Creativity and Regional Development

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FOREWORD

The Regional Issues Project at IIASA is emphasizing dynamic aspects of processes and policies in spatial development. A major component in this effort comprises the analysis of the role that metropolitan regions play in national economies and in the world economy as places for R&D activities, and birthplaces of innovations and technological renewal.

This paper focuses specifically on knowledge and creativity in a spatial context as prerequisites for the development of new products and production processes, and as a fundamental factor in Schumpeter's view of economic change as a process of creative destruction. The analysis focuses on the concept of "creative regions", represented, e.g., by the contemporary San Fransisco Bay Area as well as the Shinkansen and Milano regions.

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ABSTRACT

In this paper, research and development, knowledge and creativity are analyzed within the context of economic development theory. It is demonstrated that size and spatial structure play an important part in the creative process. Furthermore, it is argued that only a very limited set of policy conclusions can be drawn from non-spatial theories of R & D.

A vital concept is the "creative region", of which very few examples are encountered in each historical period. Historically, Vienna stands out as an interesting example. Today, regions such as the San Francisco Bay Area, Shinkansen, and Milano would be of potential interest for closer scrutiny as possible creative regions.

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CREATIVITY AND REGIONAL DEVELOPMENT

Åke E. Andersson

1. INTRODUCTION

Since the days of Schumpeter and his Theory of Economic Development, little has been written on the interactions between economic and technological development. This is all the more surprising since both have been spectacular in this century.

Schumpeter's major contribution was to subdivide economic activity into two behaviorally distinct branches: (1) a general equilibrium or circular flow branch of the economy, and (2) a disequilibrium or development branch.

Schumpeter argued that the general equilibrium branch of the economy tends to be profit free, because it holds no surprises and is founded on "rational expectations". In an economy with free entry and exit, profits tend to go hand in hand with technological and economic development.

It is the intention of this paper to review the role of technological development in social and economic development and to add some contributions to our understanding of the mechanisms of creativity as a key factor in economic development. The paper is written in a neo-Schumpeterian spirit.

2. TECHNOLOGICAL KNOWLEDGE, R & D, AND INTERREGIONAL COMPETITION

Knowledge is a precondition for all forms of production. In the literature, expansion of the stock of knowledge is often called research and development (R & D). R & D is both a quantitative kind of investment which is vital for all modes of production, and a qualitative factor for changing the characteristics of products.

The aim of R & D is to create new products for an economy as well as new and better methods for producing existing products. Studies of the international competitiveness of developed economies indicate that technological R & D is of utmost importance. In a system of open regions, there is no fundamental difference between competing in the domestic market and competing on other markets. The consequence of increasing R & D associated with a sector of production normally first improves the capacity of that sector to compete with imported commodities. If R & D investments in a certain commodity group become very large compared to other producer regions it is after some time probable that other regional markets will be captured with export surplus as a consequence. This argument is illustrated in Figure 1.

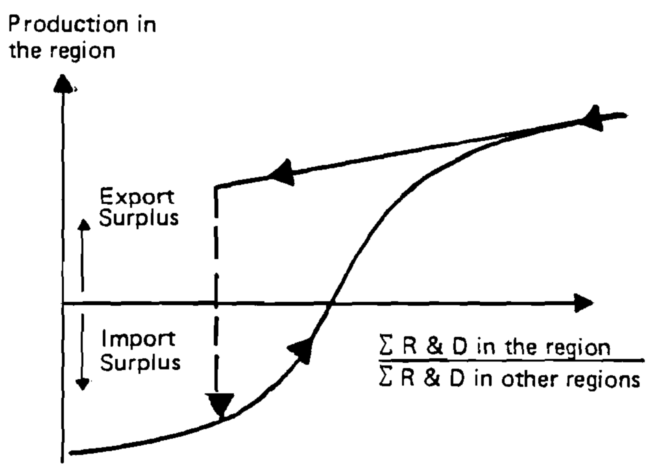

Figure 1. Fundamental relationship between specialization and relative R & D investments.

A relatively large research and development effort can (according to this figure) generate a substantial comparative advantage for the region or country embarking on a given comparative R & D strategy. The response is, however, highly assymmetrical in most cases. Each region tends to be small compared to the total production capacity for a commodity. This means that a high level of R & D expenditure on a certain commodity relative to other regions must be of a very temporary nature. It is very easy for the surrounding world to counteract with larger R & D efforts, while building on the level of knowledge already achieved.

The general positive correlation between R & D and improvements in international competitiveness has been tested extensively. Table 1 gives a general response pattern for Swedish building materials in terms of R & D activities and international competitiveness.

TABLE 1. The level and change of international competitiveness and R & D intensity of Swedish building material industries during the 1970s.

	Improved international competitiveness 1968-1981	Stable or deteriorated international competitiveness 1968-1981	Total
Export surplus 1981	Four out of eight buildingmaterial-industries with high R & D share*	One out of ten with high R & D	18
Import surplus 1981	Two out of five with high R & D	None out of ten witn high R & D	15
Total	13	20	33

* A high R & D share is defined to be a situation with more than 3.5 percent of the value added devoted to R & D.

Source: SOS, Företagen 1977 och SOS, Utrikeshandel and SOS, Industri, 1968-1981.

This table shows that R & D is of importance for competitiveness irrespective of the export position of a commodity group. It also shows that almost none of the commodity groups with a low relative level of R & D could improve their competitive position during the period of study. The loss of a certain market will follow another and more catastrophic trajectory.

The relation in Figure 1 is very hard to test empirically, because of the scant data on R & D policies over longer periods of time. Discussions with researchers in the Swedish drug industry, however, indicate that for these short-lived commodities the general response pattern seems to follow the assymmetrical competition curve in Figure 1.

3. SOME FUNDAMENTAL CHARACTERISTICS OF R & D

One of the fundamental problems with R & D is the uncertainty of net returns, namely the revenues and cost to be expected. R & D is by definition an activity with uncertain results. Research and development is designed to <u>create</u> new information and therefore it is impossible to make forecasts about the outcome with the same degree of certainty as is often possible with material investments. It is obvious that these problems of uncertainty increase with the degree of basic analysis.

A fundamental breakthrough is an extremely rare event in research. This means that more fundamental research necessitates larger research units in order to generate an even flow of results, thereby justifying a continuation of the research activity.

The research process is often looked upon as "a search in the fog" for hidden relations and unknown structures. This is a reason why research that sets out to solve problems within one area often generates solutions to problems that were not defined at the outset. This tendency to solve the "wrong" problems is a very strong argument for the existence of economies of scale of another form in R & D activities. While the formally defined uncertainty generates a need for a large R & D volume there is also a need to develop some kind of horizontal integration of industrial R & D activities.

Apart from the economies of scale caused by uncertainty, there are also conventional reasons for operating research and development activities on a large scale. Indivisibilities are extremely pronounced in technological

R & D. The use of specialists and laboratory equipment often requires a large and stable research activity. Problems of indivisibilities may increase considerably if there is a need for diversified competence among members of the research team.

The economies of scale, due to uncertainties or resource indivisibility, create problems which confront all research and development activities. The effect of economies of scale on R & D expenditures can be illustrated with empirical material. Table 2 summarizes the relation between size and relative R & D effort in Swedish companies engaged in manufacturing industry.

TABLE 2. The relation between size of firms and R & D expenditures as per cent share of value added.

Size of company	R & D expenditures in relation to value added	Size group share of total industrial R & D expenditures
Less than 100 employed	0.35 percent	1.0 percent
Between 100 and 500 employed	1.50 percent	5.0 percent
More than 500 employed	7.70 percent	94.0 percent

Source: Svensk Industriell Utveckling; Faktabakgrund och Framtidsbedömningar, Sektionen för Samhällsekonomi FOA 1, STU information nr 162-1979.

One message from this table is extremely clear. The larger manufacturing firms in Sweden have an R & D output ratio <u>twenty</u> times larger than the smallest.

4. COLLECTIVITY OF PRIVATE R & D

Research and development can be regarded as investments in knowledge expansion. Conventional methods for the evaluation of profitability of material investments may also be useful in evaluating the profitability of R & D investments. It is easy to show that the use of a common price of capital and a common rate of interest in combination with the market system for decision making is compatible with maximum social efficiency in the allocation of material investment resources. However, it is also possible to show that use of the same market principles for decisions about allocation of R & D investments is not compatible with maximum social efficiency.

We will assume that an individual company wants to maximize its profits by an optimal allocation of the capital under its control. We obtain the optimization problem

$$\max Q_i(K_i, G_1, \ldots, G_i, \ldots, G_n) - rK_i - pG_i = \text{profit} \ ,$$

where K_i denotes material and G_i knowledge capital in firm i, Q_i is a profit function, r is the cost of capital, and p is the rate of interest.

The necessary conditions for a profit maximum are that the firm allocate its potential capital and knowledge so as to fulfill the following conditions:

$$\frac{\partial Q_i}{\partial K_i} - r = 0 \quad \text{and}$$

$$\frac{\partial Q_i}{\partial G_i} - p = 0 \ .$$

Maximizing the <u>sum</u> of profits over the total economic system implies:

$$\max \sum_i Q_i(K_i, G_1, \ldots, G_i, \ldots, G_n) - r\sum_i K_i - p\sum_i G_i \ .$$

The necessary conditions for a social maximum are not the same as the private profit maximizing rules:

$$\frac{\partial Q_i}{\partial K_i} - r = 0 \ ; \ (i = 1, \ldots, n) \quad \text{and}$$

$$\sum_j \frac{\partial Q_j}{\partial G_i} - p = 0 \ ; \ (i = 1, \ldots, n) \ .$$

These conditions show that only profit maximization includes an analysis of the consequences of R & D investments upon the investing firm itself. This is done in a situation when a decision to invest in new knowledge can be assumed to be of great value to other agents in the system. With a private profitability calculation, one would in most cases underestimate the total efficiency of the R & D investment.

There is ample evidence that such an analysis holds true in the real world. In a sample of 37 innovations covered by an American study, it could be shown that the average profitability calculated for all companies is approximately three times as large as company internal profitability (Table 3). The large difference between socially and privately defined profitability is a strong argument for using some kind of public cost-sharing system. This does not imply that research and development activities ought to be executed by public institutes. The only implication is that R & D investments should in one institutional form or another be subsidized or otherwise promoted by society.

The classical method to reduce the conflict between individual costs and public revenues from R & D is to employ some patent or licensing system. In this way, companies try to secure some of the profits of their development of new knowledge. Patents and secrecy measures do not seem to be frequently used at the private or at the societal level of R & D policy making. Through patents and secrecy solutions much of the public benefits of R & D can be lost. The conclusion of this discussion is that any well organized government must subsidize socially beneficial R & D, wherever it is performed.

5. OPTIMAL R & D POLICY AT THE MACRO LEVEL

A macro-economic R & D policy is obviously needed for the share of R & D in total resource use to become optimal. This can be regarded as a problem of determining the optimal share of investment funds to be allocated to R & D.

If one assumes that an agreement has been reached on how to distribute the costs of R & D, then the "level" must be decided. This could be approached as a problem of determining a rate of taxation (τ) for R & D financing out of total investment resources. I furthermore assume that the level of production is determined in a "putty-clay" fashion. This means that the growth of production is determined by the equation

$$\Delta Q = f(I,R) \quad , \qquad (1)$$

TABLE 3. Social and company internal profitability of 37 different R & D projects.

R & D project	Percentage profitability Social	Company internal
Primary metals innovation	17	18
Machine tool innovation	83	35
Components for control systems	29	7
Construction material	96	9
Drilling material	54	16
Drafting innovation	92	47
Paper innovation	82	42
Thread innovation	307	27
Door-control innovation	27	37
Chemical product	71	9
Chemical process A	32	25
Chemical process B	12	4
Major chemical process	56	31
Household Cleaning device	209	214
Stain remover	116	4
Dishwashing liquid	45	46
Industrial product A	62	31
Industrial product B	negative	negative
Industrial product C	116	55
Industrial product D	23	0
Industrial product E	37	9
Industrial product F	161	40
Industrial product G	123	24
Industrial product H	104	negative
Industrial produkt I	113	12
Industrial product J	95	40
Industrial product K	472	127
Industrial product L	negative	13
Industrial product M	28	23
Industrial product N	62	41
Industrial product O	178	148
Industrial product P	144	29
Industrial product R	103	55
Industrial product S	29	25
Industrial product T	198	69
Industrial product U	20	20
Median value	70	25

Source: Beardsly, et al., Social and Private Rates of Return from Industrial Innovations, Quarterly Journal of Economics, May 1977, p. 221.

where

$\Delta Q = Q - Q_{-1}$ = growth of production between two consecutive periods of time,

I = rate of material capital accumulation (net investment),

$R \equiv \Delta G$ = rate of knowledge accumulation (research and development investment),

f = a continuously differentiable, strictly concave growth function.

The rate of investment is determined by a Keynesian investment function:

$$I = s(1-\tau)Q_{-1} \quad , \tag{2}$$

where

I = rate of investment,

s = savings (investment) ratio,

τ = R & D-taxation ratio,

Q_{-1} = rate of production in the preceding period.

The rate of knowledge accumulation is determined by the simplified function

$$R = g\tau Q_{-1} \quad , \tag{3}$$

where g is the productivity of the R & D-producing sector. Optimizing the rate of accumulation of knowledge and capital can be effected by formulating the Lagrangian

$$\max_{\{R,I,\tau\}} \Lambda = f(I,R) - \lambda_I(I-s(1-\tau)Q_{-1}) - \lambda_R(R-g\tau Q_{-1}) \quad . \tag{4}$$

Conditions for a maximum are

$$\frac{\partial \Lambda}{\partial I} = \frac{\partial f}{\partial I} - \lambda_I = 0, \quad \frac{\partial \Lambda}{\partial I} = \frac{\partial f}{\partial R} - \lambda_R = 0 \; ,$$

$$\frac{\partial \Lambda}{\partial t} = - \lambda_I s Q_{-1} + \lambda_R g Q_{-1} = 0, \tag{5}$$

$$\frac{\partial \Lambda}{\partial \lambda_I} = I - s(1-\tau)Q_{-1} = 0, \quad \frac{\partial \Lambda}{\partial \lambda_R} = R - g\tau Q_{-1} = 0.$$

At the optimum, this implies that the condition

$$- \frac{dR}{dI} = \frac{\partial f}{\partial I} = \frac{\partial f}{\partial R} = \frac{s}{g} = \frac{\lambda_R}{\lambda_I},$$

must hold.

We can now forumulate a golden rule of taxation for R & D:

> The rate of taxation for accumulation of knowledge should be adjusted so that the ratio between the rate of savings and the marginal productivity of the R & D-sector equals the ratio between marginal growth effects of investments and of R & D.

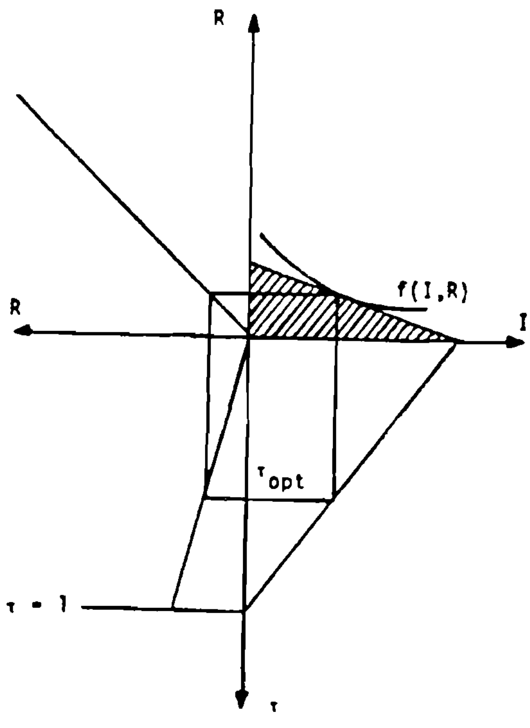

Figure 2. Determination of the optimal rate of taxation.

This model of optimal R & D can be illustrated in a pedagogical diagram. Figure 2 depicts how the propensity to save, the productivity of the R & D-sector and the growth function properties jointly determine the optimal rate of taxation.

It is clear that any increase in the savings ratio or the productivity of the R & D sector must increase the rate of growth. What will happen to the optimal rate of taxation is unclear. In order to assess the importance of the possiblities of substitution, we assume the growth function to be of the CES-form:

$$f(I;R) = (\varepsilon_1 I^{-\rho} + (1-\varepsilon_1)R^{-\rho})^{-1/\rho}, \tag{6}$$

$$\frac{\partial f}{\partial I} = \varepsilon_1 I^{-(1+\rho)} (\varepsilon_1 I^{-\rho} + (1-e_1)R^{-\rho})^{-(1+1/\rho)}, \tag{7}$$

$$\frac{\partial f}{\partial R} = (1-\varepsilon_1)R^{-(1+\rho)} (\varepsilon_1 I^{-\rho} + (1-\varepsilon_1)R^{-\rho})^{-(1+1/\rho)}. \tag{8}$$

If growth is regulated by a CES-function, the optimal rate of taxation is determined by the equation:

$$\frac{1-\tau}{\tau} = \left\{ \frac{1-\varepsilon_1}{\varepsilon_1} \right\}^{\sigma} \left\{ \frac{s}{g} \right\}^{\sigma-1}.$$

The following proposition can then be formulated:

Proposition: Given a CES growth function, investment function (2) and R & D-function (3), the optimal rate of taxation τ for R & D will decrease with an increasing (s/g) if the elasticity of substitution is greater than one. The opposite result holds if the elasticity of substitution is less than one.

6. REGIONAL GENERALIZATION OF THE MODEL OF R & D AND GROWTH

The regional dimension is extremely important in all studies of public goods. Collectively without spatial restriction is extremely rare (like world peace and other 'goods' of this kind). Knowledge is quite different. The availability of technological information is clearly greater at shorter rather than longer distances. Accessibility is a reasonable way of representing the economic effects of the spatial distribution of a public good like technological knowledge. A general representation is given by

$$a_r = \sum_s h(d_{rs})G_s, \tag{9}$$

where

a_r = accessibility from region r,

$h(d_{rs})$ = a non-increasing function of the distance from region r to region s ($d_{rs} \geqq 0$),

G_s = level of knowledge in region s.

A regional growth process (with an optimal or non-optimal τ) can now be formulated:

$$\dot{K}_r = s_r(1-\tau)Q_r(K_r, a_r), \qquad (r = 1,\ldots,n)$$

$$\dot{G}_r = H_r(g\tau Q_r), \qquad (r = 1,\ldots,n) \tag{10}$$

with

$$a_r = \sum_s h(d_{rs})G_s.$$

A theorem by Nikaido can be used to prove the existence of a balanced growth solution for this system (Nikaido, 1968). Simulations with this model have shown that it is relatively stable for any set of neo-classical production functions.

By linearizing the system, it has been shown (Andersson and Mantsinen, 1980) that

(a) a decrease of any distance increases the balanced rate of growth of all regions;

(b) an increase of any regional rate of savings increases the rate of growth of all regions; and

(c) the structure of production generally changes with changing research priority and regional investment priorities.

The most interesting property of these models is their tendency to transform spatial distances into time lags.

Growth rates of peripheral regions generally increase at a later stage than growth rates of centrally located regions. This implies that an increase in the general research priority ratio (or tax ratio), τ, normally leads to increasing regional disparities.

Most of the economic activity located in peripheral regions is small-scale or based on natural resources. A tendency for these regions to lag behind in terms of benefits from technological development is thus combined with a lower-than-average research priority in the natural resource sectors and in the small firms dominating such peripheral regions.

7. CREATIVITY AND R & D - MICRO ANALYTICAL CONSIDERATIONS

The problem of technological development and the interaction between the formation of new knowledge and economic development has been discussed at the macro-economic level in previous sections. This section offers a modest contribution to our understanding of creativity and social and economic development at the micro scale and at the higer, interactive meso scale of an individual region.

It is necessary here to introduce some related concepts. These are *information, knowledge, competence, and creativity.* The ordering of these concepts is not random, but represents a ranking.

Information is the most elementary concept. It has a very limited structure and can consequently be disaggregated and aggregated without losses. It is the smallest element in our system of concepts.

Knowledge is structurally ordered information. As a parable, one can view information as variables whereas knowledge is a set of equations containing these variables. Concepts, ideas, and patterns are subsets of knowledge.

Competence can be seen as embodied knowledge. This means that competence is knowledge regulated by the human body in its relations to other humans, machines, and the environment. This implies that competence can be subdivided into at least three specific types:

- instrument-oriented competence,
- sector-specific competence, and
- regional-specific competence.

Creativity is the concept of highest order. Creativity presumes the capacity to order and reorder information with the aid of a knowledge system. We assume that the creative process is synergetic. This implies that information, knowledge, and competence are brought into an intensive interaction with each other in order to fashion new creative knowledge or competence.

To provide an example of these synergetic interactions in the creative process, we refer to the story of Gutenberg as told by Arthur Koestler:

> "At the dawn of the fifteenth century, printing was no longer a novelty in Europe. Printing from wooden blocks on vellum, silk, and cloth apparently started in the twelfth century, and printing on paper was widely practiced in the second half of the fourteenth century. The blocks were engraved in relief with pictures or text or both, then thoroughly wetted with a brown distemper-like substance; a sheet of damp paper was laid on the block and the back of the paper was rubbed with a so-called *frotton* - a dabber or burnisher - until an impression of the carved relief was transferred to it. Each sheet could be printed on only one side by this method, but the blank backs of the sheets could be pasted together and then gathered into quires and bound in the same manner as manuscript-books. These "block books" or *xylographs* circulated already in considerable numbers during Gutenberg's youth."

Oddly enough, the starting point of Gutenberg's invention was not the block-books - he does not seem to have been acquainted with them - but playing-cards. In his first letter to Cordelier he wrote:

> For a month my head has been working; a Minerva, fully armed, must issue from my brain... You have seen, as I have, playing-cards and pictures of saints... These cards and pictures are engraved on small pieces of wood, and below the pictures there are words and entire lines also engraved... A thick ink is applied to the engraving; and upon this a leaf of paper, slightly damp, is placed; then this wood, this ink, this paper is rubbed and rubbed until the back of the paper is polished. This paper is then taken off and you see on it the picture just as if the design had been traced upon it, and the words as if they had been written; the ink applied to the engraving has become attached to the paper, attracted by its softness and by its moisture...
>
> Well, what has been done for a few words, for a few lines, I must succeed in doing for large pages of writing, for large leaves covered entirely on both sides, for whole books, for the first of all books, the Bible...
>
> How? It is useless to think of engraving on pieces of wood the whole thirteen hundred pages...
>
> What am I to do? I do not know: but I know what I want to do: I wish to manifold the Bible, I wish to have copies ready for the pilgrimage to Aix la Chapelle.

Here, then, we have skill No. 1: the printing from woodblocks by means of rubbing.

In the letters which follow, we see him desperately searching for a simpler method to replace the laborious carving of letters in wood:

> Every coin begins with a punch. The punch is a little rod of steel, one end of which is engraved with the shape of one letter, several letters, all these signs which are seen in relief on a coin. The punch is moistened and driven into a piece of steel, which becomes the "hollow" or "stamp". It is into these coin-stamps, moistened in their turn, that are placed the little discs of gold to be converted into coins by a powerful blow.

This is the first intimation of the method of type-casting. It leads Gutenberg, by way of analogy, to the *seal*: "When you apply to the vellum or paper the seal of your community, everything has been said, everything is done, everything is there. Do you not see that you can repeat as many times as necessary the seal covered with signs and characters?"

Yet all this is insufficient. He may cast letters in the form of coins, or seals, instead of engraving the wood, yet they will never make a clear print by the clumsy rubbing method; so long as his search remains confined to this one and only traditional method of making an "imprint", the problem remains blocked. To solve it, an entirely different kind of skill must be brought in. He tries this and that; he thinks of everything under the sun: it is the period of incubation. When the favorable opportunity at last offers itself, he is ready:

> I took part in the wine harvest. I watched the wine flowing, and going back from the effect to the cause, I studied the power of this press which nothing can resist...

At this moment it occurs to him that the same, steady pressure might be applied by seal or coin - preferably of lead, which is easy to cast - on paper, and that owing to the pressure, the lead would leave a trace on the paper - Eureka!

> ...A simple substitution which is the ray of light... To work then! God has revealed to me the secret that I demanded of Him... I have had a large quantity of lead brought to my house and that is the pen with which I shall write.

"The ray of light" was the bisociation of wine-press and seal - which, taken together, became the letter-press. The wine-press has been lifted out of its context, the mushy pulp, the flowing red liquid, the jolly revelry - as Sultan's branch was wrenched out of the context of the tree - and connected with the stamping of vellum with a seal. From now on these separate skills, which previously had been as different as the butcher's, the baker's, and the candlestick-maker's, will appear integrated in a single, complex matrix:

> One must strike, cast, make a form like the seal of your community; a mould such as that used for casting your pewter cups; letters in relief like those on your coins, and the punch for producing them like your foot when it multiplies its print. There is the Bible!"

Gutenberg had used all his competence in printing technology, but the creative process was a failure, *because the competence of one area is insufficient. When the possibility to print with lead was combined with the old regional wine pressing competence the printing process could be created.*

8. SOME THEORETICAL SUGGESTIONS AT THE MICRO LEVEL

A theory of the creative process at the micro level must include three basic concepts:

- competence (and its relationship to knowledge and information),
- synergisms, and
- structural instability.

The synergistic relationship of different competences in the creation of a new idea has been illustrated by the printing process. The fundamental importance of structural instability can be illustrated in a number of ways. The first illustration is of a more fundamental character.

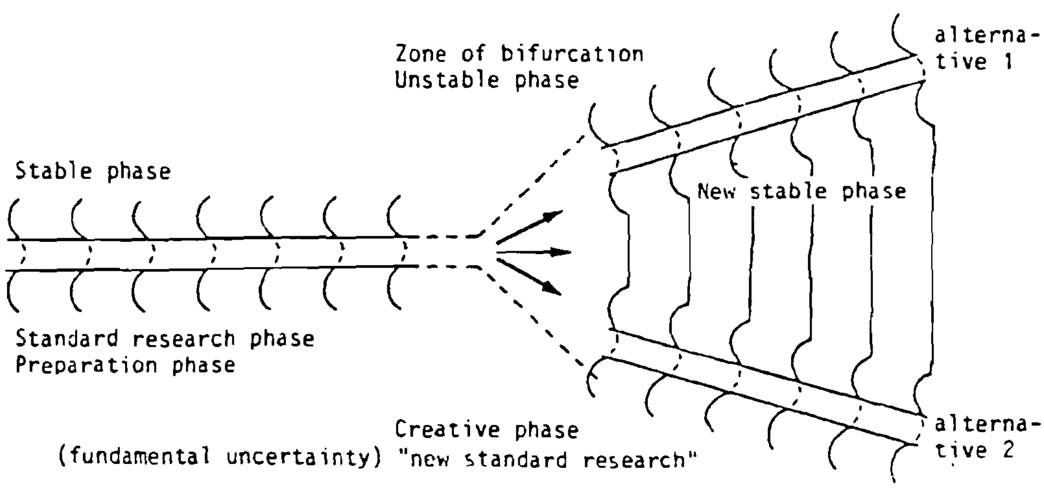

Figure 3. The creative process as a flow.

Structural instability is illustrated in Figure 3, where the creative process can be regarded as a flow. Short, unstable bifurcating periods interrupt long periods of structural stability. The basic idea of this paradigm (closely related to ideas by Kuhn and Prigogine) is to ascertain "when the time is ripe". Only in a period of structural instability can synergism (in an otherwise stable, linear, system of equations) be of a fundamental importance.

For the majority of a research process, the activity is a structurally stable equilibrium process. The researcher proves theorems, develops successive hypotheses within this framework, and improves upon the logical consistency. The designer in a similar process develops products created in an earlier phase, improves upon the functional characteristics of the products and develops its finish. In this stable process, however, an instability may also develop. Inconsistencies become obvious in the search for more general versions of the theory, as the set of deviations from fundamental properties is enlarged. In the development of products, problems emerge. Enlarging the tests and range of possible applications sooner or later leads to the detection of fundamental structural flaws.

In a situation of fundamental synergistic competence, an unstable situation can be usefully transformed into a creative situation. A completely new approach to an old problem can emerge because there is no stabilization to prevent the force of synergism.

The importance of instability for the development of new R & D ideas can be illustrated by two examples:

Example 1

At the end of the 19th century many technicians were engaged in the search for a motordriven aircraft, heavier than air. Many of these technicians were extremely competent in aerodynamics for non-motorized aircrafts. In spite of this, most of them failed in the construction of a controllable airplane. The hidden mistake was their belief in aerodynamical stability as a required property.

The brothers Wright (consciously or unconsciously) constructed an *unstable* motorized aircraft. To the surprise of most people, this unstable aircraft was controllable in the hands of a clever and fast pilot. The brothers Wright had in a very practical way showed that *destabilization* was a necessary condition for a new control strategy.

Example 2

In pictorial and architectural design, structural instability has been extensively employed in the creative process. Stable equilibrium patterns are the conclusion of the creative process. The introductory phase is a search for patterns which have a great potential for change into a number of possible stable equilibrium patterns. Figure 4 illustrates a hexagon with somewhat irregular radial lines.

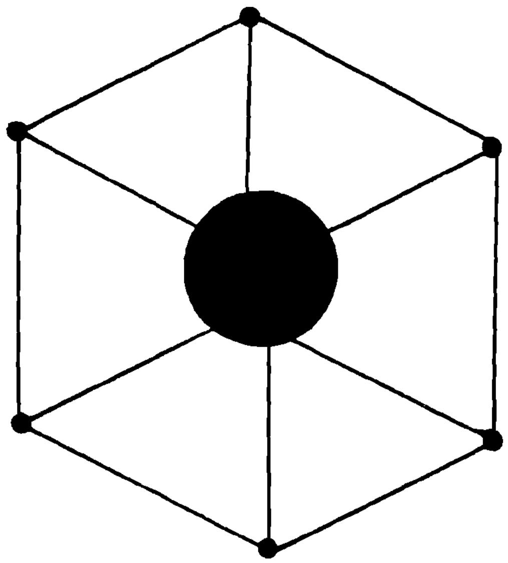

Figure 4. Example of a stable equilibrium pattern; potential of creativity: 0.

With very few changes to the preceding figure, we can generate an unstable cube in which the two centrally located corners "jump" back and forth in an unstable multiple equilibrium fashion (see Figure 5).

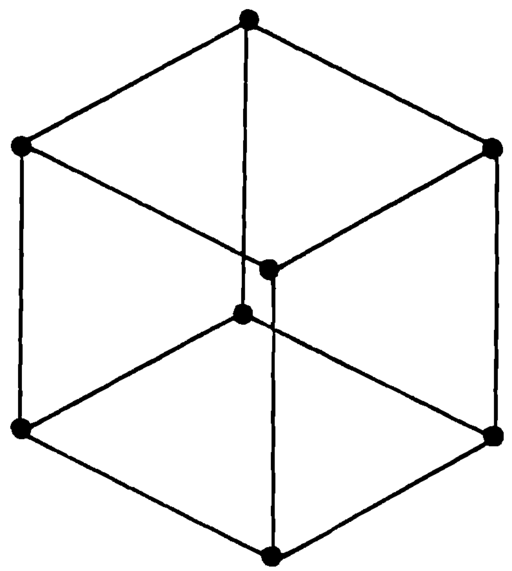

Figure 5. Example of an unstable, multiple equilibrium pattern; creative potential: 3.

With little effort, it is possible to generate three different stable equilibrium patterns out of this unstable, multiple equilibria. After such a process, the system is no longer unstable (structurally), but has been transformed into a stable equilibrium pattern without creative potentials.

Research, design, and development are creative processes. They must be fundamentally uncertain. This fundamental uncertainty is a consequence of structural instability, which is the fundamental precondition for the creation of new, more satisfying stable equilibrium structures. Multiple competence and structural instability are thus two necessary conditions for the creative process.

9. THE CREATIVE REGION

We have now developed some ideas concerning the creative process. One of the basic ingredients is the structural instability of a human brain interacting with objects or theories. The structural instability of the human brain is a precondition for probing beyond the immediately obvious. The synergistic elements of the object or theories under study can only occur if a structural instability is generated.

The goal of this section is to develop this micro-theory of creativity at a social level - the meso level of the region. Our problem is to define the environmental conditions at the regional level that can stimulate a creative development at the social level. It is almost impossible to judge if a current environment is more creative than others. We could use examples from the ancient Greek city region of Miletos or descriptions of Paris, London, or Brussels in the 19th century. It would also be possible to concentrate on post-war conditions in New York, Tokyo, or Silicon Valley. Instead, Vienna during the period 1890 to 1930 is the choice of region. The reason for choosing Vienna is the ample evidence of creativity there during this period.

What was the reason for the fundamental scientific and artistic achievements in a diverse set of activities like philosophy, theory of science, economics, medicine, psychiatry, mathematics, poetry, music, painting, architecture, theater, and journalism in the same period and in the same region (Janik and Toulmin, 1973)?*

Vienna at this time was a city of many scholarly institutions generating a very high level of academic competence. A few of the important names will suffice:

- Ludwig Wittgenstein, philosopher,
- Sigmund Freud, psychologist,
- Joseph Schumpeter, economist,
- Ludwig Boltzmann, physicist,
- Heinrich Hertz, physicist,
- Otto Wagner, architect,
- Adolf Loos, architect,
- Gustaf Klimt, painter,
- Karl Kraus, political ideologist.

These provided the necessary level of competence and the diversity required for a potentially synergetic situation.

*The negative side of this development was the emergence of new political movements, political upheaval, and even civil war.

Communication is a key word in understanding the fundamental role of metropolitan regions in the creative process. In those days, Vienna was the center of international, cultural, political, and scientific communications; paralleled only by Paris. Vienna was also an extremely dense city with overcrowding and a rich public life. Closely-knit networks were facilitated by close walking distances between all learned institutions. All the cultural and scientific personalities were in permanent communication with each other, even across the academic borders.

Vienna was also a city of unsatisfied human needs. The crumbling empire was in a permanent state of poltical repression on all social levels. The First World War provided the complete destabilization of the political system, propagating a wave of creativity through the social network.

On the basis of this and similar examples, we may conclude that creativity as a social phenomenon primarily develops in regions characterized by:

1. High levels of competence.
2. Many fields of academic and cultural activity;
3. Excellent possibilities for internal and external communication;
4. Widely shared perceptions of unsatisfied needs; and
5. A general situation of structural instability facilitating a synergetic development.

10. DISEQUILIBRIA AND THE CONTROL OF CREATIVITY

The social sciences have borrowed concepts and theories, primarily from classical physics. This is particularly true for the analysis of economic equilibria.

In recent years, disequilibrium analysis has become increasingly popular among economists as well as physicists and chemists. Much of the interest in thermodynamics is now concentrated on dissipative structures which are far away from equilibria. In these structures, macro regularity of processes may occur despite violent fluctuations on lower levels. Order through disorder is the rule in these structures. Identical experiments in these systems do not yield exactly the same results. Reactions do not follow identical patterns through time.

The old Japanese art of origami provides an interesting example of these principles. Figure 6 depicts the possible shapes that can be made from quadratic paper with predrawn folding lines which are the same for all final shapes. The path from the first potential pattern to the nine alternative figures traverses a few strategic bifurcation points. Intermediate stages do not reveal the final outcome. It is those stages when the final outcome is uncertain that are the stages of structural instability and creativity.

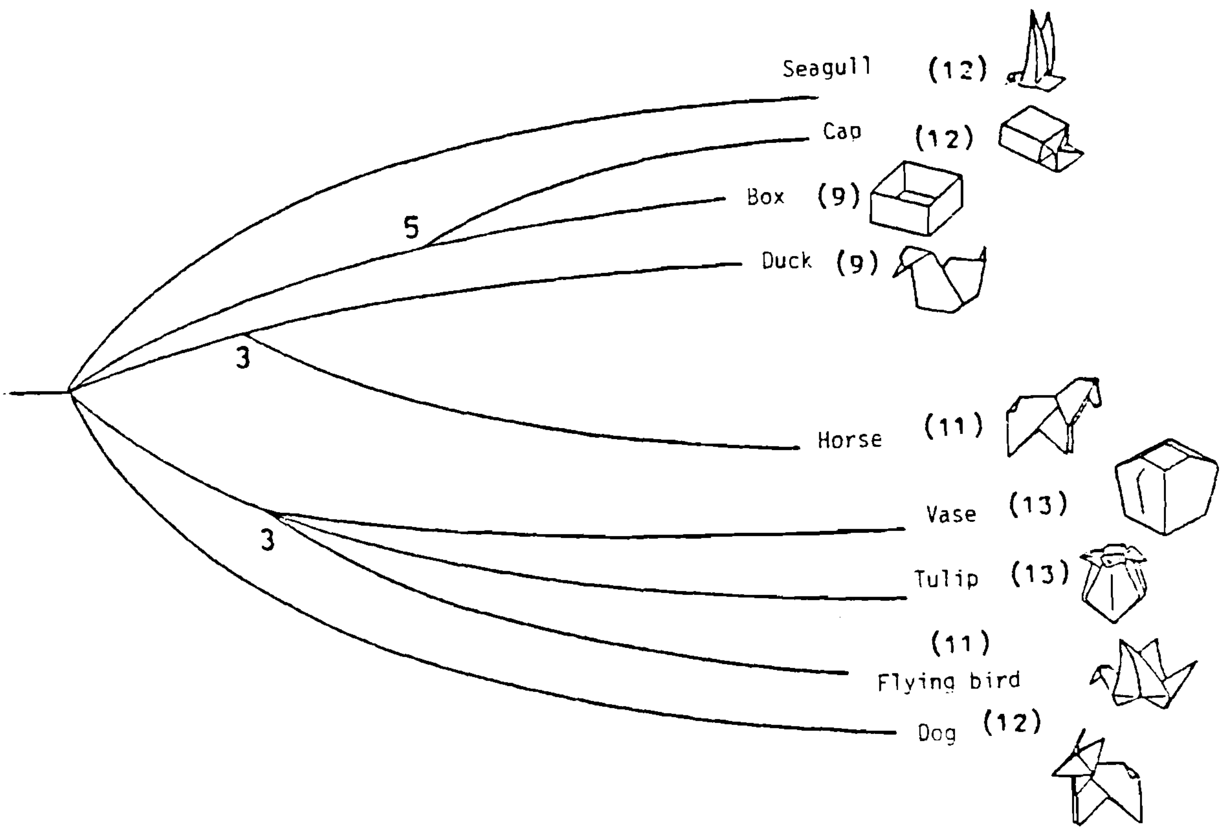

Figure 6. Possible shapes that can be made from quadratic paper - the old Japanese art of origami.

11. CONCLUSIONS

It is difficult to assess the importance of structural instability for the social sciences. In terms of understanding the conditions of research, development, and creativity, however, it is essential. The most important conclusions from our discussion are:

- Uncertainty is fundamental to research and creativity. Uncertainty of this kind is not an obstacle but rather a precondition for a creative state. In this context, it is equivalent to structural instability.
- Long-term technological forecasting is thus impossible, except at the macro level.
- Research and creativity are not controllable processes, except in macro terms (e.g., money and human resources allocated to such activities).
- Potential constraints on creativity can be alleviated by society.
- Creativity is often realized at the regional level.
- A creative region is characterized by
  - strongly perceived unsatisfied needs,
  - intensive internal and external communication,
  - a wide spectrum of competences (a wide and deep cultural environment), and
  - a situation of structural instability, perceived by many as a state of fundamental uncertainty.
- No single region is permanently creative.

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