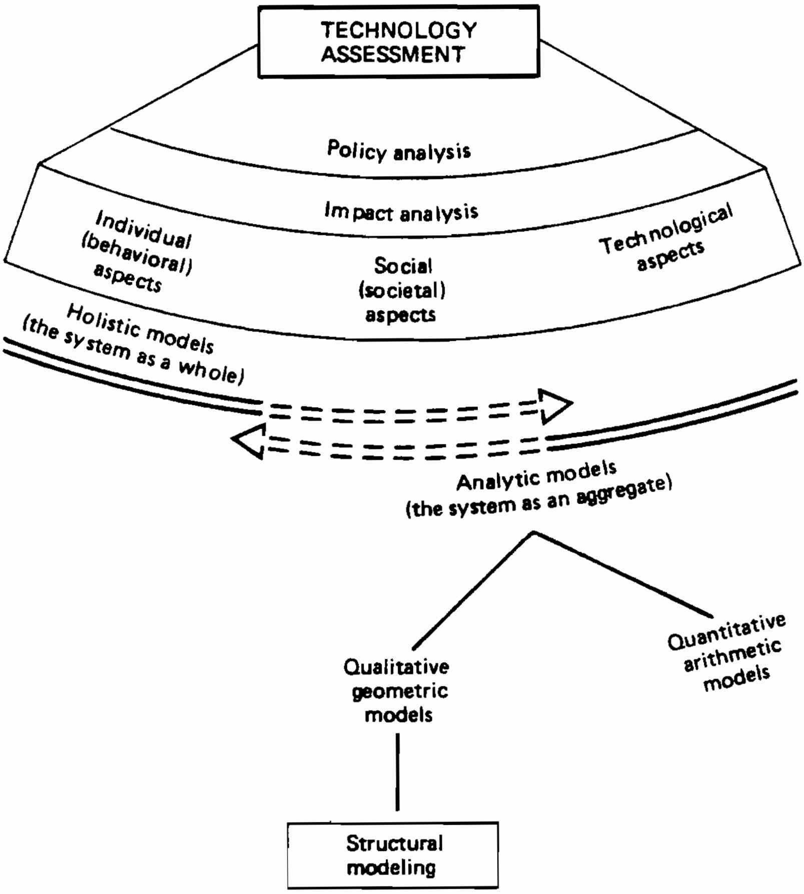


FIGURE 3 Another view of the role of digraph/matrix SM tools in technology assessment.

(1) Computers should not be used unless paper and pencil prove unmanageable. Try to construct digraphs, trees, and/or hierarchies manually first. You will be surprised how much can be learned from such an effort. Computers are needed for quasistatic systems if the number of elements is large and for dynamic systems which are known to involve complex interactions among the elements. But we have often found that the learning which occurs during, and as a result of, computer sessions is less than expected. This comment does not belie the value of structural modeling; rather it suggests that the computer be used, if needed, only after manual efforts at SM.

(2) Do-it-yourself structural modeling (with expert support) is nearly always preferable to buying packaged studies done by outside organizations. Much, if not most, of the value of SM comes from the "hands on" activity, the process rather than the output. This is where the learning is most effective and where the insights are gained.

(3) The important built-in assumptions that accompany the use of an SM tool must not be taken for granted.

(4) Considering these assumptions the use of multiple models and other, non SM, approaches such as historical analyses is vital.

(5) Figure 4 presents a schematic guide to assist in tool selection.

4. BEYOND TODAY'S STRUCTURAL MODELS

SM is preoccupied with a minute class of representations, trees, digraphs, networks, and matrices. This shows a woeful lack of imagination, a creature in flatland unable to conceive of more than two-dimensional space. Why should so many systems be reduced to digraphs? Are they the only simple structure we can envision? Complex systems practice self organization, can create new structures: a spiral or a helix with few elements might tell us more than a hierarchy with many levels (Linstone and Simmonds 1977, p.258).

In fact, the emphasis on hierarchical structures strikingly reflects a thought pattern characteristic of Western culture. And the limited range of structures considered underscores the dominance of the principle of homogeneity. More attention to other cultural patterns, based, for example, on heterogeneity and mutual causality, should generate quite different structural models, as suggested by Maruyama (Linstone and Simmonds 1977, pp.142, 260).

Prigogine's "order through fluctuation" and Holling's work may also be leading us toward structural modeling more appropriate to complex human systems. Thus fluctuations lead to unpredictable changes (analogous to biological mutations) which create a new, stable, and very different, possibly more advanced, system structure. With time, fluctuations may begin again, become more pronounced, and repeat the cycle. Such evolutionary, self-organizing processes should be of utmost significance, but cannot be analyzed with today's state of the art in SM.

4.1. A Misfit Variable Technique, Synoptic Organizational Patterning Analysis (Fried and Molnar 1978)

Synoptic Organizational Patterning Analysis (SOPA) comes from anthropology, specifically the study of the effect of the introduction of a technology into a culture. It seeks points of mismatch on the assumption that these create problems in introducing a technology. It is less reductionist in its approach than the digraph/tree/matrix concepts and more attuned to the "organizational" or social perspective. The model uses variables which represent relational concepts linking technology to states

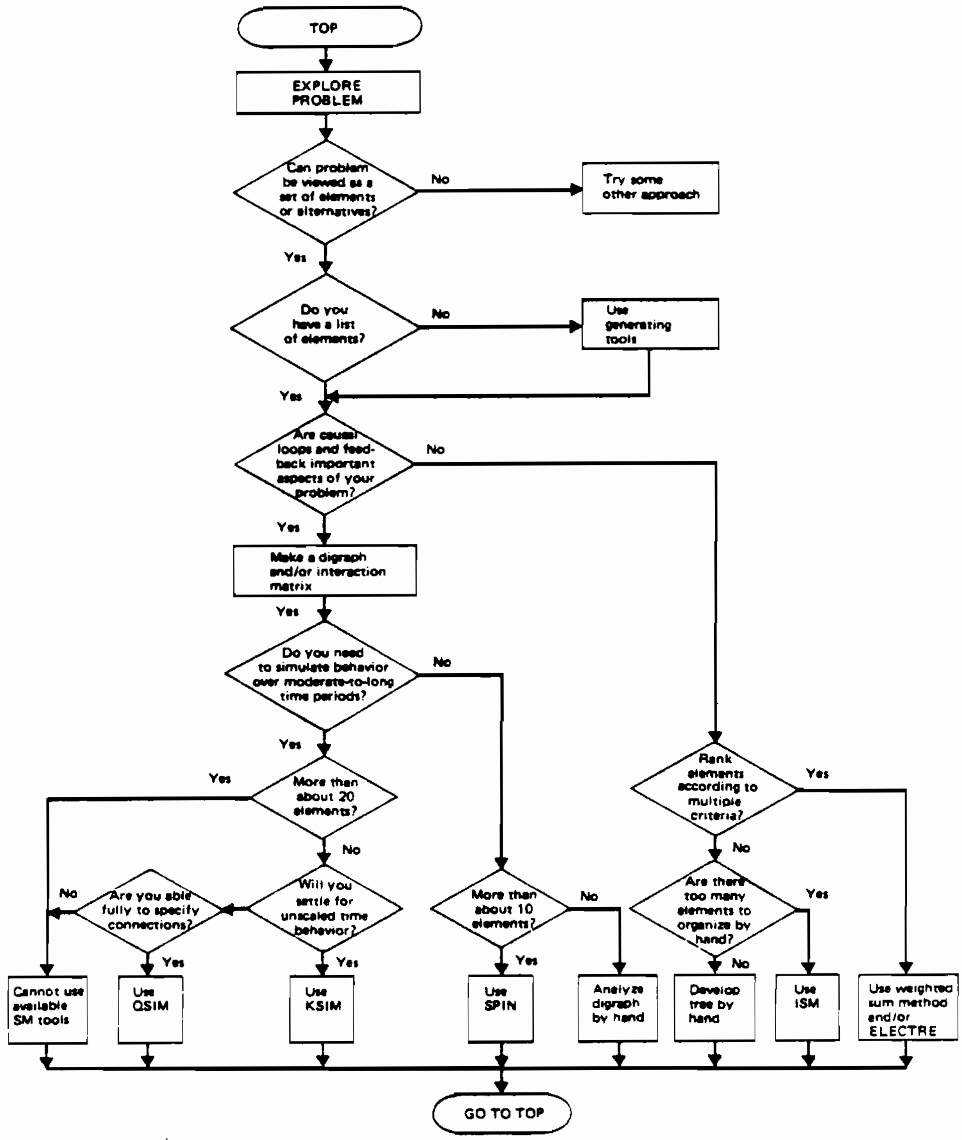


FIGURE 4 Guide for choosing among the recommended SM tools. (Note: if a question is difficult to answer, make a tentative assumption. Then use the results of the SM tools to verify whether the assumption was reasonable. If not, try a different path, etc.)

of political and managerial organization. These variables are then used to measure behavior at three critical levels of analysis: the technological, the managerial, and the political.

Usually, interviews provide the means of deriving all required input. The analyses proceed from interpretation of the implications of a given organizational state in terms conducive to achievement of the desired ends. Scales serve to indicate good and poor matches, and thus sources of trouble for fitting a technology into a society and culture. Thus an application to electronic funds transfer indicated a mismatch between the technological and managerial/political zones (Linstone *et al.* 1978, Vol.2. App.I).

4.2. The Allison Models

Allison (1971) has introduced three perspectives or "models," the rational actor, the organizational process, and the bureaucratic politics model, and used them in complementary fashion to obtain insights on a single complex problem. We now briefly describe a current research project to explore the feasibility of applying the Allison models to the assessment of technology. It is our current hypothesis that we must step outside the quasitechnological modeling area to develop insights on the impacts of new technology.

Consider the following comments about technology assessment. Technology assessment involves questions that are in principle beyond the capacity of science to answer (Majone). The "real expertise" in TA is social and moral, not technical (Skolimowski 1977). The outcome (of TA implementation), whether negative or positive, tends to be more determined by political momentum and bureaucratic balance of power than by a rational process (Menkes 1977).

The traditional systems analysis approach based on science and technology is termed by Allison a "rational actor" or Model I perspective. Structural modeling, as discussed in the previous sections and portrayed in Figure 3, falls squarely into this category. The other two perspectives (Models II and III) are summarized and compared with Model I in Table 3 (Linstone 1979). It is evident that Models II and III offer complementary perspectives in a way analogous to a series of aerial photographs of a ground object. Each picture alone may not make identification possible, whereas the set, combining views from very different angles, permits ready recognition.

Model II of Allison is the "organizational process" model which sees action as organizational output in a framework of present capabilities and constraints. Problems are factored to fit existing organizations and alternatives are chosen from the organization's standard operating procedures. Problems are arrayed according to parochial priorities and the first acceptable, rather than the best, alternative is chosen in resolving a problem. Change is resisted and uncertainty is avoided whenever possible.

Model III is the "bureaucratic politics" model in which action is a political resultant of bargaining and compromise. Individuals, their styles, goals, and preferences, are the key to understanding.

TABLE 3 Allison's three models.

Allison's labels	Rational actor	Organizational process	Bureaucratic politics
Emphasis in system view	Quasitechnological	Organizational	Individual
Basic unit of analysis	Action as choice of total system	Action as organizational output in framework of present capabilities and constraints	Action as political resultant (bargaining, compromise)
Organizing concepts	Unitary decision maker (e.g. government) One set of goals (e.g. national) Solution a steady-state choice among alternatives Action a rational choice based on goals/objectives, alternatives/options, consequences, and value maximizing selection	Constellation of loosely allied units topped by leaders Problems factored; power fractionated Parochial priorities Goals are constraints defining acceptable performance of organization Sequential attention to goals Standard operating procedures (SOP) Programs and repertoires Avoidance of uncertainty Problem-directed search Central coordination and control	Players ("where you stand depends on where you sit") Parochial priorities and perceptions Goals include personal interests Players' impact based on relative power Action channels structure the game Rules sanction some tactics (bargaining, coalitions, bluff) but not others
Dominant inference pattern	Actions are maximizing means to achieve ends	Actions predicated on standard operating procedures	Action resultant of bargaining game among individuals

General propositions	Likelihood of any action results from a combination of relevant values and objectives, perceived alternative courses of action, estimates of various sets of consequences, and net valuation of each set of consequences Increase in costs of an alternative reduces likelihood of its selection Decrease in costs of an alternative increases likelihood of its selection	Behavior of organization at time t similar to $t-1$, at $t+1$ similar to t Program is a cluster of routines satisfying rather than maximizing (first acceptable rather than best alternative) Long-range planning institutionalized, then disregarded Incremental change Trade-offs neglected Organizational health implies growth, imperialism Administrative feasibility a major dimension Directed change possible when organization is in crisis	Peculiar preferences and stands of individual players Styles of play vary Face of issue differs from seat to seat Fuzziness useful to get agreement Focus on immediate decision rather than on doctrine Views: Looking down – options Looking sideways – commitment Looking up – show of confidence Frequent misperception: Misexpectations Miscommunications

SOURCE: Allison (1971).

Model I provides a quasitechnological perspective; it assumes a scientific, systems analysis mode of problem solving. Model II offers an organizational perspective and Model III an individual one.

Allison (1971) writes: "The utility (of the models)...derives in large part from their effect on analysts' predictions about future outcomes. While most analysts' predictions tend to be generated in terms of some variant of Model I, the attempt to make predictions based on Model II and Model III should permit improvements... . They should also sensitize analysts to certain warning signs... that they might otherwise overlook." That analogues of the three models can be used to analyze outcomes in areas of public policy outside foreign and military affairs should be obvious. As shown below, examples can be drawn from many domains.

4.2.1. Model II perspective (organizational process)

Organizational health implies growth: in the Apollo project the search for missions by the United States Air Force and United States Army was important in triggering the civilian (NASA) project.

Standard operating procedures: the New Drug Application (NDA) is the key instrument in obtaining Federal Drug Administration (FDA) approval of a new drug in the US.

Power fractionated: conflict between two agencies, the Federal Aviation Authority (FAA) and the National Transportation Safety Board, hinders commercial aircraft safety management.

4.2.2. Model III perspective (bureaucratic politics/individual)

Goals include personal interests. The positions of Senators Lyndon Johnson and John F. Kennedy, in contrast to the negative stand of President Eisenhower, were crucial factors in activating the Apollo program.

Peculiar preferences and stands of individual players made a difference: MER/29, an anticholesterol drug, was approved by the FDA on the basis of falsified data (e.g. with the suppression of data on recognized harmful effects) in the NDA, provided, according to Fine, by a laboratory head in a department of the drug manufacturer. Thalidomide was not approved by the FDA despite heavy industry pressure, owing to the strong will of Dr. Frances Kelsey of the agency to resist inadequate data.

Action can be the resultant of bargaining among individuals: after the near accident involving an American Airlines DC-10 cargo door blowout, personal contacts between McDonnell Douglas and FAA top level personnel (formerly aerospace industry) proved crucial.

Model I focuses on the technological requirements and most effective action programs to make the enterprise operationally effective. Models II and III emphasize the appropriate settings or conditions to achieve Model I goals. Model II considers the infrastructures which affect, or are affected by, the innovation. How can an organization realistically adapt to technological change? How can a standard operating procedure of the organization be modified? Which organization offers the best path for monitoring or controlling new technology?

Model III treats the individuals who affect, or are affected by, the organizations in Model II (or possibly directly by the innovation). It should indicate who is likely to push a technology the hardest and who can be expected to resist it most strongly. The introduction of a technology by an entrepreneur is likely to proceed very differently from the same goal undertaken by a technologist or a government agency director.

It is the potential mismatches among these three perspectives which are the source of difficulties in implementing technological innovation.

The hypothesis of the present project is that "use of these three models, or rather perspectives, significantly improves the ability to assess technological innovations." Specifically, the addition of Models II and III should strengthen the aspects of technology assessment which are almost invariably the weakest.

It is not our purpose to evaluate the desirability of multiple analytic models. We already recognize the value of multiple models (Linstone and Simmonds 1977, p.148), but as long as they are confined to the "rational actor" perspective, they leave a wide gap in the needed insight. It is the contention of this effort that the Allison perspectives shows the way to close this gap.

The "usefulness" of TA should be particularly reflected in the facilitation of action on recommendations and policy formulation as well as more informed dialogue between clients and groups at interest.

Models II and III focus on the behavior of organizations and individuals concerned with implementation. As two students of TA have recently observed:

> The best technology assessment is useless if the existing political framework provides no way in which recommendations and policies based on assessment can be implemented and enforced. (Inouye and Susskind 1977).

It is a corollary of our hypothesis that a mix of talent is needed to do justice to the three perspectives: it is broader than that usually found in a TA performed in an institute or university. The individual superbly suited to a Model I approach should not be expected to feel at home with Models II or III or vice versa. The paradigms are quite different, as is shown in Table 3. This dichotomy is not really a question of disciplinary versus interdisciplinary, but more one of balance between (a) the sequential thinking, analytic, reductionist type and (b) the spatial thinking, holistic, synthetic type. Loye (1978) has noted two such kinds of thinking in forecasting and Taylor (Arnstein and Christakis 1975) in technology assessment. Rossini's work on TA (Rossini *et al.* undated) appears to support the distinction between the disciplinary/interdisciplinary and the (a)/(b)-type categorizations. The systems analyst may be interdisciplinary but he is still in the (a) mold. He notes that "the percentage of (TA) team members with a "systems" or multidisciplinary background correlated negatively with overall substantive integration." He also finds that "the greater the intellectual distance... and the lower the percentage of systems, mixed, and professional backgrounds of the core team members, the more substantively integrated the (TA) study output." The "intellectual distance" appears to draw in more diverse paradigms than the systems analyst's "interdisciplinary."

As with nearly all ill-structured problems, the research design cannot hope to prove conclusively the validity of our hypothesis. However, our aim is to provide a clear indication of whether it has a reasonable claim to validity and whether its implementation is feasible.

If such is the case the output will focus on guidelines for assessors, i.e. concrete dos and don'ts for implementing Models II and III in support of desirable technological innovation.

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LONG WAVES IN INNOVATION: THEORY, EVIDENCE, AND IMPLICATIONS

A.K. Graham and P.M. Senge

1. INTRODUCTION

Worldwide concern has developed in recent years over the slackening pace of productivity and declining technological innovation. In the US, productivity per man-hour increased between 1947 and 1966 by an average of 3.2 percent per year; in 1966 to 1973 the rate of increase slowed to 2.1 percent; in 1973 to 1979 the increase was down to 0.8 percent per year (Bowen 1979). During a recent quarter year, productivity actually fell. Declining productivity growth is often attributed to a slackening pace of major technological innovation. In the words of a National Science Foundation study in 1974, the vast majority of innovations between 1953 and 1973 represented "mundane improvement," or "minor product or process differentiation" (cited in Mensch 1979, pp. 30–31). Only a small fraction (less than 0.5%) represented basic innovations. By contrast, many studies have shown a much higher percentage of basic innovation during the 1930s and 1940s. Not only the percentage, but the number of basic innovations was greater during the 1930s and 1940s than during recent decades, despite ever-increasing efforts to innovate during the postwar period. R&D expenditure in the US rose every year from 1955 to 1976 (US National Science Foundation 1976). So, clearly, one cannot attribute the slackening pace of innovation and productivity growth to a low level of social commitment to research.

This paper suggests that lagging productivity growth and innovation is a natural consequence of a long-term wave in economic behavior characterized by build-up, overexpansion, and relative decline of the capital-producing sectors of advanced economies. The period of this cycle ranges from 40 to 60 years. The long wave behavior creates a shifting historical context for the implementation of new inventions. When a capital expansion is in midstream, opportunities for applying new inventions which require new types of capital are poor. The nation is already committed to a particular mix of technologies and the environment greatly favors improvement innovations over basic innovations. During a long wave downturn, basic innovation opportunities gradually improve, as old capital embodying the technologies of the preceding build-up depreciates. Near the trough of the wave, there are great opportunities for creating new capital embodying radical new technologies. This explains why times of economic depression, such as occurred in the 1830s, 1880s, and 1930s in many developed economies, are periods of unmatched basic innovation.

The long wave theory outlined above derives from our work on the System Dynamics National Model, a large computer simulation model which attempts to explain how the major patterns of macroeconomic behavior arise out of microlevel decision making. Section 2 describes the model and develops the long wave theory in more detail. Section 3 examines a variety of empirical data which corroborate the long wave behavior. Included are data on long-term movements in economic aggregates such as capital: labor ratio, total construction per capita, and unemployment, as well as data on historical patterns of innovation recently collected by Mensch.

Section 4 identifies general policy implications of the long wave theory of innovation in three areas:

(1) Macroeconomic stimulation of innovation
(2) Corporate strategy
(3) Social Innovation

It is argued that current attempts to stimulate innovation via encouraging capital investment are unlikely to succeed, and that corporate research strategy must go beyond current standards of short-term payback on new innovations and look for basic innovations for the next upswing, which may be 10 years in the future. Perhaps the greatest current innovation opportunities lie in social and managerial innovation, where there are great needs for more effective organizational design and means of relocating individuals in over-expanded industries.

2. THE LONG WAVE THEORY

The heart of the long wave theory developed in the System Dynamics National Project concerned growth of the capital-producing sector of an economy. This section describes behavior and mechanisms underlying that growth and traces out the view of shifting incentives and opportunities for innovation implicit in the long wave theory.

2.1. The System Dynamics National Model

The System Dynamics National Model (SDNM) is a large multisector computer simulation model of the structure of an economy. (For a fuller description of the model see Forrester *et al.* 1976. For other descriptions of the long wave see Forrester 1976, 1977, 1978.) Here only the central mechanism underlying the long wave will be discussed. These involve the interaction of the sector producing capital goods and the sector producing consumer goods. Figure 1 indicates the major linkages between the two sectors. The consumer goods sector responds to demand for consumer goods. Both the consumer goods and the capital sectors utilize labor and capital as factors of production. Labor is supplied at a wage and hiring delay which vary in response to relative demand and supply of additional workers. (The overall size of the workforce is determined outside the model.) Capital (the aggregate of plant and equipment) is supplied by the capital sector, in accordance with the capacity of the capital sector to meet demand. An important structural feature of the model is the "self ordering" which takes place in the capital sector. The aggregate capital sector supplies itself. Orders for capital generated by the capital sector combine with orders generated by the consumer goods sector to determine the total capital demand. Likewise, shipments of capital goods are received by both sectors (see Figure 1).

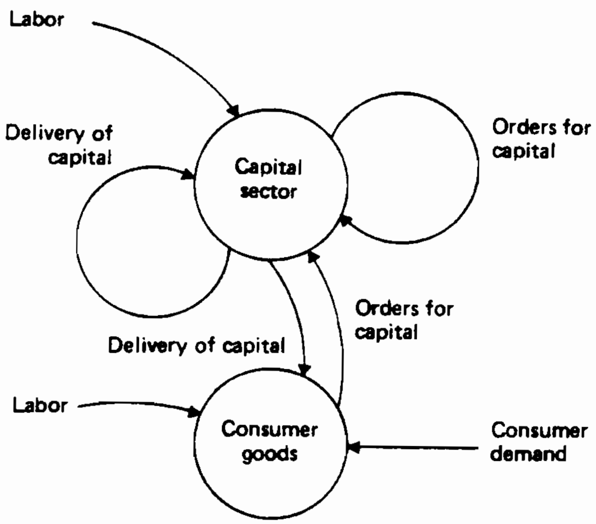

FIGURE 1 The major interactions between the capital sector and the consumer goods sector.

2.2. Long Waves in Capital Expansion

Figure 2 shows model behavior in response to small random fluctuations superimposed on a constant rate of consumer demand. (The standard deviation of the random component of demand is 3% of the underlying deterministic component. The random component has an exponential autocorrelation function with a 1-year time constant.) The figure shows several modes of fluctuation. Figure 2(a) shows two distinct modes for variables in the consumer goods sector. (1) Labor, shipments, and output inventory exhibit a short-term business-cycle-type variation with periods between peaks ranging between 3 and 10 years. (For discussion of the correspondence of this behavior with historical trends see Mass 1975, 1976; Senge 1979.) Extensive analysis of the model has shown that interactions between employment decisions and inventory and backlog management are most important in generating the business cycle behavior. (2) Backlog of unfilled orders for capital in the consumer goods sector (Figure 2(a)) exhibits a "Kuznets cycle" type of oscillatory behavior with periods in the range of 10 to 30 years. (For further discussion see Mass 1975 and Senge 1978.) Chief among the mechanisms central to understanding this behavior mode are pressures for adjusting capital intensity in the consumer goods sector.

Capital sector behavior shows evidence of both the business cycle and the 10-30 year fluctuation. However, the capital sector's most distinct pattern of behavior in the Kondratieff cycle is a fluctuation. Observe, for example, how the stock of capital in the capital-producing sector peaks at years 20, 68, and 124. "Long wave" behavior is also present in delivery delay for capital and production capital, and many other capital sector variables not plotted in Figure 2(b).

Long wave behavior appears to be caused by strong positive feedback in the relationships between the capital sector and the rest of the economy. Figure 3 shows three positive feedback loops involved in the self-ordering of capital from the capital sector. In each loop desired capital in the capital sector is sited into a pattern of causation that stimulates further desire for capital goods in the capital sector.

Figure 4 shows two more reinforcing positive feedback loops in which high wages stimulate capital acquisition in both capital and consumer sectors, which leads to increased hiring; the loops in Figure 3 have the effect that desire for capital leads to greater desire for capital.

As the capital sector expands, rising delivery delays for capital further feed the expansion. This creates still another positive feedback loop, as shown in Figure 5. Rising order backlog in the capital sector boosts delivery delay as capital producers have increasing difficulty meeting current demand. Rising delivery delay forces many customers to order further ahead and place orders with multiple suppliers in an attempt to ensure reasonable lead times in capital acquisition. (Mitchell 1923 gives a detailed account of the "illusory demand" created by rising delivery delays.) Ordering further ahead and placing multiple orders results in increased desired capital on order, increased orders for capital, and further increase in order backlogs in the capital sector.

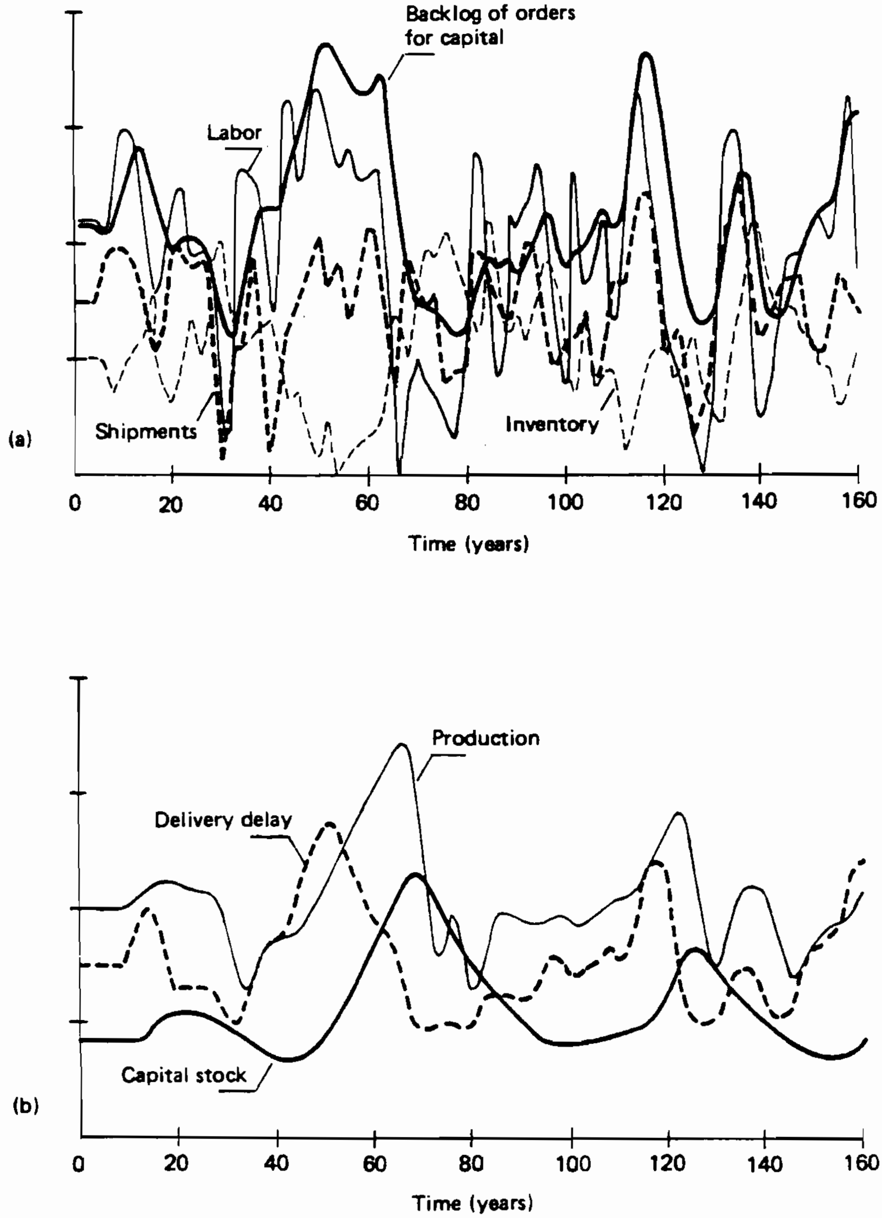

FIGURE 2 160-year simulation of coupled capital and consumer goods sector: (a) variables for consumer goods sector; (b) variables for capital sector.

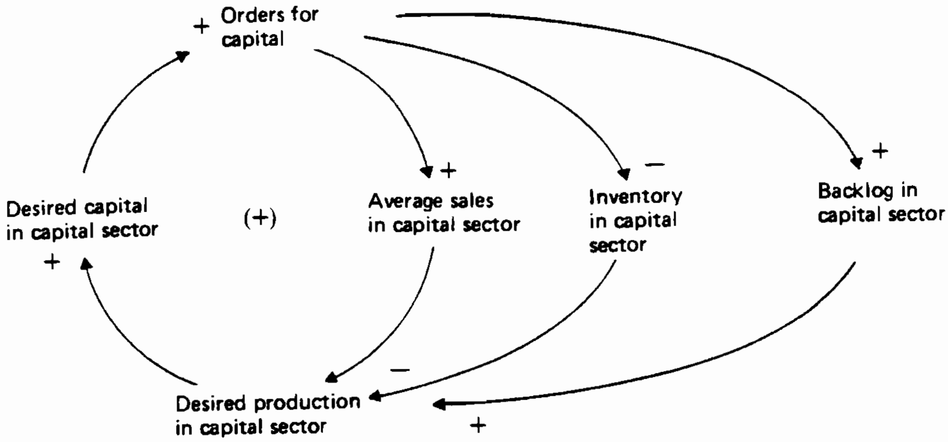

FIGURE 3 Positive feedback loops affecting desired production in the capital sector.

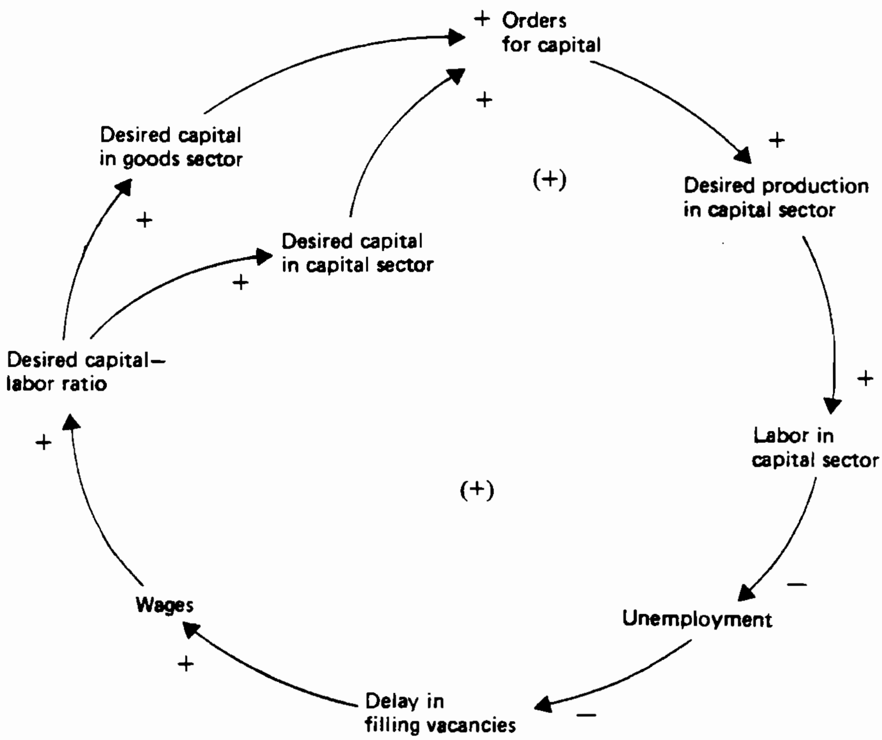

FIGURE 4 Positive feedback loops affecting the desired capital–labor ratio in both sectors.

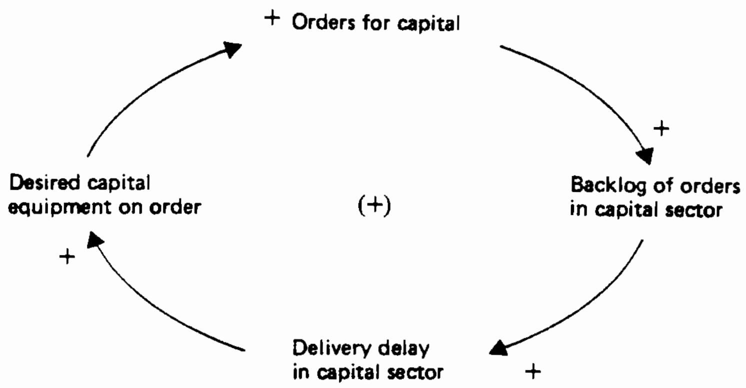

FIGURE 5 Positive feedback loop affecting capital delivery delay and capital ordering.

Capital price appears to create still further reinforcing pressures. Rising delivery delays for capital tend to push up the price of capital. As shown in Figure 6, this raises return on investment and encourages orders for capital both because high return encourages producers to invest to take advantage of profit-making opportunities, and because, being a key index of creditworthiness, high returns encourage financial investors to support capital expansion. Both responses increase backlogs of unfilled orders in the capital sector and further drive up capital delivery delays.

The forces described above combine to produce long wave behavior. Imagine an expansion initially stimulated by an increase in consumer demand which leads to an increase in demand for capital in the consumer goods sector. In responding to this increased demand for capital, the capital sector must expand its own capital stock, which adds still further to orders for capital. Initial expansion in capital production relies heavily on expansion in employment. After a period, available labor is reduced and wages begin to be bid up. As producers gradually perceive a persisting increase in labor costs relative to capital costs, desired capital intensity begins to rise, adding further to capital ordering. At the same time, rising order backlogs and delivery delays are forcing many producers to order capital further ahead, while rising capital price is creating a high return on investment and thereby further supporting expansion.

The positive feedback loops driving the capital sector cannot continue generating growth forever. Eventually the sector expands well beyond the point required to supply the capital demands of the consumer goods sector and to replenish its own capital stock. Once this occurs, the reinforcing processes which created rapid growth reverse. Falling orders for capital reduce desired capital production and further reduce capital orders. Falling desired production lowers labor demand, increases unemployment and brings down wages. Pressure develops to substitute labor for capital in both sectors, further lowering orders. Falling capital orders also lower backlog in the capital sector and cause delivery delay to turn

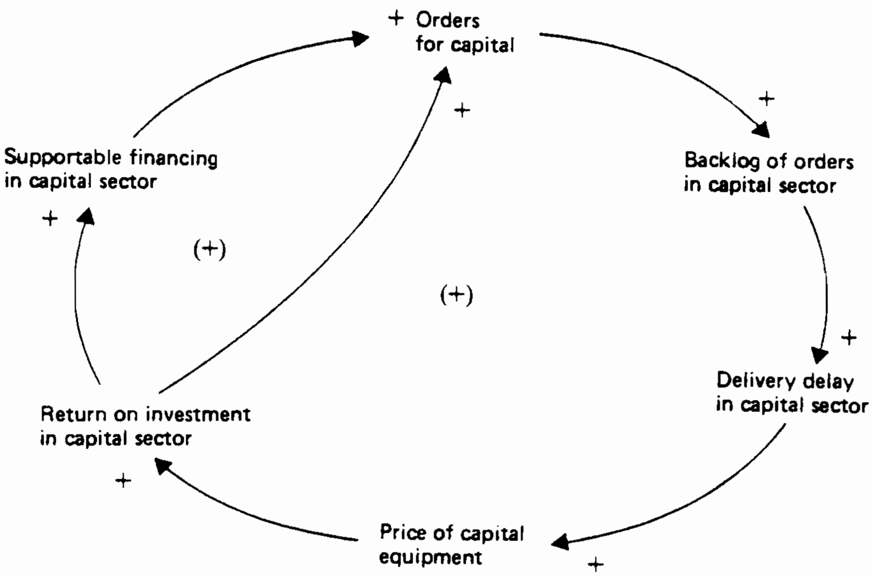

FIGURE 6 Positive feedback loops involving return on investment in capital sector.

down. Desired capital on order declines along with capital price and return on investment, further lowering orders. This rapid reversal of forces is evident in the precipitous decline in capital production, delivery delay, and return on investment accompanying each long wave downturn in Figure 2(b) (e.g. see behavior between years 72 and 84).

The sharp cutback in capital production caused by a long wave downturn eventually leaves the system with inadequate capital production capability. The stage is then set for another long wave expansion. More importantly for the present discussion, the stage is then set for creating new types of capital embodying new technologies. As the overexpanded capital stock from the preceding expansion depreciates, unparalleled opportunities emerge to replace the old capital with radically new types of capital. This is the essential implication of the long wave theory for innovation.

2.3. A Long Wave Hypothesis for Innovation

Innovation activity has not yet been incorporated explicitly into the System Dynamics National Model. Nevertheless the long wave behavior examined above produces a sequence of economic circumstances whose implications for innovation seem sufficiently clear to venture a tentative hypothesis for how innovation might vary over the wave. Many of the ideas below are also developed in Forrester (1979).

Relating the long wave theory to innovation requires first distinguishing between invention and innovation. Following accepted practice, we refer to invention as the discovery of a new idea or technical process and innovation as the first practical application of the invention on a significant scale. Similarly, we distinguish basic innovations from improvement innovations. Mensch (1979, p.47) defines basic innovations as "...innovations which produce new markets and industrial branches... or open new realms of activity in the cultural sphere, in public administration, and in social services. Basic innovations create a new type of human activity." In contrast, improvement innovations can be thought of as incremental improvements upon an existing technology that does not alter its fundamental nature.

In order to examine the implications of the long wave for innovation, consider first the conditions present at a trough in the long wave. The economic climate is uncertain and capital investment low. Market forces that would impel inventions through the development process and out onto the market are rising, and managers and investors tend to avoid the uncertainty of new innovations. But as the expansion wave begins, investment picks up and the future looks brighter. There are greater incentives to take risks, since demand is growing. As new technologies are tried and succeed, incentives for risk taking improve still further. For the Great Depression of the 1930s it is the period of late depression and early upswing that gave us nylon, jet airplanes, helicopters, electronic computation, radar, television, catalytic petroleum refining, and many other important innovations.

As the long wave upswing continues, the nature of capital investment and innovation gradually changes. As physical capital is put into place, it embodies the earlier basic innovations. For automotive technology, a whole system of paved roads, factories, service stations, and car dealers was gradually put into place. Homes and businesses began to locate in suburbs to take advantage of the automobile. For television, transmitters and home sets slowly spread. The physical capital gradually becomes committed to the earlier technology. And there is an increasing social and managerial commitment as well, as the society learns to deal with the innovations. People begin to make careers out of auto repair. Dealerships in parts, crude oil, and gasoline are organized. Financial institutions adapt to the specific needs of the technology — finance companies emerge that do virtually nothing but auto loans. And engineers learn how to make cars very efficiently. The earlier basic innovations are followed by numerous improvement innovations.

As the economy develops a physical and managerial infrastructure committed to a particular mix of technologies, incentives shift away from further basic innovations toward improvement innovation. An improvement innovation has a ready-made market, so that even minor improvements may be worthwhile. In contrast, a radically different basic innovation faces a hostile reception. There is no demand in evidence for it, people may not know how to market or finance it, customers may not understand it, there will be imperfections (it has no series of improvement innovations), one may not be able to use current manufacturing technology to make it, and development engineers probably do not understand it. In this light, it is not surprising that attempts to introduce radically new transportation technologies or to substantially alter private automobiles face enormous resistance if these attempts occur when the automobile economy is healthy. Generally by the midpoint of a long wave expansion, innovation has become an institution. What little headway is made by determined innovators usually falls far short of mass acceptance of a new product or process.

So as the upswing progresses, basic innovations become less frequent. This is not to say that the scientific progress on basic inventions slows down. Rather, the basic inventions do not become commercialized and available. A backlog of untapped technology builds up, awaiting the next upturn. Most of the innovations of the 1930s and 1940s rest solidly on scientific achievements of earlier decades.

However, major economic depressions dramatically alter the climate for basic innovation. Capital embodying the technology of the preceding long wave is not replaced. Bureaucracies which resisted radically new ways of doing things weaken. During such times, determined innovators find the forces opposed to change far less formidable. Once a large enough portion of the workers previously involved in automobile-related tasks are unemployed, there would probably be greater willingness for employment constructing alternative transportation systems utilizing technological advances which improve upon the innovation. The theory suggests sharp clustering of basic innovations near a long wave trough. It also suggests that, once the pattern of technologies characterizing a particular long wave has been established, society finds it much easier to accommodate "improvement" innovations which do not threaten basic technological mixes but offer marginal improvements in the efficiency or incremental extensions in service. Hence, a long wave may see several generations of improved automobiles, televisions, airplanes, or computers, rather than witness a radical technology supplant an established technology.

This preliminary theory of long wave behavior in innovation conflicts with theories advanced by innovation experts such as Schumpeter (1961) and Mensch (1979) which attribute to innovation the leading causal role in producing long waves. We agree that successive waves in basic innovation give a unique character to each long wave. Insofar as different types of innovations encourage or discourage highly interdependent development, they may have some bearing on the extent to which a long wave "locks in" on a particular mix of technologies and precludes further basic innovation. But, our work with the System Dynamics National Model clearly shows that innovation activity is not necessary for generating long wave behavior. Such behavior arises as a result of reinforcing processes in expansion of a capital-producing sector with no explicit inclusion of innovation. At this stage, it is an unresolvable question how much innovation contributes to long wave behavior. The answer must await a model that includes both the capital investment mechanisms described above and explicit representations of innovation.

3. EMPIRICAL EVIDENCE

Corroborating the long wave theory of innovation presented above must proceed along two lines. First, the structural assumptions underlying the theory must be examined from the viewpoint of showing that they describe real economic interaction. The second line of corroboration focuses on the dynamic behavior generated by the model: what evidence is there for the long wave behavior predicted by the model? The following section briefly discusses evidence for the long wave in economic aggregates such as commercial construction and unemployment. The section also discusses in detail evidence of long wave behavior in innovation.

3.1. Long Waves in Macroeconomic Behavior

Several well-known economic historians have identified long-term fluctuations in economic development with a period of 40 to 60 years. One of the first to note long wave behavior was the Russian economist Nikolai Kondratieff (1935). Van Duijn (1977) points out that several earlier economists had also identified long wave behavior. From his examination of long-term time series, especially price levels, covering the 19th century and first part of the present century, Kondratieff concluded that "There is, indeed, reason to assume the existence of long waves of an average length of about 50 years in the capitalistic economy...." Because of Kondratieff's pioneering work, the long wave is often called the Kondratieff wave.

Similarly, Simon Kuznets built on the earlier work of Schumpeter to identify long wave depressions in 1814–1827, 1870–1884, and 1925–1939 (Kuznets 1953, p. 109). Kuznets noted, as had others before him, that each long wave cycle was associated with a particular mix of technologies: cotton textiles, iron, and steam power for the "Industrial Revolution" wave from 1787 to 1842, wood-powered railroads for the "Bourgeois" wave from 1843 to 1898, and coal-powered railroads, electricity, and automobiles for the "Neo-Mercantilist" long wave starting in 1898.

More recently, the Dutch economist J.J. van Duijn has extensively reviewed the long wave evidence and literature and proposed a revised long wave dating which extends up to the present day (van Duijn 1977). He dates long wave depressions in 1826-1837, 1875-1884, and 1929-1938 (van Duijn 1977, p. 563).

Van Duijn's and Kuznets' datings do not relate directly to long wave behavior of the model, because they are based on diverse statistical and nonstatistical data drawn from different countries. Kuznets' pre-1900 datings are based primarily on data for the UK; his post-1900 datings are based on data for many countries, including the US. Van Duijn attempted to consider the scanty US data from about 1870. Also, the overall long wave datings give little indication of whether the particular mechanism identified by the System Dynamics National Model, namely capital overexpansion, is evident in historical long wave behavior. For more specific corroboration of the long wave behavior predicted by the System Dynamics National Model, we would like to examine long-term trends in variables related to capital investment and innovation in particular countries. Ideally, data for the capital-producing sector of an economy provide the clearest indication of the mechanisms outlined in the foregoing. Unfortunately, the few long-term physical time series available aggregate all production sectors. Nonetheless, the available data do provide some indication of behavior consistent with the model's predictions.

In Figure 7 is plotted data for capital and labor inputs to overall production reprinted from Mensch (1979). Both (a) and (b) trace out a distinct pattern of economic evolution. The graphs suggest a four stage development pattern. For example, the lower graph shows that labor and capital both expanded from 1889 to 1918, although the overall rate of capital growth somewhat exceeded the rate of labor growth. This corresponds to the early stage of a long wave expansion in which all factors are expanding. From 1918 to 1929 labor growth slackened while capital is being substituted for labor owing to the relatively low price and delivery delay for capital.

Labor then declined from 1929 to 1932, while capital held more or less constant. Once the long wave peak in capital production has occurred, reducing production requires massive cutbacks in employment, particularly in the capital-producing industries. Lastly, the period from 1932 to 1938 was characterized by rising labor and declining capital. This corresponds to the later stages of the long wave decline in which capital–labor rations in the model decline owing to the relatively low cost and high availability of labor.

Figure 7(b) suggests a similar pattern since World War Two. Just where we currently are on the cycle pattern is somewhat unclear. Since 1975, when the figure was originally published, labor and capital inputs have risen somewhat in the UK but employment is only slightly higher than in 1974 and the rate of capital growth has been low since 1975.

Figure 8 presents similar "data" taken from the model simulation shown in Figure 2. The data cover the long wave which begins about year 40 in Figure 2. It should be noted that the present simplified model assumes a nongrowing trend in economic activity, while in reality long wave behavior has occurred superimposed on an underlying growth trend. Consequently, the model understates long wave expansions and overstates long wave contractions. Nonetheless, Figure 8 shows that each of the four stages of long wave development described above are present in the model behavior.

Figures 9 and 10 present data for two physical time series for which long-term US data are available: total construction per capita and unemployment rate. The series show major economic downturns at about 40 year intervals. For example, if one ignores the declines in construction caused by the two World Wars, the major downturns in construction occurred in 1892 and 1896 and between 1926 and 1933. In the 1890s, construction activity fell 34%; in the 1930s construction activity declined 77%. The third largest nonwar decline occurred between 1973 and 1975 — a drop of 25%. Similarly, the two highest unemployment levels occurred in 1894 and 1933. The unemployment rate in 1975, 8.5%, was the highest since the Great Depression.

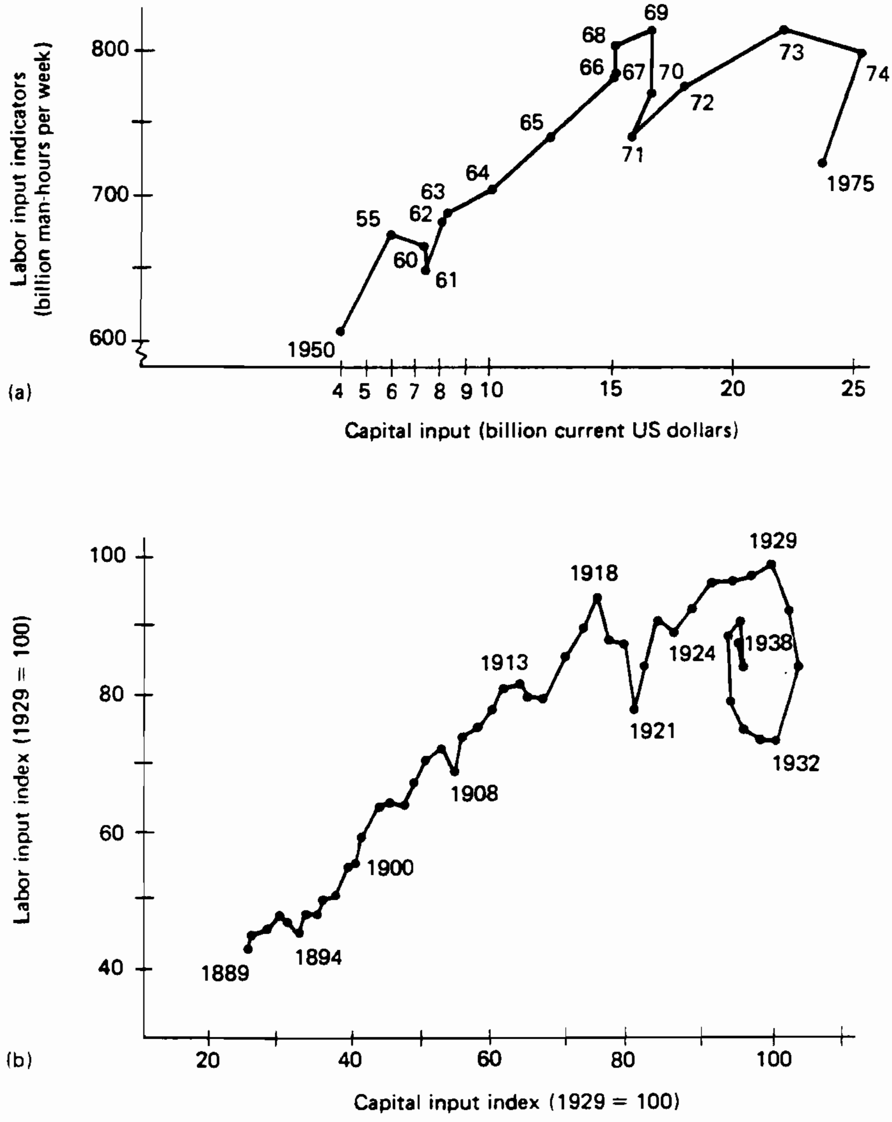

FIGURE 7 Data for capital–labor allocation in the US. Source: Mensch (1979, p. 76). Data sources: (a) Statistical Abstracts of the USA (1976) Series 1303; ILO Yearbook, 1958, 1966, 1976. (b) Kendrick (1961).

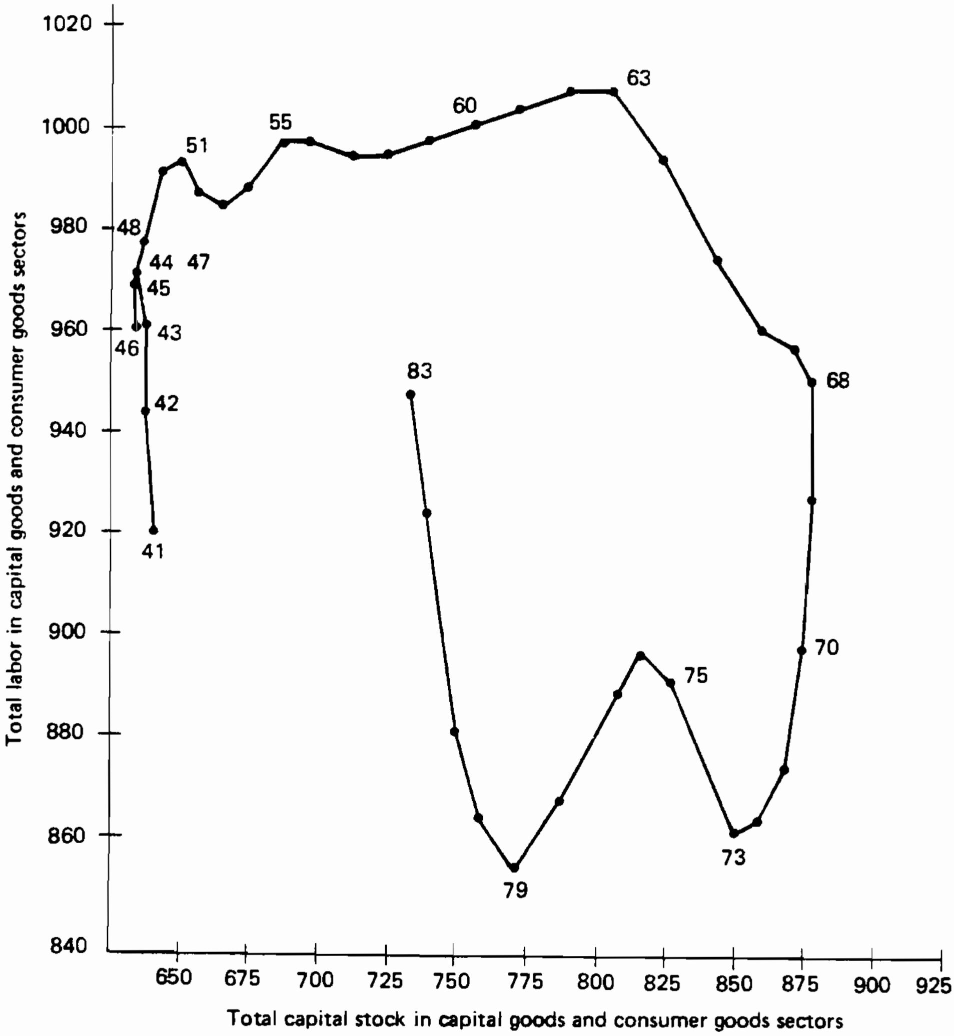

FIGURE 8 Model-generated data for capital–labor allocation.

Two points need to be made about Figures 9 and 10. First, that the major downturn in the 1890s does not match the dating of the long wave downturns given by Kuznets and van Duijn. Indeed, the dating of the long wave in the later 19th century is ambiguous. Kuznet's dating scheme is based on data for the UK until about 1900. Van Duijn considered US data from about 1870, but the US data during this period are very limited. The US experienced a substantial downturn in the mid-1870s, as evidenced by the absence of almost any growth in the decade construction estimates from 1869 through the 1870s. However, the limited data prevent us from determining clearly whether one or the other of these two downturns was

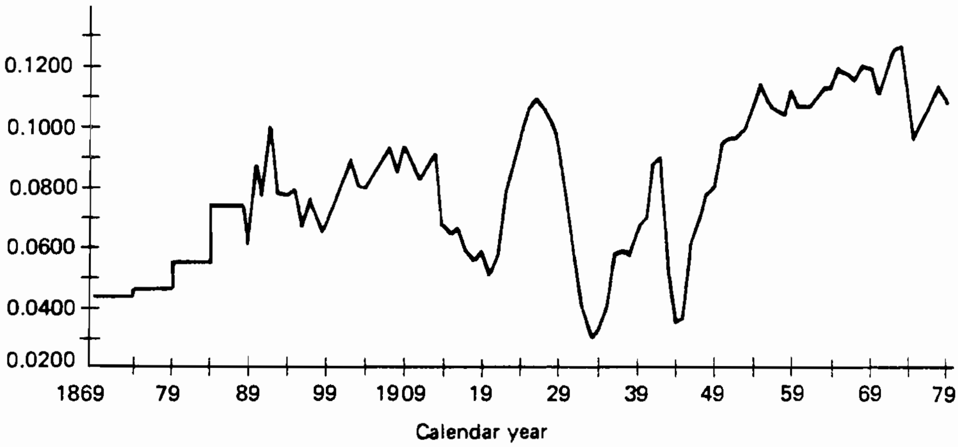

FIGURE 9 Total construction per capita in 1929 dollars (data prior to 1889 based on 5-year averages). Source: US Department of Commerce, *Historical Statistics*, Series N71; Bureau of the Census.

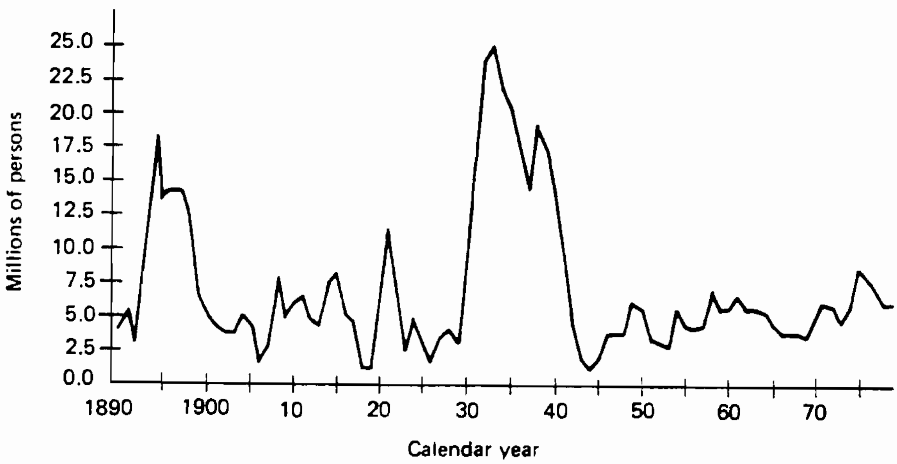

FIGURE 10 Unemployment rate. Source: US Department of Commerce, *Historical Statistics*, Series D85; Bureau of Labor Statistics.

clearly a long wave downturn. In fact, several scholars have argued that the rapid westward expansion in the US buoyed the economy sufficiently during the latter half of the 19th century that a representative long wave downturn never occurred. However, the limited data available do suggest long wave forces sufficient to produce declines in capital expansion and employment during this period much more severe than typical business-cycle declines.

Secondly, the data presented in Figures 9 and 10, as well as the data presented in Figure 7, suggest that the US may once again be moving into a period of capital excess and potential major downturns. Further examination of post-World War Two data reinforces this supposition. The total private investment as a fraction of GNP has been on a downward trend since the mid-1960s (according to the Bureau of Economic Analysis). The ratio of investment to GNP peaked at 8.6% in 1966. Since then, a lower peak value has been reached at each successive business cycle. Investment equaled only 7.4% of GNP in the first quarter of 1979, the apparent peak for the present business cycle. Capacity utilization shows a similar downward trend since the mid-1960s (Board of Governors).

In Figures 11 and 12 are plotted the ratio of labor return to cost and ratio of capital return to cost; they are used as proxies for the profitability of expanding output by adding one unit of labor and one unit of capital respectively. Thus, the ratio of labor return to cost rises when the dollar value of adding a unit of labor rises more quickly than the wage rate. When the ratio of labor return to cost exceeds unity, profits can be increased by adding a unit of labor. In the model, the ratio of capital return to cost begins to decline about halfway up a long wave expansion as pressures to substitute capital for labor begin to subside. However, the ratio of capital return to cost remains above one until near the peak of the long wave, at which point increases in capital intensity are no longer justified. Figure 12 shows that the empirical estimate of this ratio began declining in the mid-1960s. Conversely, Figure 11 shows a long-term increase in incentives for labor-intensive production in the economy, although the estimated labor return to cost was still below unity in 1975. Much has been said in recent years about the impact of higher energy prices on capital intensity. These figures clearly show that the current pressures towards more labor-intensive production have historical antecedents which far predate the energy crisis.

3.2. Long Waves in Innovation

Gerhard Mensch has presented a variety of data on long-term trends in innovation which are consistent with the long wave hypothesis. Figure 13 shows the frequency of basic innovations in Western countries in 22 ten-year periods from 1740 to 1960. Mensch's data show that basic innovations have tended to cluster in certain historical periods including the mid-1760s, the mid-1820s, the mid-1880s, and the mid-1930s. These periods correspond closely with troughs in the long wave. Thus, the innovation frequency data in Figure 13 support the hypothesis that the long wave creates unique periods of opportunity for implementing new inventions.

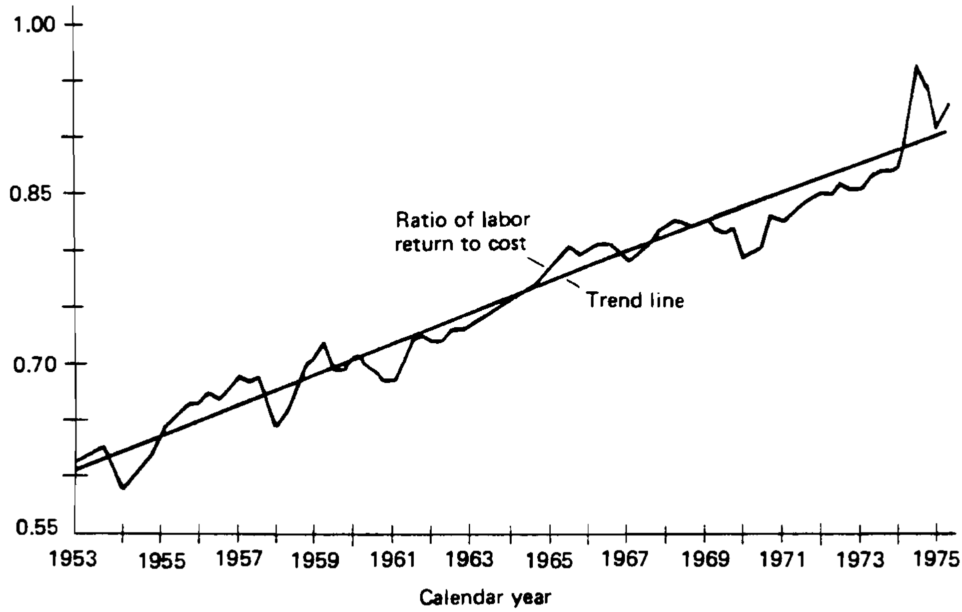

FIGURE 11 Empirical estimates of labor return to cost.

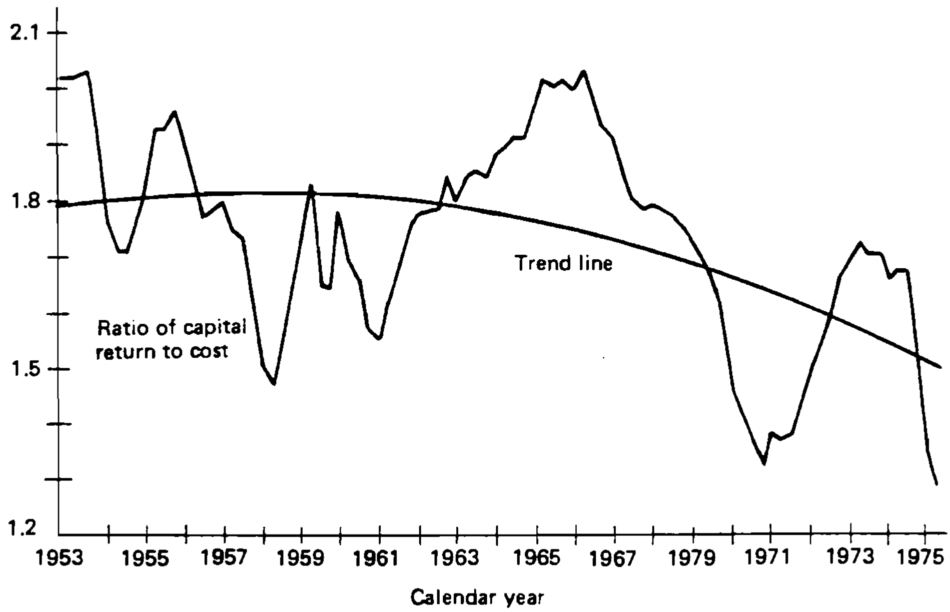

FIGURE 12 Empirical estimates of capital return to cost.

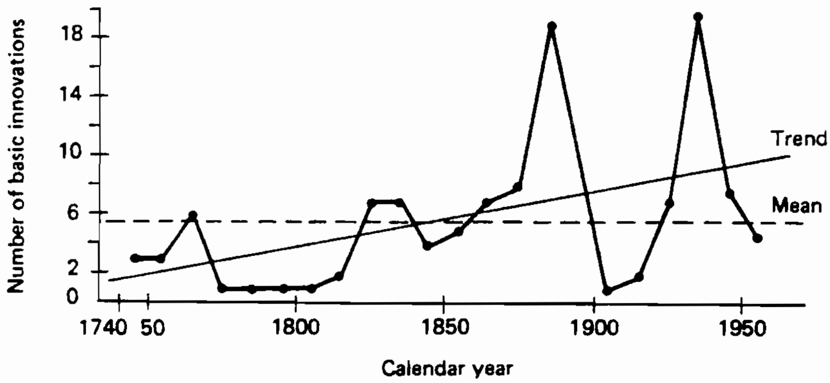

FIGURE 13 Frequency of basic innovations, 1740 to 1960. Source: Mensch (1979, p. 130).

The correlation of capital expansion waves with basic innovation can also be seen in Figure 14, in which is plotted the percentage of total energy use contributed by three different energy sources: wood, coal, and petroleum and natural gas. Shifts in the dominant energy source are a clear indication of shifts in the type of capital in use. The figure shows three distinct waves in the dominant energy source. The wood wave died out in the latter part of the 19th century as coal supplanted wood. The coal wave ended in the early part of the present century, with the rise of petroleum and natural gas. Mensch's basic innovation data are superimposed on the energy data in the figure, showing a clear correlation of basic innovation surges with the beginning of a new wave in energy usage.

The data in Figure 15 further indicate the role of capital overexpansion and decline in altering the climate for applying basic inventions. The figure compares the frequency of basic inventions and basic innovations underlying the innovation surges in the mid-1820s, the mid-1880s, and the mid-1930s. As noted earlier, the distinction between basic inventions and basic innovations reflects the distinction between scientific discovery and practical application. Figure 15 shows that the two processes differ sharply in their degree of continuity. The flow of basic inventions is much smoother than the flow of basic innovations. These data clearly dispute the hypothesis that the innovation surges are due to prior surges in basic inventions (i.e. echo effects) but also suggest that innovation lead time is not simply random.

If there were an echo, i.e., if all basic inventions took X years to become basic innovations, each set of frequency curves for inventions and innovations in Figure 15 would have identical shapes. If there were complete random variation in invention lead time, innovations would be evenly dispersed in time following the surge in inventions (see Forrester 1961, pp. 86-92). Figure 15 shows exactly the opposite characteristic: the dispersion in basic innovations is distinctly less than the dispersion in basic inventions but does not show an echo. Such behavior cannot be

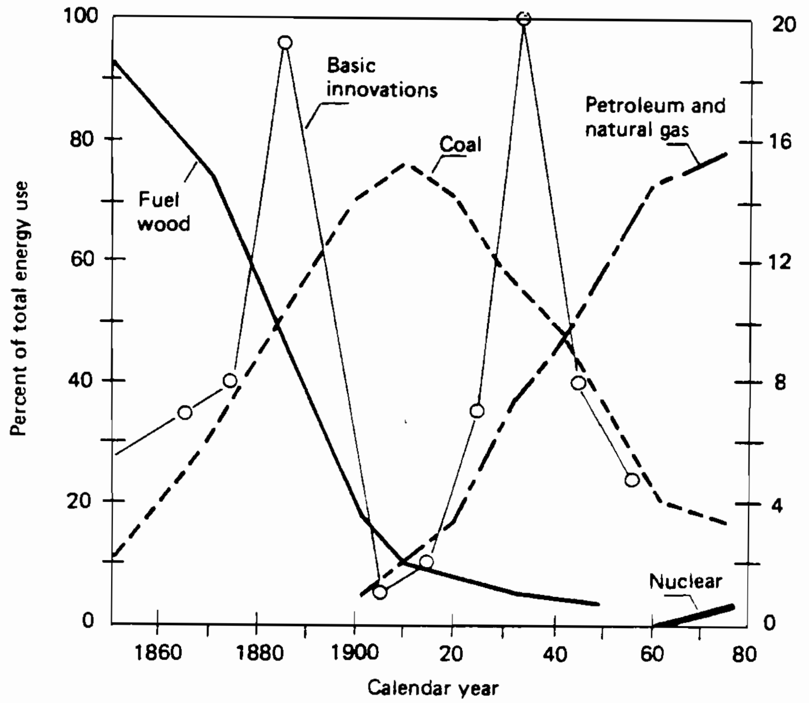

FIGURE 14 Long waves in dominant energy source and basic innovations. Source: US Energy Resource and Development Administration (1976).

explained by any simple filter-down model relating invention to innovation. (Mensch rejects the echo effect hypothesis by showing that there is a distinct probability — approximately 0.3 — that the apparent clusters in basic inventions in Figure 15 are random. The probability that the clusters in basic innovation are random is very small. He rejects the echo effect on the basis that a random phenomenon cannot cause a nonrandom phenomenon.)

However, the relationship between invention and innovation shown in Figure 15 is exactly what is predicted by the long wave theory. The theory states that long wave behavior in capital alters the climate for innovation, tending to bunch innovations in long wave troughs and the early period of a new wave of expansion. The theory as articulated in the preceding section suggests little about the pattern of basic invention. Rather, it simply says that the opportunities for a new long wave expansion will lead society quickly to draw down the "backlog" of unexploited inventions, whatever the pattern of past invention activity. (The theory could be readily extended to include invention activity, insofar as such activity is the result of organized research effort. Research expenditures tend to be greatest during periods of the greatest economic prosperity —

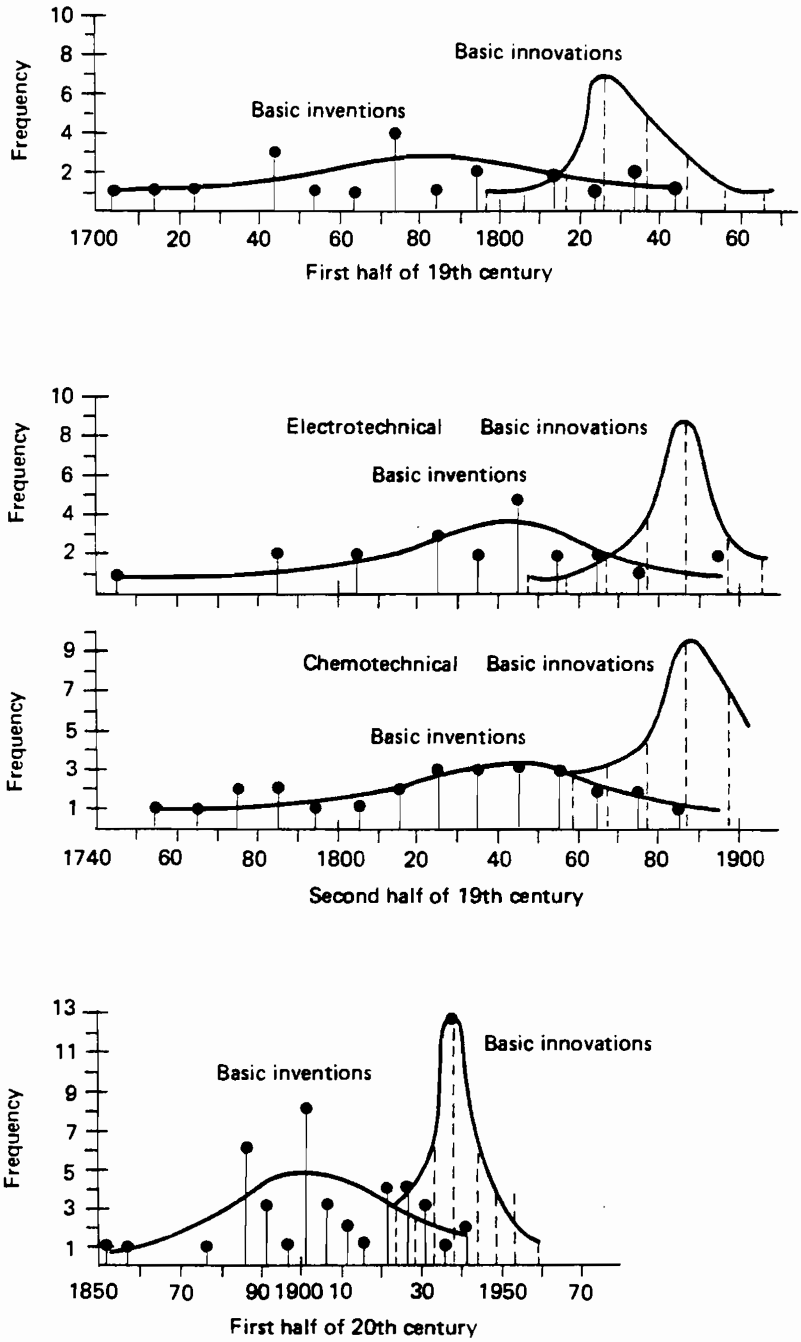

FIGURE 15 Frequency of basic inventions and basic innovations. Source: Mensch (1979, pp. 146–148).

that is, during long wave expansions. Hence, one would expect a higher frequency of basic inventions during long wave expansions, which is borne out in Figure 15. This hypothesis is consistent with Schmookler's (1966) finding of high correlation between inventions (patents) and economic activity. According to this view, the decline in the dispersion of basic inventions for each successive cycle may reflect the increasing organization of the research effort.)

The data in Figure 16 clearly show this quickened drawing down of the invention backlog during long wave troughs. Each point on the figure indicates the date of a basic invention and the number of years which elapsed before the basic invention became a basic innovation. The data show a dramatic shortening of the innovation lead time around long wave troughs. This phenomenon is progressively more evident for each long wave. For example, the curve D_4 traces through the inventions which become innovations in the wave beginning in the 1930s. The oldest invention exploited during this period was almost one hundred years old. The downward slope of the curve shows that as one approaches 1930 and 1940, the innovation lead time shortens dramatically. Several inventions in the 1920s and 1930s found their way into application within about 10 years.

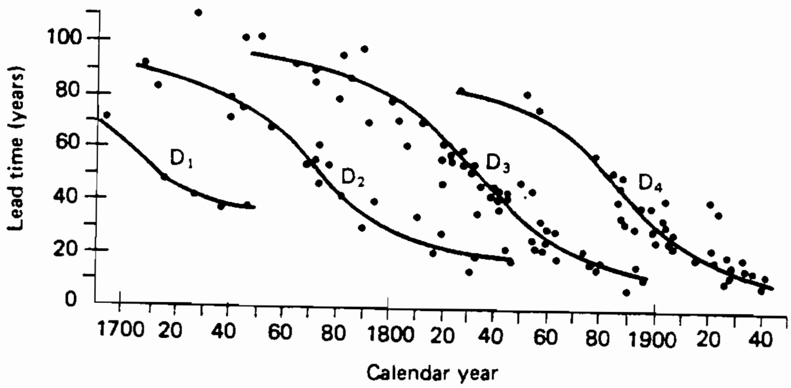

FIGURE 16 Lead time from basic invention to basic innovation for four successive long waves. Source: Mensch (1979, p. 168).

4. IMPLICATIONS OF THE LONG WAVE HYPOTHESIS FOR INNOVATION POLICY

The theory and evidence presented in previous sections suggest that the current slumps in innovation, productivity, and investment are not random and temporary occurrences. They arise from powerful forces that have been building up for decades. These forces are: general adequacy of physical capital, overexpansion of physical capital producers, and physical and managerial commitment to the pervasive older technologies. This economic and technological environment can strongly influence the success or failure of actions involved with innovation.

General implications of the long wave hypothesis regarding innovation fall into three main categories: innovation policies for macroeconomic improvement, corporate innovation strategies, and opportunities for social innovation.

4.1. Innovation Policies for Macroeconomic Improvement

Throughout the 1950s and 1960s, standards of living rose in many countries throughout the world, resulting in equal parts from increasing capital investment per worker and innovations that increased productivity. When such conditions persisted for decades, conventional wisdom naturally came to regard investment stimulation policies as necessary and constructive including lower corporate income taxes, various kinds of low-cost government financing, investment tax credit, and rapid depreciation accounting that amounts to postponement of taxes.

However, the economic climate has changed in a manner suggesting that we are near the peak of long wave. Many sectors show signs of excess physical capacity; although increased investment may seem locally desirable (for example, to better meet foreign competition), it does not seem to be universally needed. In such an environment, stimulative policies can have only very limited impact. Indeed a recent Brookings Institution study found that in recent years the various kinds of investment incentives in the US have had remarkably little impact on investment activity (Clark 1979).

So general economic incentives seem unlikely to elicit significant outpourings of investment. To the degree that investment can be stimulated, such a response seems unlikely to engender basic innovations that can have a substantial effect on the standard of living.

As suggested above, near the peak of a long wave, innovations are more likely to be incremental improvements rather than fundamental breakthroughs. The world is ready for more gasoline-efficient autos; the world is not ready for massive conversion to automotive power sources other than petroleum. Incremental improvement innovations have a vast and ready market and an infrastructure that supports them, whereas basic innovations do not.

Investment stimulus is one commonly suggested area for improving the standard of living through innovation. The other major area might be termed "project research:" direct and massive research and development efforts aimed at some specific outcome. During the early and middle part of the present long wave upswing, project research produced atomic power, radar, the high speed electronic computer, and put a man on the moon. But project research does not always produce success. The "war on cancer" begun a decade ago has won several skirmishes, but no major battles.

One major barrier to producing basic innovations through either project research or investment is that the effectiveness of basic innovations often depends on the technologies of other basic innovations. The development of the high speed electronic computer would have been virtually impossible without the high speed test equipment developed as a part of radar research. And radar sprang from much of the same electronic technology that produced television. Similarly, the advances in automotive technology during the 1920s and 1930s created almost overnight in historical terms the need for chemical technology that produced a catalytic cracking refinery in 1935 and nylon in 1938. Seemingly, chemical technology would have been difficult to develop without automotive technology. Mensch (1979, pp. 205–212) has shown that with few exceptions, the order in which basic inventions occur is exactly the same as that in which the corresponding basic innovations later occur. This "natural order" suggests an interdependence among basic innovations that would make project research especially unfruitful during times of capital overexpansion.

Thus far, it has been argued that macroeconomic stimulation for innovation is unlikely to succeed, either through attempting to stimulate capital investment or through project research aimed at producing particular basic innovations. However, there appears to be more hope for individual research and development (R&D) efforts aimed at basic innovation. These possibilities are addressed in the following section.

4.2. Strategies for Innovation Research

Studies of R&D management tend to focus on R&D tactics — how to fund projects, criteria for stopping projects, how to manage communications among staff, and so on. The long wave hypothesis suggests that there are critical strategic questions as well: what will the technologies of the next wave be, and what can we do about them now?

The long wave hypothesis implies that many of the basic innovations of the next wave currently exist as working laboratory prototypes. Specifically, if one takes the six-stage chronology for the innovation lifecycle proposed by Mensch, for conditions that represent a long wave peak, the scenario that emerges looks like this.

(1) Perception: Virtually all of the operating principles that the next wave of technology will use have already been identified.

(2) Conception: Most of the applications of those principles to inventions have already been conceived of.

(3) Feasible invention: Most of the next ensemble of basic innovations have already worked to some extent in the laboratory.

(4) Development: About half of the basic innovations have begun to be developed.

(5) Decision: Less than a quarter of the next wave of basic innovations have been selected to be marketed.

(6) Basic innovation: Very few of the innovations of the next long wave are available commercially.

The extrapolated scenario above might seem rather hopeful in terms of opportunities to enter on the ground floor of the technologies of the future. Yet in the 1930s, only a few individuals and companies took such opportunities: innovations at the end of a long wave upswing whose market and payback are close at hand. The basic inventions of the next wave aim at undeveloped markets and offer uncertain payback. They involve technologies which differ from the technologies of the last wave as radically as airplanes differ from rail travel. Thus it is not surprising that basic innovations for the next long wave tend to be overshadowed by the more attractive improvement inventions.

How might an R&D operation be run to be more likely to develop the basic inventions of the next long wave? There is an image of research and development that pervades the literature. It might be simplified as follows: ideas come randomly from technical people. The manager's task is to select those ideas with the best potential payback and shepherd those ideas along. This image is not suitable for getting into the innovations of the next wave for at least two reasons.

(1) Search for basic innovations requires forceful direction. If most of current technology relates to the present wave rather than the next, and if one gives researchers free rein to find new ideas, then most of the ideas will relate to the technology of the last wave. The alternative style of management is to set up a specific line of technological development, hopefully directed toward the technology of the next wave. For example, the electronics industry seems to have a specific line of development planned toward an "office of the future" fully integrated with communication and computation systems. Projects that move a company toward the technology of the next wave offer greater long-term potential than projects that cannot be followed with other successful projects even if the initial project is more profitable in the short run.

(2) Payback is an inappropriate criterion. The payback period indicates how soon a project pays for itself; the payback period indicates absolutely nothing about how much profit there can be after the project pays for itself. Basic innovations might almost be defined as development projects whose returns are slow at first and huge later (as the innovation penetrates the entire economy). In short, use of the payback concept systematically discourages R&D on future basic innovations.

4.3. Social Innovation

If previous reasoning is correct, 1980 is near the point of maximum accumulation of physical capital and hence maximum commitment to past technologies; opportunities for new technologies exist but a major surge in new technological innovation may be a decade in coming. Policies aimed at stimulating technological innovation will probably have low leverage in coping with the long wave downturn.

Where are the areas of higher leverage? One candidate is social (rather than technological) innovation. Historically, the peaks through the troughs of long waves have been times of considerable social change. In the US, movements for women's rights have appeared in long wave downturns, with Women's Liberation in the 1970s, Suffrage (the right to vote) in the 1920s and so on (see Schuman and Rosenau 1976). The hardships of the Great Depression gave rise to many social experiments, some of which survived and flourished (the "New Deal" role of government in economic matters), and some of which did not (national socialism and the Third Reich in Germany).

The point of maximum physical wealth may be the point of highest leverage for social innovation policy: only a small fraction of our population produce the physical goods upon which society is founded. The remaining people (in management, government, services, and so on) are in a sense overheads that could be redirected through social innovation.

One area of potentially effective social innovation is organizational design. The hierarchical organization structure common to most organizations represses creativity and personal responsibility and may be particularly ill-suited to a long wave downturn. New concepts in organizational design which emphasize local profit centers encourage entrepreneurial development and vitality while increasing overall corporate profits (Forrester 1965). Moreover, such decentralized organizations may be much better suited to cope with a long wave downturn than top-heavy hierarchical structures. The decentralized organization may be able more readily to cut back unprofitable ventures without financial losses spilling over into all lines of business. Employees who share responsibility for relatively small profit centers have far greater incentives to stay attuned and adapt to shifting economic conditions, rather than waiting for word from "up top" on how to respond to major economic change.

The long wave hypothesis implies a pressing need for a variety of societal innovations to cope with the downturn. Companies and institutions expire, and people lose jobs that never return. If a long wave downturn does occur in coming years, current philosophies of government intervention may not only fail to soften crises, but may actually intensify them. For example, consider the current handling of unemployment in the US. If people lose their jobs, unemployment compensation payment from the government provides income to sustain them until they regain their jobs. But during a long wave downturn, jobs in the capital goods production sector can disappear for years. When the "jobs" reappear, they will use new technologies and require different skills. Unemployment compensation encourages people to wait, as dependents of the government, for capital sector jobs that will not come back.

Social innovations are needed to facilitate movement of people out of collapsing industries and into more active sectors, so even in a long wave downturn there will remain numerous undone tasks, especially in the energy area. People will not remain trapped on unemployment compensation if it is made easy enough to locate positions that provide a measure of on-the-job training. For example, consider modifications to income tax laws that could facilitate movement between sectors. Current US income tax laws provide a small amount of relief from drops in income by taxing the average of several years of income. Suppose this income-averaging feature was negative for people with a clear record of earnings who experience a sharp drop in income? If the income tax cushion convinces people to get off unemployment compensation and to start new careers outside the capital sector, the former subsidy to unemployment has turned into a subsidy to starting a new career.

As another policy that would facilitate movement between sectors, businesses could be relieved of part or all of the taxes they pay on employees (Social Security in the US, for example) if the employees have been on unemployment compensation for a period of time, or have experienced a drop in income. In effect, this would provide short-term subsidy for firms to train people whose experience is no longer directly relevant. Now an analysis of these tax programs with regard to costs, benefits, and loopholes is clearly beyond the scope of this paper. Nonetheless, there are clearly opportunities for innovation in the area of labor mobility.

Another area needing social innovation is preparing institutions for massive failure. Even today, the sudden bank failures during the 1930s are well remembered. Hyman Minsky (1975) has documented the extent to which the lessons of the 1930s have been forgotten; individuals, corporations, and governments are increasingly indebted, and increasingly vulnerable to adversity. Governments are often called on to make loans to troubled banks (such as Franklin National) or corporations (Lockheed, Chrysler), or even to run railroads. The argument usually boils down to the need for short-term help to achieve long-term health. But in a long wave downturn, there may not be any long-term health for these organizations. Government bailouts may not serve society when limiting the downside risk encourages more risk-taking by the banks or corporations not yet in trouble.

So it may be more constructive in the long run not to come to the aid of corporations in trouble. Indeed, after watching corporations approach bankruptcy and systematically neglect needed long-term investments (track maintenance in the Pennsylvania Railroad, engineering in Chrysler Corporation), one might conclude that the bankruptcy laws should make bankruptcy much more easy and rapid to prevent inefficient use of the society's resources.

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THE USEFULNESS OF NATIONAL MODELS FOR IDENTIFYING CHARACTERISTICS FOR FUTURE FIELDS OF INNOVATION

Rolf Bauerschmidt

INTRODUCTION

Modeling technological change on a national level is difficult. No existing national models deal explicitly with technological change or innovations (macroeconomic production functions and diffusion models should be excluded in this context). The problem appears to stem from problems of definition and measurement.

When trying to describe mathematically the economic effects of technological change one must confront the question which effects on the economic system should be regarded and how to measure them. Research in innovations scarcely addresses these problems and deals mostly with the factors influencing the process from invention to application.

Macroeconomic growth theory largely deals with the effects of technological change on economic growth. In the production function of Cobb-Douglas this is embodied in the two other factors, capital and labor (Cobb and Douglas 1928). In the production function of Tinbergen (later also used by Solow and others) technological change was disembodied in a third factor (Tinbergen 1942).

Although there are fundamental difficulties in modeling technological change itself on a national level, many effects of technological change are implicit in all national models which deal with economic development or parts of it as well as in more technically oriented production models. The IIASA Innovation Task Group has chosen one of these, the national model for the FRG, to investigate whether this might be useful in answering some questions related to the innovation process and innovation policy.

THE NATIONAL MODEL FOR THE FRG

This model contains a 19-sector input–output model of the FRG economy. Many different input factors have been determined for each of the sectors. The initiative for the model came from the national ministry of research and technology which was interested in adapting the Mesarovic–Pestel World Model to questions relevant for research and technology from the viewpoint of the Federal Republic. The task was divided into two parts and was performed by two groups.

(1) A further disaggregation of the regionalized World Model within the region of Western Europe, the development of additional model features and the improvement of existing ones by the Cleveland Group, headed by Professor Mesarovic.

(2) The development of a national model for the FRG by the Hannover Group headed by Professor Pestel.

The national model was developed to present a picture of the past development and possible future trends in some important areas of the national system. The main question was to determine which grave problems the Federal Republic will face in these areas in the next 20 to 25 years, provided that the observed trends of the past will continue in the future and the factors which caused these trends will still be effective. The results were compared with major national goals and gaps and unsatisfactory results were shown. Next, alternative scenarios were developed. These scenarios were put together to illustrate cohesive self-consistent approaches to lessen the gaps and lead to a more acceptable future. Therefore, the purpose of the model was not to predict the future, but rather to show the effect on the national system of different possible and justifiable developments in these areas. (For further description see Pestel *et al.* 1978).

The whole approach consists of two parts:

- analysis of the past development by establishing a data base and deriving a lot of cross-section data; and
- scenario analysis of possible future developments by simulation runs with the actual model.

The investigation for both parts is done for the same areas of the national system at the same aggregation level and for the same variables; therefore a consistent view of both the past and the future can be drawn from this.

The following attribute list should give a general perspective of the model.

- Areas included: Population, education, economy, labor market, energy, and materials.

- Procedure: The model itself contains the important system elements and the connections between them; the future development of the uncertain parameters are represented in scenarios.
- Structure differs between submodels: The economic submodel is an input–output model with a feedback via investments and capital stock, while the population model is a very simple feedback structure and the demand for energy and labor is derived in a linear fashion from the economic development in economic sectors.
- Aggregation level: This again differs for different submodels, and is high because there is no differentiation between different jobs. Aggregation in the economic submodel might be called medium because it is divided into 19 sectors, and on the supply and demand side several components are included. Aggregation in the population submodel is low, because it contains 86 age-groups, male and female as well as native and foreigners.
- Endogenization is low: The development of nearly all important variables is driven by exogenous variables. This is true for uncertain parameters as well as for policy variables.
- Time horizon is medium term: Analysis for the past goes from 1950 to 1974 and the simulation for the future from 1975 to the year 2000.
- Project lifetime is very short: Finances were given for 1 year. The two groups worked on this project for approximately 2 years. Further improvement is going on all the time.

As already mentioned, the economy is divided into 19 sectors, which are given in Table 1. For these 19 sectors, input–output tables for several years are established by aggregating tables of the 56 sectors of the Deutsches Institut für Wirtschaftsforschung (Stäglin and Wessels 1973). Additional economic variables such as consumption, government expenditure, imports and exports, value added and gross production, and investments by origin and destination are taken from the publications of the same institute or from the statistical year books. The investment flows from origin to destination are represented in investment flow-matrices and from this the capital stock of each sector is derived for different kinds of investments, such as buildings, vehicles, or machinery. All this was done for the whole period of 1950 to 1974, year by year, with the exception of the input–output tables, which are available only in 4-year intervals. We believe that this gives a good insight into the economic changes which have taken place in the past, and creates the opportunity of saying something about future changes in the economy.

But with this information only it would be difficult to make a statement about the underlying technological changes which have, of course, greatly influenced these developments. Therefore additional input factors have been determined, such as:

- labor in number of employees and hours worked

TABLE 1 Economic sectors in the National Model.

1	Agriculture
2	Energy
3	Mining (other than energy)
4	Stones and clays, glass
5	Food processing
6	Textiles
7	Clothing
8	Wood, paper, and printing
9	Chemistry
10	Metal production
11	Metalworking
12	Production of vehicles
13	Machinery
14	Construction
15	Trade
16	Transportation
17	Dwellings
18	Governmental services
19	Other services

- energy in different kinds of primary and secondary energy carriers
- materials in different kinds of ferrous, nonferrous, and synthetic materials.

All input factors are listed in Table 2. These input factors together with capital inputs of different kinds were called technological input factors, because they are the precondition for the technological process or transforming different inputs into a useful output (Bauerschmidt 1978).

SPECIFIC INPUTS AS INDICATORS FOR THE ECONOMIC EFFECTS OF TECHNOLOGICAL CHANGE

With respect to technological change, the absolute volume of inputs is less important than relative proportions of inputs to output or to other measures of production volume. The relationship between inputs and gross output has certain disadvantages because inputs are incorporated in gross output and because gross output is influenced by many other factors. Therefore we propose to take value added instead of gross output as a measure of production volume.

Taking the relationship between inputs and value added makes sense in other respects. The inputs of labor, energy, and materials are direct inputs into a sector. This should be compared with the own contribution of the sector to final product. Total output, on the other hand, should be compared with total inputs, that is direct inputs into the sector and indirect inputs which are needed to produce the intermediate products.

TABLE 2 Technological inputs to the National Model.

Labor	*Qualifications*
	High
	Medium
	Low
Energy	*Secondary energy*
	Coal
	Oil
	Gas
	Electricity
	District heat
	Primary energy
	Hard coal
	Brown coal
	Raw oil
	Natural gas
	Nuclear energy (plus water energy)
Materials	*Ferrous metals*
	Steel
	Castings
	Nonferrous metals
	Aluminium
	Copper
	Tin
	Zinc
	Lead
	Synthetic materials

Therefore we can define two relations between inputs and outputs:

$$R_D = \frac{\text{Direct input}}{\text{Value added}}$$

$$R_T = \frac{\text{Total input}}{\text{Gross output}}$$

R_D might be called specific direct input and R_T specific total input. As we have considered many different inputs, both R_D and R_T are vectors with a number of elements according to the number of input factors.

Changes of a specific direct input R_D are affected mainly by the technological changes in that specific sector, especially of its production processes, while the changes of specific total input R_T are affected by the technological changes in all sectors related to that sector, so that this shows the effects on final products.

We have determined some 40 technological input factors for each sector (including 19 kinds of capital goods). This gives a multidimensional picture of all changes which have taken place in that sector and which have been affected by technological change. However, the analysis even for specific direct inputs is not easy. If one goes on to include indirect inputs one would have to look at several hundred of them for each sector and examine their changes over time. However, different inputs are not of similar importance to each sector, and one can therefore limit analysis to the important ones. How detailed this analysis has to be and how important inputs are defined depends on the question being investigated. If one is simply interested in the contribution of each sector to overall economic change, an analysis of those sectors and inputs which represent a certain share of total input is sufficient. If one wants to identify the major technological changes which caused these effects, a very detailed analysis seems to be necessary, perhaps sometimes including indirect influences.

Knowledge of the change of a variety of specific inputs alone is insufficient to derive which technological changes have caused these effects. Additional information about the real technological development which has taken place during this time is also needed. The change of specific inputs is a measure of the economic effects on a sectoral basis, not of the technological change itself.

One might ask why we do not investigate the economic effects of a single new technology by comparing the inputs and outputs needed by the new and the previous technology. This would certainly be possible for some new technologies, but it would be very difficult to examine all changes which have happened in a sector on a microbasis and transpose them to a macropicture for a whole sector. Therefore, in our opinion, the only feasible approach is to regard the changes of all input coefficients on the macro (sectoral) level and relate them to the major technological changes on the microlevel in that particular sector.

DESIRABLE CHARACTERISTICS OF FUTURE INNOVATIONS

Model simulations often indicate unsatisfied national goals or gaps between projected demand and available supply. Politicians usually react to such projections by proposing or introducing certain measures to lessen problems in single areas separately without looking at the effects on other areas. Often, several goals are conflicting; in this case the problem cannot be solved by such measures. Additionally, a policy action is mostly restricted to sole economic measures and tends to neglect the very importance of technological (and social) innovations.

In our opinion, there is no proper solution without taking into consideration technological changes and the possibilities of their changing economic conditions. One should try to influence technological change in a direction which serves some, or at least more than one, of the national goals and which leads to more satisfactory results in some areas of the national system simultaneously.

For that, the following are necessary:

- to find out in which areas of the national system gaps or unsatisfactory developments are to be expected in future
- to determine indicators of which direction technological change should take to promise better results, and to derive certain characteristics that future innovations should have
- to find out favorable areas in which these characteristics can be reached by innovations and in which they will affect the overall results most.

Of course, not all innovations can or should be influenced by political measures. That part of technological change which is created by new ideas coming from technical laboratories and which is adopted by the market without any promotion needs no government aid and it seems to be better not to influence it at all. In some cases it might be appropriate to restrain or even to forbid a new technology, because its effects would take an undesired direction, but this should be an exception and not the normal case. But there are other new technologies, the effects of which would take the desired direction, but which are not adopted by the market, because they are in present conditions either too expensive or not appropriate in other respects.

This kind of new technology should be promoted by governmental aid, so that it is either adopted by the market or improved to get favorable characteristics. This kind of aid depends on how far the technology is from a marketable condition and how advanced it is technically. Many different direct and indirect measures ranging from direct price subsidies to support of technological research, to indirect aid such as using information policy to improve the climate for certain new technologies, could be used to stimulate this process.

To be more specific, we will give some results obtained from the national model for the FRG and derive from these results the direction of desired changes as well as certain characteristics future innovations should have. It should be pointed out that the model was not developed for this purpose, so that it cannot fulfill all requirements, at least not without further investigations, but it suffices for showing the principles involved.

Direction of Desired Changes

Unsatisfactory results are shown by the model runs (see Table 3).

- In the labor market where the number of unemployed people increases from 1 million (4%) today to 2–2.5 million (8 to 10%) in the eighties and decreases again until the end of the century. The quantitative problem is also a qualitative one because the number of people with high level education will increase steadily while education, their main field of occupation, will need fewer people owing to a rapid decrease in birth rates. On the other hand the number of people with low qualifications will diminish rapidly.

TABLE 3 Direction of desired changes.

		Medium term	Long term
Labor	In general	+	(0)
	High qualification	++	
	Low qualification	−	
Energy	In general	−−	(?)
	Oil	−−	
	Electricity	−	(?)
	Gas	+	(−)
	Coal	++	
Materials	In general	−	
	Energy intensive	−−	
	Less energy intensive	0	
Capital	In general	+	(−)

- In the energy field, energy demand increases by a factor of two by the year 2000, and can only be met by increasing imports of oil, gas, and nuclear fuels. This might raise problems because of resource shortage or because of political pressures (oil) and social disadvantages (nuclear energy). Therefore the demand for oil especially, and the demand for electricity (because of low efficiency in the conversion from primary to secondary energy) might remain unsatisfied.
- In the materials field the picture is unclear owing to uncertainty about future supplies. It seems that there are no major problems with respect to resource shortages, but there might be indirect problems because the sectors producing basic materials are very energy intensive and therefore it might be necessary to substitute or to conserve materials to reach a higher recycling rate.
- In the capital goods field there seems to be no problem in the FRG in the medium term, although the high investments in exploring the recovering of new energy sources and in new plants for synthetic energy carriers might absorb investments from other sectors, so that capital might be a limiting factor in the long run.

Desirable Characteristics of Future Innovations

Desirable new fields of innovation are (see Table 4):

- In the energy sector, intensive production technologies which increase energy efficiency by means such as cogeneration of heat and electricity, using heat pumps to substitute gas and mainly coal for oil and restrict electrical appliances to those where electrical energy is really needed.

TABLE 4 Desirable characteristics of future innovations.

Labor	Less labor saving in the medium term, in the long run labor saving again Using moie labor with high qualification Substituting low-qualified labor
Energy	Very much energy saving, especially oil saving or substituting by gas or coal Electricity saving to a certain extent Using renewable energy sources Gas saving in the long run
Materials	Materials saving in general Substituting energy-intensive materials by less energy-intensive materials
Capitals	More use of capital allowed in the medium term, in the long term less capital-intensive production necessary
Other characteristics that are not derived from a model should be added, such as:	Environmental protection (air, water, soil, etc.) Better working conditions Special risks

- In material-intensive production, reduction of material usage through more sophisticated construction, substitution of less energy-intensive materials, improvement of construction so that materials can be more easily recycled, and substitution of electronics for mechanical aggregates.
- In labor-intensive production, substitution of high qualification jobs (which might be reached by a hierarchy of substitution where low qualification jobs are substituted by medium qualification jobs, and these by higher qualifications and so on) for low qualification jobs, and trying to restrict labor-saving new technologies to applications where a real improvement of the production process is achieved.

These results, of course, might be derived by a mental model without any computer simulation. But the use of a computer model is advantageous in at least some respects:

- more factors and areas can be taken into account simultaneously than in a mental model
- the degree of importance of the different changes can be obtained
- the most important areas can be seen
- research can be done more systematically.

CONCLUSIONS

The main question to be answered in this paper was whether national models, or at least special kinds of national models, might be useful for innovation policy. The chapters dealing with the innovation process and the measurements of the economic effects of innovation have shown that even the fundamental questions concerning these subjects are not yet answered satisfactorily. Therefore it is, of course, more difficult to derive results from more globally oriented national models.

It should be stated clearly that national models are not useful for answering specific questions related to the innovation process. But the investigation has shown that they seem to be useful in the following three respects.

(1) Showing the economic effects of technological change.

(2) Deducing desirable characteristics for future innovations.

(3) Giving hints for new fields of innovation.

Quick answers should not be expected by just looking at the results; however, results seem to justify continuing in the way outlined in this paper. There is much detailed research to be done, which might go in three directions: (1) comprehensive overview of the specific changes of all technological input factors for some or all sectors (and trying to specify the major technological changes which caused these changes); (2) detailed analysis of desirable characteristics for future innovations in one or more sectors including consideration of all direct and indirect influences; (3) showing the fields or future innovations where these characteristics can be applied favorably.

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TECHNOLOGICAL INNOVATION AND PRODUCTIVITY GROWTH IN US AGRICULTURE*

Yao Chi Lu**

INTRODUCTION

A possible declining rate of agricultural productivity growth is one of the most important issues in US agriculture today. After two and a half decades of accelerated growth, the rate of productivity growth in US agriculture began to slow in the late sixties. From 1939 to 1965, total factor productivity, as measured by output per unit of all inputs, increased 2.1 percent annually. However, from 1965 to 1970 total factor productivity increased only 0.4 percent annually (US Department of Agriculture 1978). Although the rate of productivity growth increased since 1970 (1.7 percent), the declining productivity growth rate in the late sixties has alarmed many people. Some fear that the limit to agricultural productivity growth has been reached.

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* This paper is based on the results and methodology presented in the report "Prospects for Productivity Growth in US Agriculture," by Yao Chi Lu, Philip Cline, and Leroy Quance, United States Department of Agriculture, ESCS, Agricultural Report No.435, September 1979. In this paper, projections of agricultural productivity were updated and extended from the year 2000 to 2025 and two scenarios were added to evaluate the effects of reduced funding for research and extension on agricultural productivity growth.

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While the rate of agricultural productivity growth may be declining, demand for food, especially export demand, is increasing. It has been projected that the developing countries' population of 2.8 billion will reach at least 4.8 billion by the turn of the century, whereas the population of the developed countries will increase from 1.2 billion to 1.5 billion. To feed this growing world population, even at current low nutritional levels, annual world food grain production must increase from the current 1.3 billion tonnes to about 2.0 billion tonnes by 2000. If nutritional gains are to be made in developing countries, annual food grain production will have to reach about 3.0 billion tonnes (National Academy of Sciences 1976). To close this apparent gap between the production and demand for food, we must increase productivity.

The purposes of this paper are to examine historical changes in agricultural productivity, to identify factors which affect productivity change, to establish quantitative relationships between productivity and its sources, and to simulate future productivity growth paths to the year 2025 under alternative scenarios.

TECHNOLOGY AND PRODUCTIVITY: HISTORICAL PERSPECTIVE

Technology is generally recognized as one of the most important forces behind productivity growth. Generally, when an agricultural technology is introduced for commercial adoption, its initial impact on productivity is small. Only a few farmers adopt the new technology, and they cannot evaluate its profitability immediately. As the early adopters benefit, more farmers are attracted to the technology, and productivity then grows at an exponential rate. Eventually, the growth rate declines as the technology's potential is realized. Thus, productivity grows along a classical S-shaped growth curve.

However, as productivity approaches its limit under a given state of technology, other new technologies may emerge. Emergence of a new technology breaks through the earlier limit and shifts productivity growth to a new S-shaped growth curve.

Thus, whether limits to agricultural productivity growth exist, then, depends on whether scientists can continue to produce commercially viable new technologies.

Let's use this hypothesis to examine US agricultural productivity growth over the past 200 years. These 200 years can be divided into four periods according to the major sources of technological change: the American Revolution to the Civil War, the Civil War to World War One, World War One to World War Two, and World War Two to the present. We identify an S-shaped growth curve for each period and view the productivity growth curve for the past 200 years as containing a series of shorter, but successive S-shaped growth curves (Figure 1).

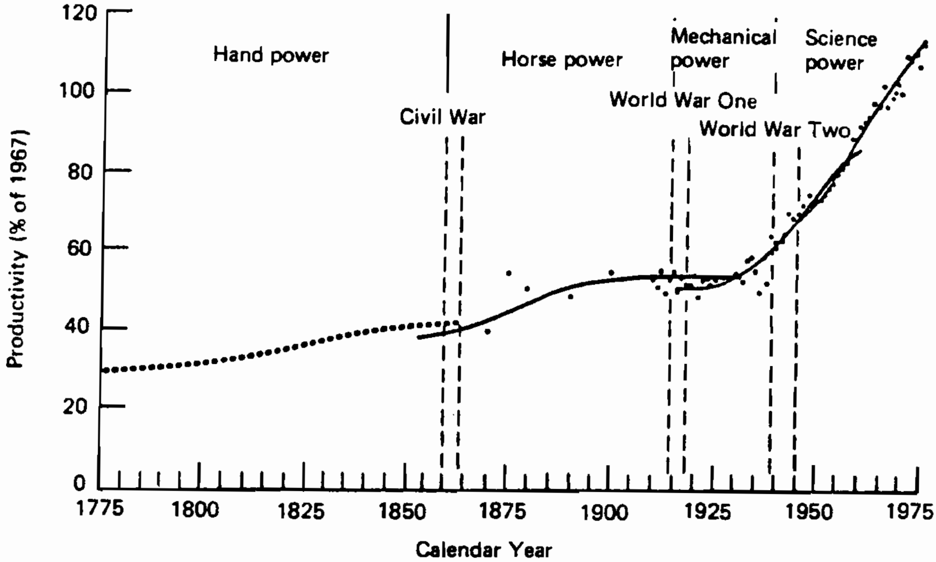

FIGURE 1 US agricultural productivity growth during the past 200 years.

The American Revolution to the Civil War (Hand Power)

During this first period of American agriculture, technology was dominated by hand power. After the American Revolution, leaders such as George Washington and Thomas Jefferson invented and adopted many improved farming practices, mixed fertilizers, and hand-powered tools and machinery. Productivity increased gradually. Although lacking any measure of agricultural productivity during this period, we conclude that it grew very slowly in the late 1770s and early 1800s and leveled off about 1830 when the limits to hand power were approached (the dotted line in Figure 1).

The Civil War to World War One (Horse Power)

Toward the end of the hand power epoch, many horse-drawn machines, including reapers, grain drills, corn shellers, hay bailing presses, and cultivators, were invented. These new machines cost more than labor, so farmers lacked incentive to switch. But during the Civil War, a war-induced labor shortage, high demand for food and fiber, and high food prices led farmers to adopt labor-saving horse-drawn machines. Productivity accelerated after the Civil War until about 1880 and then tapered off toward the beginning of World War One as the potential of horse power was approached.

World War One to World War Two (Mechanical Power)

The first practical self-propelled gasoline tractor was built by John Froelich in 1892. Internal combustion engine tractors were not widely adopted, however, until World War One, when high farm prices and high wages relative to machinery prices caused rapid conversion from horse power to mechanical power. Increasing demand for food and fiber, fostered by the general economic recovery and war in Europe, accelerated mechanization of US agriculture. Transition from horse power to mechanical power was virtually completed by World War Two. But, unlike previous epochs, productivity growth accelerated rather than leveling off because of a continuous flow of other technologies into agricultural production.

World War Two to the Present (Science Power)

Mechanization is only one cause of the phenomenal growth in agricultural productivity since World War One. Genetic, chemical, and mechanical engineering research developed many new technologies. Farmers increased crop yields through irrigation, lime and chemical fertilizers and insecticides, widespread use of legumes, and adoption of improved varieties. They adopted improved breeds, practiced artificial insemination of livestock, and increased livestock feeding efficiency. Each new technology shifted the productivity growth curve upward before it could reach the growth limits of the existing technology.

PRODUCTION AND DISSEMINATION OF TECHNOLOGY

Productivity growth results from the interactions of many factors: farm policies and programs, weather, relative prices of production factors, and technology. Weather not only directly affects short-term productivity owing to fluctuating yields from year to year and long-term productivity owing to weather cycles, but can also influence adoption of new technologies.

Technology is the most important factor contributing to long-term productivity growth. However, technological advance does not occur automatically. Investments in research and development are required to generate new knowledge. New knowledge may be applied by farmers directly or embodied in capital or intermediate inputs.

To affect agricultural productivity, new knowledge must be disseminated to, and adopted by, farmers. The rate of diffusion of a new technology is affected by profitability, degree of uncertainty, and capital requirements (Mansfield 1966, p.123).

Profitability is by far the most important determinant of the rate of diffusion. Griliches' (1958) study indicates that hybrid corn diffused more rapidly in areas where it was more profitable than in areas where it was less so. The profitability of a new technology depends upon relative prices and productivity, that is, the prices of outputs relative to the prices of inputs, the prices of new inputs relative to the prices of old inputs, and the productivity of the new technology relative to the productivity of the old technology.

Uncertainty about a new technology is another important factor in determining its diffusion. The degree of uncertainty is reduced by increased education and training which enable farmers better to absorb, understand, and evaluate information about new products, new inputs, and new processes. Therefore, increasing farmers' education and increasing extension activities will reduce uncertainty about a new technology. Because many new technologies take the form of physical capital inputs (such as tractors), adoption also depends on availability of credit to finance the purchase of new capital goods.

AGRICULTURAL PRODUCTIVITY SIMULATION MODEL

As indicated, to sustain US productivity growth we must continually invest in research and extension (R&E) to produce new technologies that will feed into the agricultural production system. Is current support for agricultural R&E programs adequate? If not, how much more should we invest?

First, we need to estimate relationships between productivity growth and public R&E expenditures and other sources of growth. As many factors influence productivity growth, we can include only the most important, observable, and measurable variables in the agricultural productivity simulation model. We omit farm programs and relative prices, although important, because we have not been able to separate the effect of prices from the impact of technological change. And attempts to measure the impacts of farm programs on agricultural productivity have not been successful, primarily because of measurement and data problems. We also exclude private research expenditures for lack of data. Thus, our study attributes changes in agricultural productivity to production-oriented public agricultural R&E expenditures, the education level of farmers, and weather.

Based on the above observations, the productivity growth model is specified as:

$$P_t = \prod_{i=0}^{n} R_{t-i}^{\beta_i} \, E_t^{\beta_{n+1}} \, e^{\beta_{n+2} W_t} \tag{1}$$

where P_t = the value of the aggregate productivity index for US agriculture in year t, R_{t-i} = the lagged values of production-oriented R&E expenditures* aiming directly at increasing agricultural production, E_t = the value of an index of educational attainment of farmers in the current period, W_t = the value of a US weather index in the current period, n = the length of lag measured in years, and β = the coefficient.

*Non-production-oriented R&E expenditures such as rural development food and nutrition, and agricultural marketing were originally included as a variable in the model, but because the coefficient of the variable was not statistically significant, that variable was eliminated.

It is hypothesized that the form of the distributed lag weights follows an inverted U shape.

To estimate the parameters, equation (1) was transformed into the logarithmic form. Durbin's (1969) two stage procedure and Almon's (1965) polynomial lag method were employed to fit the equation to the time series data for the US agriculture. The results are as follows (see Lu *et al.* 1979):

$$P_t = R_t^{0.0009} R_{t-1}^{0.0017} R_{t-2}^{0.0024} R_{t-3}^{0.0029} R_{t-4}^{0.0033} R_{t-5}^{0.0036} R_{t-6}^{0.0037} R_{t-7}^{0.0037} R_{t-8}^{0.0036}$$

$$R_{t-9}^{0.0033} R_{t-10}^{0.0029} R_{t-11}^{0.0024} R_{t-12}^{0.0017} R_{t-13}^{0.0009} E_t^{0.7851} e^{0.0020} W_t .$$

Results indicate that a 1 percent increase in public R&E expenditures in a specific year will increase productivity gradually for the first few years, reach its peak impact within 6 to 7 years by increasing agricultural productivity by 0.0037 percent each year, then decline gradually for the following 6 years at the end of which time its impact is negligible. The total increase in productivity over the 13-year period is 0.037 percent. We also estimated that a 1 percent increase in the education index in any given year will increase productivity 0.78 percent.

Agricultural productivity depends heavily on nature. During 1900 to 1972, weather variations caused productivity to rise or fall below its normal growth level more than 2.2 points in one out of 3 years (on the average). Should weather be 1 percent more favorable in a given year, agricultural productivity would increase 0.2 percent. However, given the present state of knowledge, it is unlikely that such technological breakthroughs will occur by the year 2025.

FUTURE PRODUCTIVITY GROWTH

Since both current and future research investment decisions affect the path of productivity growth, we need a set of assumptions representing possible decisions that result in certain rates of R&E investment.

We consider the following five scenarios:

- No R&E, all public R&E expenditures to be cut starting in 1980.
- Negative R&E growth, public R&E expenditures are maintained at −2 percent per year in real terms.
- Zero R&E growth, public R&E expenditures are maintained at a zero growth rate, i.e. nominal increases in R&E just keeping pace with inflation.
- Baseline, real R&E growth is 3 percent per year, the same as during the 1929 to 1972 period.
- High R&E growth, a 7 percent real R&E growth rate is assumed to make more unprecedented new technologies available.

For all scenarios, the farmers' educational attainment is assumed to increase along an S-shaped curve. Since 1939 the educational attainment of farmers has advanced at an increasing rate. However, there is a practical limit to how many years of education a farmer can undertake. It is assumed that the educational attainment will eventually level off and approach a limit. It is hypothesized that the index of educational attainment will follow an S-shaped curve of the form shown in equation (2) with an upper limit at which all farmers have at least 4 years of post-high-school education.

$$E_t = \frac{k}{\left[1 + be^{-at}\right]} \tag{2}$$

where: E_t is the index of educational attainment of farmers in year t, k is the upper limit of the education index, and a and b are parameters. On fitting the education index data from 1939 to 1972, equation (2) yields:

$$\hat{E}_t = \frac{424}{\left[1 + 3.682e^{-0.029t}\right]}$$

which was used to project the education index through the year 2025.

Weather was included in the model as a normally distributed stochastic variable where probability distribution was estimated from the measured weather index from 1900 to 1972. The results indicate a mean value of 100.6 and a standard deviation of 11.4.

The projected education index and the alternative R&E growth rates were used to project future agricultural productivity. To simulate weather conditions for the 1980 to 2025 period, 200 values of the weather index were generated for each future year from the normal distributions. For each year, the mean, the standard deviation, and the range of the productivity index were computed. However, only the mean value of the productivity index is reported in this paper.

The Baseline Projection

The projected productivity index under the baseline scenario is shown in column 4 of Table 1. In this scenario the expected value of the 2025 with annual rates of increase of 1.1 percent for the 1978 to 2000 period and 0.8 percent for the 2000 to 2025 period. Although the limit to growth will not be reached by 2025, the long-term rate of productivity growth is declining.

This declining rate of productivity growth indicates that currently productivity growth might have entered the era of diminishing growth rate in the growth curve of the science power era which began at the end of World War Two. Since the 3 percent annual increase in public support for R&E assumed in the scenario is probably just enough to produce a series of minor technologies to stay on the current growth curve, no new unprecedented technologies are expected to emerge to shift productivity to a new growth curve.

TABLE 1 Projections of US agricultural productivity, 1980–2025 (1967 = 100).

	Projected productivity indexes under alternative scenarios				
	No R&E	Negative R&E	Zero R&E	Baseline	High R&E[a]
1978	117.0	117.0	117.0	117.0	117.0
1985	104.4	126.3	126.4	126.6	126.8
1990	87.9	132.6	133.0	133.7	134.5
1995	86.3	138.3	139.3	140.7	142.6
2000	90.1	144.0	145.5	147.8	150.8
2005	93.8	149.4	151.6	154.8	159.2
2010	97.6	154.6	157.6	161.8	167.5
2015	101.1	159.8	163.3	168.7	175.8
2020	104.5	164.6	168.9	175.3	184.1
2025	107.8	169.2	174.2	182.4	192.4

[a]This projection does not account for the impacts of emerging unprecedented technologies, discussed later.

Effect of Reduced Funding

Reduced public support for R&E is one of the major concerns in agriculture. The 1967 to 1980 data indicate that USDA funding of research and education programs increased at about 1 percent a year in real terms. State funds, having grown at a faster rate, bring the federal state combined total real growth to about 2 percent per year, in contrast to a 3 percent annual increase assumed under the baseline scenario (Table 1). (The data on USDA funding of research and education programs were obtained from internal budget information and the state data were derived from the Current Research Information System.)

To estimate the long-range effect of reduced funding for R&E, productivity growth was projected assuming zero and −2 percent R&E growth rates, and no R&E. Under the zero growth scenario, the agricultural productivity index is expected to increase from 117 in 1978 to 146 in 2000 and to 174 in 2025 (column 3, Table 1) and the rate of growth will decrease to 1.0 percent per year for the 1978 to 2000 period and 0.7 percent per year for the 2000 to 2025 period.

With current inflation rates exceeding 10 percent a year, nominal increase in R&E funding of less than the inflation rate will result in a negative rate of increase. Under the negative R&E growth scenario, which assumes that the real R&E expenditures will be reduced 2 percent per year starting in 1980, productivity increases at a much slower rate, as shown in column 2 of Table 1. The productivity index is projected to increase from 117 in 1978 to 144 in 2000 and 169 in 2025. The annual rate of increase will be 0.9 percent from 1978 to 2000, and 0.6 percent from 2000 to 2025.

Because of long lags required to create a new technology, reduced funding for R&E has very little effect in the short-term, but it produces tremendous impact in agricultural productivity in the long-term. For example, the difference in the productivity index between the baseline and the negative R&E growth scenario is less than one index point in 1990, but by 2025 the difference increases to 13 index points.

The effect of reduced funding for R&E is dramatized in the no R&E scenario, which cuts off all public R&E activities starting in 1980 (see column 1 of Table 1 and Figure 2). Productivity does not plummet immediately, owing to the residual effects of previous investment in R&E, but it declines. Since the average length of the lag between investment in R&E and its ensuing effect on productivity is 13 years for US agriculture, the productivity index reaches its minimum in 1993 and then increases gradually owing to the greater educational attainment of farmers.

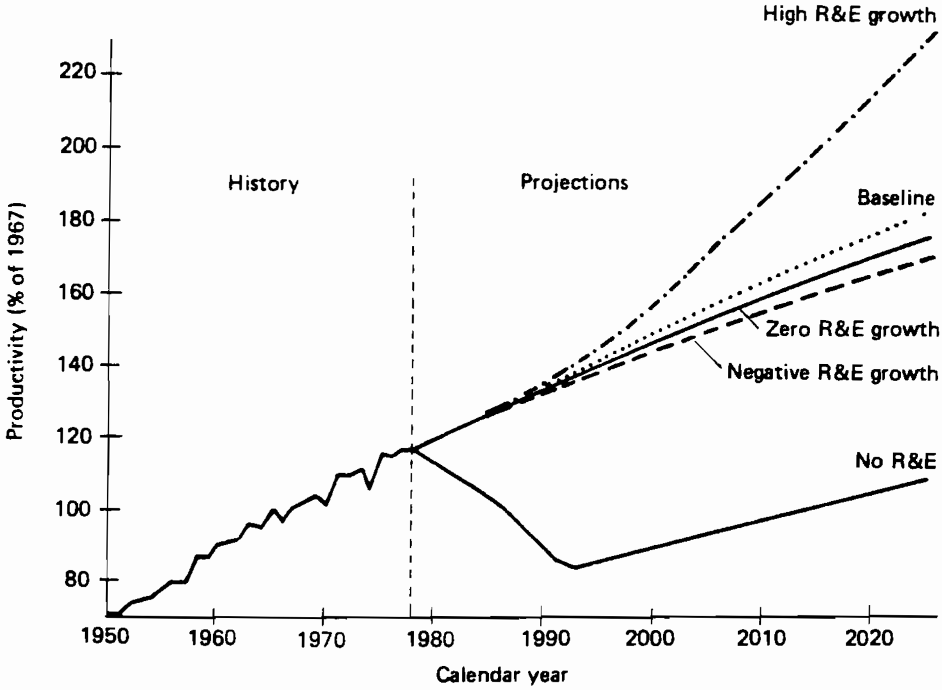

FIGURE 2 Productivity growth under alternative scenarios.

TECHNOLOGICAL BREAKTHROUGHS

Under the high R&E scenario, public investment in R&E is assumed to increase at 7 percent annually. We assume that this greater support for R&E will lead to development and adoption of unprecedented new technologies which shift productivity growth to a new S-shaped curve.

What might these new technologies be and how will they affect crop and livestock production? To answer these questions, we conducted a study in 1974. Existing literature on emerging technologies was reviewed, and agricultural researchers were interviewed using modified Delphi and relevance tree methods.

Emerging Technologies

Our interviews suggested the following 12 emerging technologies as having significant impact potential for agricultural productivity (Cline 1974).

(1) Enhancement of photosynthetic efficiency: improving the amount of photosynthesis in crops.

(2) Water and fertilizer management: increasing efficiency of inputs used in production through combined water and fertilizer management systems.

(3) Crop pest control strategies: adopting total pest management systems that incorporate resistant varieties, sex attractants, juvenile hormone analogs, and other biological controls.

(4) Controlled environment or greenhouse agriculture: using plastic or glass covers over plants with or without heat and carbon dioxide.

(5) Multiple and intensive cropping: double cropping and intensive cropping.

(6) Reduced tillage: expanding use of minimum or reduced tillage techniques.

(7) Bioregulators: using certain natural and synthetic compounds to regulate the ripening and senescence of horticultural products.

(8) New crops: developing new and improved hybrids and searching for alternate food crops.

(9) Bioprocessing: extending traditional agricultural production to convert unpalatable raw products into edible protein, fats, and carbohydrates.

(10) Antitranspirants: inhibiting the tendency of plants to lose water through evaporation.

(11) Developing plants with increased resistance to drought and salinity.

(12) Twinning: enhancing multiple births in beef cattle.

Most researchers believe that adoption of many of the above technologies will be required to maintain present productivity growth, i.e. their adoption is implicit in our base projections. Only three technologies, twinning in beef cattle, bioregulators, and photosynthesis enhancement, are believed to have the potential for unprecedented impacts on agricultural productivity; their impacts are included in the high R&E scenario.

Impact Analysis

To estimate the expected impacts of each of these three emerging technologies on agricultural productivity, we hypothesized the following equation:

$$X_{kj} = \sum_{t=1}^{k-1} q_{tj}\, a_{k-t}\, r_j\, f_j$$

where: X_{kj} is the expected value of the impacts of the jth technology in the kth year; q_{tj} is the probability of occurrence of the jth technology in year 5, where $t = 1,2,\ldots,n$ and year 1 denotes the first year of projections; a_{k-t} is the percentage of adoption of the new technology k , t years after commercial introduction; r_j is the output of the jth commodity as a percentage of the total output, and f_j is the net increase in productivity of the jth commodity of the new technology.

Adoption profiles vary among different technologies. The length of time from introduction to the point that adoption reaches its maximum ranges from about 35 years for twinning in beef cattle production to over 50 years for photosynthesis enhancement. For each technology, the adoption rate is assumed to increase along an S-shaped growth curve as shown in Figure 3, regardless of when the technology is introduced.

On the further assumption that the impacts of the three technologies are additive, the total expected increase in productivity due to the adoption of the three technologies in year k can be obtained as:

$$X_k = \sum_{j=1}^{3} X_{kj} = \sum_{j=1}^{3} \sum_{t=1}^{k-1} q_{tj}\, a_{t-k}\, r_j\, f_j$$

The estimated impacts of these three technologies on productivity projections are incorporated in the high R&E scenario.

Expected productivity growth incorporating the effect of adopting twinning, bioregulators, photosynthesis enhancement, and the combination of all three technologies are listed in columns 1 through 4 of Table 2.

For the year 2000, the expected values of the productivity index under the high R&E scenario are boosted to 152, 155, and 151 owing to twinning, bioregulators, and photosynthesis enhancement respectively and to 156.0 from the effect of all three technologies. The annual rate of productivity growth is 1.3 percent.

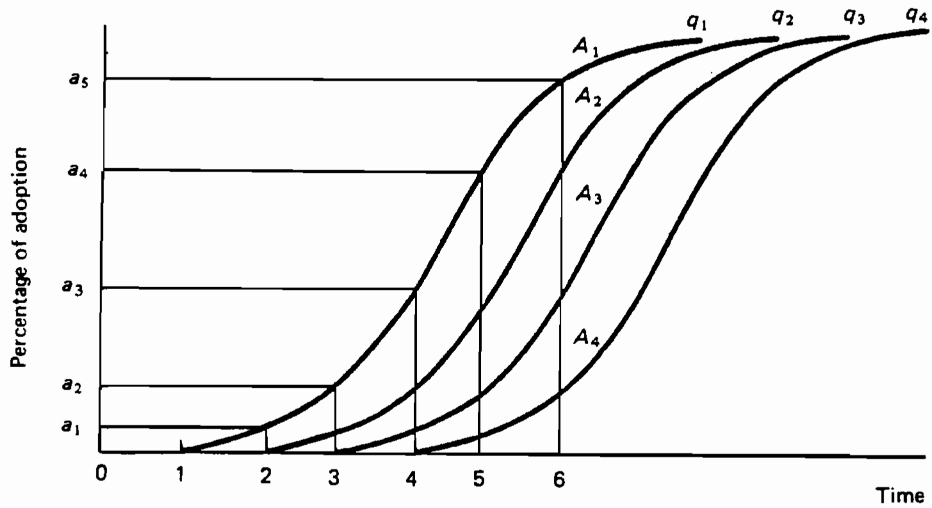

FIGURE 3 Profile of technology adoption by farmers.

TABLE 2 Impacts of emerging technologies on agricultural productivity, 1980–2025, under the high R&E scenario (1967 = 100).

	Expected values of productivity index adjusted for given impacts			
	Twinning	Bioregulators	Photosynthesis enhancement	All three technologies
1978	117.0	117.0	117.0	117.0
1985	126.8	126.9	126.8	126.9
1990	134.5	135.1	134.5	135.1
1995	142.7	144.4	142.7	144.6
2000	152.2	154.5	151.2	156.3
2005	163.9	164.6	160.5	170.6
2010	175.9	174.1	170.2	185.2
2015	187.0	183.0	181.0	199.4
2020	197.2	191.8	193.2	214.0
2025	206.9	200.7	206.9	229.7

Because most of these technologies would not be ready for commercial adoption until the 1990s and it takes decades to complete the adoption process, their expected impacts on agricultural productivity by the year 2000 will be small. Thus the projected productivity growth rate of

1.3 percent per year from 1980 to 2000 is still less than the 1.6 percent rate observed over the past 50 years. However, by 2025, as adoption becomes widespread, productivity would be expected to grow to an average of 1.6 percent per year from 2000 to 2025, thus attaining the historical average of the past 50 years.

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FACTOR PROFILES OF THE INNOVATION PROCESS AS AN ANALYTIC TOOL FOR INNOVATION POLICY

Heinz-Dieter Haustein

INTRODUCTION

Factor analysis can be a powerful tool for many aspects of the study of innovation. Prominent studies using factor analysis techniques include Myers and Marquis (1969) and project SAPPHO.* Thus far, documented use of factor analytic techniques has been largely confined to market economies, and has been shaped by the economic realities and evaluative criteria of market economies.

The present paper describes a parallel attempt to use factor analytic techniques in a fashion that is appropriate to the managerial needs of a planned economy.

STUDY DESIGN

Central management and planning plays an important role in planned economies. Among the information that planned economy managers need is what, within their economic system, stimulates and inhibits technological innovation. Therefore we designed our study to address the questions: How strong is the influence of factors that inhibit the innovation process on the level of state-owned enterprises? How effectively do the firms use their own ideas and measures to overcome bottlenecks and barriers in the innovation process?

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*These are described in greater detail in the accompanying paper by Geschka *et al.* (1980).

On the basis of our observation of innovative activity in planned economies we hypothesized 20 variables that may block innovation in planned economies. This list was tested on a sample of 15 managers from state-owned enterprises, and on the basis of their reaction to it, it was increased to 26 variables (listed on the left column of Table 1). Then we randomly chose 32 successful innovations (nine products, nine processes, seven materials, seven manufacturing processes) in 32 enterprises, and asked the managers responsible for the innovations.

(1) what degree of influence p each of the 26 blocking variables had on the innovation in question, and

(2) what degree of influence q the firm's own measures had in reducing blocking variables.

The degree of influence was measured on a scale of 0 to 4 with the following designations: 0 = not important, 1 = of little importance, 2 = medium importance, 3 = highly important, 4 = extremely important.

RESULTS

Effectiveness in Overcoming Barriers

Our aim was to identify the capacity of the firm to overcome barriers and bottlenecks in the innovation process. We expected that the activity q of a firm might somehow be correlated with the intensity p of blocking variables. What were the results of this investigation?

The correlation coefficient between q, ability to overcome barriers, and p, the barrier's importance, was 68.28% over 32 innovations and 79.22% over 26 variables. Both are statistically significant at an error level of less than 0.1%. It was necessary to investigate more deeply the specific patterns of influence for certain combinations of variables. Table 1 shows the number of statistically significant correlations between the variables.

According to this and to the average values of p and q we obtained the following results (Table 2). The five variables found to be most important in inhibiting innovation in the 32 firms were:

- inability to master the process after handing over by the development group (6)
- differences between managers and experts (10)
- failures in development stages (5), and
- failure of the management (insufficient engagement of responsible managers) (8).

Some blocking variables were found to be highly interconnected, indicating that they operate together in reality, and should be managed as a system of interrelated parts. The most interlinked blocking variables were:

- differences between managers and experts (10)

TABLE I Number of statistically significant correlation coefficients between 26 variables influencing innovations for inhibiting intensity p and promoting intensity q.

No.	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	Insufficient supply from the supplier industry	–																									
2	Technical difficulties		–																								
3	Stress caused by other production tasks			–																							
4	Insufficient supply of machines and means of rationalization				–																						
5	Developmental failures not abandoned					–																					
6	Inability to master the process after release by the development group						–																				
7	Lack of personnel in research and development							–																			
8	Failures of management; insufficient interest on the part of managers								–																		
9	Long time required by managers for coordination									–																	
10	Differences of opinion between managers and experts										–																
11	Failures in preparation for production											–															
12	Delay in construction activities												–														
13	High costs; planned economy not reached													–													
14	Insufficient technological and qualitative level														–												
15	Conservative and obsolete views															–											
16	Inexact and changing objectives																–										
17	Delay in recognition of problems; failures in communication																	–									
18	Changing demand																		–								
19	State orders limiting the project																			–							
20	Insufficient transfer of know-how between branches																				–						
21	Economizing measures																					–					
22	Unfavorable price relations																						–				
23	Insufficient special knowledge																							–			
24	Uncoordinated development among several branches																								–		
25	Better solutions from competitors																									–	
26	New solutions replacing the initial project																										–
	Number of significant relations for p	6	3	4	3	2	2	6	3	0	11	3	6	0	1	9	2	5	7	5	2	1	1	1	9	7	8
	Number of significant relations for q	6	3	8	3	1	1	3	4	3	6	4	3	3	2	10	7	11	7	10	12	5	8	3	7	3	6
	Sum of significant relations for p and q	12	6	12	6	3	3	9	7	3	17	7	9	3	3	19	9	16	14	15	14	6	9	4	16	10	14

NOTES: ◢ correlation for p; ◤ correlation for q; ■ correlation for both p and q. Level of significance: 0.05.

TABLE 2 Rank order of variables by various measures.

No.	Variable	Average p	Average q	$\Sigma pq\ q$	Relations between		
					p	q	Sum
1	Insufficient supply from the supplier industry	19	18	22	8	11	9.5
2	Technical difficulties	10	6	15	14.8	19.5	19
3	Stress caused by other production tasks	12	9	4	12	5.5	9.5
4	Insufficient supply of machines and means of rationalization	2	2.5	7	14.5	19.5	19
5	Developmental failures not abandoned	4	2.5	3	18.5	25.5	24
6	Inability to master the process after release by the development group	1	10.5	19	18.5	25.5	24
7	Lack of personnel in research and development	24	23	1	8	19.5	13.5
8	Failures of management; insufficient interest on the part of managers	5	4.5	9.5	14.5	14.5	16
9	Long time required by managers for coordination	7	1	2	25.5	19.5	24
10	Differences of opinion between managers and experts	3	14	8	1	11	2
11	Failures in preparation for production	25	25	25	14.5	14.5	17
12	Delay in construction activities	17	19.5	17	8	19.5	13.5
13	High costs; planned economy not reached	8	7	12	25.5	19.5	24
14	Insufficient technological and qualitative level	11	4.5	5	22.5	24	24
15	Conservative and obsolete views	18	16	16	2.5	3.5	1
16	Inexact and changing objectives	13	22	20	18.5	8	13.5
17	Delay in recognition of problems; failures in communication	21	19.5	18	10.5	2	3.5
18	Changing demand	26	24	21	5.5	8	7
19	State orders limiting the project	22	21	23	10.5	3.5	5
20	Insufficient transfer of knowhow between branches	23	26	26	18.5	1	7
21	Economizing measures	15	12.5	6	22.5	13	19
22	Unfavorable price relations	16	8	13.5	22.5	5.5	13.5
23	Insufficient specialist knowledge	6	17	24	22.5	19.5	21
24	Uncoordinated development among several branches	14	12.5	9.5	2.5	8	3.5
25	Better solutions from competitors	9	10.5	13.5	5.5	19.5	11
26	New solutions replacing the initial project	20	15	11	4	11	7

- conservative and obsolete views (15)
- uncoordinated development in social branches (24)
- new own solutions, overcoming the initial project (26), and
- changing demand.

The most important variables promoting innovation were:

- better coordination with superposed management (9)
- own production of rationalization means (4)
- reduction of failures in development stages (5)
- improvements in management (8)
- improvements in technological and qualitative level (14).

As with blocking variables, promoting variables were found to be interconnected. The most interlinked promoting variables were:

- better knowhow transfer with other branches (20)
- faster recognition of problems and improvement in information (17)
- better adaptation to new state orders and laws (19)
- positive changes in views and approaches (15)
- reducing stress by other production tasks (3).

IDENTIFICATION OF THE MAIN FACTORS INHIBITING OR PROMOTING INNOVATIONS

In the overall picture, mastering the innovation process has several major components. First, as many specialists stress, there must be creative or innovative potential. However, if this potential is not channeled in an effective direction, the results will be disappointing. Therefore a second required component is appropriate firm strategy and long-term orientation. Innovation potential and appropriate strategy, however, will not succeed in bringing about innovation if the innovative unit faces heavy stress from other production tasks. Capability of mastering ongoing processes is therefore the third component of success. The innovation process is a very complex process touching the whole network of supplier and buyer relations. Therefore a fourth factor is cooperation and coordination.

These four components of success are more or less related to the main stages of the innovation process and therefore we came to the following classification (Table 3).

We classified the 26 variables in a matrix juxtaposing the four components I, S, O, C, to the four stages R&D, production, marketing, and management, on the basis of our knowledge of system dependences. To investigate the hypothesized relationships we used multivariate factor analysis. Multivariate factor analysis permits identification of the main factors among many variables by investigating their latent intercorrela-

TABLE 3 Determinants and stages of the innovation process and their measurement through the variables.

Component of innovation success	R&D	Prediction	Marketing	Management in all stages
Innovation potential *I*	2,5,7,11,14,26	2,6,13,	14	6,8,10,15,23
Strategic orientation *S*	1,7,14,17	22	18	9,10,15,16,17
Capacity for ongoing processes *O*	3,7	3,13,21	18	8,9,10
Cooperation and coordination *C*	1,4,24	1,4,20	20.25	1,9,10,17.19

tion. As a criterion we used factor loading of a variable at a level of a least 0.40. By the criteria we identified seven main factors in the case of inhibiting variables (Table 4) and also seven main factors in the case of promoting variables (Table 5). If we relate these factors to determinants and stages of the innovation process we find that:

- innovation potential and cooperation and coordination play their greatest role both as blocking and as promoting variables in the R&D stage
- strategic orientation, the cost and know-how factors and economic mechanisms (price relations, planning mechanisms and other incentives) were important in all stages
- strategic orientation, capacity for ongoing cooperation and coordination were important in promoting variables in all stages
- innovation potential was important as a promoting factor in the production stage.

Innovation potential, strategic orientation, cooperation, and coordination were identified as the main determinants of the strongest inhibiting variables. Conversely the development of innovation potential was not found to play a major role as a promoting variable. Three other determinants were also identified as important:

- economic mechanism, including price relations, planning mechanisms and other incentives
- knowhow factor, and
- cost factor.

And so we arrived at an improved scheme for factor analysis (Table 6). This gives us an impression of the practical complexity of innovation management.

An effective way of displaying the influence of inhibiting and promoting variables in a given firm is through use of what is called a factor profile — a graph displaying the numerical values assigned to blocking and promoting variables as point locations of inhibiting variables.

By means of such profiles we can begin to recognize consistent patterns in the organization of innovation by industry and for the nation as a whole. Furthermore by analyzing the individual profiles of firms and comparing them with the profiles on industry or societal levels, we can gain

Table 4 goes here

TABLE 4 Variables inhibiting innovation and their factor configurations.

No.	Variable	Loading factor
Factor 1		
11	Failures in preparation for production	0.81
7	Lack of personnel in research and development	0.69
15	Conservative and obsolete views	0.63
25	Better solutions from competitors	0.62
19	State orders limiting the project	0.41
Factor 2		
18	Changing demand	0.74
16	Inexact and changing objectives	0.70
1	Insufficient supply from the supplier industry	0.66
17	Delay in recognition of problems; failures in communication	0.55
12	Delay in construction activities	0.52
Factor 3		
24	Uncoordinated development among several branches	0.66
21	Economizing measures	0.64
4	Insufficient supply of machines and means of rationalization	0.61
26	New solutions replacing the initial project	0.55
12	Delay in construction activities	0.41
Factor 4		
22	Unfavorable price relations	0.75
3	Stress caused by other production tasks	0.74
19	State orders limiting the project	0.46
Factor 5		
6	Inability to master the process after release by the development group	0.72
2	Technical difficulties	0.60
23	Insufficient specialist knowledge	0.42
Factor 6		
13	High costs; planned economy not reached	0.62
21	Economizing measures	0.42
19	State orders limiting the project	0.41
Factor 7		
8	Failures of management; insufficient interest on the part of managers	0.67
10	Differences of opinion between managers and experts	0.58
5	Developmental failures not abandoned	0.54

TABLE 5 Variables promoting innovation and their factor configurations.

No.	Variable	Loading factor
Factor 1		
17	Delay in recognition of problems; failures in communication	0.87
20	Insufficient transfer of knowhow between branches	0.84
12	Delay in construction activities	0.64
11	Failures in preparation for production	0.59
15	Conservative and obsolete views	0.42
1	Insufficient supply from the supplier industry	0.40
Factor 2		
25	Better solutions from competitors	0.71
24	Uncoordinated development among several branches	0.67
26	New solutions replacing the initial project	0.67
22	Unfavorable price relations	0.66
15	Conservative and obsolete views	0.65
14	Insufficient technological and qualitative level	0.57
Factor 3		
23	Insufficient specialist knowledge	0.74
16	Inexact and changing objectives	0.68
10	Differences of opinion between managers and experts	0.66
7	Lack of personnel in research and development	0.63
18	Changing demand	0.50
14	Insufficient technological and qualitative level	0.45
Factor 4		
4	Insufficient supply of machines and means of rationalization	0.83
21	Economizing measures	0.62
1	Insufficient supply from the supplier industry	0.41
13	High costs; planned economy not reached	0.41
Factor 5		
3	Stress caused by other production tasks	0.63
10	Differences of opinion between managers and experts	0.50
14	Insufficient technological and qualitative level	0.45
19	State orders limiting the project	0.43
8	Failures of management; insufficient interest on the part of managers	0.42
Factor 6		
6	Inability to master the process after release by the development group	0.73
4	Insufficient supply of machines and means of rationalization	0.58
13	High costs; planned economy not reached	0.50
Factor 7		
9	Long time required by managers for coordination	0.68
8	Failures of management; insufficient interest on the part of managers	0.44

TABLE 6 Determinants and factors at various stages of the innovation process, as measured by 26 variables.

Stage	Determinant and factor													
	1 Innovative potential (I)		2 Strategic orientation (S)		3 Cooperation and coordination (C)		4 Capacity for mastering ongoing processes (O)		5 Economic mechanism (E)		6 Knowhow (K)		All	
	p	q	p	q	p	q	p	q	p	q	p	q	p	q
Research and	*11*		7	*17*	*24*	*25*	3				5			
development	*7*		14	*20*	*21*	*24*	7				12			
	15		17	12	*4*	*26*					20			
	25			11	26	22					23			
	24			*15*	12	15								
	19			1	(3)	14								
	(1)			(1)		(2)								
Production	6	*6*	16				3				6			
	13	*14*	20				13				20			
	23	13	24				21				23			
		(6)												
Marketing	14		18				18				14			
							23				18			
Management	8		*18*	*23*	*4*	*4*	*13*	*3*	*22*		*6*		*8*	*9*
(whole process)	10		*16*	*16*	*21*	*21*	21	*10*	*3*		*2*		*10*	*8*
	15		1	10	*1*	*1*	19	14	*19*		*23*		5	(7)
			17	7	13	13	(6)	19	(4)		*20*		(7)	
			12	*18*	(4)	(4)		*8*			(5)			
			(2)	14				(5)						
				(3)										

NOTES: p = variables inhibiting innovative activities; q = variables promoting innovative activities; numbers in parentheses are factor numbers; figures in factor fields are variables from multivariate analysis; numbers in italics show other appropriate variables. The cost factor is omitted because it is of little importance.

insight on the management of the firm as well as for national innovation policy.

POLICY IMPLICATIONS

The consequences of an inadequate policy for innovation in an industrial firm are not always immediately apparent. It may take a long time to develop and to use creative potential. Main attention should be given to human factors and to appropriate combinations of the main factors of the innovation process.

For easy identification of appropriate factor combinations we propose the use of a specific factor showing the strength of inhibiting factors as well as the strength of a firm's ability to promote innovation with its own ideas and measures, over the stages of the innovation process. Figure 1 presents such a profile for the whole sample of 32 innovations in the sectors of the consumer goods industry investigated.

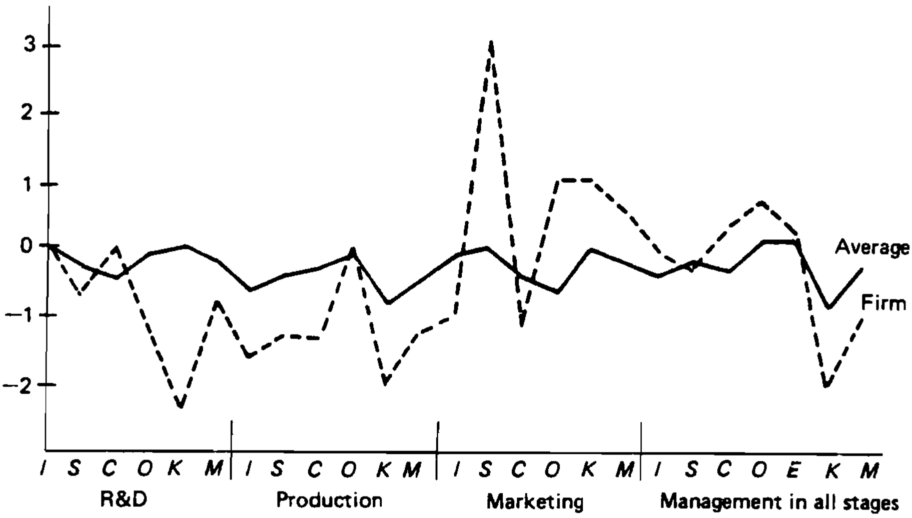

FIGURE 1 Difference between strength of promoting factors and inhibiting factors of the innovation process for 32 firms and for a single firm: *M*, mean average; *I*, innovation potential; *S*, strategy; *C*, cooperation; *O*, ongoing business; *K*, knowhow; *E*, economic mechanisms.

Using this approach we find the greatest differences between the strength of inhibiting factors and the strength of the firm's own capabilities — and thus the areas needing greatest attention — in the following determinants and stages:

- cooperation and coordination —R&D
- innovation potential —production

- knowhow factor — production
- capacity for ongoing processes — marketing.

Therefore a long-term development program for the given industry should include measures for improving R&D organization as well as the necessary increase of qualification level in production. We can state that the present organizational changes in the GDR industry have the explicit goal of mastering the complexity of the innovation process and enabling firms to implement their new products, and exchange of experience between enterprises plays an important role.

Comparison of enterprises (Betriebsvergleich) is a remarkable tool for recognizing bottlenecks as well as opportunities. For example, in Figure 1 a single firm's profile is compared with the average of the investigated sample. This shows that this firm might have good experience in marketing, useful for other enterprises. Further, in former times, comparison of enterprises was mainly oriented toward technical and economic indicators. Comparison of determinants of innovation process, innovation potential, and knowhow factor could be a useful addition to traditional tools of management.

METHODOLOGICAL CONCLUSIONS

From the profiles one can derive major gaps and bottlenecks and directions for a deeper investigation of obstacles and blocking factors. This can be an instrument for the management on the level of cooperation. Under conditions of a socialist economy exchange of experience and emulation movements play an important role. In these fields the firm's profile gives a further explanation to the quantitative indicators of efficiency. On the other hand we can assume that these profiles show significant differences among branches and also among stages of the efficiency cycle. Moving along the stages of efficiency cycle (take-off, rapid growth, maturation, saturation) is connected with structural changes which should be organized with close contact to the upper level of management and planning. For example, a large program of process innovation in our textile industry from 1972 to 1976 was launched by a governmental decision, prepared by the State Planning Commission and the Ministry for Light Industry in close contact with the Textile combinates and enterprises. This investment push has a strong impact on the firm's profile, though it is more indirect in its impact. The profile describes rather the subjective capabilities, which are of course interlinked with the objective factors.

Investigation of firm's innovation management profile should be continued, searching for regularities and dependences which have an importance for practical use. The profile could also be a good analytical instrument for interface management, which is so crucial for the innovation process.

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NEED ASSESSMENT AND INFORMATION BEHAVIOR IN THE PRODUCT INNOVATION PROCESS

H. Geschka, I. Paul, and K. Storvik

INTRODUCTION

This paper is concerned with several aspects related to assessment of user needs and problems as a basis for innovation planning. It begins with a description of the process of innovation, then describes some empirical findings on the innovation process. Thereafter it reports preliminary results from an international study on the innovation process — Needs Assessment in Innovation Behavior (NAIB). It closes with remarks on systematic need assessment as a basis for innovation planning.

THE PROCESS OF INNOVATION

Innovation is the result of a long and complex process of planned and accidental activities and events. It is this whole process of innovation which has to be planned, organized and controlled — in general terms, managed — to secure a steady flow of new products or processes within a company. As innovating seems to be one of the most important means to secure the position of a firm in the market, the process of innovation should be steered systematically even in its very early beginnings.

In industrial firms the innovation process is carried out under the influence of two different and principally independent processes: the development of science and technology and the economic process (satisfaction of individual and societal needs).

The innovation process may be initiated from either of these influencing processes. However, the product idea emerges as fusion of a recognized need (problem) and a technological possibility. Then the idea must be realized through applied research and development. In the realization phase, manufacturing equipment has to be prepared and market introduction planned. The innovation process ends up as satisfaction of an identified need, and the product diffuses into the market.

The innovation process is characteristically:

- Irregular: innovation is not straightforward but a process with many stops, feedback, iterations, accidents, etc.
- High risk: only a small percentage of ideas taken into serious consideration ever come on to the market as new products, new systems, or a new product generation. According to an empirical investigation in Europe, of 100 ideas brought into the planning procedure only 2-5 come to the marketplace. The situation varies greatly from sector to sector: it is much lower in the pharmaceutical industry — a few per thousand — and is much higher in the machinery sector: here 20-30% of all seriously considered ideas eventually appear on the market.
- Slow: in most cases the time between the first perception of an unsatisfied need and the market introduction is between 5 and 10 years. Very, very seldom is this process shorter than 2 years. This long time-span of the innovation process results in a very serious planning problem. When an innovation is initiated it is necessary to anticipate what needs will be at the time the product is marketed. An innovation has to be planned for problems effective in the future and not for present problems.

There is also uneven cost distribution. According to a 1972 study conducted by the US Department of Commerce, innovation costs are distributed as follows: research and fundamental development, 5–10%; product development and design, 10–20%; preparation for production, 40–60%; starting production, 5–15%; market introduction, 10–25%. From these findings it is apparent that a major decision point should be scheduled before the investment phase (preparation for production). Before investing in hardware it should be assured that there is a market for the new product; also the development work and investigations on the patent situation should be done carefully, and thoroughly.

SOME EMPIRICAL FINDINGS ON THE INNOVATION PROCESS

Innovation research has studied the process of innovation from various perspectives. The main interest of empirical investigations has been identification of the factors determining successes or failures of innovations.

Many studies investigated how successful innovations were initiated — from the needs side or from the side of technological opportunities. It appears from these studies that basic innovations tend to arise out of technology pull while incremental innovations tend more to be market pulled. The findings show that 60-80% of successful innovations are of the market pull type.

Most innovations in industrial firms are, however, of incremental or improvement character. This fact has fundamental importance for systematic R&D and innovation planning.

A famous project in innovation research is the so-called project SAPPHO. In this investigation pairs of innovations of similar character in the same market field were analyzed. As the external factors were equal, the factors determining success or failure have to be found inside the firm. From statistical analysis the following five success factors were derived:

- understanding of user needs
- attention to marketing and publicity
- efficient development work
- utilization of outside technology and scientific advice not necessarily in general but in the specific area concerned
- presence of a product champion who was a senior person or a person of great authority.

Kulvik, a Finnish researcher, applied the SAPPHO methodology in a more international and cross-sectoral scope and found the following success factors:

- extensive development knowhow in the new field
- thorough understanding of user needs
- extensive marketing knowhow in the new field
- compatibility between the company's marketing organization and the new product.

Arthur D. Little, in a study on barriers to innovations, found nine main barriers of which seven related to market information and marketing. The following qualitative conclusions were given:

(1) Lack of understanding of the markets for new technology is critical. Massive efforts are needed to understand user needs and to match them with technical capability.

(2) The chief blind spot in the flow of technology is the lack of a clear definition and understanding of user needs.

Robertson, one of the researchers of the SAPPHO projects, states that "it is misleading to assume that there is a market waiting for new and ingenious products. The customers even do not articulate their unsolved problems; they have to be discovered by a special effort of the innovation firms." They should not make early assumptions about what potential users want; they should however derive product ideas and specification from a thorough study of present, potential, and future needs.

In sum it seems that better understanding of user needs is the key factor for innovations. Conventional market research studies factors such as market volumes, market shares, and behavior of competitors. These methods do not go deep enough to detect the not yet articulated unsatisfied needs or unsolved problems. A special kind of methodology has to be developed — need assessment methods — providing adequate information on needs which thus can serve as an input to R&D planning.

The NAIB Project — Preliminary Findings

Having identified a need for methods to assess needs, Professor Knut Holt at the Norwegian Institute of Technology initiated a program called NAIB (need assessment and information behavior in the product innovation process). In its first phase this project is studying what industrial firms do to study user or customer needs and how they use information on needs for the R&D/innovation planning process. In a second phase recommendations for need assessment will be given and special methods will eventually be developed.

Researcher groups from 17 countries, including the main Western industrialized countries, intend to work in a coordinated manner in this program. Three groups started their investigations in 1977: Germany, Battelle-Frankfurt; Italy, IFAP in Rome; and Norway, Holt and his assistants in Trondheim. This collaboration within the NAIB Programme is called the GIN project. Preliminary findings of the GIN project are as follows:

> Only very few firms carry out need assessment systematically and consciously. We estimate that only 10-20% of firms apply special measures or organizational forms for need assessment. In this respect differences between small and big firms were not found. However those firms which carry out need assessment systematically pursue diverse, interesting, and original ways.
>
> The form of need assessment used is determined mainly by the manufactured product program and the existing relations to the customers. Personal contacts to customers, end users or experts in which problems are identified in free discussion (as opposed to formal and prestructured interviews) are the most fruitful and informative approach to need assessment. In the capital goods and also technical consumer — consumer durables — sectors, nontechnical personnel do not seem to be capable of perceiving the real needs and discussing them with customers.
>
> In the consumer goods sector a special difficulty arises as the consumers themselves are not able to express their unsatisfied needs or unsolved problems, or are even unaware of them. In this case, objective observation techniques (i.e. with video cameras or one-way mirrors) have to be applied. Another way to find out consumer wishes is by psychological interviews.

As a general obstacle in firms it was found that those staff having operations contacts with customers in the course of their normal activities are not motivated or supported to detect unsolved problems and needs and report them to other internal units which have the responsibility for collection and evaluation.

We classify the various approaches we have identified into three categories: utilizing existing relations to customers/users; utilizing other existing information sources; and methods for generating new information concerning user needs. In the following, methods belonging to these groups are listed through interesting and successful examples.

Utilizing existing relations to customers/users

Analysis of complaints, service and installation reports: Example: To make it easier for consumers to communicate with them directly, a number of firms have invited customers to make use of toll-free telephone arrangements established for this purpose. Most of the calls are concerned with complaints and difficulties related to the use of the products. However, some companies report further uses of these facilities, such as for asking callers about attributes they would prefer new products or services to have, for determining exactly how the firms products or services are used by the caller, or for finding out what product or service features are salient in the customer's buying decision (E. Patrick McGuire 1973).

Analysis of reports from the sales force: To make this source efficient the salesmen should be motivated to detect and report customer problems; a formal reporting system should be introduced.

Analysis of inquiries, tenders, orders, and suggestions from customer/users: Example: Based on a published tender from a specialized clinic, Siemens-Dental developed additional equipment for dentist's chairs. Specifications and requirements were defined by the clinic. The tender was won. After the special task was completed the product was modified for series production.

Cooperation with customers/users: Example: Some firms carry out coordination meetings with close customers. The producers show long-range technical developments, while the customers indicate their future demands and needs in qualitative and/or quantitative terms. A long-range development concept is then worked out mutually. For example, a firm makes an exclusive sale of a new generation of a production technology to a big electro-firm: in exchange for the advantage of an early utilization of a technology with higher productivity the electro-firm is willing to report all weaknesses and to propose improvements. For the producer of the production equipment this arrangement is an ideal testing phase.

Utilizing other existing information sources

Surveillance of competitors (in order to discover functions satisfying needs not yet satisfied or badly satisfied by their own program): Example: Manufacturers of consumer products, small articles, machines and the like commonly buy the corresponding competitor products, and strip and analyze them. For example, a producer of printing machines frequently buys used competing machines on the market, undertakes practical application tests, and then resells them.

Surveillance of government regulations: Example: A supplier of chemicals and chemical process equipment, by studying current discussions of regulations and requirements concerning waste water was able to develop a new generation of process equipment meeting certain standards before any official regulation was brought forth.

Analysis of written information: Example: A printing machine manufacturer studies the technical journals of the printing industry to identify customer problems. One man in the development department has the task of reading these journals and identifying problems.

Utilization of technical standards (including participation in committees): Example: Producers, users, neutral experts and government representatives are brought together in a committee for standards. The users introduce their needs and requirements which are then discussed from various points of view. Producers may utilize this information for new product development.

Employing persons with user experience or engaging consultants: Example: A producer of plastics and fibers created a staff function within the development planning department called "problem scouts." Persons from outside the company with experience and expertise in the customers' sector were employed to discover problems of significance in the respective sectors using whatever methods or means they deemed appropriate. Lists of problems were then evaluated by other planners and were the most important input for the R&D planning process.

Methods generating new information concerning user needs

Active need experience (need confrontation): Example: A paint manufacturer founds or buys a painting firm and thus acquires a means of testing products and discovering problems.

User observation: Example: A producer of dentist's instruments observed dentists during working procedures through video films and physiological measurements. These observations were used to discover and focus attention on working phases where physiological measures showed peaks or other anomalies. The film material was then intensively studied (slow motion analysis) and the dentists were asked for comments.

Simulation of need situations (ergonomic studies, motion analysis): Example: A large manufacturer of household equipment built a test kitchen and employed two "professional housewives" (masters of domestic science) to use the different products. This helped to reveal malfunctioning details and problems related to the product application. Development engineers sometimes observed these housewives at work to identify problems and find ideas for improvements.

User questioning (panels, interviews, polls, internal and external): Example: Fella, a manufacturer of agricultural machines, organized a so-called "invention game" during a 1978 technical fair. Visitors were given combined information sheets/questionnaires asking about technical, agricultural problems that were not satisfactorily solved, about work that might be made easier, and about especially difficult work. Problems, ideas, suggestions for improvements, etc. were to be written on an attached postcard. All received cards were put into a lottery for 50 valuable gold coins. The action is reported to be very successful, and to have generated many useful ideas. Some of these ideas have already been realized, while others have been put aside for later use.

Application of creativity techniques: Example: A producer of detergent carried out several brainstorming sessions with housewives on surface cleaning in the house. High moderation skill was necessary to ensure fluency and creative thinking and to avoid criticism and lengthy discussions.

Application of structuring techniques: Example: A manufacturer of gear boxes set up a morphological matrix relating technical variants of gear boxes to application fields in order to study their possible applications. Working through the morphological matrix revealed unsolved problems which could be solved by means of gear boxes.

Application of forecasting techniques: Example: A big chemical firm constructed five different scenarios on its raw material situation. These scenarios revealed future problem areas which were then differentiated in detail and research proposals were derived from them.

SYSTEMATIC NEED ASSESSMENT AS A BASIS FOR R&D PLANNING

Need assessment should be carried out as far as possible using existing contacts to customers or other accessible information sources. In the consumer sector, or when there are no direct relations to users, or when a company is diversifying into a new market field, other approaches have to be applied.

For this case the following sequence of steps of investigation are recommended:

(1) Identification of problem areas: (a) creativity technique; (b) scenario technique; or (c) Delphi technique may be helpful.

(2) Structuring selected problem areas: (a) morphological matrix; (b) relevance tree; or (c) functional analysis may be helpful.

(3) Identification of single problems: (a) many of the problems described above could be applied depending on resources to be spent.

(4) Selection of problems: consideration should be given to (a) relevance of the problem for the society: number of people involved; economic values in danger; and ethical values; (b) relevance of the problem for the firm: is it within the strategic frame? and can it be solved with the means of the company? (c)

market relevance: how much will users be willing to pay for a problem solution.

In one case assessment was accomplished by a sequence of check questions:

- Is the problem really a problem of importance?
- Can the problem be solved by technical means?
- Are there already problem solutions on the market?
- What price is the potential user willing to pay for the problem solution?

Using this checklist about 100 ideas were reduced to a dozen. For all approaches it is useful to fill out a problem sheet. Such a sheet may be structured as shown in Figure 1.

Date:	------------------------------------
Suggested by:	------------------------------------
Field:	------------------------------------
Problem classification:	------------------------------------

Problem Description:

What is the essential nucleus of the problem?

What is the importance and urgency of the problem?

Possible ways to solve the problem?

Where can detailed information be found?

Remarks for evaluation:

FIGURE 1 Example of a problem sheet.

BRIEF CONCLUSIONS

Need assessment is a key element to a successful innovation policy; it is a new field, many methods are available for it, but approaches are generally not systematic or well proved; nevertheless one can pursue sensible strategies of need assessment. In so doing it is most important to make the market-related staff conscious of their importance for need assessment.

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EPILOGUE

RESEARCH PRIORITIES IDENTIFIED BY WORKSHOP PARTICIPANTS

A.J. Harman and H.-D. Haustein

At the end of the workshop, a survey form was distributed for comments on target areas for further research by each of the workshop participants (see Figure 1). This form was devised in recognition of the fact that no one theory or model of the innovation process has achieved widespread acceptance among researchers in the field, and that an understanding of the impacts and effectiveness of deliberate policies to influence the innovation process is also far from perfect. Moreover, for any particular analytical approach or policy instrument, research could conceivably be focused on one of various levels of aggregation or disaggregation. The row and column headings are self-explanatory, with the possible exception of "Comprehensive" under "Approach," which was explained at the time to include both methodological and empirical approaches within some unified approach. Participants were asked to place a "T" in the appropriate row(s) and column(s) of the form to indicate research areas they believed to be of importance — either intrinsically or of special importance as a possible IIASA focus — and were especially instructed to provide comments on their choices, since the designations themselves were quite possibly not as interesting as the reasoning behind them.

Of the approximately 60 workshop participants in attendance, 19 responded: 8 (53%) of the American participants responded, 4 (100%) of the Scandinavians responded, 2 (22%) of the participants from the Socialist countries responded,* (20%) of the Japanese participants responded,*

*In the case of participants from the socialist countries and from Japan, these results are clearly based on too small a sample to make inferences about in-

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Problem area	Approach			Policy	
	Descriptive/ empirical	Methodological	Comprehensive	Specific	General/ comprehensive
More than one nation . . . global					
National					
Sectoral/ enterprise					
Project					
Process					

T: Target areas for further research

Participant:

Comments: ------------------------------

(Last name, please)

FIGURE 1 Sample survey form from the first IIASA workshop.

and 3 (14%) of the non-Scandinavian Western European participants responded.* Since the Scandinavian responses were so complete, they are given separately from the other Western European comments in the data presented here.

Before describing the results of this survey, we should point out very clearly that this is a very preliminary indicator of research interests by the various NMO countries, in that the participants are also a self-selected group. We report these results to the conference participants and other interested individuals as feedback on recently expressed viewpoints and as background for the recent refinement of IIASA's research agenda on this topic.

To give an indication of the kind of responses received, the numbers of individuals indicating target areas for further research from the United States are portrayed in Figure 2.** It can be seen that the US responses focused heavily on "sector-specific policy research" and also on "comprehensive sectoral analyses." Several individuals also identified a

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terests from these NMO areas —only one or two people in each case provided indications of further research target areas. However, perhaps even as very preliminary results they will provoke further discussion of this subject.

*One other Western European responded by saying "unworkable scheme." This response was of no further use to us, so it has not been included in the above tally.

**This category was only asked for the US responses, since the sample size (from the other areas) did not allow such a distinction.

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Problem area	Approach			Policy	
	Descriptive/ empirical	Methodological	Comprehensive	Specific	General/ comprehensive
More than one nation . . . global	11	1	11	1	11
National	111=*	11	11	111=*	111=*
Sectoral/ enterprise	111=*	1	1111=**	11111=**	11
Project	11		1	1	
Process	11				1

T: Target areas for further research

Participant:

Comments: ______________________________

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(Last name, please)

FIGURE 2 Summary of the US views.

priority for further "descriptive empirical" research at the "sectoral" and "national" level, and for both "specific" and "general/comprehensive" analysis of policies at the national level. Where four or more individuals indicated a target for further research this was considered to be a "very high priority" in the summary chart (**); where three responses were obtained this was identified as a "high priority" topic (*); and where any one or two individuals identified a research area, this was indicated as a "priority" (+).

A similar tallying was obtained for each of the groups of NMO countries mentioned above (the breakdown of simply "high priority" and "priority" was considered when the sample size was small). The results of this compilation are displayed in Figure 3 for all four areas —in the upper left of each criss-cross for each segment of the chart is the result for the United States, in the lower left of the criss-cross is the result for Western European participants, with the results for the Scandinavian participants indicated separately in parentheses; in the upper right is the indication of results for the Socialist countries and the lower right is the result for Japan. Obviously, few spots on the entire table are left without some interest having been expressed in further research.

Perhaps of greatest interest are those areas in which several NMO areas expressed a common interest in further research. These are summarized in the synthesis chart (see Figure 4). For those areas of research in which "high priority" was expressed from at least two NMO

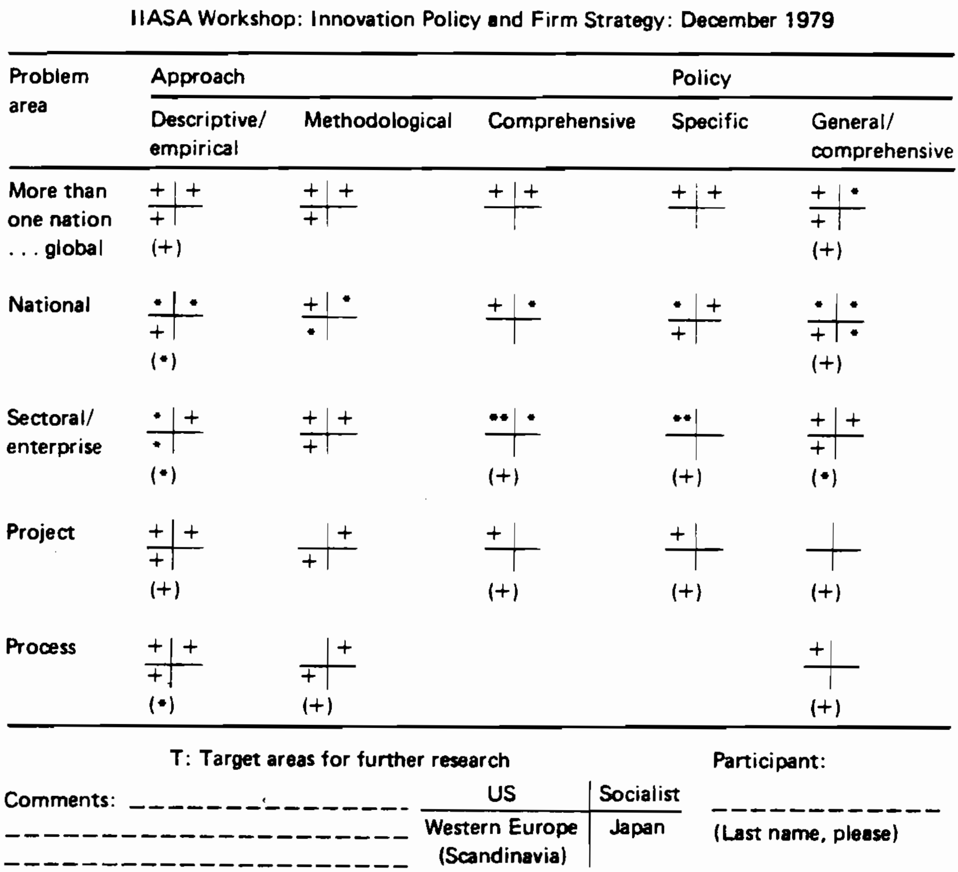

FIGURE 3 Summary of all respondents.

areas with a "priority" interest from at least one more, an * is placed in the chart; for those subjects for which a "high priority" is indicated by one NMO area with "priority" from at least two others, a + is indicated. One "very high priority" item, **, is also included — general and comprehensive national policies; this was an area of "high priority" identification from all four of the NMO areas. This summary reveals a widespread interest in descriptive and empirical studies as well as in policy-focused analyses.

Finally, many of the detailed comments included with the indications of target research areas are of particular use in shaping a detailed research strategy. We have attempted to summarize many of these comments in the following list (usually virtually directly quoting from the participants' own comments).

- It would be useful to have international comparisons of government innovation policies, putting emphasis on clarification of actual effectiveness and deficiencies of respective policy means, as well as differences of background conditions.

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Problem area	Approach			Policy	
	Descriptive/ empirical	Methodological	Comprehensive	Specific	General/ comprehensive
More than one nation . . . global					+
National	*	*		+	**
Sectoral/ enterprise	*		*		+
Project	+				
Process	+				

T: Target areas for further research

Comments: ** = "High priority" from all four NMO summary (A-3) areas.
* = "High priority" from at least two NMO areas, with "Priority" from at least one more.
+ = "High priority" from one NMO area, with "Priority" from at least two others.

Participant:

____

(Last name, please)

FIGURE 4 Synthesis of results.

- Research targets should be selected both on the basis of potential policy use (which requires broad and well-established results) and on the basis of contributions to theory... . Concise descriptions of the functioning of national economics (on a nation-by-nation basis), and how innovation policy affects those economies would be particularly useful... . Descriptions of national innovation policies would be useful also.
- Empirical studies will further the state-of-the-art. Eschew large models!!!
- Describe case studies of successes and failures in very readable jargon-free form.
- Understanding underlying forces which are altering the context for innovation is the top priority today — if we misperceive the context for innovation, much of our efforts to identify effective firm and innovative strategy will be wasted effort. If we can increase consensus regarding general/comprehensive areas of high and low national policy leverage, it will then be very important to focus on industry and firm policy... . International studies should be built on understanding national issues and policy possibilities. Also, an area which has been neglected ... is innovation in organizational structure.

- For the empirical studies, understanding of social conditions, and stimuli and obstacles of innovation at the national, sectoral, project, and processes levels is very important.
- Start on a microlevel! Using a systems approach, organize different projects for micro- and macro-problems linking the various approaches together. IIASA's research focus should be primarily at the sectoral, national, and more than one nation perspective, whereas national research organizations should span the range from national to sectoral, project, and process innovation.
- Problems of financing small and medium-sized firms and of the unemployment caused by innovation should be particular focuses of research concern.
- Please look at practice.
- Good, well-formulated, descriptive empirical studies will provide governments and us with a much needed framework. Interacting with this is the need to understand the formulation of economic policies that influence and are influenced by innovation. There is also the need for analysis of the interactive effects of different countries' policies —won't all national efforts to sponsor popular technology (e.g., microprocessors) lead to a total mix-up in industries in that field over all the world in that the "market" would be "totally destroyed?"
- Integrate, codify, and communicate the knowledge currently held on innovation, both from"scientific"and anecdotal information... . Identify policies that encourage creation and acquisition of small technological companies.
- It is easier to start with "small" areas and get results that can be evaluated in a relatively short time, than with the "huge" areas.
- Study of national policies and program must all be based on a thorough microeconomic knowledge.

Thus, in formulating our future research agenda, we have chosen to organize international collaborative case studies —based on these results and considerable other discusson and deliberations. The slice of this range of research interests to be covered by these case studies is:

(1) To include sector specific and empirical studies including, selectively, project or process innovation;

(2) To allow for attempts at a comprehensive modeling and analysis at the sectoral level; and

(3) To undertake a broad range of policy analyses both at the sector and national level, including comparative national policies.

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