ARTICLES

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Evolutionary Economics: Implications for Technology Studies and Policy

The development phases of technology policy

Technology policy is an important field of government activity in all the industrialized countries. This phenomenon is by no means as new as it is often imagined. Neither has the tempo of change with regard to technology policy necessarily been as rapid as its more ardent proponents have assumed. Nevertheless, it is certainly true to say that technology policy has been one of the most dynamic instruments of the public sector.

In the initial stage of the development of nation-states, government actions were primarily directed towards the establishment and development of the basic structures of a scientific and technological system, e.g. universities and research institutes. After the Second World War, the technology policy of the superpowers was oriented towards the development of military and nuclear power technologies. The scope of technology policy was later expanded to encompass space technology (Freeman, 1982).

In the late 1960s, the development needs of industry began to assume a more important position in the priorities of technology policy (OECD, 1980, Rothwell and Zegveld, 1981). This stage also coincided with the shaping of technology policy in its present-day form in small countries. The creation of new corporate activities and the support of innovation in existing firms became the key objectives of technology policy.

The fundamental goals and points of departure for technology policy did not change essentially during the 1970s and 1980s. The amount of resources for technological development certainly grew and the range of instruments became more diverse. The most important new challenge facing national technology policy has been the strengthening of international co-operation and the role of transnational organizations (Sigurdson, 1989). The particular long-term issue – and a difficult one for technology politicians in many countries – has been the use of innovation, technology and complementary policies to

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support the goal of environmentally sustainable development.

The technology policies of different countries have converged strongly as a result of the combined effects of increased co-operation and more intense international competition. Japan has played an important and conspicuous role in this convergence process. Of course, a very important question in Europe at the moment is whether the rapidly ongoing process of European integration will further decrease the diversity of national innovation systems and national technology policies.

The basic rationale for public policy

Technology policy is a very pragmatic activity. Decision-making is based to a large extent on the personal knowledge and views of key persons. In Finland, committees or groups of experts played an important role in the formulation of technology policy in the 1970s and 1980s. The committees formed a channel for co-operation and interaction between the public and private sector organizations. In recent years the role of the committees has declined as the authority of the civil servants has increased.

Lobbying or actions taken by groups representing various interests concerned with technology policy also have an important impact. A good example of this in Finland is the activity of industry and its organizations in the development of technology, and particularly in efforts to increase public funding for corporate research and development. Lobbying began in the mid-1960s and has been fairly successful up to the present.

Another popular approach has been imitating the successes achieved by other countries. Accordingly, Japanese efforts in technology policy have been followed closely in the United States and Europe and the means which have proved successful in Japan have been adopted rather directly. In Finland, models were sought primarily from Sweden in the 1970s and 1980s. The Technology Development Centre (TEKES) established in Finland in 1983 was virtually a direct copy of the Swedish Board for Technological Development.

The best known and most frequently applied of the few theoretical attempts to explain technology policy (or more broadly, science and technology policy) is the market-failure theory based on neo-classical economics. The basic concepts were introduced by the American economist Kenneth Arrow in the early 1960s (Arrow 1961). In accordance with neo-classical economic theory, Arrow assumed that a freely operating market mechanism in general guarantees that companies allocate sufficient resources for research and development, either in the hope of obtaining additional profit or to respond to a threat posed by other companies. In fact, the problem may be more one of excess investment in the form of overlapping research and development. From the viewpoint of society as a whole this does not necessarily represent the optimal allocation of scarce resources.

Nevertheless, the market-failure approach has regarded the tendency of the market mechanism to allocate insufficient resources to research and development as a more serious problem than overinvestment. Research and development to which companies have sole rights and which is likely to be economically profitable is in the interests of companies, whereas projects involving risk and requiring persistence and projects whose results will be difficult to protect, are readily passed over.

According to the market-failure theory, government intervention is required to ensure socially optimal allocation of resources. The basic function of the government is to supplement, and to some extent replace, research and development conducted by companies with their own resources and in their own units. Moreover, it has also been felt that public research and development, with findings that are normally public and can therefore be freely applied, is more economical because unnecessary

overlapping investment and activity are reduced.

Arrow and his followers have not been particularly specific in their conclusions and recommendations concerning science and technology policy. The recommendations can be summarized as follows:

1. A free enterprise economy has a tendency to underinvest in invention and research (as compared with an ideal). This underinvestment will be greater for more basic research. Although the results of basic basic research are not normally immediately applicaple, they are essential over the long term even to the continuity of corporate operations. Government policy is needed to create and maintain the sufficient level of basic research conducted at universities and government research institutes.
2. Government should complement the operations of capital markets by sharing in the risks entailed in corporate research and development; it should provide increased incentive for research and development and reduce unnecessary overlapping investment in research and development. Tax relief for research and development expenditure, product development loans and grants, and the promotion of collaborative efforts between companies are typical means.
3. It is the function of government to see that sufficient funds are invested in research and development related to the externalities of corporate activity, e.g. to research and development that promotes environmental protection and similar objectives. Examples are emission norms, pollution taxes and public support for research and development of environmentally sound products and processes.

The market-failure theory has been criticized from at least four angles. First, since the theory relies on the basic premises of neo-classical economics (equilibrium, free competition, perfect information, rational decision-making, homogeneity of various factors), scholars who take a critical view of these basic assumptions in general take a critical view of the market-failure theory as well.

Second, the theory has been criticized for having a poorly articulated and deficient concept of government. Its task according to the theory is to complement the operations of the market mechanism. It has been said that "government failure" may be as big a problem or an even bigger problem than "market failure" (Krueger, 1990). How can civil servants have the knowledge and understanding of the needs and potentials of markets if the companies operating on them do not?

Third, although the theory would seem to legitimate government intervention in the form of technology policy, it is difficult to draw specific conclusions concerning the content, strength, etc., of intervention carried out on the basis of it. Its contribution to practical decision-making is allusive (Edquist, 1990). It is characteristic of the theory that it can be used both to defend tax incentives and oppose corporate subsidies (product development loans and grants) and visa versa (Fölster, 1991).

Fourth, the theory at least indirectly gives its full support to decision-making by experts. It does not ask whose interests are served by technological progress nor who is or should be entitled to take part in preparations and decision-making concerning the development and application of technologies. It seeks its premises and objectives from corporate developmental needs, both direct and indirect.

The contribution of evolutionary economics

In recent years the discipline or sub-discipline called "evolutionary economics" or "neo-Schumpeterian economics" has offered abundant material and points of view for international research and discussion on

technological, industrial, economic, and in the final analysis social change (Dosi, 1988; Freeman, 1994). While technological change is for neo-classical economics a black box about which certain simple assumptions are made at most, evolutionary economics seeks to open the box, both theoretically and empirically, that is to explain the factors affecting the origin, diffusion, development and significance of innovations.

The main characteristics of evolutionary economics can be described as follows:

1. Technology is the central factor affecting economic and social development. This change is realized through product and process innovations. It is impossible to analyze and comprehend the phenomenon of economic development without taking changes in technology and related market situations into account.
2. The direction and rate of technological change depend greatly on action taken by companies, because companies are largely responsible for the development of new products and processes and in the main for their introduction and application as well.
3. Technological change is a cumulative process. Its mainstream does not comprise technological breakthroughs, but consists of gradual changes in existing products and production processes. This also means that innovation is to a large extent a learning process that evolves on the basis of experience, by making and using.
4. From a modest beginning some technological inventions and innovations evolve through improvements that support, supplement and reinforce each other toward broader technological entities called paradigms, technological systems or "technological trajectories" etc. in the literature. This also means that once sufficient progress has been made along a given developmental track, a return to the starting point is difficult if not outright impossible.
5. The nature of technological change varies greatly depending on the sector of technology, industry and society in question. It also varies by region. Research and interpretation of technological change must always concentrate on the developmental stage of the technology under study and on its area of application and special features. Moreover, technological change and the ensuing economic development are more properly a transition from one state of disequilibrium to another than from one state of equilibrium to another.

Particularly John Metcalfe and Michael Gibbons (Metcalfe & Gibbons, 1991; Metcalfe, 1995) have done pioneering work to determine what conclusions for technological policy can be drawn from the basic conceptions of evolutionary economics. They stress that the function of technology policy is not to correct temporary deficiencies in the market mechanism that are understood to be static, but to influence the initiation and direction of technological change processes.

Although they emphasize the role of specific technologies, this does not mean concentration on individual technologies, industrial sectors or companies. On the contrary, it means promoting the development of broader "technological trajectories" or "technological design configurations". It could mean, for example, the use of industrial clusters as a premise for technology policy and the search for developmental needs and potentials from important nodal points within clusters.

Most significantly of all, write Metcalfe and Gibbons, there is no longer a role for the optimizing policy maker. Uncertainty, ill defined choice sets and bounded rationality put the policy maker in exactly the same position as the institutions which policy seeks to influence. The evolutionary policy maker adapts rather than optimizes. His central concern is on the innovation process, i.e. the operation of the set of institutions within which technological capabilities are accumulated. Policy should seek to change

behaviour, to create variety in behaviour without knowing who will win or loose or when.

Thus, technology policy should focus on co-evolving technological and market environments, not upon individual innovations or predetermined outcomes. A central purpose of policy becomes that of stimulating the technological and innovative capabilities of the economic system: enhancing the learning processes in firms and other institutions to generate variety in behaviour.

This means that plurality of sources of innovation requires plurality of support, and the recognition that *ex ante* one cannot predict which of the firms which are supported will be decisive in producing profitable innovations. In times like the present, it is not easy to accept these views emphasizing pluralism and the belittling of strict demands for financial performance. "Inevitably evolutionary processes are inefficient, when viewed in narrow terms waste is always apparent if one wishes to find it. Whatever way one approaches evolutionary processes they operate in the presence of considerable static inefficiencies." (Metcalfe 1995: 415).

According to Metcalfe and Gibbons, an extremely important function of technology policy is to bring organizations developing technologies together and to strengthen the links or connectivity between them. Economic support to companies and other innovators is justified when there is an obvious imbalance between the available resources and the potential for innovation. This generally means small businesses. When the incentives for innovation are weak, either because of problems related to the direct application of results or the excessive risk involved, government should see that the necessary knowledge and skill are developed and maintained. Moreover, demand for innovations should be encouraged, in other words, support should be provided not only to the developers of the innovations but to the users as well.

A Maastricht Memorandum – the technology policy manifesto of evolutionary economics

In spring 1993 a report entitled *An Integrated Approach to European Innovation and Technology Diffusion Policy. A Maastricht Memorandum* appeared (Soete & Arundel, 1993).

The report published by the European Union and financed through its SPRINT programme was drafted by a number of well-known evolutionary economists. Therefore it can be regarded as the technology policy manifesto of evolutionary economics. The goal of the report was to build a bridge between theory and action and to draw conclusions concerning the development and diffusion of technology on the basis of a system model. There are five elements or characteristics in the system.

The first characteristic consists of multi-directional links which occur at the same point in time between the stages of technical change. To succeed, innovation requires extensive co-operation and interaction both within the organization and outside it. The need for co-operation is based in part on the tacit nature of technological knowledge. Technological knowledge can rarely be articulated into precise instructions or other documents, and a significant part of it is private. It can be transferred and learned only through close interaction.

The second characteristic is the existence of cumulative and self-reinforcing processes. The ability to create new innovations depends greatly on what has been previously done and learned. Technological development consists primarily of incremental changes and improvements to existing technologies. Cumulativeness produces many advantages, although there is also a disadvantage; it may lead to lock-ins and solutions whose undoing – if it proves necessary – is difficult and time-consuming.

An important function of technology policy is to identify potential technologies and encourage their development and application, and in opposite cases to find the means to stop unfavourable development tracks.

The third characteristic is the central role played by knowledge and learning. The accumulation of knowledge and information is highly dependent on the capacity of individuals (such as scientists and engineers) to produce new data and technologies. An efficient system of high-quality education is a basic requirement for successful innovation. Technological skills can also be promoted through official and unofficial networks between the public and the private sector.

The fourth characteristic is the unique development pattern of each innovation. Because of the wide range of features within individual technologies and of industrial sectors, locational, situational and other factors, variety is characteristic of innovations and their applications. The factors and rules which appear valid in one case are not necessarily relevant at all in some other case or context.

The fifth characteristic is the sum of the preceding four elements acting together and consists of the systemic and interdependent feature of technical change. This characteristic implies that different aims, actors and institutions are dependent on one another in various ways.

The Maastrich Memorandum is aiming at contributing to the discussions on the role of government intervention in technical change in general, and in the long-term goal of environmentally sustainable development in particular. The explicit point of departure of the report is that innovation and technology policy play an essential role in achieving the goals set for environmental protection. Many problems related to present production and consumption must be resolved, new solutions that support sustainable development must be devised and care must be taken to apply new and improved methods effectively. These measures will necessitate an active technology policy or increasing government intervention in technology development.

The model which is needed for the implementation of the ideas of new active technology policy already exists. Surprisingly, its origins are in the extensive and technologically ambitious programmes for nuclear power, military and space technology implemented in the United States and leading European countries in the 1950s and 1960s. However, the similarities with the above-mentioned programmes are confined to certain basic ideas and the mode of implementation. Naturally, there are significant differences between the goals, contents and modes of implementation of the programmes.

Societal linkages (a strong societal and political background and need on the one hand and commitment, breadth, and the demanding nature of the goals set on the other) and the fact that the organization and implementation of the programmes will inevitably demand an active role on the part of government, are the most important features common to both the old programme practice and the new. The principal difference is that the goal in the earlier programmes has been to develop through public projects new (radical) technologies which are to a large extent isolated if not directly closed off from other sectors of society and the economy. This can be said despite the fact that the technologies developed in the programmes (for example the development of electronics in the military programmes) have affected the structure of the industrial sectors involved. The programmes have also had a spin-off effect on other sectors.

The thinking behind the new programme emphasizes openness, decentralized decision-making and implementation, integration of a number of different organizations with the programme and the broad diffusion and application of the innovations and other findings. It is also emphasized that although public projects would have an important role in the development of environmental technologies, such action should be combined – in accordance with system thinking – with supportive and complementary measures.

Neither is this model without gaps or problems. It incorporates a strong belief in

the government's ability to select the correct missions and to motivate companies to participate in government-led technological development. As mentioned earlier, in addition to market failure, there is also government failure (Krueger 1990), which manifests itself as the making of incorrect choices and as mistakes in the resourcing and organization of the programmes. However, I would venture to say that the new mission-oriented projects will offer plenty of perspectives and conceptual models, which should be given careful and serious consideration by technology politicians.

Conclusion

Decision-making in technology policy, like decision-making in general, is a very pragmatic endeavour. It seeks its models and ideas from sources other than research on the sector in question. Moreover, research often does not proceed decision-making, but follows it. In the worst case, research is left with the task of superficially legitimating the decisions already made.

The market failure theory based on neo-classical economics has held a central position in the discussions of the foundations and general goals of technology policy. The theory offers grounds for the contention that government intervention in the form of technology policy is not only feasible, but desirable. Since the market mechanism is unable to guarantee the optimal allocation of resources for research and development with respect to society as a whole, the gaps should be filled by government intervention and those functions that risk being left entirely outside the control of the market should be handled by government.

Unfortunately, the theory goes only half way. It is difficult to determine where intervention is needed (in which branches of industry or technology) or how and by whom it should be effected (by what means).This does not, however, mean that the theory should be rejected. It is merely inadequate and calls for supplementary measures.

The basic contribution of evolutionary economics is the idea that the most important function of technology policy is not necessarily the realization of individual innovations and the development of specific technologies, but the initiation of processes of change and development. In short, the function of technology policy is not to optimize, but to concentrate on stimulation. Therefore, the creation and maintenance of the most diverse possible co-operation and interaction among companies and research institutes, researchers and engineers, producers and consumers is essential.

Instead of individual innovations and technologies, evolutionary economics is interested in examining larger technological entities. From an evolutionary vantage point, an industrial complex, cluster, technological system or similar phenomenon would appear to offer a more fruitful basis for technology policy than individual technologies and projects.

It follows from the basic evolutionary premise that interest in pluralism will increase. This conflicts considerably with conventional technology policy and the present "Zeitgeist", which emphasizes the scarcity of resources and advocates both their concentration and the maximization of the yield available from them.

Evolutionary economics is sceptical of technology policy based largely on support to companies. The fundamental premise is that incentives to companies should be provided through general economic and tax programmes. When such support is granted, it should contribute to the development of larger entities of the type mentioned above, and support should be allocated primarily to small and medium size enterprises.

The idea expressed in the Maastricht Memorandum, an active technology policy based on support for sustainable development, and containing a "mission-oriented" development programme for environmental technology, is at least a welcome attempt to test established approaches and to widen the scope of technology policy.

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