NOT FOR QUOTATION
WITHOUT PERMISSION
OF THE AUTHOR

# NEW PROBLEMS AND OPPORTUNITIES OF GOVERNMENT INNOVATION POLICY AND FIRM STRATEGY

Harry Maier

December 1979
WP-79-126

Presented at the IIASA Workshop
"Innovation Policy and Firm Strategy"
4-6 December 1979.



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

NEW PROBLEMS AND OPPORTUNITIES OF GOVERNMENT INNOVATION POLICY AND FIRM STRATEGY

Harry Maier

## NEW CHALLENGES

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

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

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

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

If we try to assess our innovative capability we not only have to think about the problems which are facing us in our countries, but we also have to think how we are prepared to deal with the new circumstances, the global problems, which are the results of changes in the structure of the world economy. And how we can shape this structure with technical and social innovation in such a way so as to solve these problems. Without technological and social innovation it will not be possible to contribute significantly to the solution of the following problems.

-- The growing imbalances between natural and human resources. By the year 2000 we will have to feed 2 billion more people than now. More than nine tenths of them will be living in developing countries where 40% of the population is now unemployed due to the lack of social and technical innovations. 20% are undernourished and 30% lack safe drinking water and elementary medical care. (IHT, 18.11.78 p.1).

-- The anticipated shortage of natural resources, such as energy, minerals, etc. and the inadequacy of technology in substituting artificial resources for scarce natural resources. The IIASA Energy Study showed that such traditional resources as oil, coal, and gas, which currently make up more than 90% of our primary energy supply will not be able to satisfy more than 65% of our energy demand by the year 2030. This estimation took into account a high rate of energy conservation, with the help of improvement innovations. The remaining 35% will have to come from new resources such as nuclear power, solar energy, synthetic fuels, biogas, etc. These new energy resources would only be available if it is possible to change the entire structure of energy production, distribution, and consumption with the help of basic innovations. But we have to implement these innovations with land resources which are even more marginal, making the environment more vulnerable and safe waste disposal even more difficult.

-- The inappropriateness of current technologies for the better use of human resources, especially in the developing countries. In the developing countries we have more than 300 million able-bodied men and women who are currently unemployed. Assuming that each working place costs 10,000 dollars in a developing country ($20,000 in the US), then 150 billion ($10^9$) dollars per year will be required to secure enough working places in the developing countries over a 20 year period (Norman 1978). This is a lot of money, but then again it is less than half the annual world expenditure on armaments which was 350 billion dollars in 1975. This situation will become even worse in the following decades because then we will need a billion or more new jobs for the children who are born now (Club of Rome Report 1979).

-- Generate net real capital at a much higher annual rate than that of today. To secure this new capital goods are embodying highly efficient technologies so that it will be possible to hold the extension of the annual rate of investment in an accepted range. The above-mentioned IIASA Energy Study shows that to create the necessary shift from an energy system which is based on cheap oil and gas to an energy system which is based on coal, nuclear, solar, synthetic fuels and other primary energy sources we will need a significant extention of the average net investment rate. World wide energy investments necessary for exploration, production, conversion, transportation and distribution of primary and secondary energy resources were approximately 143 billion dollars in 1975. They will increase to 925 billion dollars by 2030 for the Low scenario and up to 1400 billion dollars for the High scenario. (In the IIASA Energy project the Low scenario is 26.2TW and the High scenario is 41.6TW energy demand by 2030 - Häfele 1979.) The growing amount of investment in coming years indicates the necessity of creating social procedures for the coordination of innovation cycles, thus avoiding situations in which we have unacceptable shortages of resources and in which we are not able to employ capital, material, and human resources.

-- Genuinely improve living, working, educational, and cultural conditions of people and their health standards in both industrialized and developing countries. It is especially important to improve the quality of human resources and to create the technical and social conditions for their better use. The UNESCO projections by region for 1980 show an illiteracy rate of 73% in Africa, 63% in South Asia, and 23% in Latin America. Illiteracy is closely connected with poverty. The twenty poorest countries have an illiteracy rate of 80%. However the elimination of iliteracy is only one side of the coin. The other is that we need not only literate people, but also people who are able to cope with social and technical innovations. For this we need a new type of learning which not only develops the ability to read, write and count but also develops the ability to cope with social and technological systems, and to change context and structure according to the needs of man. Such kinds of innovative learning could be a very important factor in the solution of the crucial problems of our world.

Despite some claims to the contrary, we cannot accomplish these solutions by using today's technologies much less yesterday's. We should use the growing technical capabilities of an increasing number of countries, the rapid development of the industrial sector of a number of developing countries, the beginnings of international technological and scientific cooperation, the different forms of technology and knowledge transfer between different world regions, to cope with the crucial problems which are now facing mankind. We shall try to improve our innovation policy by giving it a more concrete orientation towards human needs, to avoid disadvantages and undesirable side effects of technology, and secure the interlinkage between technological and social innovation.

SOME REMARKS ON THE DEVELOPMENT OF OUR THINKING ABOUT INNOVATIONS

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

1. In the beginning of the 60s problems of management, planning, and forecasting of R & D activities, vertical and horizontal allocation of R & D resources within the

national economy, between the different types, disciplines, and stages of R & D, and the creative character of the innovation process, were main problems of the investigation. At this time many new research disciplines and new research directions were created such as the "Science of science", and "Economics of research". More and more scholars were starting to identify the contribution of technological progress to meet national needs. The "Production and Distribution of Knowledge" and the attempt to measure its contribution to economic growth were main subjects of research at that time.

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

better understanding of the links between different phases of the innovation process, invention, technical realization, and commercialization.

3. The third phase of the innovation process, which started in the first half of the 70s, began with the recognition that the demand for innovation of a production unit very much depends on the economic environment in which it has to operate and from the stage of development of that production unit. It was found that the relationship between innovations and the efficiency of the production unit which has adopted them, has changed during the time of the production unit's development. One of the most important findings was that the high level of output and efficiency is not equal to a high innovation rate. To understand that it was necessary to investigate more carefully the development of the efficiency of the production unit, which has adopted the innovation, in comparison with the average efficiency of production units as a whole in the production field. With this approach it was possible to understand better the role of the different kinds of innovation during the innovation cycle, and the role of basic, improvement, pseudo innovation, product and process innovations and their influence on efficiency. This does not mean that we are trying to ignore the advantages which were gained in the other phases of research or that we are of the belief that the problems which were explored in the first two phases have now lost their importance. We

have only tried to demonstrate the direction which our efforts to better understand the innovation process were taking in the past, without ignoring the results which we found in this way. Ironically, the dialectic of our thinking brought us back to problems which such economists as David Ricardo, Karl Marx and Josef Schumpter have left us.

## INNOVATION AND EFFICIENCY

To gain an understanding of the dynamics and causes of innovations it is necessary to better explore the changes in the attitudes of production units as the loci for innovation during the development of their efficiency. By efficiency we mean the output/input ratio which the production unit can realize within the given economic circumstances.

Therefore the development of the relationship between efficiency of the production which have adopted the innovation and the average efficiency of all production units which are producing competitive goods to meet special needs, is very crucial for the understanding of the different strategies of firms within the process of their development and the scope of opportunities to influence them through national innovation policy.

The dominance of special types of innovation (basic, improvement, or pseudo innovation), the role of product and process innovations, the typical barriers and stimuli, appropriate management skills and tools, very much depend on the stage of development of the ratio between these different types of efficiency.

I will try to demonstrate the usefulness of this approach with the following mental model (Figure 1).

First we must develop an index of the relationship between innovation and production efficiency.

$e_i(t)$ is the efficiency coefficient of production unit i, which adopted the innovation at time t,

$\tilde{e}(t)$ is the coefficient of average efficiency for the production system as a whole at time t.

$x = \dfrac{e_i(t)}{\tilde{e}(t)}$ is the coefficient of the efficiency of an innovation process, which is adopted from the production type i, in comparison with the average efficiency of the system.

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

We consider the set of all productive units $\{pu_1,...,pu_n\}$ which produce a commodity that fulfills the same customers's need, and assume that the subset $\{pu_1,...,pu_r\}$ adopts a certain innovation and the subset $\{pu_{r+1},...,pu_n\}$ does not. Now we are interested in the development of the efficiency of the innovative subset $\{pu_1,...,pu_r\}$ compared with the efficiency of the whole productive system $\{pu_1,...,pu_n\}$.

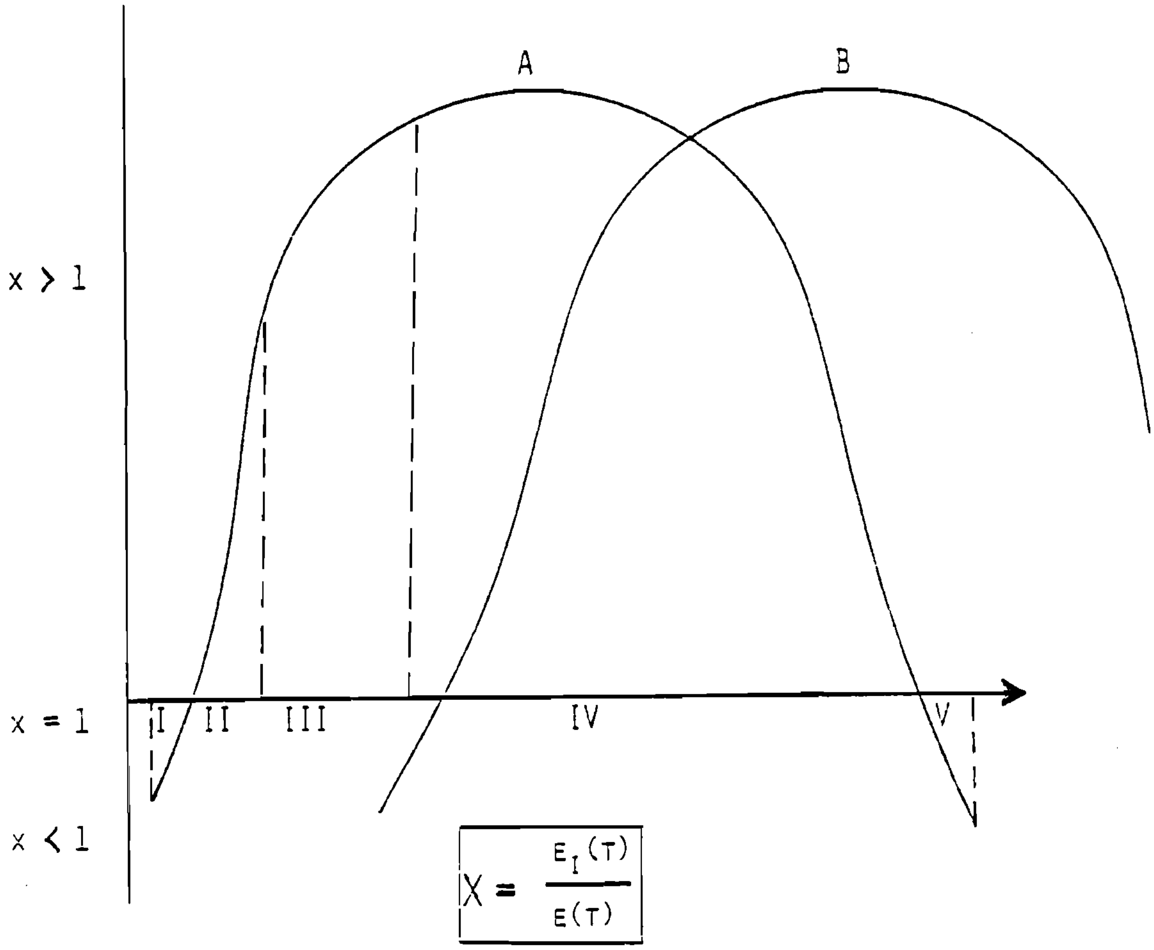
We define $e_i(t)$ the efficiency of the unit $pu_i$ at the time level and get:

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

where $O_i$ is the output to $pu_i$, and

$I_i$ is the input.

Furthermore the efficiency $e_1^r$ of the innovative subset is equal to $\sum_{i=1}^{r} e_i(t)p_i$ and the efficiency of the non-innovative subset




$E_I(T)$ = EFFICIENCY COEFFICIENT OF THE INNOVATION PROCESS AT TIME T.

$E(T)$ = EFFICIENCY COEFFICIENT OF THE PRODUCTION SYSTEM AS A WHOLE AT THE TIME T.

Figure 1. Relation between efficiency of an innovation process and efficiency of the production system as a whole, over time.

is $\sum_{j=r+1}^{n} e_j(t)\,p$ where $p_1,\ldots,p_n$ are weights which fulfill $0 < p_i \leq 1$.

Let us call $\tilde{e}(t) = \sum_{i=1}^{n} e_i(t)p_i$ the efficiency of the whole system, so we get:

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

as ratio of efficiency.

If we look at average efficiencies we get:

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

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

And resulting from that

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

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

Let me talk a little bit about x(t). Figure 1 demonstrates that the developement of x(t) during the innovation cycle can indicate three fundamentally different situations for the firm:

$x(t) > 1$ Here the efficiency of the firm which has adopted the innovation is much larger than the average efficiency of the production system as a whole. This is the growth phase of the production unit.

x(t) = 1 Here the efficiency of the production unit which has adopted the innovation first is equal to the average efficiency of the entire production field. This is because a lot of other production units were able to imitate and diffuse the innovation. This is the stagnation phase of the production unit.

x(t) < 1 Here the $pu_i$ were not dynamic enough to change the direction of production after the adopted innovation has become mature and was not able to compare with the changes in the average efficiency through the advantages of the other production. This is the crisis situation for the production unit.

It is not difficult to find examples for these different situations from real life:

1. The Japanese corporation Seiko was the first innovator of quartz watches in 1969. It now produces more than nine million quartz watches and it is still successful in gaining a greater market share. However after ten years' success in generating technical and commercial utilization of an advanced technology the Seiko management is faced with the question of whether this process will continue in the future and what the possibilities are of creating directions in production to meet needs which are still unsatisfied. In the past Seiko spent more than 5% of its turnover on R & D and gained more than 3000 patents in quartz technology (FAZ 25.10.79).
2. The Chrysler Corporation is going to have a loss of more than one billion dollars in 1979. The main reason for this is the failure of the innovation strategy to

change in order to adopt new market trends which have arisen out of the resource situation, or to create new markets in order to give the corporation new economic vitality (Neue Züricher Zeitung 2.11.79 p.13, Frankfurter Allgemeine Zeitung, 3.11.79 p.14)

3. AEG, one of the two largest electrical engineering corporations in the FRG was very successful in generating innovation in color television (Pal-System), nuclear powerstation equipment, etc. But they failed to give innovative products a dominant place in the production and marketing of the corporation. In 1979 AEG expects to run into the red by more than half a billion dollars.

These examples indicate the importance of investigating more carefully the situation in the different stages of innovation cycles in order to find the appropriate strategies for growth, change, and survival of corporations.

From my point of view it would be helpful for the analysis of the innovation process to distinguish five different stages in the development of the production unit which has adopted the innovations.

Stage I - The Take Off Stage of a Basic Innovation.

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

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

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

-- This is a fluid situation in which there are many technological options. Historical examples are the motor car and energy.

-- The market share is very low, costs high, production is unstable, and the products are far from being competitive.

-- Product design plays a decisive role at the start up phase of a basic innovation which is a major product innovation.

-- The production process at this time is still dominated by traditional process technologies.

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

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

Example:

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

Stage II - In This Stage the Basic Innovations Become More and More Efficient.

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

-- Many other enterprises will try to imitate and to improve on the basic innovation.

-- In this stage the decisive factors for the rise of efficiency are the new qualities, functions and features of the product--and they are well protected by patents.

-- Typically there is a shortage of qualified people with special knowledge and experience to apply it.

-- The recruitment of competent people and the necessary knowledge is decisive.

Example:

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

Stage III - Here Properties and Features of the Basic Innovation Are Very Important, but the Improvement Innovations Become More and More Important.

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

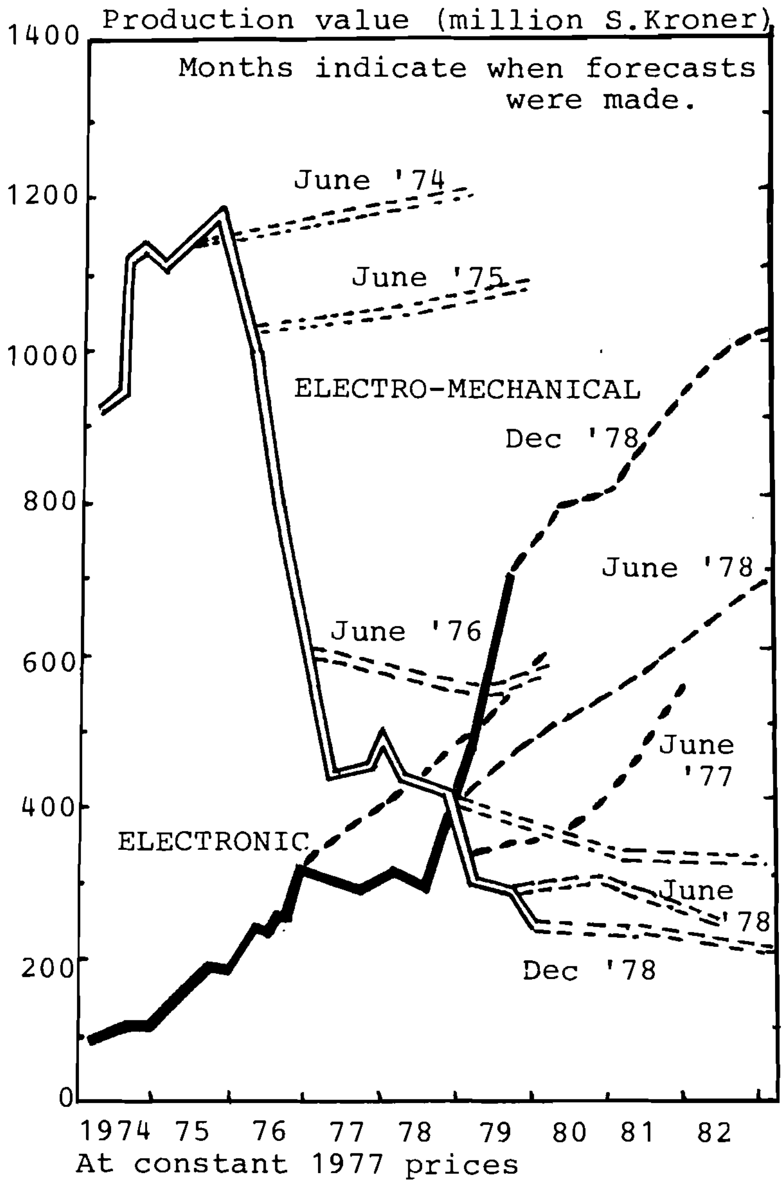



Figure 2. Forecasts versus reality: Ericsson's shift from electro-mechanical to electronic telephone exchanges.*

Source: Financial Times, 25.9.79.

*Electronic includes AXE and other exchanges.

-- The market expands and there is accelerated investment and employment.

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

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

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

Examples:

It is especially possible through major process improvement at this stage to realize a high rate of productivity. The cost of incandescent light bulbs, for example, has fallen by more than 80% since their introduction (Utterback 1979). Airline operating costs were cut by half through the development and improvement of the DC3 (Utterback 1979). Semiconductor prices have been falling by 20 to 30% with each doubling of cumulative production (Bodde 1976). The trend towards increasing the packing density and the number of functions per semiconductor chip is as yet unbroken. Figure 3 shows the rapid increase in the number of logic functions per chip versus the resulting decrease in costs within the period from 1962 to 1980. Also entered are the years

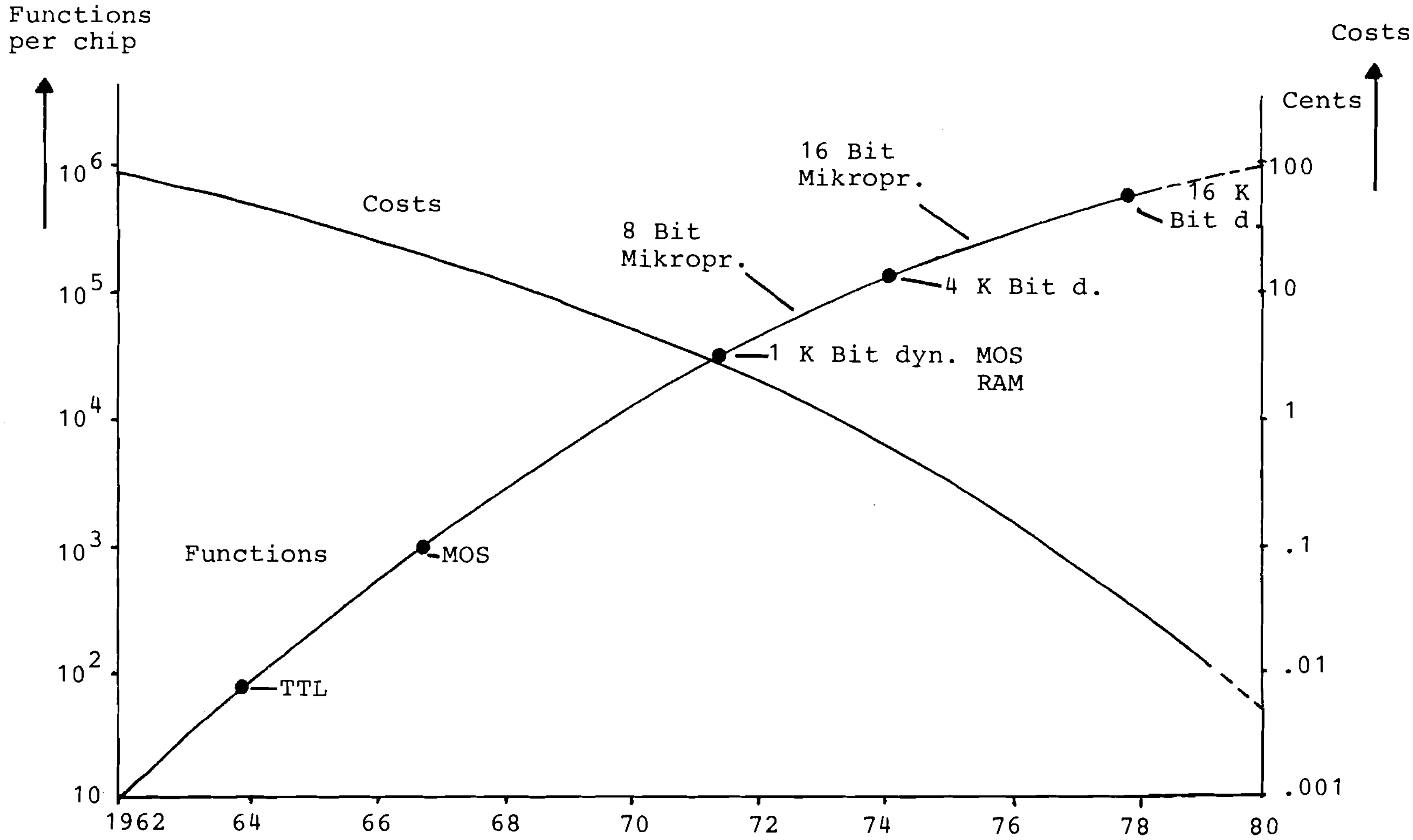



Figure 3. IC semiconductor trends.

Source: Ernst, D. (1978) New Trends in the Application of Process Computers, in A Link Between Science and Applications of Automatic Control, Pergamon Press.

in which some important semiconductor technologies such as TTL and MOS, and a number of outstanding devices were introduced. According to this curve semiconductor manufacturers are expecting very large scale integrated circuits of a million transistor functions per chip in the arly 1980s. For the systems engineer and the management of innovation this raises the question of how to use the efficiency potential which is created through such a component, in the process automation sector.

Stage IV - Mature Stage, Improvement Innovations Play a Dominant Role.

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

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

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

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

-- Otherwise the production unit will sooner or later run into stagnation, "Productivity Dilemma" (Abernathy 1979), or "Stalemate of Technology" (Mensch 1975).

Examples:

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

Stage V - Stage of Crisis

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

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

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

## CONCLUSIONS FOR NATIONAL INNOVATION POLICY AND FIRM STRATEGY

1. The first conclusion that can be drawn from the mental model of the innovation cycle is that a high degree of efficiency and output of production is not an insurance against future disadvantages through an invasion of new technological options. The highest degree of efficiency, large market share and high degree of standardization and vertical integration is the latest moment for a production unit if it will also gain in future economic vitaility, to search for new ways of satisfying a latent demand or to satisfy and existing demand with better and less expensive alternatives. One of the most important experiences in the management of innovation in all industrialized countries is the importance of a close interdependency between Government Innovation Policy and Firm Strategy. Government actions to stimulate innovations must not only be designed taking into account the change of attitude of production units as a result of the development of their efficiency but also the adverse effects which may arise from the application and diffusion of technology for the working conditions, environment, security and health of the people. On the other hand the corporations have to improve their ability to find appropriate responses to national needs, coming shortages, and to avoid not only primary but also secondary and tertiary adverse effects of innovations. This system of interdependency is far from being perfect. It cannot be improved in a straightforward manner by investing more heavily in science and technology without taking into account that:

-- the rate and benefits of innovations are very much dependent on the relationship between different types of innovation.

-- the stage of efficiency development of the production unit greatly determines the demand for special kinds of innovation;

-- the necessity to explore different side effects of technology to implement measures stimulating the positive effects of the technology by blocking the disadvantages;

-- scientific and educational infrastructure of a country is a decisive precondition for innovation;

-- government actions concerned with innovation cause very different results in different stages of the innovation process;

-- we need a global dimension for innovation policy.

2. The relationship between product and process innovation is very much determined by the stage of development of innovation process. In recent years many systems analysts have tried to find possible combinations between process and product innovation. But this has not been helpful for the management of innovation. What shall a decision maker do with information, for example, that there are more than five million possible combinations of product and process innovations. However, with our approach it is much easier to understand the role of product and process innovation in the different stages of the innovation cycle. I would like to demonstrate this with a transparency based on the excellent case study by Abernathy of US automobile production (Figure 4). Heinz Dieter Haustein was able to confirm this finding in his interesting study about the lighting industry (Haustein 1979). We have seen above that on the level of the production unit the

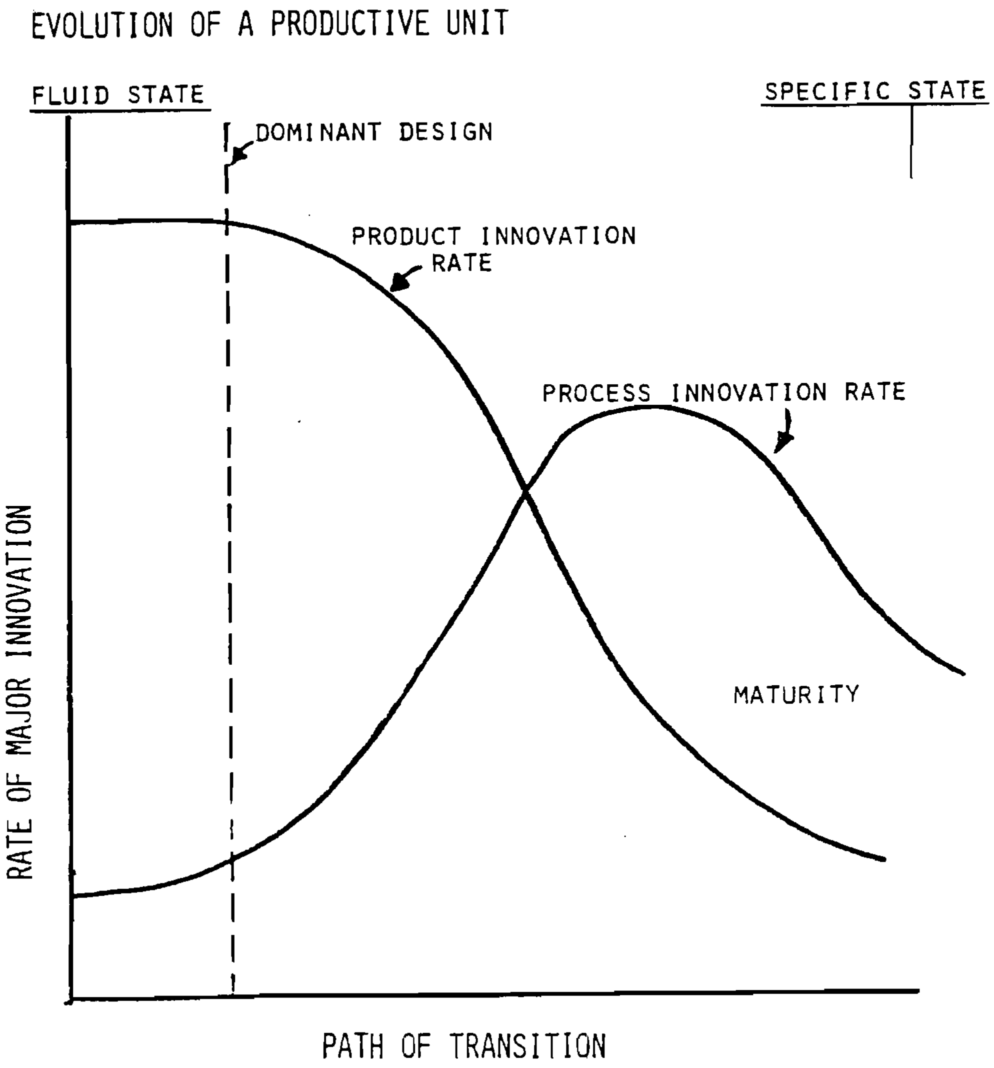



Figure 4. Evolution of a productive unit.

Source: Adapted from Abernathy and Hayes (1979) Technology and Corporate Strategy, TIMS-ORSA Conference, Hawaii.

distinction between major product, major process and incremental innovation is very important. But, on the macro-economic level it is very difficult to distinguish between major product and major process innovation. This is because that which is a product of one firm may be the process equipment, components for assembly, or materials used by another firm. Therefore we think that on the macroeconomic level the distinction between basic, improvement and pseudo-innovation is much more important (Haustein and Maier 1979). Basic innovations are innovations which create a new efficiency potential, and open new fields and directions for economic activities. The main function of improvement innovations is absorption of this efficiency potential through balancing and improving the given system. Most of them are incremental innovations. The improvement innovations become pseudo-innovations at the point when they are unable to secure higher efficiency of the production unit than the average efficiency of the whole system.

It is possible to demonstrate the role of basic, improvement and pseudo-innovations with a model similar to that for development of efficiency of the production unit. From a macro-economic standpoint the national economy or the world economy is an integrated production system of resource usage.

We have explained above the efficiency coefficient x(t).

$$x(t) = \frac{\overline{e_1^r}(t)}{\tilde{e}(t)} = \frac{\bar{0}_1^r(t)\ \bar{I}_1^n(t)}{\bar{I}_1^r(t)\ \bar{0}_1^n(t)}$$

where

$x(t)$ is the coefficient of efficiency of the production units, which have adopted innovations, in comparison with the efficiency of the entire production system in time (t).

$e_1^r(t)$ is the efficiency of the production units in time (t) which have adopted innovations.

$\tilde{e}(t)$ is the average efficiency of all production units within the entire production system at time (t).

$0_1^r(t)$ and $I_1^r(t)$ are the average output respective to input of all innovative subsets at time (t).

$0_1^n(t)$ and $I_1^n(t)$ are the average outputs respective to input of all production units of the entire production system at time (t).

With this model we can identify three different situations:

1. $x(t) > 1$ indicates a situation in which the production system is able through basic and improvement innovations to gain advantages in the growth of efficiency. The process of absorption of efficiency potential created through basic innovation accelerates at first the growth rate of efficiency, but after some time the growth rate will diminish.

2. $x(t) = 1$ in this situation the absorbing process of efficiency potential, created through basic innovation runs dry. The improvement and incremental innovations are unable to compare the decrease in average efficiency with the higher resources and infrastructure costs. This will be the "Stalemate of Technology" (Mensch 1975).

3. x(t) < 1, this is a situation in which the production process was unable to respond to new resource situations and economic circumstances with structural changes capable of opening new fields and directions for economic activity. The result will be that the efficiency will not only stagnate, but also decrease. If society is unable to implement a new push of innovations this could be the starting point for a process of "de-industrialisation" (Freeman).

It is possible to demonstrate these three situations in Figure 5.

It is beyond the scope of this paper to discuss the problems of the existence of "long waves". Important indications of their existence were discovered by Kondratieff early this century (Kondratieff 1926). Other scholars have confirmed these findings, however, the explanation for the driving forces of this phenomenon still remains an unsolved problem. However, a lot of efforts were made to create a body of ideas and dates so that we now have some evidence that allows us to assume that the relationship between innovation and structural change is an important driving

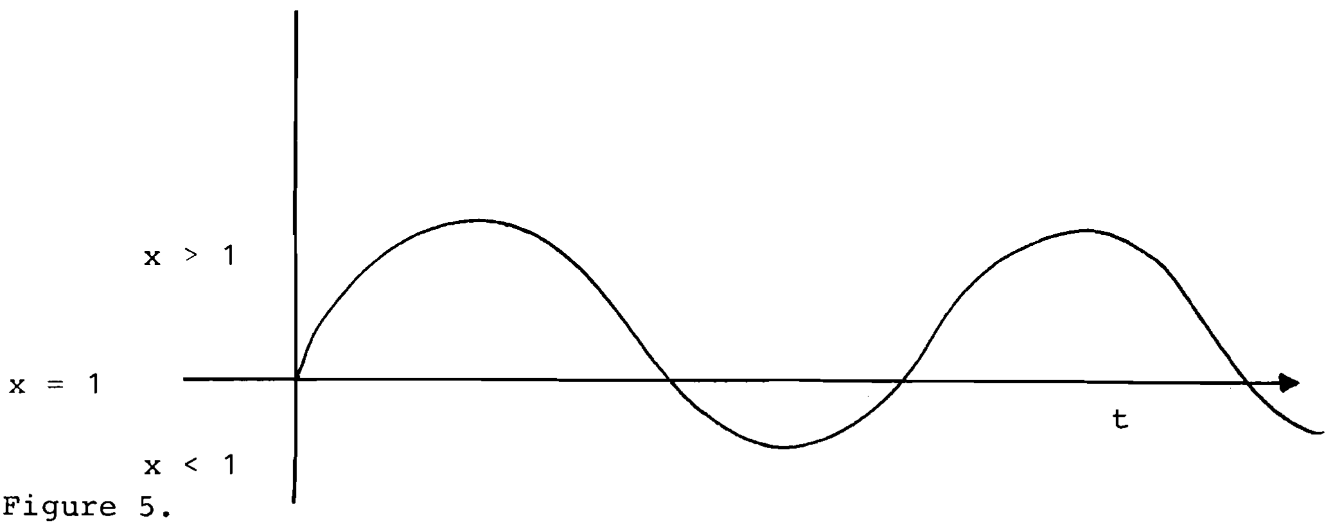


Figure 5.

force of the "long wave" phenomenon. The relationship between the resource basic and the efficiency of industrial and agricultural production is especially important within this context. This can also explain why the development of resource and food prices is an important indicator for the existence of "long waves".

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

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

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

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

4. The global dimension of the innovation policy has to play an important part in improving the capability of society in dealing with new circumstances and situation through the development of new procedures for social innovative learning. It could be disastrous and fatal in our time of growing global interdependency to learn only by shock. Social innovative learning means that our main concern should not be to find out the best alternatives between given alternatives, but to emphasize the creation of new options which are able to solve the fundamental problems which now face us. Social innovative learning could not be adaptive but must be anticipatory. (The Human Gap 1979) Whereas adaptive learning is only our reactions to external pressure, anticipatory learning tries to create new alternatives at a time

when events, circumstances and environment are not yet irreversible. But anticipatory social learning requires not only the judgements of experts and technocrats, it also requires the participation of people who are the subject and object of the innovation process. In all countries we have significant demand by the people for their participation. A growing portion of the population wants to be involved in the process of judgement, assessment and decisions about technology, which have tremendous consequences for their and mankind's future. This is a positive response to the growing complexity and international interdependency of the technological innovation process. If this is sometimes reflected in a rather irrational way, this only indicates our commitment to search for new forms for the distribution of knowledge, cooperation and dialogue with a broader range of the population, about the social consequences of innovation. But this also requires the openess to reevaluate the given social and economic structure, social and cultural values, and goals. I am convinced that the investigation of innovative learning of social systems on the firm, national and global level will become one of the most important problems for future research about innovations.

5. Social, organizational and technical innovations are different parts of a joint system. Without technological change it is impossible to alter the organizational and social system. On the other hand, technological innovations without organizational and social innovations will not improve the living conditions within the national and global framework. The need to consider both the social and technical sides of innovation has important consequences for our methodological approach. On the one hand,

we can start from single technological change and look at its social consequences and implications, or at the governmental measures needed to ensure it efficiency. This is, for example, the main aim of technology assessment. On the other hand, we can go out from social needs and goals, from existing and forthcoming leaks or bottlenecks in resource processing systems and then look at the given field of technical possibilities for a technological fix. We could call this latter approach socio-economic opportunity analysis - SOA (Figures 6 and 7).

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

Innovation is a combination of user need and a technological means of meeting that need. Often the information of the need development or technological feasibilities lies outside the organizations which are able to generate and implement the innovation. Therefore one of the most important measures in promoting and shaping innovation from the government point of view must be to provide and distribute information about the development of regional, national and global needs. It is necessary to make national and global needs more evident for the firm, to avoid contradictions between short term corporation goals and long term national needs. Therefore government innovation policy--as the major part of the economic policy of a country--cannot only be concerned about the flow of resources towards high productivity

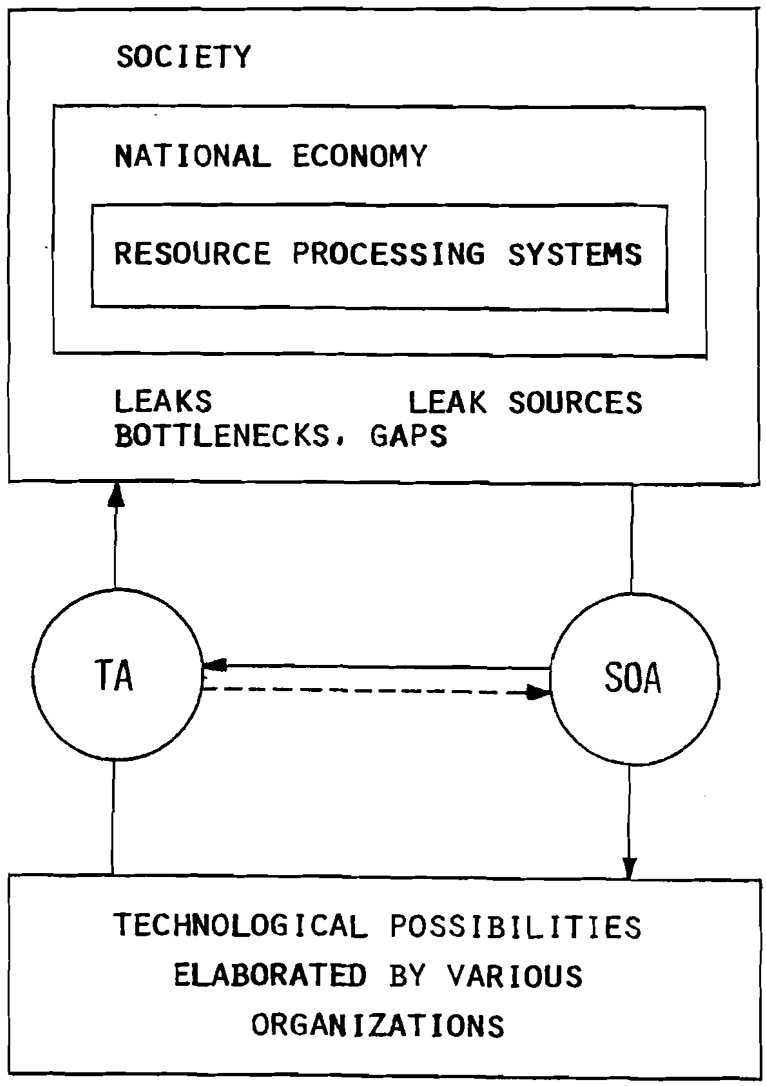



Figure 6. The role of TA and SOA.

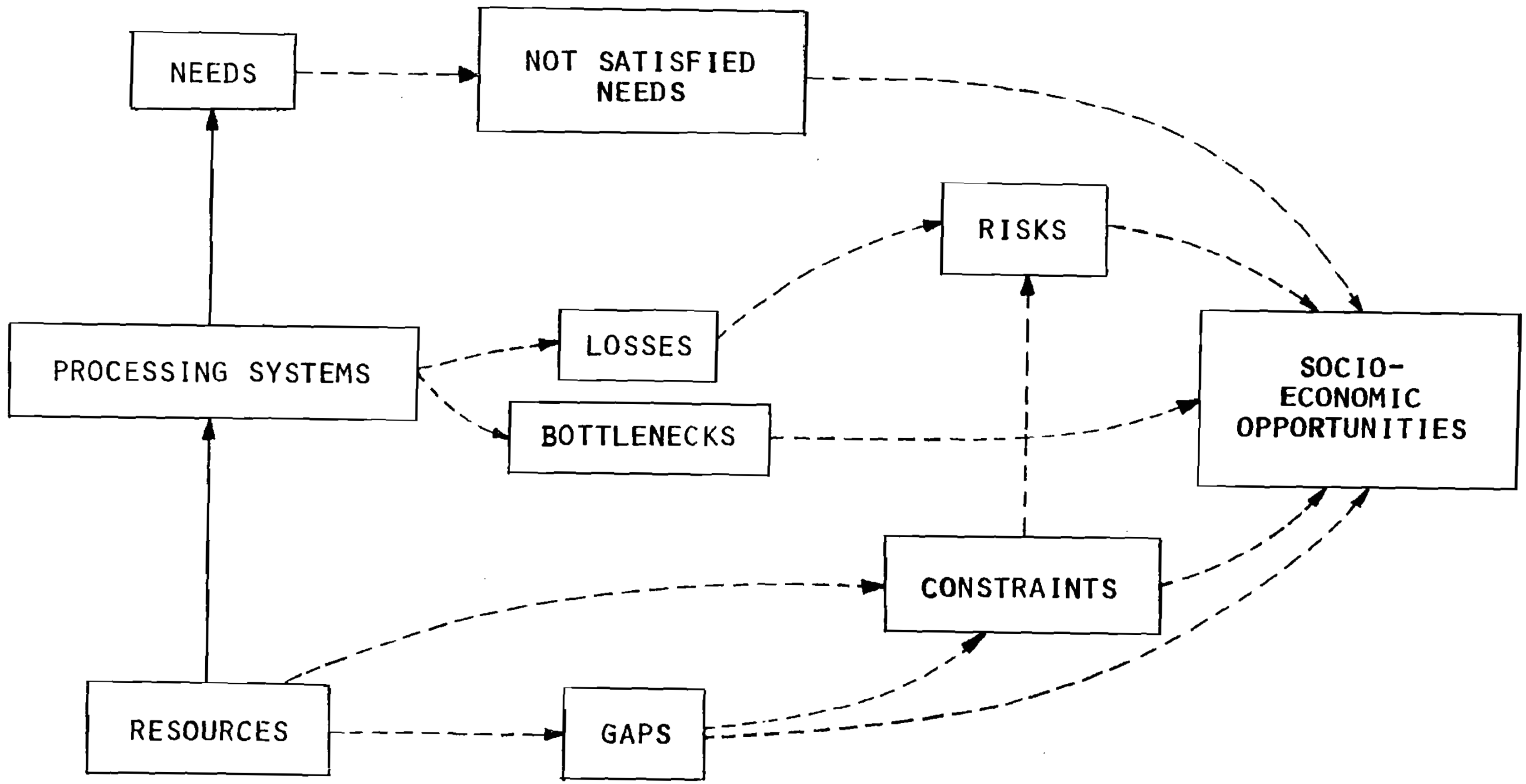



Figure 7. SOA in the context of national problems.

industries, but must also try to identify the future fields of innovation and create a social procedure to secure that the country's economy is prepared to deal with new national and global circumstances.

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

7. The adoption of innovations tends very much to depend on the degree of qualifications of management and labor forces within production units.

Most developed countries have had a significant improvement in the quality of human resources over the last two decades. On the one hand the higher quality of human resources is an important precondition for technological and social innovation, and on the other it is not possible to approach a higher quality in human resources without social and technological innovations. The creation of conditions in which the quality of human resources can grow and become a decisive social and economic force is a crucial point in national innovation policy. In the GDR for example, in the period between 1962 and 1975 the growth rate of educational funds (human capital) was essentially higher than that of the funds of fixed assets (material capital) (Figure 8).

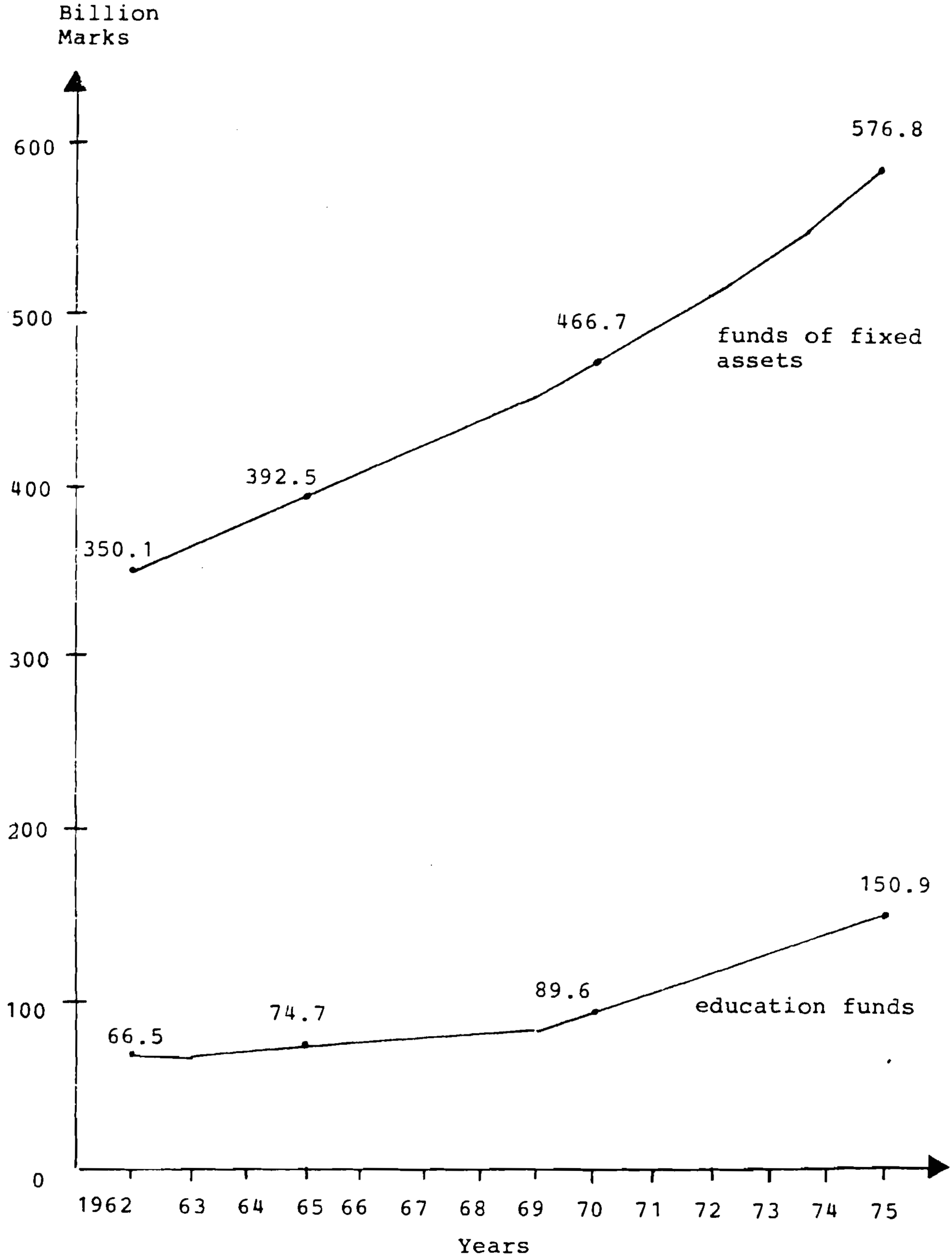



Figure 8. Development of education funds (human capital) and funds of fixed assets (material capital) in the economy fo the GDR (Billion Marks).

By this GDR industry could nearly double its share in the total of university graduates in the period 1962-1975. In 1962 every tenth university graduate of the GDR economy worked in industry, today it is every fifth.

An important problem thereby is the employment of working people according to their qualifications and the use of these qualifications to implement, control, and manage technical innovations.

For this two important preconditions are necessary:

1. To make the education process more creative. If the supply of knowledge is not connected with the development of the capability of independent thinking, with the production of sound educational motives, then these faculties which are decisive for dealing with social and technological innovation, remain underdeveloped. Innovative learning demands the development of the capability of independent and creative thinking and an optimistic attitude in participating in the solution of technical, social and cultural problems.
2. The educational system must be used better for the transfer of technology and developing skills to recognized needs, technological feasibilities, and to assess the different sides of technical innovations. This should be an especially important part of in-service training. If in-service training is too tightly bound to direct organizations and tasks of the work place it cannot fulfill its function of stimulating creative thinking and innovative skills.

The high efficiency of social expenditure for education and qualifications can also be seen in close connection between increased qualification level and a growing contribution of the innovator's movement to efficiency of the national economy. The benefit of the innovator's movement (more than 50% of the prime cost reduction in GDR industry results from it) per unit of educational funds was 2.5 times higher in 1971-1975 than during the period of 1960-65 (Figure 9).

8. Another lesson from the innovation cycle model is that national innovation policy and corporation strategies which try to achieve

-- stable development of efficiency in connection with the necessary structural changes,
-- competitiveness of production while avoiding resource wastage and securing working places and to avoiding stagflation,

will have to put more emphasis on the coordination of the innovation cycle.

National innovation policy especially must realize that the stimulation of different kinds of innovation also needs different kinds of actions. Despite the above mentioned measures to improve the climate and conditions for innovation, national innovation policy can influence the innovation process through two types of actions.

1. Technology Push Actions--that is, actions that directly support the development of new technology or modification of existing technology.
2. Technology Pull Actions--such as product characteristic interventions, and market modification actions.

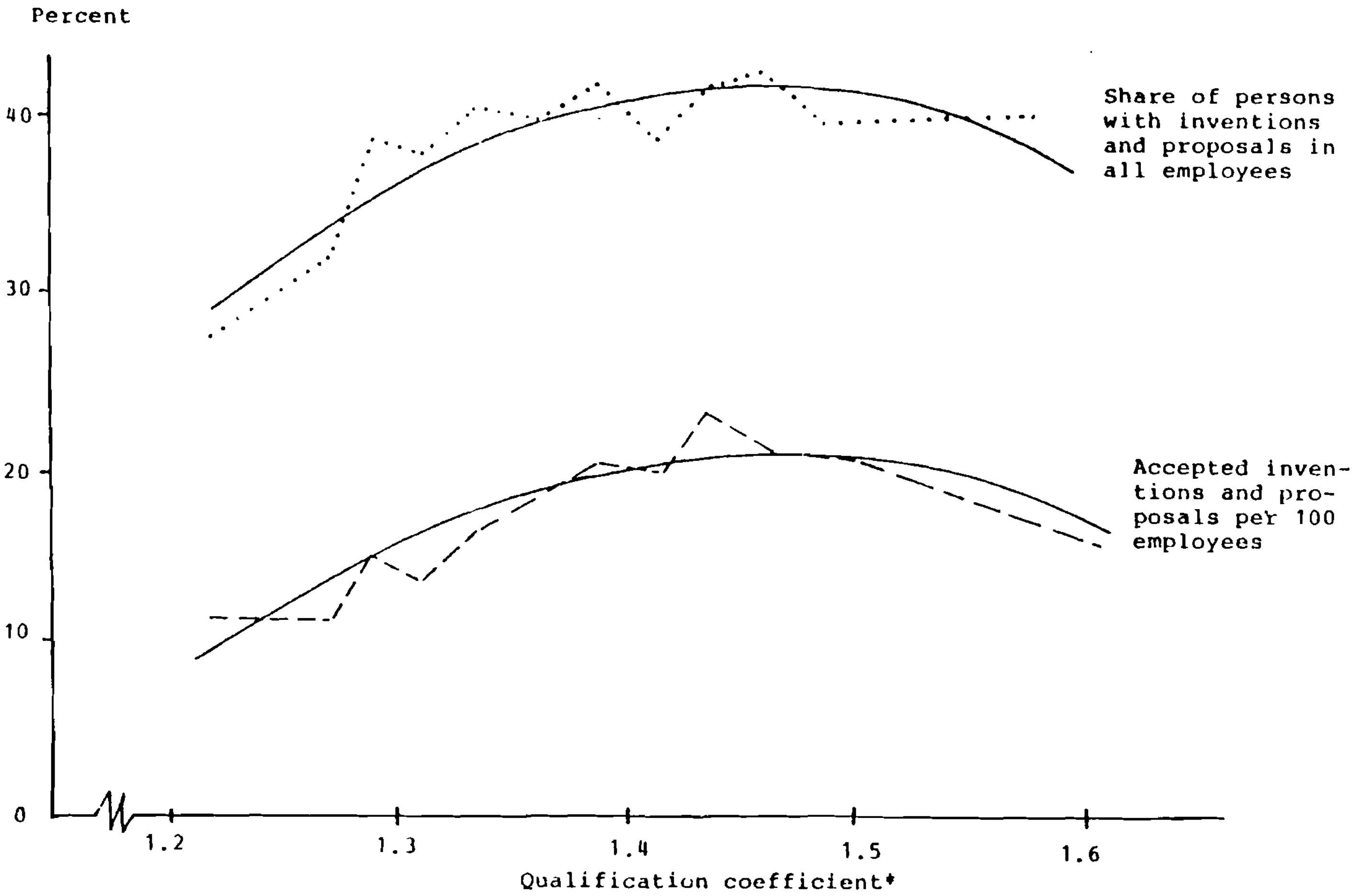



Figure 9. Average qualifications coefficient: the use of adopted innovations per 100 employees and the share of innovations over all employees.*

*The qualifications coefficient is estimated by the reduction of highly skilled work over unskilled work. As weights for the different groups of qualified work we used the reproduction costs of labor forces with different levels of qualification. For the methodology of estimating the qualification coefficient see Maier, Ludwig, and Wahse (1972).

It is beyond question that the current status of nuclear energy, computer, aircraft, space technology, and communication systems is very much the result of the technology push actions of government. In the future technological push will also remain important expecially in stimulating the take off for various synthetic fueld technologies, coal gasification, technologies to protect the environment, and to improve the communication system. Technology pull actions through product characteristic interventions are used in both market and planned economies to achieve better use of resources and to avoid undesirable side effects. For example, the GDR five year plan (1976-1980) required from firms the reduction of final energy coefficient of production through technological improvements by 2.8 to 3% per year. Other product characteristic interventions through limitations in environment, pollution, material and energy consumption etc, play an important role in shaping technological development.

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

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

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

REFERENCES

Abernathy, W.J. (1978) The Productivity Dilemma. John Hopkins University Press. Baltimore and London.

Bodde, D.L. (1976) Riding the Experience Curve. Technology Review, March April 1976, 539.

Häfele, W. (1979) Global Perspectives and Options for Long-Range Energy Strategies. Keynote address at the "Conference on Energy Alternatives", East-West Center, Hawaii, 9-12th January 1979.

Haustein, H.-D. (1979) Complex Innovation in Lighting Industry, (A Case Study on the Example of GDR Industry). Draft Paper Laxenburg, Austria: International Institute for Applied Systems Analysis.

Haustein, H.-D., H. Maier, and Jennifer Robinson (1979) Appropriate Technology. WP-79-95. Laxenburg, Austria: International Institute for Applied Systems Analysis. Presented at IFAC Symposium for Selecting Appropriate Technologies Under Different Cultural, Technical, and Social Conditions, Bari, Italy, May 1979.

Haustein, H.-D., and H. Maier (1979) Basic, Improvement, and Pseudo-Innovations and Their Impact on Efficiency. WP-79-96. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Kondratieff, N.D. (1926) Die langen Wellen der Konjunktur, in Archiv für Sozial-wissenschaften und Sozialpolitik, Tübingen, 56 Band, S.573.

Maier, H. (1979) Some Conclusions for International Technology Assessment from the IIASA Energy Study, Invited paper for the XXIV International Meeting at the Institute of Management Science, Honolulu, Hawaii, June 1979.

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

Norman, C. (1978) Massenproduktion oder Produktion durch die Massen, Europa Archiv 17. J.539

The Human Gap, (1979) The Learning Report to the Club of Rome, Pergamon Press.

Utterback, J.M. (1978) The Dynamics of Product and Process Innovation in Industry. in Hill and Utterback (eds) Technological Innovation for a Dynamic Economy, Pergamon Press, New York.