POLISH ACADEMY OF SCIENCES
SYSTEMS RESEARCH INSTITUTE

STRATEGIC REGIONAL POLICY

A. STRASZAK AND J.W. OWSIŃSKI
EDITORS

PART I

WARSAW 1985

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Paradigms, Methods, Issues and Case Studies

A. Straszak and J.W. Owsiński
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Documentation of the workshop on "Strategic Regional Policy", December 10 - 14, 1984, Warsaw, organized by the Systems Research Institute, Polish Academy of Sciences and the International Institute for Applied Systems Analysis

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III. TECHNOLOGICAL AND SCIENTIFIC ISSUES

RECENT TRENDS IN RESEARCH ON INDUSTRIAL INNOVATION AND ITS ECONOMIC IMPACT *

Tibor Vasko

International Institute for Applied Systems Analysis
Laxenburg
Austria

Twenty years ago it would have seemed somewhat strange to talk about innovation to regional development experts. Ten years ago, however, it was less strange, as by then, many innovation studies of a regional character had been developed, for example, in USA, the Western States Conference, 1970.

Presently many conferences have been and are being convened covering innovation and its regional and social ramifications (for example, Zantvoort Meeting, 1985). This is one illustration of the increasing base of innovation research, and is also the main point of this paper.

Some Semantics and Metrics

The relationship of technology, as we now understand it to economic and regional development was the focus of interest of many economists in the past. This does not mean, however, that we possess a generally applicable tool to analyze and comprehend this relationship completely.

Until now no analytically meaningful definitions of technology seem to exist. The fact that technology (or its impact) is missing in many leading economic theories is considered as one of the causes of their failure, in many applications. One can roughly distinguish three different conceptions of technology (Sahal 1981) used in analyzing economic development:

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* revised version, as of August 1985 (eds.).

1. The Neoclassical Economic Concept of a Production Function

This function relates various technically feasible combinations of inputs or factors of production with output, the most important factor being capital an labor, $Y=F(K,L,t)$. These functions are suitable for the study of factor substitution and their changes, less so for the study of innovation. Innovation (according to Schumpeter) happens not when factors are varied, but when the function itself is changed. In practice it is not easy to use production functions to distinguish among economic and technological factors. Production function has been useful in analyzing macroeconomic policy, although much less so in analyzing the impact of technology.

2. Empirical Way

This method tries to identify new technology by discrete events – inventions or patents. The advantage of this method is that it works with what can be termed an output of inventive activity and not input (for example R&D expenditures). A study of the incidence of innovation led to the idea of innovation clustering (Mensch 1975, and Marchetti 1980, although this idea was expressed earlier), classification or categorization of innovation was introduced (Valenta 1969, Langrish, *et al.* 1972, and Mensch 1975), and long-term trend studies led to persuasion of decreasing time lag from invention to application. However, it would be strange if some economists could not prove the opposite or at least question it (Burke 1980). The Economic Commission for Europe has developed other indicators, such as:

- employment of scientists, engineers and technicians;
- income/expenditure for transfer/purchase of licenses, etc;
- value of export/export of scientific equipment, etc.

Several studies (Pavitt and Soete 1981) try to correlate R&D expenses with innovative activity measured by patents issued (per capita) and economic growth.

In the USA it was discovered that while there is a good correlation between the first two variables, the correlation between innovative capacity (as measured by number of patents) and economic growth is not so positive and even becomes negative in some periods.

Nelson and Langlois (1983) points out that even the correlation in an international comparison between R&D expenditures and economic growth is not good for the USA and the UK. According to the authors this has to do with the position of the country in relation to the limits of the given technology. It does not always pay to be alone at the frontier. The imitator seems to be more effective. Therefore, the very popular paradigm used in both socialist and market oriented countries for policy guidance to increase economic growth (see figure below) is not as straightforward as many take for granted (see, for example, Nelson 1980).

R&D	Production	Application

3. A System View of Technology

A system view of technology is based on the idea that a technology is best understood (at least its economic consequences) when one analyzes its functional attributes. One can define an engineering function (Wibe 1980).

$$Y = E(X_1, \ldots, X_m)$$

where X_i are characteristics or qualities. It is then possible to relate X_i to V_i, V_i being standard economic factors,

$$\bar{X} = \bar{A} \cdot \bar{V}$$

where $\bar{A}$ is technology $n \times m$ matrix, (if we have V_i, $i = 1,\ldots,n$).

This approach has not been widely developed and used but its impact can be seen on many policy and regulatory decisions. One can mention the mileage/gallon indicator or regulation goals on cars or grams of coal equivalent per kWh produced for power plants efficiency, etc.

This can be related on a higher level to whole technology systems that may hold the key to a better understanding of the macroeconomic consequences of microeconomic impacts of new technology. The idea seems to be emerging that a *system* of mutually related and complementary technologies may create a material and technological base for economic growth. For example, the technological system developed during the second half of the eighteenth century can be represented in some detail as shown in Figure 1. It is argued (Piatier 1981) that several systems have led to an overall (global) economic growth, though not simultaneously, in all developed countries.

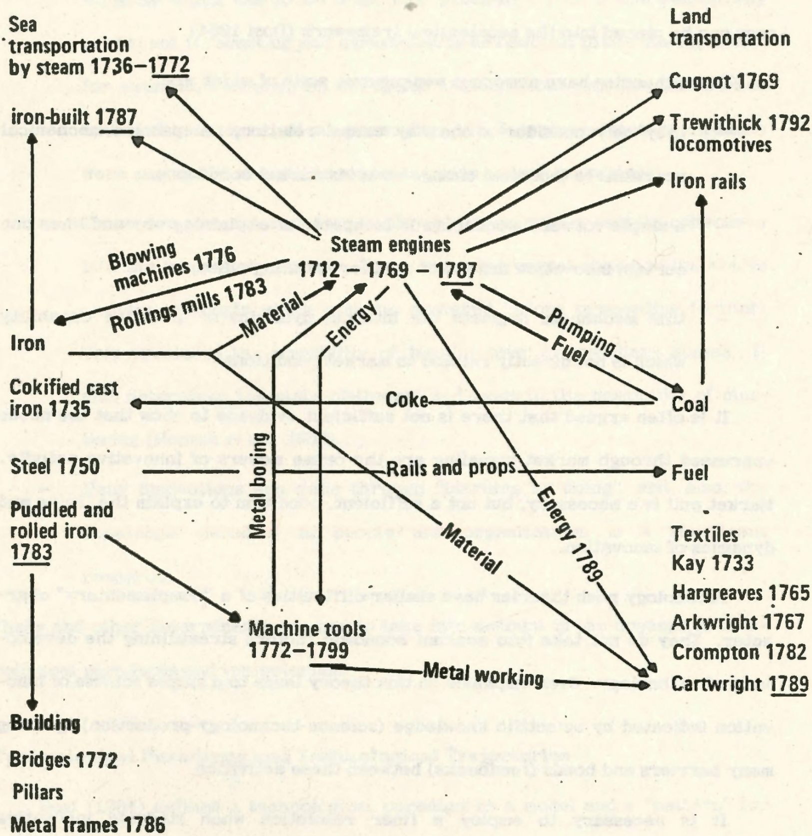
Using this reasoning, one can infer which future system is now in the making, which may not only secure further economic growth but also create a feasible and socially acceptable life style. From the knowledge available at present it is not possible to compose, beyond doubt, a technological system which could guarantee future economic and social progress, without problems, on a national scale, much less on a global one. The usage of the term post-industrial is a proof of a certain impotence of science which shows that we could not agree on the name for a new technological system so we label it by the previous one.

Approaches to the Dynamics of Innovation

With a declining economic growth, and more importantly, declining labor and capital productivity, several former theories of innovation dynamics have been questioned and new ideas forwarded.

Several events in new technology diffusion can be explained by the "technology-push, demand-pull" concept based on the idea that 1) there generally exists a possibility of knowing a priori (before the invention process takes place)

SIMPLIFIED DIAGRAM OF THE TECHNOLOGICAL SYSTEM OF THE FIRST HALF OF THE 19TH CENTURY[a]



[a] The dates correspond to the first recorded innovation, the generalized diffusion comes later.

Source: Gille [1978, Figure 4].

the direction in which the market is pulling the inventive activity of producers, and 2) an important part of the market "signaling" process operates through movements in relative prices and quantities. Under this the concept of innovative process can be placed into the neoclassical framework (Dosi 1984).

These theories have numerous weaknesses, some of which are;

- they only consider a one way causal relation, i.e. passive mechanical reactions to technical change vis a vis market conditions;
- a simple forward mechanism is incapable of explaining why and when one certain innovation instead of another is taking place;
- this mechanism neglects the internal dynamics of inventive capability which is not directly related to market conditions.

It is often argued that there is not sufficient evidence to show that the needs expressed through market signaling are the prime movers of innovative activity. Market pull is a necessary, but not a sufficient, condition to explain the timing and dynamics of innovation.

Technology push theories have similar difficulties of a "complementary" character. They do not take into account economic factors streamlining the development of technology. Over emphasis on this theory leads to a simple scheme of innovation indicated by scientific knowledge (science-technology-production) ignoring many barriers and bonds (feedbacks) between these activities.

It is necessary to employ a finer resolution when studying innovative processes. Several factors are being considered as valid, for example:

- The ever increasing complexity of R&D activities, (if larger (basic) innovation and not just improvements are sought), higher cost and the necessity for a support industry which by itself precludes a rapid response to the market. This requires a somewhat longer planning horizon. In minor innovation this is not true (Peters and Waterman 1982);

- R&D activities, on the other hand, always contain a good deal of risk and surprise which has to be dealt with promptly. This is one reason why permanent forecasting and assessment is advised (to illustrate the point, for example, research on waveguide transmissions was abandoned when optical fibers emerged as promising; the Josephson-junction elements were abandoned when GaAs elements began to look promising);
- There are also determinants in play which enforce a certain coherence into the innovation process. There are some causal chains in innovative activity, elements which must be mastered before proceeding further. This precludes the possibility of jumping over intermediary stages. It also determines the state-of-the-art and leads to the possibility of clustering (Mensch *et al.* *1985*).
- Many innovations are made through "learning by doing", and, also, the knowledge embodied in people and organizations is a significant resource.

These and other determinants one has to take into account in the concept of technological paradigms and trajectories.

Technological Paradigms and Technological Trajectories

Dosi (1984) defined a technological paradigm as a model and a "pattern" for the solution of *selected* technological problems, based on *selected* principles derived from natural sciences and on *selected* material technologies.

He also defined technological *trajectory* as the pattern of normal problem solving based on a technological paradigm.

Technological paradigm embodies strong prescriptions for the directions of technical change – which alternative to pursue and which to neglect.

As technological trajectories are explored many new processes will come into play, speeding up or slowing down the process. There are several, sometimes unrelated, innovations that can amplify the impact of innovation and create a "clustering" of innovations (swarming). For example, the invention of the combustion engine, (but also the invention of cracking and anti-knock petrol) contributed to the expansion of the automobile industry. This property of innovations is one possible (Schumpeterian) explanation of long waves.

In 1984 an interesting book by Yakovetz, in the USSR, was published in which he structures the waves into four types:

- "sequencing" of technology (machines) generation (for example, generation of robots);
- transfer to new directions of technology (partial technological revolutions);
- periodical reproduction of fixed capital on a mass scale on the basis of the generation of new machines;
- overall (general) technological revolutions, leading to basic changes in the level of productive forces.

Individual cycles are structured into several phases such as start-up, contagion, maturity, obsolescence, etc. It is argued, in this book, that general technological revolutions can be traced back to prehistoric times.

Innovation and Regional Questions

Any major technological project and its implementation has to be embedded in the region. When this is taking place usually the weakest points in the knowledge of innovation are exposed. One reason may be that the regional issues are limited to social variables which are ill defined and difficult to quantify. Yet for the success of a particular project these variables may be decisive. I have in mind

- mobility of specialists;
- availability of venture capital;
- availability of risk accepting practitioners;
- established cooperation of R&D in industry with universities;
- "infrastructure" of the particular branch; many times the requirements of R&D is only the tip of the iceberg, because technological links are expanding to other professions (in microelectronics, for example, it is optics, chemistry, physics, fine mechanics, etc.).
- support of local authorities.

Positive responses in the above determinants are necessary for the diffusion of a particular innovation in a given region. It is only wide diffusion of innovation which creates measurable economic impacts. On these problems the interest of innovation research and regional research overlaps (Brown 1981).

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DISCUSSIONS

Paper by S. Dresch

Discussion participants: R. Bolton, P. Joynt, A. Straszak, U. Loeser, L. Kajriukstis, S. Dresch.

Levely discussion centered around two issues:
How are regional problems and decisions delimited and formulated - are they substantially based or "merely" political?, and: What is the link between science, education system etc. and technological and economic change?
With regard to the first question instances were quoted where regional problems arise in a natural way out of geographical and economic circumstances, waiting only for proper solutions, engaging also political structures. The cases quoted referred to riversheds and to geographico-economic East-West situation in South America, where large areas along the Western coast have much greater development capacity than is presently released, due to economic, but also political conditions.
As to the second question it was stated that the relations in question are of the necessary, but not sufficient condition type, so that simple reasoning can fail both ways. The situation is further made even more vague by the lack of clear definitions in the domain.

Paper by A. Mouwen and P. Nijkamp

Discussion participants: A. Straszak, R. Kulikowski, L. Lacko, S. Ikeda, A. Kochetkov, A. Mouwen.

This discussion, which to a large extent continued the themes of the paper itself and of discussion to the previous paper, focussed mainly on conditions and mechanisms of knowledge and technology transfer from science to production practice. Within this context social and spatial mobility of scientists, research centers and knowledge-intensive firms was assessed. Instances were quoted of large, scientifically self-sufficient firms moving out of bigger urban centers, with the small ones moving in, for instance, to get closer to the research resources. On the other hand the example of Tsukuba was shown to indicate the real possibility of speeding up the regional development around a large scientific compound - by attracting businesses which could profit from cooperation. This development occurred over 15 years, and there is another one, chip-oriented, underway in Japan in the Kyushu region. Thus, while it was deemed important to secure the link between science and actual promotion, other conditions may play an important role, e.g. communication infrastructure or competitiveness. Experience from one place may not be fully transferable to another, and hence differences between the Dutch and the Swedich case. Knowledge-based development requires special orientation of investments - it was said that in the case of the Netherlands approx. 4% of GNP would be devoted R and D.

Paper by K. Polenske and Wm. Crown

Discussion participants: G. Bianchi, P. Joynt, K. Polenske.

The main question raised concerned the way in which the interregional coefficients can be obtained, since this was deemed to be far more difficult than for the technical coefficients. The procedure taken in the work presented started with trade tables, on which a balancing is performed. Then goals transportation data come in. Both these steps, however, do in fact still leave out some cells in the matrix. Hence, an expert-based range estimation is applied and final row and column balancing is performed. The whole procedure is implemented with two main computer programs MATHER and PASSION.

Paper by T. Vasko

Discussion participants: M. Steiner, A. Straszak, J. Owsiński, T. Vasko.

First, a clarification was asked for as to the meaning of information space. The answer consisted in statement that a general innovation is composed of simple innovations such as market innovation, product improvement etc., and that any simple innovation can hardly have an economic effect. Thus, innovations appear as compounds in the simple innovation space.

Then, a portion of discussion was devoted to identification of the logistic curves involved. Besides the very identification question, where the starting time-point was deemed of special importance, the problem of interplay of product values: exchange value, use value and production cost, was emphasized. Answering another question the speaker said that by looking at the innovations side he gets the idea that the new general economic upswing has had began by then, but that other analysts, e.g. C. Marchetti, see it coming in only about a decade.

<u>Paper by R. Funck and J. Kowalski</u> was not discussed since it was presented after the workshop.

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ADDRESS
6, NEWELSKA ST.
01-447 WARSAW
Tel. 36·44·14 , 36·81·50
Telex: 812397 ibs pl