BASIC, IMPROVEMENT AND PSEUDO-INNOVATIONS AND THEIR IMPACT ON EFFICIENCY

H.-D. Haustein and H. Maier

September 1979
WP-79-96

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

PREFACE

This paper was prepared on the basis of a research study of innovations, carried out by the authors. It's main aim is to promote a closer consensus in the discussion about innovation policy, in preparation for the forthcoming workshop "National Innovation Policy and Firm Strategy" (December 1979).

We are grateful to Gerhard Mensch, Wolfgang Sassin, Christopher Freeman, Jürgen Kuczynski and Rolfe Tomlinson for various impacts given in discussions and talks.

CONTENTS

PREFERENCE OF IMPROVEMENT POLICY - A REAL DANGER TO ECONOMY	2
INNOVATION AND INVENTION IS NOT THE SAME	8
EVOLUTION OF LARGE SYSTEMS - THE STARTING POINT OF INNOVATION CLASSIFICATION	9
EFFICIENCY IMPACT OF BASIC AND IMPROVEMENT INNOVATIONS - THE PRINCIPLE PATTERNS	13
PSEUDO INNOVATIONS AND OTHER SURPRISES IN THE WORLD OF INNOVATIONS	19
TYPOLOGY OF BASIC, IMPROVEMENT AND PSEUDO INNOVATIONS - A MORE DETAILED APPROACH.	21
INNOVATION LEVEL INDEX - A FIRST ROUGH ESTIMATION	26
TYPES OF INNOVATION AND THE EFFICIENCY CYCLE	29
REFERENCES	35

BASIC IMPROVEMENT AND PSEUDO-INNOVATIONS AND THEIR IMPACT ON EFFICIENCY

Heinz-Dieter Haustein and Harry Maier

The present need to raise the level of economic and social efficiency is realized in developed countries as well as in the developing countries on the various administration levels. This pressure existed also in former times, but now it has a new historical quality because it is interlinked with fundamental problems of existence. The whole resource processing system has changed from both sides: economic conditions for extraction of resources have worsened, often dramatically, and the structure of needs has become more dynamic. Increasing gaps between needs and resources lead both directly and indirectly to many economic and political implications, and have a widely uncontrolled feedback to the national economy. The smaller the transparency of events the greater the danger of actions accelerating the difficulties. This is correct for the national level as well as for single organizations.

Finding a new word for our ignorance we often use the word "turbulence" for all unexpected and dramatic events which change the preconditions of our plans and decisions. They occur from the rising complexity of our resource processing system, as well as from the regrouping of political and economic forces. Single instances of turbulence are mostly not foreseeable in their concrete data and parameters. But the question is whether there is any bridge between the instances of turbulence, or more precisely, to what extent turbulence and the impotence of economic actors are caused by the actors themselves.

It is now widely accepted that technological change is a mighty tool for social and economic growth, but for a long time economic theory handled technological progress as manna coming from heaven. In practice technology was always closely connected with the main economic driving forces of a given society. Formation of individual capital as well as formation of national economies paved the way for the main inventions and innovations. But obviously we also find here the explanation for the trouble our resource processing system is now faced with.

PREFERENCE OF IMPROVEMENT POLICY - A REAL DANGER TO ECONOMY

There are two tendencies which have a great impact on efficiency. Firstly, the increasing capital intensity (capital coefficient) leads to a strong orientation towards improvement of given technological systems connected with changes of lower order. Nobody is interested in essential changes if they are interlinked with big losses in advanced capital funds. Capital coefficient is only a very general measure for many specific problems on the firm level. Table 1 shows the problems arising in practice by transition from an improvement policy to basic technological changes in market production, research and development, and in management.

Therefore it is understandable that there is a strong tendency towards improvement policy (changes of lower order) in many firms. Figure 1 and Table 2 show the situation in the US over a period of twenty years. We can see that the number and the share of radical breakthroughs is declining very quickly. The same situation can be identified in other countries.

Of course the situation is different in various industries. Table 3 shows the situation in US industry from 1953 to 1973. The number of major innovations over the period from 1953 to 1973 in electrical equipment and communication is significantly greater than in textiles or paper production. To go into more detail, the age of principal technical solutions in washing

Table 1. Implications of basic technological changes and improvements on the firm level.

Factor	Basic changes	Improvements
1. Market	Demand large but unpredictable High risk of a failure Slow acceptance in the beginning Creation of new marketing system necessary	Demand well-known and foreseeable Rapid acceptance Use of well-known channels
2. Production	Obsolescence of capacities of existing labor skills and existing cooperation Interruption of learning processes New and unanticipated problems in quality, costs and effects	Maximum use of given capacities Benefits from learning processes and streamlined designs However risk in quality and process planning
3. Research and development	Advanced research potential needed Necessity of new research fields and disciplines High research and development risk	Use of existing R & D potential Basic research not necessary Risk relatively predictable
4. Management	Obsolescence of management skills, methods and organizational solutions Increase of complexity	Use of experienced management systems Amendments of given organizational solutions
5. Social consequences	Legal and social acceptance cannot be predicted	Little or no unpredicatable problems

machines, refrigerators, textile machines, batteries, electrical tools, combustion engines, and transport machines is, on average, higher than 25 years. On the other hand, the age of principal technical solutions in radio components, electronic calculators, and watches, is less than 10 years. However in general the statistical coefficient

$$\frac{\text{Number of subclasses in a product group}}{\text{Number of years from the start of the product group as a whole}}$$

is decreasing. There are studies showing the mechanisms from the example of specific industries. W.J. Abernathy (1978) analyzed

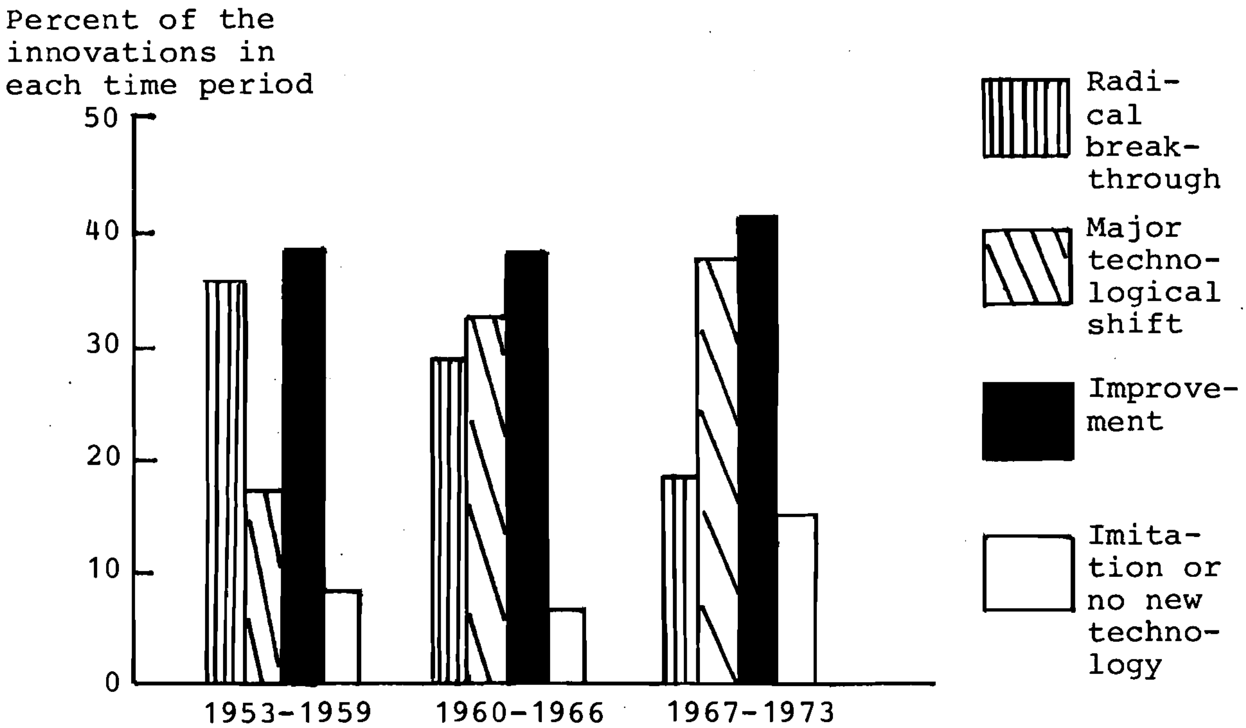


Figure 1. Estimated radicalness of major US innovations, 1953-1973.

Source: Science Indicators (1976), US National Science Foundation (1977).

Table 2. Estimated radicalness of major US Innovations, 1953-1973.

Radicalness classification	1953-73 period	53-59	60-66	67-73
	Percent distribution			
Total	100	100	100	100
Radical breakthrough	26	36	26	16
Major technological shift	28	17	31	35
Improvement	38	39	37	40
Imitation or no new technology	8	8	6	20
	Number of innovations			
Total	250	75	94	81
Radical breakthrough	64	27	24	12
Major technological shift	70	13	29	28
Improvement	96	29	35	32
Imitation or no new technology	20	6	6	8

Source: Science Indicators (1976), US National Science Foundation (1977).

Table 3. Major US innovations by industry, 1953-1973.

Industry	Number of innovations	% of total
Total	310	100
Manufacturing industries	277	89
Electrical equipment and communication	53	17
Chemicals and allied products	45	15
Machinery	44	14
Professional and scientific instruments	29	9
Stone, clay, and glass products	18	6
Motor vehicles and other transportation equipment	18	6
Primary metals	17	5
Rubber products	15	5
Aircraft and missiles	11	4
Fabricated metal products	10	3
Petroleum refining and extraction	5	2
Textiles and apparel	4	1
Paper and allied products	4	1
Food and kindred products	2	1
Lumber, wood products, and furniture	2	1
Nonmanufacturing industries	33	11

Note: Detail may not add to totals because of rounding

Source: Science Indicators (1976), US National Science Foundation (1977).

the transition process from major product changes to rising major process changes, and then to both the product and process improvements on the classical example of the automobile industry. Another classical example is the lighting industry. From 1915 to 1959 innovations in the field of incandescent lamps were mainly incremental, with an increase of efficiency nearly 30 or 40 per cent. However, from 1939 to 1969 productivity of the production process had an increase of more than 900 per cent. Therefore our study of innovations in the lighting industry (Haustein 1979) confirms the findings of Abernathy on the sequence of product and process innovation.

An overwhelming share of incremental innovations in economic growth has a strong impact on the management system as a whole. So the attention which has arisen about learning curves as a tool for planning is only a reflection of the present improvement attitude. Learning curves are applicable to all cases of step-by-step improvements, but they are not appropriate for describing all kinds of development. Their broad applicability is caused by the importance of simple experience in all activities of man. However, man is not simply an experienced tool-using animal, he is also an imaginative-thinking animal. He finds out new ways of progress, beginning new learning curves.

From the standpoint of long-term development Christopher Freeman wrote:

> The bunching of groups of related inventions and the investment needed to bring about their widespread introduction is a more probable pattern of development than the incrementalism associated with run-of-the-mill modifications to established technologies, responding to minor changes in the market (Freeman 1978).

This may be quite correct, but another question arises of how closely these investments are linked with fundamental inventions. The probability of basic innovations is smaller the more non amortised capital is bound in a given industry. A second reason for the preference of improvements is the high short-term benefits promised by all kinds of compensation or balancing processes. Reducing bottlenecks in performance or efficiency of a given system is called "compensation process" (Ausgleichsprozess). This process gives a fast rising benefit from the beginning up to the point where the equilibrium is reached and then benefits are diminishing. Technological progress leads to an increasing diversity and disproportionality of the technical basis (see Haustein 1974). So chances of compensatory processes are occurring everywhere. This is a positive feedback causing the preference of improvement policy. Compensation is a kind of improvement. Basic changes are often connected with overcompensation establishing new bottlenecks. At the beginning they have often no benefits but heavy losses and only after a longer time-period benefits become much higher than those from improvement policy alone.

If we look at a given sample of technologies in one area over a longer time, we can always realize how difficult it is to determine the benefits from expected basic changes. Table 4 shows this on the example of the energy field.

From our present standpoint breeder reactors, fusion, solar electricity, or fuels from the biomass are principally new

Table 4. The strategy of technology introduction in the US energy field.

Time of impact	Strategic element	Technology	Impact in year 2000*
Near term (now to 1985 and beyond)	Increase of efficiency of energy use and convert waste to energy	Conservation in buildings and consumer products	7.1
		Industrial energy efficiency	8.0
		Transportation efficiency	9.0
		Waste materials to energy	4.9
	Preserve and expand oil, gas, coal and nuclear	Coal-direct utilization in utility	24.5
		Nuclear-converter reactors	28.0
		Oil and gas enhanced recovery	13.6
Mid term (1985-2000 and beyond)	Accelerate development of synthetic fuels from coal and shale	Gaseous and liquid fuels from coal	14.0
		Oil shale	7.3
	Increase use of under-used (limited application) fuel forms and attract more usable energy from waste heat	Geothermal	3.1-5.6
		Solar heating and cooling	5.9
		Waste heat utilization	4.9
Long term (past 2000)	Develop the technologies necessary to use the essentially inexhaustible fuel resources	Breeder reactors	3.1
		Fusion	-
		Solar electric	2.1-4.2
	Develop the technology necessary to change the existing distribution systems to accommodate the distribution of new energy sources	Electric conversion efficiency	2.6
		Electric power transmission and distribution	1.4
		Electric transport	1.3
		Electric storage	-
		Hydrogen in energy supplies	-
		Fuels from biomass	1.4

*Quads = 10^{15}Btu.

Source: A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future, United States Superintendent of Documents, Washington, 1976.

solutions. The real benefits are unknown or relatively small in the predictable future. (Total primary energy demand in the US in the year 2000 is something approaching 120 Quads).

INNOVATION AND INVENTION IS NOT THE SAME

When speaking of the patterns of technological progress we use the term "innovation". This term is well-known since its introduction by Schumpeter (1911), and should not be mixed up with the term "invention". Innovation includes not only research and development stages, but also technical realization, and commercialization. However, looking at the great stock of innovation studies and books we see two main gaps:

-- the first is the rather micro-economic approach in most of the studies,

-- the second is in connection with the first; the fact that innovation has been considered as a single process, a single technological change in the narrow sense of the word "technological".

Our approach differs from this. We think that innovation must be treated another way.

Let us have a look at the history of technology. There are many examples where single important technical solutions had at least no socio-economic impact. One example is the big steamboat "Great Eastern" which in the middle of the 19th century was a fundamental new solution. For instance, its motive power was 100 times stronger than in usual ships, and its tonnage was up to 7 times greater. However such a ship was at that time not appropriate because ports and service facilities for repairs, etc., were not able to support its use. After several years the shipping trade firm which owned the steamboat went into bankruptcy because they had not been able to stand the bad economic consequences (see Henriot 1955).

Another example. Many inventions in electrical engineering were well-known a hundred years ago. The exhibition of electrical products in Vienna in 1883 showed such things as electric water heaters, electrical hearths, electric cushions, and electric motors (see Gross 1933), but there was no application to the existing complexes of needs and resources, and so only one of these inventions completely changed the existing demand system, and this was the case of lighting. The power station in Berlin was founded in 1885 and until 1900 electricity demand was mainly for lighting. The reason for electric lighting becoming a basic innovation was that firstly, a rapidly rising and expanded demand could be established in this field. Electrical illumination of the opera in Munich had a striking effect. Secondly, Edison, the pioneer in this area, was not only a great inventor, he was also a good systems engineer and entrepreneur. He built up a whole system of satisfying the lighting demand beginning from energy production and distribution up to usage. He determined the price for one lamp at the level of $0.40 but the cost was higher, $1.25. After three years he was able to reduce the cost to $0.37 and to have a great profit from the explosion of the demand (Oliver 1959).

From these two examples we can understand better the difference between technological change in a narrow sense and the innovation process.

EVOLUTION OF LARGE SYSTEMS - THE STARTING POINT OF INNOVATION CLASSIFICATION

Innovation is always a change in the technological system with great impact on the given socio-economic system or subsystem. Such subsystems are:

-- the complexes and subcomplexes of needs or demands (i.e., lighting demand);

-- the resource complexes or subcomplexes (i.e., energy sources);

-- the resource processing cycles from primary to final stages (i.e., wood cycle).

There are many possible ways of classifying innovations:

1. According to the elements of the production process, we differentiate between product innovations, process innovations, and manufacturing innovations. Having three

types of technological change (new, improved, old technology) we find a $3^3 = 27$ combination, as for example: a new product produced by an old process in an improved manufacturing system.

2. Accordingly the economic results of innovations: capital saving innovations and labor saving innovations, (or in more detail, material saving innovations, energy saving innovations, machine saving innovations, and labor saving innovations).

Other classifications can be created using the following other criteria:

-- classes of needs, being satisfied with the help of innovation,
-- types of resources being saved by innovation,
-- kinds of resource processing systems or industries touched by innovation,
-- necessary changes in the direction of investment (new buildings, rationalization, modernization) being interlinked with innovation,
-- source of information calling for innovation,
-- kind of knowledge used through innovation,
-- cost of innovation,
-- factors determining the rise of innovation,
-- consequences of innovation,
-- share of research and development needed for innovation,
-- impact on goals of the given system by innovation,
-- component of production process (material, machines, manpower, product, process, organization) affected by innovation,
-- level of administration needed for the realization of innovation,
-- scale of the firms implementing innovation,

-- type of property used for innovation,

-- degree of international competitiveness reached by innovation, etc.

Groups of interlinked innovations can be found with the help of cluster analysis, for example the IFO study differentiated between 20 criteria and 274 features of innovation (see Uhlmann 1978). 218 innovations were classified by cluster analysis into 18 and then later into 11 significant groups (clusters):

-- market oriented basic innovation in large scale organizations (enterprises),

-- cost reducing innovations within state owned energy enterprises,

-- innovations within non-cooperative leading technological industrial organizations,

-- market oriented innovations within leading cooperative private enterprises,

-- cost reducing innovations within large scale energy enterprises without external technology transfer,

-- innovations based on early technology transfer within small scale enterprises,

-- innovations based on technology transfer from energy distributing enterprises,

-- innovations realized from independent innovators,

-- innovations based on trial and error,

-- market oriented basic innovation according to government policy,

-- rationalization innovations sponsored by multinational corporations.

In our opinion it is not possible to find a univeral classification of innovation by using theories or empirically based methods. When we have to establish an innovation classification, we must first ask, for what purpose we are doing this. As mentioned we look at the innovation process from the standpoint of national development or corresponding subsystems and the possibilities of controlling them. These large systems have three goals:

1. To ensure their continuing existence and function by counteracting inhibiting factors.

2. To balance the inner and outer relations of the system reducing bottlenecks.

3. To find new ways of ensuring efficiency in a changing environment over a longer term.

From this point of view (the impact of a given technological change on a large system) we can differentiate between three functions controlling the large system:

-- continuation (Fortführung)

-- compensation (Ausgleich)

-- push (Antrieb).

For example in the energy system we have the function of continuing the use of existing primary resources. Then we have some bottlenecks in a given energy system with increasing negative consequences on the efficiency. It is necessary to close these bottlenecks and to ensure the balance of the whole system through mobilising new resources of energy. We also have certain technological changes, overcoming not only existing bottlenecks, but also establishing new ones. By this they give a great push to the whole system over a longer time and in reality they change the existing system into a new one.

In Table 5 we try to show the realization of the functions mentioned above through two different kinds of innovation. Type I is mainly connected with a push in the technological level, and later on the efficiency of a given option. This is often a result of overcompensation of existing bottlenecks. Type II is mainly connected with continuation of well-known processes and compensation of bottlenecks up to the standard level. In this manner we differentiate between two polar kinds of innovations, to follow the widespread terminology:

I. Basic Innovation (BI) ~ Fundamental I ~ Major I ~ Strategical I ~ Radical I ~ Discontinuous I ~ Big changes.

II. Improvement Innovation (II) ~ Incremental I ~ Minor I ~ Tactical I ~ Rationalization I ~ Continuous I ~ Small changes.

Table 5. Types of innovation and their functions.

Function type	Push	Compensation	Continuation
BI	X X X	X	
II		X X	X X X

EFFICIENCY IMPACT OF BASIC AND IMPROVEMENT INNOVATIONS - THE PRINICIPLE PATTERNS

The main function of BI is to give a push to the existing system of technology and to change it into a new system with eminently higher efficiency. The main function II is balancing the given system by improving its efficiency. However, we have to take into account that basic innovations are always a certain complex of smaller changes. In this sense the difference between type BI and II is relative. But basic innovations consist of smaller changes, leading over time to increasing returns. Improvement innovations starting from the given, more or less old technology, lead over the same time-span (10 years and more) to diminishing returns.

The relationship between push and compensation policy, with the help of two innovation types, can be demonstrated by the example of investment allocation. All investments of a given industry can be subdivided into

$$I^* = I_1 + I_2 + C \tag{1}$$

where

I_1 = Investment for overcoming bottlenecks in technical equipment, per employee (compensation investments),

I_2 = Investment for introducing principally new technological solutions (push investments), per employee,

C = Replacement and continuation investments.

Optimization is necessary only for

$$I = I_1 + I_2 \tag{2}$$

The subsequent shares of compensation and push investments are:

$$i_1 = \frac{I_1}{I}$$
$$i_2 = \frac{I_2}{I} \tag{3}$$

and $i_1 + i_2 = 1$.

If the main criterion is aving of labor force we take the replacement coefficient:

$$l_i = \frac{L_0P' - L_1}{I}\ 100 \text{ (percent)} \tag{4}$$

where

$L_{0,1}$ = number of employees at the time 0 or 1,

P' = index of output (P_1/P_0)

I = investments

$L_0 - L_1$ = absolute saving of labor force

$\hat{L} = L_0P' - L_1$ = relative saving of labor force.

So the coefficient l_i shows how many employees are (relatively) replaced by a given sum of investments. This coefficient is different for compensation and for push investments, but in both cases we find an invariance: spending more investments replacement coefficient l_i increases up to a certain point and then decreases.

If we assume a very simple dependancy including this invariance we write

$$\hat{l}_{i1} = a_{12}i_1 - a_{13}i_1^{\,2}$$

$$\hat{l}_{i2} = a_{22}i_2 - a_{23}i_2^{\,2} \qquad (5)$$

The first coefficient $\hat{l}_{i1}$ shows the relative replacement over the share of compensation investments i_1 and the second coefficient $\hat{l}_{i2}$ shows the relative replacement over the share of push investments. In general parameters a_{ij} are quite different in both cases. Compensation investments have rather high replacement effects at the beginning, but then fast diminishing effects. Push investments have rather low replacement effects at the beginning increasing later on and then diminishing.

The whole relative economy of labor is the sum of both types of replacement:

$$\hat{L} = \hat{L}_{i1} + \hat{L}_{i2} \qquad (6)$$

$$\hat{L} = I_1 \cdot \hat{l}_{i1} + I_2\hat{l}_{i2} \qquad (7)$$

$$\hat{L} = I_1(a_{12}i_1 - a_{13}i_1^{\,2}) + I_2(a_{22}i_2 - a_{23}i_2^{\,2}) \qquad (8)$$

and by $i_1 = 1 - i_2$ we find

$$\hat{L} = i[i_2(-2a_{12} + 3a_{13}) + i_2^{\,2}(a_{12} - 3a_{13} + a_{23})$$

$$+ i_2^{\,3}(a_{13} - a_{23}) + a_{12} - 1_{13}] \qquad (9)$$

$$\hat{L} = I(d_2i_2 + d_3i_2^{\,2} + d_4i_2^{\,3} + d_1) \qquad (10)$$

From

$$\frac{d\hat{L}}{d_{i2}} = I(d_2 + 2d_3i_2 + 3d_4i_2^{\,2}) = 0 \qquad (11)$$

$$i_2^{\,2} + \frac{2d_3}{3d_4}\, i_2 + \frac{d_2}{3d_4} = 0 \qquad (12)$$

we get the optimal solution

$$i_{2(1,2)} = -\frac{d_3}{3d_4} \pm \sqrt{\left(\frac{d_3}{3d_4}\right)^2 - \frac{d_2}{3d_4}} \quad . \tag{13}$$

We must state that the assumption of two quadratic equations is quite abitrary. It may be more appropriate to use an exponential function for this purpose. A more complicated problem is the real statistical identification of the two types of replacement. We used the data from the GDR automobile industry from 1955 to 1970. In the case of car motor production we had the typical behavior of compensation investments with a lower increase of equipment per employee and in the case of car assembly we had the typical behavior of push investments with a higher increase in equipment per employee. So we compared the investments of the two types on the example of the two interlinked sub-branches of automobile industry.

We determined the parameters in the following equations by analyzing the time series of investments and replacements of labor

$$\hat{l}_{i1} = 25.0i_1 - 52.3i_1^2$$

$$\hat{l}_{i2} = 61.2i_2 - 72.9i_2^2$$

The whole absolute economy of labor was 1955-1970:

$$\hat{L} = I(106.9i_2 - 70.7i_2^2 - 20.6i_2^3 - 27.3)$$

And the relative economy of labor

$$\hat{l} = 106.9i_2 - 70.7i_2^2 - 20.6i_2^3 - 27.3$$

Then we come to the equation

$$i_{2(1,2)} = -\frac{70.7}{61.8} + \sqrt{\left(\frac{70.7}{61.8}\right)^2 + \frac{106.9}{61.8}}$$

finding an optimal i_2 of nearly 60 percent. The the optimal replacement is

$$\hat{l} = 6.86 \text{ (rel. coefficient)}$$

$$\hat{L} = 126{,}000 \text{ employees}$$

The real economy of labor was l = 5.26 and L 0 96,000 employees. So the difference to the optimal solution was 30,000 employees. The share of push investments in reality was on 33 percent. Of course investment allocation in the automobile industry is not only a question of determining the share of push investments by one criterion. Our example merely gives an illustration of the opportunities of modeling better the investment allocation in accordance with innovation policy.

In general we assume the following efficiency of push and compensation policy (see Figure 2). In Figure 2 the progress of benefits under push is shown in field 1.1 and the progress of benefits under compensation is shown in field 2.2. If we overlap both functions, the efficiency situation of the two types of innovation becomes quite clear. How near this hypothesis is to real economic life can be shown in many examples. The figures in Table 4 for the energy field although given only for one time point, reflect the same principle pattern.

For short term planning we will always prefer compensation policy and only for a longer perspective will we choose a certain relationship between push and compensation policy. In practice we find many basic innovations have a dominating impact on efficiency of the whole system only 10 years or more after the first commercial use (Gold 1975). So the main problem is the length of the optimization period. The shorter this period the more important a pure improvement policy becomes. It may be interesting that the first long-term plan of a national economy oriented towards a basic innovation (electricity) - the so-called GOELRO-plan in the USSR - had a time horizon of 10 to 15 years (1920-1935).

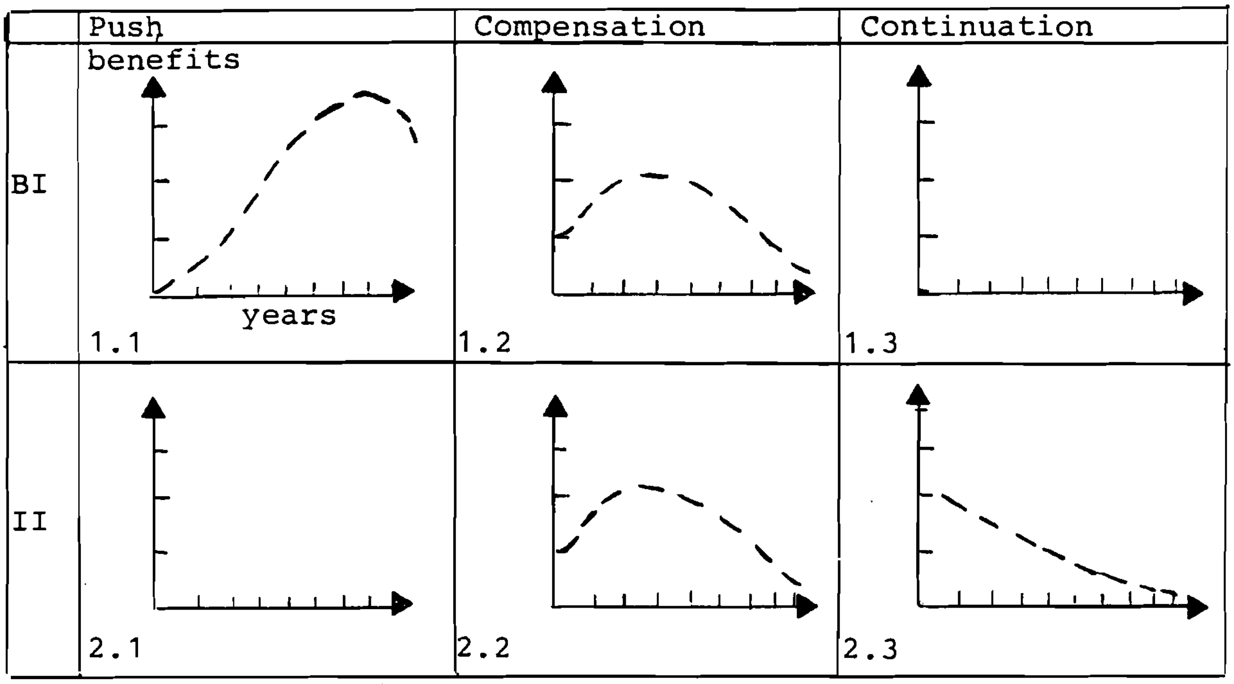


Figure 2. Typical benefits of BI and II.

The distinction between BI and II was first made by historians (Zvorykin et al 1962). Not being operational for economic decision analysis in technological policy it was a more qualitative theoretical approach.

Using the well-known terms BI and II (or revolutionary changes and evolutionary technological changes (Nick 1974)). We must stress that we give it another interpretation. In many studies this distinction means only a certain degree of technological change. Our starting point is the impact or influence of a given technological change on the socio-economic system. If we look at the average efficiency of a given system, we find a tendency to stagnate or decrease, which can be reduced by not stopped by II. Only BI are able to overcome this tendency, if their efficiency is much higher than the average and their share in output is sufficient.

The effects of BI take longer than the effects of II, but they are higher. Of course, this does not mean that we can forget about the effects of II. Over a longer period the effects of II are comparable with the effects of BI in a certain area. We have to bear in mind that BI and II are two sides of one coin.

Underestimation of II is as dangerous as the fear of BI. A major example is the development in metallurgy. Nevertheless II are not able to ensure the endless efficiency of a larger system. Limitless asymptotic increase of efficiency through better balancing of elements is thinkable only for a closed system, but when we consider the relations of the large system with the environment we have to take into account the possibility of sudden or not so sudden but tremendous changes. These changes may lead to principle bottleneck resource deficits and conflict situations which can only be mastered by complex radical solutions.

Basic innovations may have a compensatory function without a push in the efficiency of the first step of their applications. This can be the result from the delay in relaizing the basic innovation. The IIASA Energy study conducted by Wolf Häfele shows us that in the process of using final energy we can expect many improvement innovations which helps us to reduce the primary energy/GDP coefficient from the present value of 0.8 to 0.5 in the developed countries, while in the developing countries it can be brought down from 1.5 to 1.0 (Maier 1979). Conversely the study shows us that we have to be aware of a completely different development in the field of basic innovations such as nuclear energy, synthetic fuels, solar energy, biogas, etc. We expect for the next two decades a rising primary energy/GDP coefficient resulting from a very extensive demand pull and the delay in mastering the economy of the basic innovations (see Mensch 1976).

PSEUDO INNOVATIONS AND OTHER SURPRISES IN THE WORLD OF INNOVATIONS

We mentioned above only the positive functions of innovations towards the goals of large systems. However, in reality we have some innovations, seemingly appropriate to meet the goals of the socio-economic system or subsystem, but having a negative influence on it over a long time. Its primary or secondary consequences damage the efficiency of the system. We call these innovations pseudo innovations - PI. A larg share of PI we find in the consumer goods industry. In American supermarkets, where it is estimated that about 1500 new products appear each year, less

20 percent survive more than one year on the shelves, the remainder having proved unsaleable, faddish, risky, or unprofitable, or made obsolete by competitors with new models.

Furthermore we can state that positive technological changes with positive socio-economic potential can appear as negative innovations. It is necessary to repeat our differentiation between technological changes in the narrow sense of the word and innovations. This can be demonstrated by the scheme shown in Table 6.

So we can have the situation that a major technological change (potential BI) occurs only as an II or as a PI. This depends on the ability to use the innovation potential by changing many conditions and relations necessary for the efficiency of the new or renewed system. All these conditions change over time, so a potential BI may or may not become a real BI. For example automation of the production process in a given non-automated industry is a basic innovation. In reality it may become an improvement innovation if it is not possible to change the traditional process. Such automation without process changes is not very efficient. Solar energy is a potential basic innovation, but in reality it may occur only as a pseudo innovation in the cases where solar heating systems are installed in existing buildings without changing other preconditions. Another problem is that an innovation could be determined and planned as an

Table 6. Change of potential into real innovations of the three types.

Real / Potential	Real BI	Real II	Real PI
Potential BI	Automation in connection with new processes	Automation without changing the process	Retrofit solar heating system for residential buildings
Potential II	-	Oxygen process in metallurgy	Higher speed and motive power of automobiles
Potential PI	-	-	Product changes without real effect for the consumer.

improvement innovation and later on we discover that it is really a basic innovation. The qualitative potential of an innovation is often not clearly realized and the same is true for its quantitative potential.

Many innovations are closely interlinked over time. It is very important to establish positive feedbacks in the innovation process, for example the railway innovation led to higher coal demand, higher coal demand required better transport, which was possible through railways. Interference exists between BI and II also in the following context. The prehistory and the subsequent history of basic innovations is made up of groups of small innovations, for example, the incandescent lamp was a basic innovation, for which many small changes were needed, and from the time of Edison until the present day the development of the incandescent lamp has been a complex of improvement innovations. Therefore we can differentiate between II leading to BI, and II using the efficiency potential of BI. This shows us the close interaction between II and BI. BI is a result of a long selection process in a wide field of smaller innovations, which are in competition with each other. So BI is like a package of technological changes, which create a new quality for the system touched upon. When a new basic innovation develops it establishes a great efficiency potential. This can only be more or less fully mobilized by quite a lot of improvement innovations. We call this kind of improvement innovation, incremental innovation. We also have some smaller changes in the technology manufacturing process and organization where it is not possible to identify their connections with a determined basic innovation.

TYPOLOGY OF BASIC, IMPROVEMENT AND PSEUDO INNOVATIONS - A MORE DETAILED APPROACH

Concerning basic innovations we have to take into account that their technological level, their range of application and their impact on national economy are also quite different. Technological level is closely connected with the necessary type and amount of mission-oriented fundamental research, applied research and development. So it is understandable why the IFO-Institute study proposed to call all technological changes which go through research and development stages, basic innovations, (Uhlmann 1978). Another extreme is to call only the main historical breakthroughs in technology basic innovations, such as the steam engine, tool machine, electricity and several others. We cannot call BI pure scientific or technical results (inventions). These are only the first steps which may become a BI, but this depends on the concrete resource situation, the socio-economic needs and the capability of a given society to master it. Therefore, it is not possible to speak about BI without social considerations.

In our time we would propose calling basic innovations, such major technological changes which

-- are based on fundamental and applied research,

-- have a well-defined high range of application (essential modification of existing demand or application complex (e.g. synthetic fibres) arising of a new demand or application complex (e.g. TV) or changing the whole system of needs (e.g. production and consumption of electricity)

-- are connected with new scientific-technological principles of a different order.

Therefore we can differentiate between three kinds of basic innovations (see Table 7). BI gives a great push to the whole socio-economic system, having an enormous efficiency potential they are able to halt and to change the tendency of decreasing efficiency in using resources.

The technological level of innovations is also an important indicator, but its connection with efficiency of the system touched upon is not linear. We know of some historical basic innovations not based on new scientific-technological principles (for example, the Hargreave machine). On the other hand we have some innovations of a highly scientific-technological level, which did not find a wide range or field of application (for example, coal arc lamp in the 19th century).

Returning to improvement innovations we can here differentiate between four types (see Table 8): very important II, important II, normal II, and marginal II.

Table 7. Types of basic innovations BI.

No.	Type B	Fundamental Research Share	Applied Research Share	Range of Application	Push on Production System	Examples
1.	Major Basic I. BI1	High	High	Change of the whole system of needs and its structure	Change of the whole produc-tion system	Use of Micro-electronics new energy systems
2.	Middle Basic I. BI2	Middle	High	Establishing of a new demand complex (or market)	New package of industrial branches	Use of Micro-processors Nuclear energy
3.	Minor Basic I. BI3	Low	Middle	Essential modi-fication of existing demand complexes	New industrial branches	Use of fast breeders

Table 8. Types of improvement innovations II.

No.	Type	Fundamental and Applied Research Share	Development share	Range of application	Impact on production systems	Examples
1.	Very important II1	Middle	High	New demand. New product in an existing demand complex	New industrial sub-branches	Use of polyester
2.	Important II2	Low	Middle	Essential modification of the demand complex. New parameters of well-known products	New product lines or processes	Use of Thomas-Steel process Electric toothbrushes
3.	Normal II3	No	Low	Simple modification of existing demand. Improved parameters of well-known products	Improved product lines or processes	Flouride toothpaste
4.	Small changes II4 (Marginal II)	No	No	Low improvements	Low improvements	Better touch-on telephones

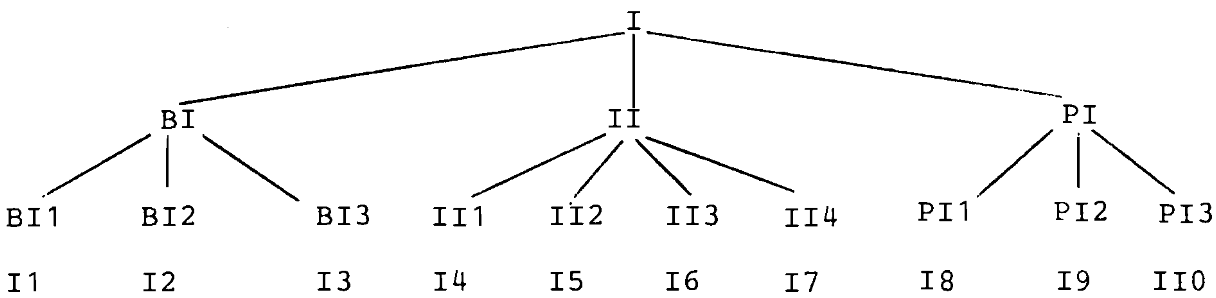
We can also distinguish between three kinds of Pseudo-Innovation (PI):

PI(1) Simple product innovations without improving efficiency of the user system. (For example, many automobile changeovers.)

PI(2) Innovations which improve efficiency in one process, but reduce the efficiency of the whole system (for example, plastic materials which are not appropriate to the needs).

PI(3) Innovations which improve the efficiency of the system only in the short term, but then lead to big losses and imbalances (for example, some process innovations in the chemical industry which later have a negative influence on the whole environment).

Therefore we have the following ten main types of innovations:



We think that these types can be identified. Of course, if we look at the ocean of innovations they all build up a certain continuum not measurable by one clear indicator. Some people consider this only as a continuum, but we have to take into account the obvious existing turning points or break-even points in complexity, in efficiency, and in manageability, in this total field of innovation. For instance, in the socialist countries all scientific-technological tasks of one planning cycle are associated with a certain level of administration from the firm to the centre. These different types of technological task have various prerequisites in management and planning.

We do not want a complete or eclectic classification of all innovation types, and therefore the above mentioned relations are the most important from our standpoint. We concentrate on the transition process from a given structure of technologies to a new structure of technologies, able to overcome major gaps in resource processing systems and socio-economic bottlenecks. We made the following more sophisticated classification by the technological level and the range of application (Table 9). So now we can differentiate between 7 × 7 = 49 kinds of innovation.

INNOVATION LEVEL INDEX - A FIRST ROUGH ESTIMATION

Establishing an innovation classifcation the next step could be a kind of quantitative evaluation by a technology level index. This was made in an OECD investigation of 1242 innovations in five countries from 1953 up to 1973. (Table 10). In column (1) a linear level index is given, used by the OECD study. However, we think that an exponential level index would be more appropriate. The distance between basic and improvement innovations should be higher than the distance between different kinds of improvement innovations. The frequency distribution in column (4) also points to an exponential pattern. Another argument can be the exponential growth of technological parameters in the transition period to new principle solutions and the exponential saturation in the improvement period. If we assume that the importance of innovations w (a coefficient between 1 and 100) follows an exponential function and the two parameters i_k and ν_k are connected in a multiplicative form, we can write:

$$w = i_k \cdot \nu_k \qquad (14)$$

$$w = e^{ak} \cdot e^{bk} \qquad (15)$$

$$w = e^{(a+b)k} \quad .$$

Taking a simple symmetric scheme (a = b) we then have

$$w = e^{1ak} \qquad k = 0,1,\ldots,6$$

Table 9. Classification of innovations by technological level and range of application.

NO	Range of Application / Scientific-Technological Level	V_k	II				BI		
			Quantitative growth of existing demand	Simple modification of existing demand (Improved parameters of existing products or processes)	Essential modification of existing demand (New parameters of existing products and processes)	Arising of a new demand (new product or process) in the existing demand complex	Essential modification of existing demand complex by new products or processes	Arising of a new demand complex or subcomplex	Change of the whole system of needs
	ik		1,0	1,5	2,2	3,2	4,6	6,8	10,0
1	Quantitative growth of the existing technical basis	1,0	1	1,5	2,2	3,2	4,6	6,8	10,0
2	Improvement within well-known technical prin.	1,5	1,5	2,3	Bentwood Furniture 3,5	Bicycle 4,8	6,9	10,0	15,0
3	As 2 but with essential changes of 1 factor (mats., tool func. design)	2,2	2,2	Oxygen process 3,3	Thomas process 4,8	Diesel engine 7	Paper production 10	15	22
4	As 3 but with ess. changes of sev. fac.	3,2	3,2	4,8	Stitching bond 7	Atomic ice-breakes 10	Electrical railway 15	22	Spinning Jenny 33
5	New solutions within well-known basic principle	4,6	4,6	6,9	Gyrocompass 10	Polyethylene 15	Detergents 22	Vacuum lamp 33	46
6	New basic prin. within same form or struc. level of substance	6,8	6,8	10	15	22	Synthetic fibres 33	Incandescent lamp 46	68
7	New basic prin. changing form or struc. level of substance	10,0	10	15	22	33	Radar 46	Transistor 68	Electricity 100

Table 10. Frequency and level of innovation activities in five OECD countries 1953-1973.

No.	Types	Level Linear 0 to 100	Level Exponential 1 to 100	Frequency abs.	Frequency per cent
	(0)	(1)	(2)	(3)	(4)
1.	Marginal	0-44	1-2	760	61
2.	Normal II	45-55	3-5	239	19
3.	Important II	56-66	0-10	149	12
4.	Very Important II	67-78	11-21	62	5
5.	Radical II	78-89	22-46	29	2
6.	BI	90-100	47-100	7	1
		0-100	1-100	1242	100

Source: Mensch, G (1976) Gemischtwirtschaftliche Innovations praxis.

According to $1 \leq w \leq 100$ (percent) we find for $k = 6$

$$100 = e^{12a}$$

$$a = \frac{\ln 100}{12} = 0{,}38376$$

From that we find the coefficients of importance of each level within the $7 \times 7 = 49$ field (see Table 9).

When we try to adjoin one innovation in the $7 \times 7 = 49$ field (Table 9) we realize that we often have some difficulties in making an exact estimation and so we feel that it is not appropriate to sophisticate the main innovation classification too far. This does not mean that for special studies and innovations we do not need a more detailed typology.

TYPES OF INNOVATION AND THE EFFICIENCY CYCLE

The investigation of the different role of basic and improvement innovations can help us to better understand why the innovation process is not as one would assume, a continuous process, but rather an interrupted sequence of innovation pushes and innovation lacks. It is the relationship between basic and improvement innovations which drives the process of technological and economic development. This relationship is the core of the special circumstances surrounding the birth, growth and decline of each successive new branch of industry. This shows why the simple market-demand models or science-push models are inadequate explanations of the process of innovations in specific branches of manufacturing in the economy as a whole. The interaction between science, technology, and economy varies in its nature and intensity over time and among various industries.

We cannot say that inventions are always the simple result of demand pull. Needs and demand are the main driving factor in the diffusion process. So when we look at the innovation process in a retrospective manner we find that they are all caused by an existing need. But in reality the more important inventions were made in a rather probabilistic cognition process arriving at goals not having been realized before. So it was in the case of penicillin, saccharin and synthetic rubber. At the end of the invention process needs were satisfied which were not the original aims of their research and development processes. Often demand pull is the main reason for incremental innovations using the efficiency potential of basic innovation. But fundamental inventions are less or not so directly connected with the market demand or concrete needs. Basic innovations create new fields for production and efficiency. The basis for this could be a series of new scientific discoveries and technological advances. The connection between these advances and the developing needs of the society is often realized very slowly.

The role of basic and improvement innovations in the development of efficiency can be demonstrated with the following simple model (Figure 3)..

What is the impact of basic and improvement innovations like in relation to the economy. Efficiency is in general

$$e_0 = \frac{E_0}{C_0} \qquad (16\ )$$

where

E_0 = the sum of benefits or revenues at the time t = 0

C_0 = the sum of costs or expenditures at the time t = 0.

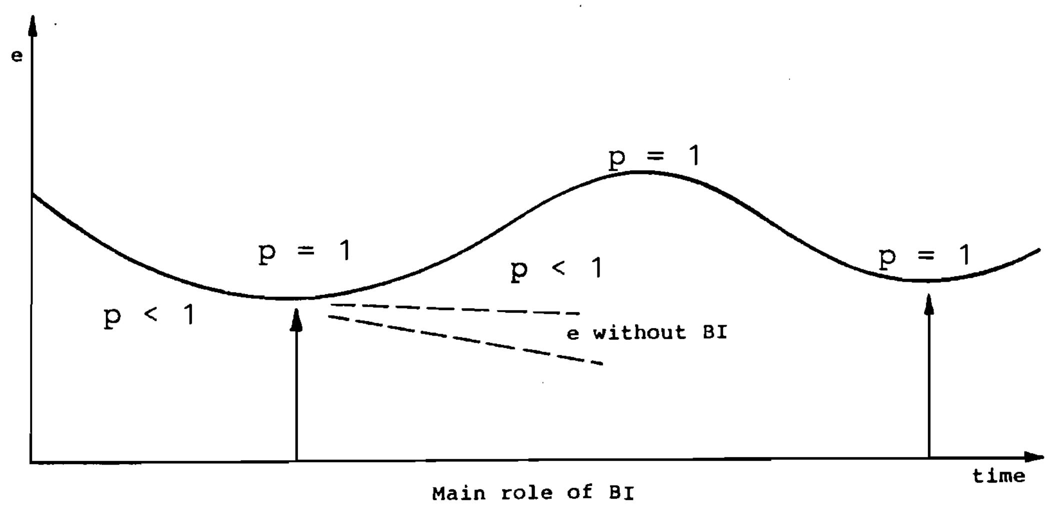


Figure 3. Development of efficiency.

At the time $t = 1$ we find,

$$e_1 = \frac{E_0 + \Delta E}{C_0 + \Delta C} = e_0 \quad \frac{1 + \frac{\Delta E}{E_0}}{1 + \frac{\Delta C}{C_0}} \tag{17}$$

$$\Delta E = E_1 - E_0 \tag{18}$$

$$\Delta C = C_1 - C_0 \tag{19}$$

The increase of E can be divided into

$$\Delta E = \Delta E_N + \Delta E_A \tag{20}$$

ΔE_N = increase in benefits or revenues from new processes and products,

ΔE_A = increase in benefits or revenues from old processes and products.

And in the same time for costs,

$$\Delta C = \Delta C_N + \Delta C_A \tag{21}$$

Therefore we come to

$$e_1 = e_0 \left(\frac{1 + \frac{\Delta E_N + \Delta E_A}{E_0}}{1 + \frac{\Delta C_N + \Delta C_A}{C_0}} \right) \tag{22}$$

$$e_1 = e_0 \cdot p \tag{23}$$

A pure improvement policy gives us

$$\Delta E_N = 0 \quad ,$$

and

$$\Delta C_N = 0 \quad .$$

However, at the first time high benefits ΔE_A in connection with moderate expenditures ΔC_A. Therefore we have $p > 1$. But later on we have diminishing returns and therefore we get $p < 1$ and a certain decrease in efficiency.

A pure or dominant improvement policy leads to a situation described by many authors as "productivity dilemma" (technologisches Patt). In this situation the main attention is given to short-term gains, and new basic innovations do not occur or they are delayed. The inertia of the given technological system becomes a major barrier for further economic progress. Therefore efficiency e is declining because it is not being stopped by gains from substantial improvement innovations. The reason for this is the inevitable increase in costs for resources, environment, and infrastructure.

This situation is critical for the further development of the economy. If we are not able to implement a new push of basic inventions which can open new directions and fields of economic activity and thus improving efficiency, the result must necessarily be the decline of the capability of society to meet national and personal needs, to overcome shortages in the resource situation, to avoid unemployment, and also to promote the conditions for business activity especially in the field of investment. In the case $p < 1$ the innovation process has run dry because of pseudo innovations (i.e. innovations without positive influence on the efficiency) or through improvement innovations which are not able to compensate the increasing costs. The result of this tendency is stagnation and crises with great social and political consequences. The nature of these resource crises is different from the usual ups and downs in the business cycle of capital reproduction (7 - 10 years).

The very different forms of discontinuous development of the economy also need different social and managerial responses. The response of the resource crisis could only be a push of social and technological innovations. This is why many investigations were devoted to identifying a significant relationship between resource crises and basic innovation frequency. The realization of basic innovation was always a complicated social process which coincided with the arising social problems. We have enough examples in history in which the inability to realize basic technological innovations has resulted in social and political crises (Kuczynski 1975, Mensch 1975, Freeman 1978, Forrester 1978, Freeman 1979). Such historical analysis may help us to better understand the responsibility we have in mastering the process of innovation to meet social needs more appropriately and prevent social catastrophes.

REFERENCES

Abernathy, W.J.(1978) The Productivity Dilemma. Roadblock to Innovation in the Automobile Industry. John Hopkins University Press, Baltimore and London.

Forrester, J. (1978) Innovation and the Economic Long Wave, MIT, D-2990-1.

Freeman, C. (1978) Technology and Employment: Long Waves in Technical Change and Economic Development, Holst Lecture.

Freeman, C. (1978) The determinants of innovation, market demand technology, and the response to social problems. Page 213, Futures.

Gold, B. ed. (1975) Technological Change: Economics, Management and Environment. Pergamon Press. Page 131.

Gross, A.T. (1933) Die Glühlampe als Wegbereiterin der Elektrizitätswirtschaft. Technik-Geschichte. Beiträge zur Geschichte der Technik und der Industrie. Berlin.

Haustein, H.-D. (1974) Die Proportionalität der technischen Basis. Akademie Verlag, Berlin.

Haustein, H.-D. (1979) Innovations in the Lighting Industry. (forthcoming) Laxenburg, Austria: International Institute for Applied Systems Analysis.

Hartmann, W.D. and H.-D. Haustein (1979) Leitung industrieller Forschung und Entwicklung, Akademie Verlag Berlin.

Henriot, I. (1955) Geschichte des Schiffbaus. Urania Verlag, Leipzig-Jena. Pages 19-22.

Illich, J. (1977) Toward a History of Needs. Pantheon Books, New York.

Kuczynski, J. (1975) Vier Revolutionen der Produktiv-kräfte, Berlin.

Maier, H., and W. Marschall (1978) Ed. Ökonomische und soziale Wirksamkeit des wissenschaftlich-technischen Fortschritss. Akademie Verlag Berlin.

Maier, H. (1979) Some Conclusions for International Technology Assessment from the IIASA Energy Study. Laxenburg, Austria. International Institute for Applied Systems Analysis. Presented at the XXIV International Meeting of the Institute for Management Sciences. The Challenge of Global Interdependency, Honolulu, Hawaii. June 18-22, 1979.

Mensch, G. (1975) Das technologische Patt. Frankfurt am Main.

Mensch, G. (1976) Gemischtwirtschaftliche Innovationspraxis, Göttingen. Page 92.

Nick, H. (1974) Die Wechselwirkung revolutionare und evolutionaire Verinderungen in Wissenschaft, Technik und Produçtion., in E. Gatovskij, H. Maier, F. Kutta, Wissenschaft, Okonomie, Fortschritt, Berlin. Pages 87-101.

Oliver, J.W. (1959) Geschichte der amerikanischen Technik. Düsseldorf. Page 354.

Schumpeter, J.A. (1952) Theorie der wirtschaftlichen Entwicklung. Duncker und Humblot, Berlin (first edition 1911).

United States National Science Foundation (1977) Science Indicators, 1976.

United States Superintendent of Documents (1978) A national plan for energy research, development and demonstration: creating energy choices for the future. Overall Economic Perspective for the ECE Region up to 1990, UN ECE/EC.AD./17. Page 155.

Uhlmann, L. (1978) Der Innovationsprozess in westeuropäischen Industrieländern. Der Ablauf industrieller Innovationsprozesse. IFO-Institut für Wirtschaftsforschung. Duncker und Humblot. Berlin-München.

Zvorykin, A.A., N.I. Osmova, V.I. Černyšev, S.V. Šuchardin (1962) Istorija techniki. Moscow.