STEP report **ISSN 0804-8185**

R-08
•
1999

Johan Hauknes
Lennart Nordgren

Economic rationales of government involvement in innovation and the supply of innovation-related services

Johan Hauknes (STEP)
Lennart Nordgren (NUTEK, Stockholm)

STEP
Storgaten 1
N-0155 Oslo
Norway

Paper prepared within the framework of the TSER/RISE Program, for the European Commission (DGXII)

Oslo, December 1999

STEP group

Studies in technology, innovation and economic policy
Studier i teknologi, innovasjon og økonomisk politikk

Storgaten 1, N–0155 Oslo, Norway
Telephone +47 2247 7310
Fax: +47 2242 9533
Web: http://www.step.no/

STEP group

STEP publiserer to ulike serier av skrifter: Rapporter og Arbeids-notater.

STEP Rapportserien

I denne serien presenterer vi våre viktigste forskningsresultater. Vi offentliggjør her data og analyser som belyser viktige problemstillinger relatert til innovasjon, teknologisk, økonomisk og sosial utvikling, og offentlig politikk.

STEP maintains two diverse series of research publications: Reports and Working Papers.

The STEP Report Series

In this series we report our main research results. We here issue data and analyses that address research problems related to innovation, technological, economic and social development, and public policy.

Redaktør for seriene:
Editor for the series:
Dr. Philos. Finn Ørstavik (1998-99)

Abstract

This paper presents the economic rationales of government intervention into innovation activities and into the supply of innovation-related services as inputs in innovation processes. There are two approaches to the question of the economic rationale of government involvement in technological advance and innovation activities. One is the neo-classical of market failure and the other is the evolutionary economics or the innovation system approach of system failure. The traditional rationale for technology policy has been that of market failure. Government can intervene to provide for public goods and to mitigate for externalities, barriers to entry, information asymmetries etc. However recent research demonstrates ways in which the factors shaping technological progress call for government measures to address system failure i.e. the lack of coherence among institutions within an innovation system.

Following a review of the static efficiency market failure approaches to innovation and technology policy, the paper surveys various approaches to identify and describe system failures. System failures within an evolutionary framework may create low-growth traps where the growth-generating evolutionary mechanisms themselves are impaired. Given the characteristics of the market system in an evolutionary framework, these failures in dynamic efficiency terms imply considerably enhanced challenges for the policy maker.

Current trends in technology and innovation policies reflect the change in the perception of the rationale and effectiveness of government measures. The traditional core of technology policies has comprised interventions such as managing the science base and designing financial incentives to industrial R&D as solutions to market failures. This repertoire has been enhanced with instruments to overcome system failures such as promoting co-operation between firms, universities and government laboratories and changing the design of institutions and incentives (Andersson, 1998).

Systemic evolutionary innovation implies that policy making itself becomes an adaptive and learning-based activity. The current standpoint of the OECD is that market and system failures are not mutually exclusive but that both require attention by policy makers. Each has its limitations and pitfalls. Market failure remains the basis for technology policies in many areas. At the same time factors shaping technological progress increasingly call for strategies that can cope with system failure and achieve coherence among underlying institutions and incentive structures. Government has a role to optimise the contributions of innovation and technology diffusion for the economy as a whole (OECD, 1998).

Keywords: Innovation; Market failure; Policy; Services

Table of contents

Economic rationales of government involvement in innovation and the supply of innovation-related services

Market failure

The Arrow-Nelson rationale

The basic economic justification for science and technology policies in the post-war period (in addition to the fulfilment of government and public needs such as defence, health and environment) has been a market failure argument. Markets may fail to operate efficiently for a variety of reasons including externalities, asymmetric information, economies of scale and scope, indivisibilities, barriers to entry etc.

Innovation - the attainment of a competitive advantage over competitors - is basically about generating and using knowledge of what to produce and how to produce it. The question is then: Are there sufficiently efficient markets for such technical knowledge? Arrow (1962), see also Nelson (1959), gave the answer to this question: no, there are not such markets! Generation of such knowledge (the prime model being through R&D) by the market system is insufficient to achieve optimality. There are three basic factors that limit the attainment of a social optimum through private profit optimisation:

- Outcomes of knowledge generating processes are *uncertain*.
- Knowledge is a (quasi-) *public good*, implying inappropriability.
- There are substantial *indivisibilities* in knowledge generation.

The Arrow-Nelson argument, which grew out of US policy debate in the 1950s on the role of federal S&T policies, has been widely used and further corroborated in the international S&T policy debate since then. The argument grew out of a debate that primarily questioned the role of the federal basic science enterprise (see Nelson 1959), and was particularly attuned to strengthen the basis for an idea of a 'social contract' that arose in the aftermath of the Vannevar Bush report. A requisite for the argument for public intervention to hold, is an acceptance of science-based knowledge as being more or less directly productive, requiring not more than routinised transformation/interpretation from its generic, usually codified forms to the specific, mostly tacit, forms that are directly 'applicable' in productive activities. As a consequence there is no need for distinguishing between a science infrastructure, i.e. a science-based knowledge stock, and a stock of productive intangible assets comprising the industrial technology/competence/knowledge base.

Underlying this interpretation is the microeconomic theory of the firm. This theory implies a particular interpretation of technical information and knowledge: such

knowledge is *generic*, *codified*, *immediately accessible* and *directly productive*. Hence there is no difference between capabilities, knowledge and information. Technological knowledge and technological competences are in essence just the possesion of technical information. These properties are necessary conditions to attain optimality – allowing rational optimising behaviour by firms – and for a very simple reason. Any restrictions of these would violate the conditions for competitive behaviour. Here lies the first limitation of the rationale. By equating productive capabilities and information its foundation is at most limited to 'technological clubs', and then to applied rather than basic research - whereas the latter is what the rationale originally was developed for. For a discussion of this see Hauknes 1998b.

The market failure rationale is in principle a strong rationale. It provides:

- A general rationale (optimisation of social benefits);
- A guide to policy action (a framework for assessing links between benefits and policy inputs including funding); and
- A guide for determining optimal use of government expenditure (where; how much).

The policy recommendation that follows from the Arrow-Nelson rationale implies that such socially beneficial knowledge generation (read R&D) should be publicly provided or subsidised. The implications of this classical market-failure rationale can best be summarised as follows. Create favourable *framework conditions* to facilitate the smooth and dynamic functioning of markets, e.g. through vigorous competition policy, smooth macroeconomic policy or regulatory reform and through enabling new markets for S&T products (as through patent regulation. Then correct essential market failures by public provision or subsidising private production of the S&T products. This proved a strong argument for public R&D policies from the late 1950s onwards. Its strength was achieved not the least as it complemented three trends and views in this period:

- A 'production line' interpretation of R&D and innovation - the so-called *linear model*;
- Economic growth and technical change were regarded as dominantly *capital embodied* - sophisticated capital equipment codifying productive knowledge; and
- Advanced manufacturing and new industrial (techno-)structures were vanguard sectors - *'technology push'*.

Appropriation of returns and uncertainty

The activities that foster technological advance and innovation, i.e. R&D, are primarily affected by two types of failures; imperfect appropriation of returns and uncertainty, which lead to underinvestment from society’s point of view in R&D carried out by firms (OECD, 1998).

Market failure in relation to knowledge production and innovation means that the social rates of return from R&D is commonly higher than the private rates of return.

This is because the innovator is able to appropriate only part of the gains with the rest accruing to consumers and/or competitors. Moreover many innovations contribute to further innovations without the original innovator receiving any reward. While such externalities or spill-overs increase the benefits from R&D the downside is that fewer resources are devoted to innovation activities than would be socially desirable (OECD, 1998, Pavitt 1991).

Uncertainty is inherent to innovation. It is difficult to predict the cost and duration of a project and the commercial success of its outcome. Failures are common. Risk measures the possibilities that actual outcomes will deviate from the expected outcome. Society faces less risk than the individual firm and for each particular technological problem society cares only that at least one firm solves the problem and that at least one is successful in introducing the innovation into the market. Facing higher risk a private firm discounts future returns at a higher rate than does society. Therefore the private firm value future returns less, and from society's perspective, will invest too little into R&D. Socially useful projects will accordingly be rejected. Further when the firms expected returns falls short of society's expected return, the firm has less future returns to value than society does and again underinvestment in innovative activites will be the result (Link and Scott, 1998).

Research has shown that in the majority of OECD countries, the social rate of return on investments in R&D and human capital largely exceeds the private rate of return (Mohnen, 1996). The argument about externalities is true in fields such as energy, the environment, infrastructure or large-scale innovation projects on the electronic highway. This argument is central to the discussion on publicly funded research in universities and public research institutes. Stimulating co-operation between firms and the public R&D infrastructure (universities, research institutes) may increase the social return on publicly funded R&D. More firms will be able to profit from public R&D efforts, potentially increasing in the diffusion of knowledge, particularly towards small and medium-sized enterprises (SMEs). In most countries, SMEs have not yet been able to fully capture the benefits of increased external linkages and knowledge sharing. Many SMEs are unaware of the opportunities offered by co-operation with other firms and knowledge institutes.

Most countries show a variety of organisations conducting basic and/or applied R&D that are completely or partly financed by public funds. This fact has been explained with arguments that to a large extent refer to Nelson (1959) and Arrow (1962). The following list shows arguments that are repeatedly stated as rationale for State intervention in the generation of research (Dosi 1988, Pavitt 1991, Brooks 1994, Senker 1991, Faulkner and Senker 1994, Nelson 1996, Dasgupta and David 1994, Edquist 1999).

- The public-good character of R&D and knowledge constitutes a lack of incentives to engage in private R&D.
- Competitive regimes produce less basic research than desirable for the economy as a whole.

- Private investors tend to be risk-averse and will not invest in major technological advancements with an insecure outcome.
- Companies' profit orientation leads to short-term innovation policies and neglects the long-term benefits of complex research programmes.
- Benefits from basic research are difficult to appropriate.
- Basic research shows economies of scale which would remain unexploited, if the research were carried out by individual firms.
- Most small and medium-sized firms could not afford large R&D departments and are therefore not able to provide the technological basis for their innovation activities.
- Basic research in publicly financed institutions has spillover effects that stimulate research in private companies.
- The results of basic research should be available to the general public in order to guarantee the rapid diffusion of new technologies and thus to enhance technical progress in all industries concerned.
- Secrecy in knowledge production due to private appropriation of research results hinders technology diffusion and the modernisation of the economy.

Hence government funding of R&D seems to play a vital role for technological and economic development. The rationale for public involvement in knowledge production is that if let alone markets will underinvest in such activities due primarily to inadequate appropriability conditions and uncertainty. The policy implication is the removal of the sources to failure in order to create optimal conditions for the production of knowledge. The solutions offered to government are subsidising the activity (financial incentives to industrial R&D), providing suitable terms and duration of property rights (patents) and public knowledge production (managing the science base). The policies work by changing net marginal returns to developing technology in firms, thus increasing their R&D-activities (Lipsey, 1998). The policy maker acts as an optimising social planner aiming to improve the behaviour of firms by correcting imperfect initiatives (Metcalfe and Georghiou, 1998).

Edquist stresses the superiority of markets in economic activities and points out that markets have to have failed and that the state has to have the ability to solve the resulting problems to justify state intervention. The advantages of public actors in this context are that the state may use non-market mechanisms, and that state actions can improve the functioning of markets or create new markets (Edquist, 1999).

Although market failure provides a general rationale for policy intervention in knowledge production and innovation processes it is inherently imprecise in its detailed prescriptions. Theory tells us nothing about the optimal rate of R&D. Firms may spend too much or too little on innovation, they may innovate too quickly or too slowly, they may undertake excessively risky projects or be too conservative. The appropriate policy therefore depends on the specifics of the situation and requires the policy maker to have a detailed knowledge of what are necessarily conjectures held by firms (Metcalfe and Georghiou, 1998). One indicator of underinvestment in innovative activities often used by policy makers is the R&D-volume in firms,

sectors and nations. A low R&D-volume in the nation compared to other nations is taken as an indication of under-investment.

Government as a player in markets

One increasingly used rationale for government action in the area of innovation can be construed as being classical in origin, and is that government itself is an important player in some markets. This provides an opportunity for governments to put pressure on the various market players to produce innovative solutions to societal problems. In some countries, technology procurement policies have been transformed into public procurement policies with a view to enhancing innovation. Driving such a change is the notion that without a demanding customer, able to pull innovations from start to finish, some innovative activity would not occur. The aim of these new-style government procurement policies is not to support national industries, but instead to challenge firms and groups of firms to develop innovative solutions. For government, this approach often means new ways of procurement, e.g. using different forms of contracting out or setting functional instead of detailed technical specifications during the tendering process.

System failure

The need for new rationales

The strength of the neo-classical market-failure argument is its clarity. It suggests a simple criterion for judging when government intervention is appropriate. However it still has limitations in capturing the key elements of technological progress and thus has limits as a rationale and guide for technology policy making (OECD, 1998). Limitations of market failure analysis in regard to technological progress and innovation have been analysed in the 80s and 90s. The complexity of the process makes it difficult to identify and even to define market failure. Firstly it ignores the broader institutional framework that defines how markets work. Secondly it implicitly assumes that the market mechanisms have a competitive advantage over other mechanisms in all industrial technological and interface activities relevant for policy purposes. Lastly it may fail in providing direction and focus to policies when externalities are pervasive (Teubal, 1998). Absence of markets may rather be a strong signal that other coordinating mechanisms are more effective in terms of resource allocation, viz. networks, associations, communities a.o. (Nelson, 1987).

Neo-classic economic analysis has not totally ignored the subject of technology. Rather an explicit examination of technology and of knowledge about technology has simply been suppressed by introducing certain assumptions into the theory of the firm. Central have been the assumptions of a given set of tastes and some given stock of technological knowledge. Given this knowledge of tastes and technology the firm

determines its optimal behaviour including the choice of technique through the explicit consideration of factor prices (Rosenberg, 1994).

Is the Arrow-Nelson or market failure rationale sufficient as a basis for innovation policies? It is not. It involves a misrepresentation of what underlies the dynamics of advanced economies. Learning is active, interactive, collaborative and ongoing. Innovation is multi-organisational, multi-functional and systemic. These insights lead to the need of rethinking the basic arguments for the use of innovation policies and their objectives.

Though still rudimentary, the understanding of systemic innovation has emphasised the importance of a resource based, evolutionary theory of the firm. Such models of the firm have as main aspects the role of non-price competition on markets, that firms rely in their activities on a wide range of techno-economic capabilities that must be essentially learned, the boundedness of the capabilities and rationalities that shape firm behaviour, leading to satisficing behaviour, a non-optimising form of behaviour. Such arguments lead on to the role of evolution and selection in shaping economic change, and to structures innovation patterns, to innovation regimes and trajectories.

With this approach to economic change, capitalist systems are economic systems where variety generation and adaptation are basic ingredients, and where innovation on the one hand and diffusion on the other – are complementary processes. The diffusion process is in itself a process of continual adoption, adaptation and reorientation by firms, of innovation; innovation and diffusion turns a Janus face towards us. The processes of change in economic systems are processes that are crucially linked to heterogeneity, to 'bootstrapping' of economic growth and to structural change. In contrast to the market failure framework that allow use of the welfare theorems, the inefficiency related to knowledge generation is not limited to separated markets, it is a feature affecting all markets. In a sense the situation may be characterised by saying that all is market failure.

That relations between actors and hence co-ordination of production activities in any economic system involve two dual and concomitant processes, flows of economic resources in transaction and production processes and transformation and transmittal of information that shape co-ordination and behaviour, is an integral part of our understanding of economic systems. The last decades have shown increased attention to the complexity and important role of the latter process in shaping economic development. Though our understanding of the why's and how's of these processes and their relations are still lacking, our understanding of them is substantially improved. The notion of information as public good has increasingly been turned around by the realisation that the functionalities of bridging between the two, which necessarily involves interpretation of externally acquired information, indeed gives information properties of (at least partial) excludability and rivalry.

In evolutionary economic theories technology change and innovation is the most important factor behind economic evolution. The study of how technology advances

and its driving forces and consequences is at the center of evolutionary analysis. Technological change is presented as a two-stage process: one stage for generating variety in technology (innovations) and one stage for selecting across that variety to produce patterns of change (diffusion of innovations). There is also a third stage, namely feedback from the selection process to the development of further variation. If an evolutionary perspective is applied to the traditional sources of market failure, the analysis changes in subtle but important ways. Far from constituting failures, asymmetric information is essential if the competitive process is to work in an evolutionary fashion. Without asymmetry there can be neither novelty nor variety. Spillovers only make sense in a world where firms are fundamentally differentiated with respect to what they know (Metcalfe and Georghiou, 1998).

Technological advance and innovation is characterised by constant interplay and mutual learning between different types of knowledge and actors. Technological change can be seen as a learning process, which is gradual and cumulative in character and leads to a relatively ordered pattern of innovations (technology trajectories). Firms build upon their existing knowledge base when they search for new innovation opportunities, but they also use external sources of knowledge in this search (Metcalfe and Georghiou, 1998, Carlsson and Jacobsson, 1997). Overall performance is thus not only dependent on how specific actors perform but also on how they interact with each other as elements of an innovation system. This division of labour in the generation of innovations means that no firm can be self-sufficient in regard to knowledge and thus gains from linkages with other knowledge generating organisations. Through their innovative activities firms establish relations with other organisations such as other firms, universities and R&D-institutes. If these market and non-market organisations interact poorly, technology change may be slowed. Mismatches between elements in an innovation system are by OECD defined as systemic failures. If systemic failure exists then there is a rationale for policy intervention aiming at accelerating the rate of technological advance and innovation (OECD, 1998).

It is however right to say that the improvement in understanding of innovation in market systems has not been paralleled by development of the basic rationales of policy formulation and intervention. There has, however, over the last years been prominent attempts to raise issues and formulate some of the questions involved. The aim of what follows is not to give a review of these developments but to raise some aspects that are shared by these and conclusions as to the policy making process. The prime shared aspect of these approaches, that is in fact shared by all known approaches to innovation analysis, is the acceptance of the significance of beneficial externalities of technical knowledge, and the importance of innovation as a determinant of economic growth and welfare development. As phrased by Bengt-Åke Lundvall recently, “Innovation is at the core of the competitiveness of firms, regions and nations” (Lundvall 1998).

The recognition of innovation as a process involving many actors and taking place in a complex institutional system is the basis of system failure rationales for policy; a

policy that focuses on promoting the generation of innovations. The innovation processes are influenced not only by market forces but also by the character of the entire innovation system. Thus system rationales give justification for going beyond remedying market failures (Carlsson and Jacobsson, 1997). According to these rationales policies should try to alter the structural conditions under which technology advance and innovations occurs rather than just as in the market failure rationale altering the cost and pay off associated with R&D.

System based rationales

The system failure rationales for public intervention make a case for innovation policies. Policies that in all important aspects are about facilitation, i.e. facilitating the emergence of new technology and innovation opportunities by building an innovation infrastructure (Lipsey, 1998, Metcalfe and Georghiou, 1998). Innovation policies include the policy domains of education, science, technology, labour market and industry. Policy becomes a much more complex issue than in the market failure rationale. It should design and create an institutional structure that supports the innovation processes in firms. The focus is on enhancing the innovative possibilities of firms by improving their access to knowledge.

System failure rationales do not preclude such policy instruments as intellectual property rights and R&D subsidies per se. Rather they provide a rationale for additional domains of policy intervention (Lipsey, 1998, OECD, 1998). The need to encourage technology advance through policies can be thought of as a response to market failure. Markets fail when they do not lead to some desirable and attainable state of technology. In a system perspective the market constitutes only one element in the context of innovation and diffusion. Institutions and networks are other constituting elements and their functioning also influence the process of technology advance. There is a need for government to respond to externalities as in the market failure approach but in addition also to alter the structural conditions under which technology advance occur. In the market failure approach the technological capabilities in firms within an existing technology is increased by changing the net marginal returns to technological development. In the system failure approach the technology possibilities that firms faces are enhanced by improving their access to knowledge (Lipsey, 1998).

What then are the instruments that government can use to overcome system failure and increase the rate of innovation? In order to answer that question it is first necessary to distinguish between different types of system failures.

Different types of system failures

Evolutionary 'traps' or failures are low-growth traps where 'the unfolding of an evolutionary process and a high rate of innovation and diffusion' is impaired

(Malerba 1998). Malerba identifies four main types of failures, which he describes as follows,

- *Learning failures:* firms or industries may not be able to learn rapidly and effectively and may be locked into existing technologies, thus being unable to jump to the new technologies.
- *Exploration-exploitation and variety-selection trade-offs*: industries may be characterized by a lot of variety generation with weak selection processes or by tough selection with little variety generation. Tough selection may rapidly kill off variety, experimentation and competition quite soon and lead the system in a "one-view" situation On the contrary, weak selection processes may allow the persistency of too much experimentation and too many inefficient firms, thus blocking the exploitation of technologies. Similarly, firms may do a lot of exploration and experimentation, but without exploiting what has been discovered. On the opposite, firms may be engaged into a lot of exploitation, modifications and incremental innovations, without exploration and experimentation.
- *Appropriability traps*: too stringent appropriability may greatly limit the diffusion of advanced technological knowledge and eventually block the development of differentiated technological capabilities within an industry.
- *Dynamic complementarities failures*: the appropriate dynamic complementarities required for successful and sustained innovative activities may not be present within an industry or an innovation system or, when they are present, they may not be connected, so that the positive effects from complementarities may not take place. (Malerba 1998)

While the market failure approach refers to intervention towards specific missing or inefficient markets, Malerba's evolutionary failures refer to the mismatches and traps in the evolutionary mechanisms themselves.

Keith Smith (1998) identifies four types of system failures:

- *Failures in infrastructural provision and investment:* Infrastructures have a number of specific technical characteristics which lead to serious problems of investment appraisal, Smith (1997). This is a serious problem, since studies of the nature of industry knowledge bases, indicate an important role in enabling and structuring technological opportunities of firms for knowledges developed within these kinds of infrastructures. The provision and design of infastructures, and policy makers' capabilities to do so, indicate a substantial role for public sector support. This entire area is problematic at the present time, since increasing pressures on public expenditure in most EU countries have led to strategies of privatization and/or marketization which have serious implications for infrastructural operations.
- *'Transition failures':* Any innovation-based theory of the economic process must stress transitions and dynamics; particularly systems theories which stress the pervasiveness of innovation. But firms - and especially small firms - are necessarily quite limited in their technological horizons. Systems approaches imply serious problems for firms and sectors in adapting to transitions. Firstly, even in the normal course of innovative activity it is almost certain that firms will

frequently encounter technological problems outside their existing capabilities. Secondly, there may be changes in technological opportunities or demand patterns which push the market into new areas of technology. These transitions can be particularly difficult since they often imply completely new generic technologies, with relevant outside the existing structure of capabilities.

- *Lock-in failures:* System or network externalities and technologies being closely linked to their social and economic environment means that technological alternatives must compete not only with components of an existing technology, but with the overall system in which it is embedded. Technological regimes persist. The socio-economic system can be "locked-in" to particular technological paradigms. This lead to serious problems of lock-in. Such paradigms are complex systems of integrated technologies. This is an important rationale for public action in a systems context.
- *Institutional failures:* Systems approaches emphasize the institutional context as a defining and structuring element in the system. This includes regulatory frameworks, technical standards, risk-management rules, health and safety regulations, as well as wider context of political culture and social values. These institutional/regulatory processes may develop through conscious choice or through the evolution of cooperation, but invariably discussed and implemented through policy agencies. The need for monitoring and assessment of regulatory performance, and if necessary changes in regulatory systems, provides a rationale therefore for public action.

Carlsson and Jacobsson (1997) divide system failures into:

- Network failures
- Institutional failures

Networks partly compensate for limitations in a firm's search space and improve a firm's resource base and degree of freedom. The connectivity of the organisations in a system matter and a well-functioning system with positive and reciprocal external economies between actors results in a common vision of future technology advance. This means a reduction of perceived risks and co-ordination of investments among independent organisations. Networks do not necessarily grow spontaneously and there may be obstacles to the growth of a collective identity and shared technological vision. Network failures means that organisations in a system interact poorly and that this leads to a lack of a collective vision of future technology expectations and co-ordination of investment. Such a vision is created by good connectivity i.e. reciprocal flows of information and knowledge, which ties together actors in the system (Carlsson and Jacobsson, 1997).

In relation to network failure the building of bridges between organisations for mutual accumulation of knowledge is an important policy area. In this aspect of system failure innovation policy is about facilitating the emergence of new innovative opportunities by building connections between firms and the knowledge base. Such networking policies usually focus on improving the relations between firms and universities/research laboratories i.e. integrates the R&D-activities of these actors. Establishing and intensifying connections involve a range of policy instruments such as joint R&D-programmes, programmes for increasing the mobility of persons. The policy task is to increase the number and intensity of linkages among

firms, among firms and R&D-organisations. The linking together of organisations that has had little or no contact with each other are especially important. The result of a strong connectivity is the creation of a common vision among actors of future direction of innovations and technology advance. Publicly managed technology foresight exercises are an instrument for formulating a common technology vision. R&D grants for co-operation projects, which are combined with foresight activities, are another way to establish R&D-co-operation and a common base for future activities (Metcalfe and Georghiou, 1998, Lipsey, 1998).

Institutions in the innovation system approach are of two types. Organisations are characterised as *hard institutions;* laws, regulations, culture, attitudes etc are characterised as *soft institutions*. Firms are the prime agents in innovation systems. They develop and introduce innovations in the market. Universities are also important players by fostering a high technological competence and variety in innovation by pursuing high-risk research as well as education. Other hard institutions are those performing bridging roles within a system such as public R&D-institutes. Soft institutions are important in innovation processes in many ways e.g. by influencing the willingness to share resources with other actors and by influencing the entrepreneurial spirit. Institutional failures mean that some organisations in the system are lacking or performing poorly or that laws, regulations etc. hamper interaction and the entrepreneurial spirit (Carlsson and Jacobsson, 1997).

Important public organisations in relation to institutional failure are those who design, formulate and implement policy initiatives, those who perform research and development (universities and R&D-institutes), those who support diffusion of knowledge and innovations (bridging organisations), regulatory agencies, standard setting agencies and patent offices. The behaviour of these organisations must be conducive to innovations in firms and their behaviour can be influenced by government regulations and laws, e.g. rules for universities and public R&D-institutes (Edqvist and Johnson, 1997)

A central responsibility for government is to build strong and flexible education and research organisations i.e. universities and public R&D-institutes which can identify new technology and shape awareness of these among firms, exploit new technology by spin-offs, increase absorption capacity by accelerating education and research in new technology areas. These organisations must be characterised by flexibility in expansion of research and education in new fields. Decision-making systems and incentive structures should be designed to make it easy and fast to change into new fields and expand research and education. The important tasks of fostering firms awareness of new technology opportunities, monitoring technology development and disseminate the information to enhance the opportunity set can also be performed by government agencies and programs (Carlsson and Jacobsson, 1997).

Policy can alter soft institutions, e.g. laws and regulations, to assist necessary adjustments in an innovation system. Areas of importance for policy are assuring free entry of new firms into markets, stimulating entrepreneurship in new technology-

based firms, assuring the supply of venture capital (venture capital supply funds, absorbs risk and provide management competence). Especially important in regard to innovation is to remove obstacles to the growth of venture capital by tax changes and legislation changes. (Carlsson and Jacobsson, 1997).

Given the strong path-dependence of technology and innovation and the powerful market mechanism that weed out most new initiatives an important area for public policy is to build institutions which sustain and increase variety in innovation. Variety is necessary for long-term stability of economic growth. The most important vehicle for variety is free entry of new firms into markets. A special form is the formation of new technology based firms through spin-offs from existing firms, universities or R&D-institutes building upon and utilising knowledge which otherwise may not have been commercially exploited. The frequency of spin-offs and the evolution of these firms depends on a range of factors outside of the individuals starting the firm, factors that can be influenced by policy, e.g. the functioning of the venture capital market and conditions for commercialising academic research results (Carlsson and Jacobsson, 1997).

What all these approaches have in common is the opening up for much richer, and more difficult, innovation policies. We may describe the characteristic aspects of innovation policies that are based on understanding of systemic innovation in five core theses:

- Innovations are firm-based activities.
- Innovation requires substantial integration of factors and activities in firms, as development of competencies and capabilities, product development, market understanding and insight, design, organisation, etc.
- The variety in firms' prerequisites and abilities for innovative activities is large, even within functionally homogenous groups of firms.
- Innovation involves a dynamic interaction between firms and their business environment, involving customers, suppliers and competitors, as well as R&D institutions, advisory and diffusion organisations, industrial networks and organisations, provision of financial and other business services, regulation, etc.
- Innovation is contingent to a framework that is substantially shaped and organised through public policies, as physical and immaterial infrastructures, regulation and legislation, fiscal systems, public funding and programmes, as well as education and R&D policies.

The approaches to system failures described above implies that with these organising theses for formulation of innovation policies the main focus should be on the shaping of (technological) variety generating and selection mechanisms that underlies the basic structures of innovation systems.

Balancing systems - Existing systems and new systems

In the innovation system literature an important distinction is made between existing and new systems. There are two possible directions for public policy, namely

strengthening existing systems and creating new systems. The most important but also most difficult task is to promote the creation of new systems. The issues are how to influence the receiver competence of the actors, the connectivity and network formation and how to influence the creation and maintenance of variety (Carlsson and Jacobsson, 1997)

The receiver competence of firms determines their ability to exploit new technology opportunities and is raised by R&D, hiring of competent personnel, training of personnel and accumulation of experience. The possibilities of public influence lies in the educational sector and university R&D, but also in the opportunities of creating positive externalities through various forms of spillovers. The universities influence receiver competence by identifying new emerging technologies and shaping an awareness of their potential, they are the base for spin-offs that exploit new technology and they increase the competence by accelerating research and education in these technologies. The main public responsibility is to ensure that education and research is characterised by an early expansion into new fields (Carlsson and Jacobsson, 1997).

The key players in the formation of a new technology system are so called prime movers. They raise awareness, undertake investment in the new technology, give legitimacy and diffuse it through various mechanisms to other actors. The issue of who the prime movers are and under what conditions they perform these functions are crucial for policy makers. A key issue is to create conditions and institutions conducive to monitoring the international scene and to encourage the establishment of prime movers and to promote strong links to other actors. Government can influence the emergence of prime movers by foster industry awareness of new technology opportunities. Monitoring technology developments around the world, identifying the technology frontier and disseminate the information are important functions in large multinational firms. However these activities can be supplemented and enhanced through public agencies i.e. expand the perceived opportunity set. (E.g. programs for establishing links between research and potential users to make them aware of new opportunities). Moreover advanced public procurement policies can ensure that the prospective prime movers undertake the necessary investments in the new technology. A competent buyer should specify price, performance and contribute to product design. By paying for the sellers R&D it reduces the risks of venturing into new technology. Government can also co-ordinate private demand for new technology when it is poorly articulated and fragmented. (Carlsson and Jacobsson, 1997).

There is no optimal public policy

Distribution within a framework, or changes in the frameworks themselves?

In neo-classical ('contractualist') models of the economy, technological change processes appear as intermittent processes, sudden (instantaneous) bursts of change affecting all economic agents alike. In this framework there is thus no (transient-creating) technological competition. All firms are at any time on the same production technology, using the same behavioural rules.

In contrast to this approach, evolutionary approaches to innovation-led economic change emphasise variety in firm behaviour, that firms are different is a basic ingredient in these approaches. The factor that is neglected in the traditional, 'neo-classical' approach is argued to be of central importance. Why this change of emphasis? The basic point here is that *the main focus of economic analysis has been fundamentally changed*. The main focus is no longer on distributional characteristics of economic systems, within given framework conditions (often expressed as 'given technology'), but rather on how economic agents contribute themselves to change these framework conditions; the attempts are to endogenise technical change. There is a fundamental shift from consideration of static to dynamic efficiency of market systems. Those who adopt this view generally argue that technical change amenable to endogenisation, with a concomitant extension of the 'economic' system to an 'innovation' system, is the consequence of an evolutionary process. Metcalfe (1998) gives an outline of such evolutionary approaches to economic change. The evolutionary process is based firstly on the generation of behavioural variety at firm level ('innovations') through deliberate interactive searching/learning activities, a variety that arises as firms respond to composite price and technological market competition characteristics, through formation of expectations of what fits these characteristics. These learning processes, the expectations and techno-economic choices are necessarily contingent factors on the firms' existing capabilities and socio-economic environment.

Secondly behavioural patterns, i.e. innovations, are exposed to a selection process as a consequence of the market competition, viz. the 'markets select surviving behavioural patterns'. The selection process thereby changes the information and learning generating environment of firms. That firms differ in exposure to (through localised and finite-time diffusion, hence local, bounded horizons) and ability to accommodate new information has one important consequence. The game of economic competition changes character from unique sets of optimal behaviour, from perfect rationality, to optimalisation that is contingent on local (technological, geographical, social) characteristics, to bounded rationality. In most cases this implies that the selectivity of the competition is blunt. Not only does it cause existence of complementary 'species' of firms, within any single specie the competition allows co-existence of a variety of firms. In the next round this will also

change the characteristics of the selection process; firms do not just have to update to new information, through these stages the rules of the game change as well.

The social planner and the social adaptor – New roles for the policy maker

Endogenous and systemic innovation and technical change, implies that there is no longer any well-defined optimum allocation of resources. Hence, there is no single, optimal public policy. Rule based policies as follows from the market failure approach are not any longer viable. Current trends in technology and innovation policies reflect change in the perception of the rationale and effectiveness of government measures. These trends involve a shift from the traditional core of technology policies such as managing the science base and financial incentives to industrial R&D, to more novel realms such as facilitating growth in new demand, designing an institutional framework for consistent formulation and implementation of policy. The trend towards collaborative work, foresight analysis and the creation of specialist bridging institutions are supportive of the system perspective. There is a shift in emphasis from subsidies of firm level R&D or similar activities to developing appropriate framework conditions for firm-level innovation performance, to generation of an appropriate infrastructure for innovation and diffusion performance and incentives. The objectives of such policies towards technological infrastructures includes enabling firms to exploit existing innovation opportunities, and to enhance their innovation opportunities.

This policy shift means a change from the optimising policy maker to the adaptive policy maker. Policy is no longer only about correcting imperfect incentives for private agents but rather about facilitating the emergence of new opportunities by building innovation infrastructure. Since policy making cannot be optimising, it follows that there is no room available for any variant of the social planner. The emphasis of adaptive policy making is upon co-ordination of actions leading to innovation by non-market methods recognising that once innovations occur they will be co-ordinated by the market process. These policies are to a large extent trial and error experiments. Policy experimenting and formulation must be based on a mixture of theory (important variables), measurement (indicators, benchmarking) and subjective judgement. Hence if the policy maker is to learn and adapt, emphasis must be given to evaluation of these policies (Metcalfe and Georghiou, 1998). Theory and benchmarking help develop informed judgements about areas in which the chances of useful intervention are relatively high and empirical analysis can identify the nature of failure.

Governments should be guided by common core principles regarding the policy rationale for intervention. The market failure rationale point to the fact that at any stage of economic development there are invariant common principles to which government in market economies should adhere. The system failures provide complementary guidance to address the implications of the evolutionary nature of

technology and innovation policy. Such rationales require an attempt to understand and gauge the interplay between a range of issues and mechanisms, which by definition will be country specific. Experience gained in pursuing principles of market failures is readily transferable across countries but in the systemic approach it is much more difficult to draw lessons from experiences of others (OECD, 1998). Thus, the guidelines deduced from theory do not always translate into similar priorities and instruments depending on country-specific institutional features (Lipsey, 1998). The role of a particular institution in the innovation process can differ between countries. R&D-institutes are important in some countries but not in others. Legal systems, rules, norms, values also differ. Comparisons of national innovation systems are important for the identification of system failures but it is necessary to understand how different innovation systems work in order to understand how a specific initiatives influence the innovation process (Metcalfe and Georghiou, 1998, Edqvist, 1997).

The international dimension reduces the reach of national comparisons and the scope for national innovation policy. The challenge for policy is to put in place conditions that allow for complementarity between increased internationalisation in knowledge flows and domestic innovation capacity. In practice it is neither possible nor desirable to prescribe any single general strategy for maintaining or attracting innovative production capabilities. Countries differ with respect to competitive advantages as well as their possession of favourable assets or conditions, which are attractive (Andersson, 1998).

An important aspect of the system approach is the emphasis put upon how to create an appropriate institutional setting for policy formulation, implementation and evaluation. Common core principles for policy do translate into different priorities and instruments. The innovation system approach requires an understanding the interplay between a range of issues and mechanisms, which are country specific. This means that it is difficult to draw lessons from experiences of others and that no single policy can be prescribed. Thus it is necessary to involve all stakeholders in the formulation and implementation of public initiatives. The system approach requires co-ordination mechanisms between ministries and between ministries and other public agencies and between them and other stakeholders. Government initiatives must be co-ordinated and instruments should be made conditional on the implementation of acceptable evaluation practices to check against government failure and to encourage the policy learning process (Andersson, 1998).

As policy initiatives are trial and error experiments, their evaluation is essential in order to check for government failure and for policy learning purposes (Metcalfe and Georghiou, 1998, Lipsey, 1998). Equally important is the use of wider theoretical and empirical analysis as a basis for adaptive policy making. Policy learning must be an integrated part of the policy making process. The policy shift outlined above changes and increases rather fundamentally the requisite policy capabilities and competencies of policy makers, Smith (1998). But what then is non-optimising, adaptive and learning-based policy making? And how can effective learning be

encouraged? What does the 'innovation system' of policy makers look like? These are questions that still are open and which will be addressed as part of the RISE project.

Policy and the supply of innovation-related services

Introduction

The economic rationale for public intervention in the generation of knowledge and in the innovation process is a failure of the market or the innovation system. Market failure means underinvestment in R&D-activities, while system failure means underdevelopment of innovations. As we have seen provision of RTO services by public agencies or publicly funded R&D institutions is one of the main mechanisms for public policies to address relevant market failures. In fact this rationale has proved a strong driver for the development of national RTD systems in the post-war period. A central question is then; does the argument that market failure rationales are misguided also imply that these policy developments were equally misguided? Are there any rationales and guidelines for public involvement in the provision of RTO and similar innovation-related services? It is evident from the preceding discussion that innovation-related services are vital elements in the innovation process. Providers of such services are universities, government laboratories and joint public/private R&D-institutes as well as private firms. So evidently there are system rationales for public provision of such services, though it is equally clear that they will not be as simple as in a market failure framework.

Market failure rationale

In the market failure rationale to government intervention the issue is whether there is an underinvestment in those R&D activities that generates innovation-related services. If a failure is the case the question is how government should act in order to remove the failure. If private firms provide the services and there is a positive externality associated with non-rivalrous technological knowledge then it is appropriate to offer general assistance. The policy prescription can be either to lowering the cost of generating new knowledge or raising the payoff to that knowledge. The policy instruments according to this rationale are more embracing and more enforceable patents that give more returns to innovators and direct support for R&D in the form of subsidies or tax relief that lower the costs (Mowery and Ziedonis, 1998). However, private firms are not the only suppliers of innovation-related services. Public and semi-public R&D-organisations also provide such services.

The empirical validity of arguments for public research funding has been tested in several contexts (Nelson 1986, Acs et al. 1992, Mansfield 1991, Mansfield 1995,

Senker 1991, Faulkner and Senker 1994, Pavitt 1991, Nelson and Rosenberg 1994, Beise and Stahl 1998). The general result of all studies was that research conducted in Research and Technology Organisations (RTOs) did have positive effects on companies' innovativeness and that thus public funding was justified. However, the studies differ with respect to the most important features of research from which private firms could benefit and with respect to efficient channels of knowledge transfer. Beise and Stahl (using the same method as Mansfield, 1991) conclude that only a certain type of RTO (Fraunhofer Institutes) has a significant impact on company performance (Beise and Stahl, 1998). The most important reason for public spending is the training in research skills, which happens in public RTOs. For private firms the incentive to engage in training is small, because they will not benefit from it when researchers move on to another company.

Subsidising R&D-activities and thereby changing the marginal returns is only applicable to private firms. Patents are applicable to all knowledge producing organisations. To the public suppliers, especially universities, the question is whether the possibility to patenting knowledge is a suitable instrument for increasing their R&D and output of services. Richard Nelson argues that basic research produces essentially public goods for which the creation of private property rights is undesirable since the results of basic science can improve the productivity of applied research efforts. He further argues that the applied research efforts of both private and public organisations also produce important generic knowledge, as information on materials properties or standards, manufacturing process know-how and basic scientific research findings that underpin technological innovations in many sectors. This knowledge is best kept in the public domain, because it aids and accelerates the innovation process. Pricing the results of these activities is thus socially inefficient (Mowery and Ziedonis, 1998).

The use of patents as a policy instrument for universities and other public R&D-organisations is a way of making them more responsive to industrial needs and changing the direction of activities than increasing research per se. Recent experiments in the US science and technology policy have relied on the creation of markets in intellectual property to encourage technological commercialisation and inter-organisational interactions. The key question is whether the instrument employed for promotion of these collaborations is appropriate. The emphasis on the creation of markets for intellectual property paradoxically may discourage or impede some desirable forms of interaction. This policy also raises hazards for the universities that it seeks to influence. The universities may be too responsive to such incentives and thus impair their research and training roles. This policy has a narrow view of the channels through which universities interact with industry and effect the innovation process. They may lead to one channel being favoured at the expense of others and thereby diminish positive spillovers and thus in the long run impede technology advance (Mowery and Ziedonis, 1998).

According to this rationale government involvement in the supply of innovation-related services is only justified when a market-failure exist. Government should

supply services that can be characterised as public goods. To the extent that they are not public goods government should support the private providers by subsidising their R&D or by providing suitable property rights. The balance between public and private providers of innovation-related services, seen as innovation intermediaries, is dependent on the character of the services and it is an empirical task to identify which services are public goods and which are not. Thus, before formulating a policy to overcome the barriers that lead to market-failure it is necessary to determine whether market failure exists, to identify the nature of the market-failure and to analyse the effects of different instruments. Evaluations of the implemented policy are also imperative and the issue is if the intervention has led to increased activity.

System failure rationale

In the system failure rationale the justification of government intervention is based in the working of the innovation system. The issues are whether the appropriate institutions of the innovation system are at place and if the connectivity between actors is satisfactory. The policy instruments to be used depend on the kind of failure that exists.

From the point of view of the producers of innovations innovation-related services are knowledge inputs in the process of developing an innovation. These services can be generated in different types of organisations, such as universities, government laboratories, joint public/private institutes and private firms. These organisations have different goals and work under different conditions. Research in universities generates knowledge that can be transferred as services to firms and used in their innovation processes. This knowledge can also serve as a starting point for service innovations in existing firms or for spin-off firms. Universities also produce trained personnel that can be hired by firms and make contributions in their innovation processes. Government laboratories and semi-public R&D-institutes contribute to innovation processes in similar ways, supplying innovation services to the firms that develop innovations. Public R&D organisations don't work under the same conditions as does private firms that supply services to innovators. Firms carry out their activities under market-conditions. This means that the possibilities for government to influence the supply of innovation-related services differ between the different types of suppliers. Public universities and government laboratories are under the control of government as are to some degree semi-public institutes. Firms however are not. This means that the instruments open to government varies.

What then can governments do in relation to innovation-related services and their producers when system failures are acknowledged? For example, if there is an institutional failure certain instruments can be used and if there is a network failure other instruments are needed. Failures in *soft institutions* can mean that government has to change laws and regulations that influence the suppliers and users of these services. Failures in *hard institutions* can require changing in the working conditions of universities and government laboratories as well as establishing new public R&D-

organisations or supporting the emergence of new firms. Remedying *network failures* require other instruments. This failure means that a common vision of future technology advance among the actors of the system is lacking. Such a vision presupposes intense connections and collaboration between the actors. Government can increase the linkages by establishing bridging instruments of different kinds (e.g. R&D-programmes involving different types of actors with partial public funding), change the rules for universities and government labs in order to increase co-operation with firms, manage technology foresight activities and so on.

The system failure rationale focuses on actors in an innovation system and their interaction. The function of supplying innovation-related services to innovators can be carried out by public or private organisations. If any best balance between these types of organisations exists it is not possible to deduce it from theory. If suppliers of certain services are lacking government should try to "create" such organisations. The public good argument of the market failure rationale can be used to decide whether they should be private or public.

The system failure approach to public policy also raises the question of what system to intervene in? The concept of innovation systems can be used at different levels of aggregation: national, regional or local and defined by different criteria: industrial or technological. At the national level some of the elements that constitutes the system are found that don't differ between systems e.g. institutions such as laws, culture and attitudes to business. In relation to innovation-related services the most appropriate level of government intervention is one where linkages exists between producers of these services and their users i.e. industrial or technological systems of innovations.

As in the case of market failure rationale the system failure rationale to government intervention in the supply of innovation-related services presupposes the identification of the nature of the failure before formulating a policy to overcome the barriers that leads to failure. In this rationale to government involvement the recommended methods of identifying failures are the use of benchmarking and best practice. The areas to be compare and assessed in these activities can be deduced from theory of national innovation systems. It is important to stress the necessity of empirical analysis of whether failures exist within specific areas if the benchmarking process indicates a failure. Questions to be addressed in such studies are:

- What are the sources and content of innovation-related services in the client industries
- Are the client industries underutilising innovation-related services
- What is the nature of the failure that leads to underutilisation by clients

When the nature of the failures have been identified they can serve as a guidelines for formulating measures to overcome the failure. But there are many instruments open to government in trying to remedy different kinds of failures. It is therefore necessary to involve the stakeholders in the process of design of public initiatives. It is also important in regard to government failure and for policy learning purposes to evaluate implemented policies.

Conclusions

This paper has dealt with the question of the economic rationale to government involvement in innovation and innovation-related services. Two theoretical approaches and rationales have been presented. One is the neo-classical approach of market failure and the other is the evolutionary and innovation system approach of system failure. The first approach is the traditional rationale for intervention and the latter is newer. The two rationales have different implication for what policy can and should do in relation to innovation and innovation-related services. Both rationales give justification for government involvement in the supply of innovation-related services but in different ways and they prescribe different policy instruments. However, market and systematic failures are not mutually exclusive, both require the attention of policy makers. Each approach has its limitations and pitfalls and missing out on one of them is likely to hamper effective policy-making.

The policy implications in relation to innovation of market failure are that government can increase R&D in firms by changing their incentives to carry out R&D by subsidies and extended property rights of knowledge (i.e. creating a market for knowledge). This increase the net marginal returns to R&D. Government can also provide R&D by activities in public organisations i.e. universities and R&D-institutes. The policy implications of system failure are that government can design an institutional system that facilitates innovation activities in firms. The system should stimulate intense linkages among organisations in order to steer innovation system to greater strategic competence in firms, clusters, regions and countries. The system failure approach means a shift in emphasis from subsidising firms to developing appropriate framework conditions for the generation and diffusion of innovations. There is however no optimal innovation policy. Policymaking must be based on informed use of theory, information and subjective judgement. There is a need for an adaptive policy maker (as opposed to an optimising policy maker) and policy learning as an integrated part of the policy making process. In this approach the policy maker is seen, not as knowing better than firms but as knowing different things.

Indicators of the supply and usage of innovation-related services for policy steering purposes should tell us something about the need of public intervention. This means that indicators should reflect different reasons for market or system failure. According to the market failure rationale there is always a tendency for underinvestment in R&D by private firms. However, theory tells us nothing about the optimal rate of R&D. Comparisons of the volume of R&D between countries and sectors are often used as an indicator of underinvestment in innovative activities. In the innovation system approach the methods of benchmarking and best practice are used to identify promising areas of intervention and policy initiatives. The system failure rationale identifies the areas to be included in such exercises. But this is only the first step in identifying what government should do. The literature review shows that in both rationales there is a need to empirically establish if there is a failure in

regard to the supply of innovation-relate services and the nature of this failure before any public intervention.

The economic rationales say that government should intervene in the supply innovation-related services only if a market or a system failure exists. According to market failure the production of services may be better kept within the public sphere if they can be characterised as public goods, while the others should be left to private firms. It is an empirical task to identify which services are public goods and which are not. The system failure rationale focuses on actors in a system and their interaction. Innovation-related services can be supplied by public or private organisations. The policy implications are not evident but the potential scope for public provision of innovation-related services is substantial. If any right balance exists between public and private suppliers it is not possible to deduce it from theory.

The system failure approach opens up for innovation policies that focus on the shaping of technological variety generation and selection mechanisms. In this approach not only R&D are in focus but also other policy domains such as education, competition and labour markets. All elements of the system need to work together towards a common goal. Thus, in the design and implementation of policy initiatives all stakeholders should be involved. The initiatives should also be co-ordinated at the ministerial and public agency levels. Due to the complexity of innovation systems there is justification for policy experimentation. This in turn means that evaluations of initiatives are necessary for the purpose of policy learning and for avoiding government failure.

While neo-classic theory is one of static equilibrium and contractual agreement between actors, the evolutionary theory and the innovation system approach is one of interaction and learning processes and dynamics in innovation system. In the RISE-project the key words are dynamics, interactivity and learning. Thus the system failure rationale for intervention has more to offer than the market failure rationale in terms of areas an instruments for government involvement in the supply and use of innovation-related services.

References

Acs, Z., Audretsch, D., Feldman, M (1992): "Real Effects of Academic Research: Comment", *American Economic Review* 82, pp. 363-367.

Andersson, T. (1998), "Managing a Systems approach to Technology and Innovation Policy", *STI Review*, No. 22, pp. 9-29.

Arrow, K. J. (1962), "Economic Welfare and the Allocation of Resources for Invention", in: Nelson, R. (ed.), *The Rate and Direction of Inventive Activity: Economic and Social Factors*, Princeton University Press, Princeton, pp. 609-625.

Beise, M. and Stahl, K. (1998), *Public Research and Industrial Innovations in Germany*, ZEW Discussion Paper No.98-37.

Brooks, H. (1994), "The relationship between science and technology", *Research Policy* 23 (1994) pp. 477-486.

Carlsson, B. (ed.) (1997), *Technological Systems and Industrial Dynamics,* Kluwer Academic Publishers.

Carlsson, B. and Jacobsson, S. (1997) "In Search of Useful Public Policies: Key Lessons and Issues for Policy Makers" in Carlsson, B (ed.), *Technological Systems and Industrial Dynamics,* Kluwer Academic Publishers.

Dasgupta, D.and David, P.A. (1994), "Toward a new economics of science", *Research Policy* 23, (1994) pp. 487-522.

David, P.A, Mowery, D. and Steinmuller, W. (1988), "The Economic Analysis of Payoffs from Basic Research - An Examination of the Case of Particle Physics Research", *CEPR Publication* No. 122, Center for Economic Policy Research, Stanford University, California.

Dosi, G. (1988), "The Nature of the Innovative Process", in Dosi, G., Freeman, C., Nelson, R., Silveberg, G. and Soete, L. 1988, *Technical Change and Economic Theory*, Pinter, London and N.Y.

Edquist, C. (ed.) (1997), *Systems of Innovation: Technologies, Institutions and Organizations*, Cassel.

Edquist, C. and Johnson B. (1997), "Institutions and Organisations in Systems of Innovation", in Edquist C. (ed.), *Systems of Innovation: Technologies, Institutions and Organizations*, Cassel.

Edquist, C. (1999), *Innovation Policy - A systemic Approach*, Paper presented at the European Socio-Economic Research Conference, Brussels, 28-30 April 1999. Session A: The Globalising Learning Economy.

Ehrnberg, E and Jacobsson, S. (1997), "Technological Discontinuities and Incumbents' Performance", in Edquist C. (ed.), *Systems of Innovation: Technologies, Institutions and Organizations*, Cassel.

Faulkner, W. and Senker, J. (1993), "Making sense of diversity: public-private sector research linkage in three technologies", *Research Policy*, vol. 23, no.6, pp. 673-695.

Faulkner, W. and Senker, J. (1995), *Knowledge Frontiers*. Clarendon Press

Galli, R and Teubal, M. (1997), "Paradigmatic Shifts in National Innovation Systems.", in Edquist C. (ed.), *Systems of Innovation: Technologies, Institutions and Organizations*, Cassel.

Gibbons, M , Limoges, C , Nowotny, H , Schwartzman, S , Scott, P and Trow, M. (1994), *The New Production of Knowledge*, SAGE Publications

Guerrieri, P. and Tylecote, A. (1997), "Interindustry Differences in Technical Change and National Patterns of Technological Accumulation", in Edquist C. (ed.), *Systems of Innovation: Technologies, Institutions and Organizations*, Cassel.

Hanel, P. and Palda, K. (1992): "Appropriability and Public Support of R&D in Canada", *Prometheus* 10 (1992) pp. 204-226.

Heitor, M., and Conceiçao, P. (1999), "Towards A New Role For The University in the Learning Economy", *forthcoming, in: Science and Public Policy*, 1999.

Link, A and Tassey, G. (ed.) (1989), *Cooperative Research and Development: the Industry-University-Government Relationship*, Kluwer.

Link, A and Scott, J. (1998), "Assessing the Infrastructural Needs of a Technology-Based Service Sector: a New Approach to Technology Policy Planning", *STI Review*, No. 22, pp. 171-207.

Lipsey, R. (1998), "Technology Policies in Neo-classical and Structuralist-Evolutionary Models", *STI Review*, No. 22, pp. 31-73.

Meyer-Krahmer, F. (1997), "Science-based Technologies and Interdisciplinarity: Challenges for Firms and Policy", in Edquist C. (ed.), *Systems of Innovation: Technologies, Institutions and Organizations*, Cassel.

Mansfield, E. (1991), "Academic research and industrial innovation", *Research Policy* 20 (1991), pp.-12.

Mansfield, E. (1995), "Academic Research Underlying Industrial Innovations: Sources, Characteristics, and Financing", *Review of Economics and Statistics* 77, pp. 55-65.

Metcalfe, J.S. and Georghiou, L. (1998), "Equilibrium and Evolutionary Foundations of Technology Policy", *STI Review*, No. 22, pp. 75-100.

Mohnen, P. (1996), "R&D Externalities and Productivity Growth", *STI Review*, No. 18, pp. 39-66.

Mowery, D. and Ziedonis, A. (1998), "Market Failure or Market magic? Structural Change in the US National Innovation System", *STI Review*, No. 22, pp. 101-136.

Nelson, R. R. (1959), "The Simple Economics of Basic Scientific Research", *Journal of Political Economy* 67 (1959), pp. 297-306.

Nelson, R.R. (1988). Institutions supporting technical change in the United States. In Giovanni Dosi et al (Eds) *Technical Change and Economic Theory*, Pinter.

Nelson, R.R. (ed.) (1993), *National Innovation Systems –A Comparative Analysis*, Oxford University Press.

Nelson, R. R. (1996): "What is "Commercial" and What is "Public" about Technology, and What Should Be?", in: Rosenberg, N., Landau, R. Mowery, D.C: (eds.) *Technology and the Wealth of Nations,* Stanford University Press.

Nelson, R. R. and Rosenberg, N. (1994), "American universities and technical advance in industry", *Research Policy* 23 (1994) pp. 323-348.

NUTEK (1998), *The Swedish National Innovation System*

OECD (1998), *Technology, Productivity and Job Creation - Best Policy Practice.*

Pavitt, K. (1991), "What makes basic research economically useful?", *Research Policy* 20 (1991) pp. 109-120.

Porter, M. (1990), *The Competitive Advantage of Nations*, MacMillan Press.

Rosenberg, N. (1994), *Exploring the black box. Technology, economics and history*, Cambridge University Press.

Senker, J. (1991), "Evaluating the funding of strategic science: Some lessons from British experience", *Research Policy* 20 (1991) pp. 29-43.

Smith, K. (1997), "Economic Infrastructures and Innovation Systems", in Edquist C. (ed.), *Systems of Innovation: Technologies, Institutions and Organizations*, Cassel.

Teubal, M. (1998), "Policies for Promoting Enterprise Restructuring in National Systems of Innovation: Triggering Cumulative Learning and Generating System Effects", *STI Review*, No. 22, pp. 137-170.

STEP rapporter / reports

ISSN 0804-8185

1999

R-01-1999
Heidi Wiig Aslesen, Thor Egil Braadland, Keith Smith and Finn Ørstavik
Economic activity and the knowledge infrastructure in the Oslo region

R-02-1999
Arne Isaksen (red.)
Regionale innovasjonssystemer: Innovasjon og læring i 10 regionale næringsmiljøer

R-03-1999 (A)
Eric J. Iversen, Svein Olav Nås, Nils Henrik Solum, Morten Staude
Utvikling og fornyelse i NHOs medlemsbedrifter 1998. Del A: Analysedel

R-03-1999 (B)
Eric J. Iversen, Svein Olav Nås, Nils Henrik Solum, Morten Staude
Utvikling og fornyelse i NHOs medlemsbedrifter 1998. Del B: Tabelltillegg

R-04-1999
Heidi Wiig Aslesen, Thor Egil Braadland, Louise Hvid Jensen, Arne Isaksen and Finn Ørstavik
Innovation, knowledge bases and clustering in selected industries in the Oslo region

R-05-1999
Heidi Wiig Aslesen, Thor Egil Braadland, Anders Ekeland and Finn Ørstavik
Performance and co-operation in the Oslo region business sector

R-06-1999
Eric J. Iversen and Aris Kaloudis
The changing role of patents and publishing in basic and applied modes of organised research

R-07-1999
Heidi Wiig Aslesen
Governance and the innovation system of the fish processing industry in Northern Norway

R-08-1999
Johan Hauknes and Lennart Nordgren
Economic rationales of government involvement in innovation and the supply of innovation-related services

R-09-1999
Johan Hauknes
Technological infrastructures and innovation policies

1998

R-01-1998
Arne Isaksen
Regionalisation and regional clusters as development strategies in a global economy

R-02-1998
Heidi Wiig and Arne Isaksen
Innovation in ultra-peripheral regions: The case of Finnmark and rural areas in Norway

R-03-1998
William Lazonick and Mary O'Sullivan
Corporate Governance and the Innovative Economy: Policy implications

R-04-1998
Rajneesh Narula
Strategic technology alliances by European firms since 1980: questioning integration?

R-05-1998
Rajneesh Narula and John Hagedoorn
Innovation through strategic alliances: moving towards international partnerships and contractual agreements

R-06-1998
Svein Olav Nås et al.
Formal competencies in the innovation systems of the Nordic countries: An analysis based on register data

R-07-1998
Svend-Otto Remøe og Thor Egil Braadland
Internasjonalt erfarings-grunnlag for teknologi- og innovasjonspolitikk: relevante implikasjoner for Norge

R-08-1998
Svein Olav Nås
Innovasjon i Norge: En statusrapport

R-09-1998
Finn Ørstavik
Innovation regimes and trajectories in goods transport

R-10-1998
H. Wiig Aslesen, T. Grytli, A. Isaksen, B. Jordfald, O. Langeland og O. R. Spilling
Struktur og dynamikk i kunnskapsbaserte næringer i Oslo

R-11-1998
Johan Hauknes
Grunnforskning og økonomisk vekst: Ikke-instrumentell kunnskap

R-12-1998
Johan Hauknes
Dynamic innovation systems: Do services have a role to play?

R-13-1998
Johan Hauknes
Services in Innovation – Innovation in Services

R-14-1998
Eric Iversen, Keith Smith and Finn Ørstavik
Information and communication technology in international policy discussions

R-15-1998
Johan Hauknes
Norwegian Input-Output Clusters and Innovation Patterns

1997

01/97
Svein Olav Nås and Ari Leppãlahti
Innovation, firm profitability and growth

02/97
Arne Isaksen and Keith Smith
Innovation policies for SMEs in Norway: Analytical framework and policy options

03/97
Arne Isaksen
Regional innovasjon: En ny strategi i tiltaksarbeid og regionalpolitikk

04/97
Errko Autio, Espen Dietrichs, Karl Führer and Keith Smith
Innovation Activities in Pulp, Paper and Paper Products in Europe

05/97
Rinaldo Evangelista, Tore Sandven, Georgio Sirilli and Keith Smith
Innovation Expenditures in European Industry

1996

01/96
Arne Isaksen m. fl.
Nyskapning og teknologiutvikling i Nord-Norge. Evaluering av NT programmet

01/96 - **kort**
Arne Isaksen m. fl.
NB! Kortversjon
Nyskapning og teknologiutvikling i Nord-Norge. Evaluering av NT programmet

02/96
Svein Olav Nås
How innovative is Norwegian industry? An international comparison

03/96
Arne Isaksen
Location and innovation. Geographical variations in innovative activity in Norwegian manufacturing industry

04/96
Tore Sandven
Typologies of innovation in small and medium sized enterprises in Norway

05/96
Tore Sandven
Innovation outputs in the Norwegian economy: How innovative are small firms and medium sized enterprises in Norway

06/96
Johan Hauknes and Ian Miles
Services in European Innovation Systems: A review of issues

07/96
Johan Hauknes
Innovation in the Service Economy

08/96
Terje Nord og Trond Einar Pedersen
Endring i telekommunikasjon - utfordringer for Norge

09/96
Heidi Wiig
An empirical study of the innovation system in Finmark

10/96
Tore Sandven
Technology acquisition by SME's in Norway

11/96
Mette Christiansen, Kim Møller Jørgensen and Keith Smith
Innovation Policies for SMEs in Norway

12/96
Eva Næss Karlsen, Keith Smith and Nils Henrik Solum
Design and Innovation in Norwegian Industry

13/96
Bjørn T. Asheim and Arne Isaksen
Location, agglomeration and innovation: Towards regional innovation systems in Norway?

14/96
William Lazonick and Mary O'Sullivan
Sustained Economic Development

15/96
Eric Iversen og Trond Einar Pedersen
Postens stilling i det globale informasjonsamfunnet: et eksplorativt studium

16/96
Arne Isaksen
Regional Clusters and Competitiveness: the Norwegian Case

1995

01/95
Heidi Wiig and Michelle Wood
What comprises a regional innovation system? An empirical study

02/95
Espen Dietrichs
Adopting a 'high-tech' policy in a 'low-tech' industry. The case of aquaculture

03/95
Bjørn Asheim
Industrial Districts as 'learning regions'. A condition for prosperity

04/95
Arne Isaksen
Mot en regional innovasjonspolitikk for Norge

1994

01/94
Keith Smith
New directions in research and technology policy: Identifying the key issues

02/94
Svein Olav Nås og Vemund Riiser
FoU i norsk næringsliv 1985-1991

03/94
Erik S. Reinert
Competitiveness and its predecessors – a 500-year cross-national perspective

04/94
Svein Olav Nås, Tore Sandven og Keith Smith
Innovasjon og ny teknologi i norsk industri: En oversikt

05/94
Anders Ekeland
Forskermobilitet i næringslivet i 1992

06/94
Heidi Wiig og Anders Ekeland
Naturviternes kontakt med andre sektorer i samfunnet

07/94
Svein Olav Nås
Forsknings- og teknologisamarbeid i norsk industri

08/94
Heidi Wiig og Anders Ekeland
Forskermobilitet i instituttsektoren i 1992

09/94
Johan Hauknes
Modelling the mobility of researchers

10/94
Keith Smith
Interactions in knowledge systems: Foundations, policy implications and empirical methods

11/94
Erik S. Reinert
Tjenestesektoren i det økonomiske helhetsbildet

12/94
Erik S. Reinert and Vemund Riiser
Recent trends in economic theory – implications for development geography

13/94
Johan Hauknes
Tjenesteytende næringer – økonomi og teknologi

14/94
Johan Hauknes
Teknologipolitikk i det norske statsbudsjettet

15/94
Erik S. Reinert
A Schumpeterian theory of underdevelopment – a contradiction in terms?

16/94
Tore Sandven
Understanding R&D performance: A note on a new OECD indicator

17/94
Olav Wicken
Norsk fiskeriteknologi – politiske mål i møte med regionale kulturer

18/94
Bjørn Asheim
Regionale innovasjonssystem: Teknologipolitikk som regionalpolitikk

19/94
Erik S. Reinert
Hvorfor er økonomisk vekst geografisk ujevnt fordelt?

20/94
William Lazonick
Creating and extracting value: Corporate investment behaviour and economic performance

21/94
Olav Wicken
Entreprenørskap i Møre og Romsdal. Et historisk perspektiv

22/94
Espen Dietrichs og Keith Smith
Fiskerinæringens teknologi og dens regionale forankring

23/94
William Lazonick and Mary O'Sullivan
Skill formation in wealthy nations: Organizational evolution and economic consequences

STEP arbeidsnotater / working papers

ISSN 1501-0066

1999

A-01-1999
Johan Hauknes
Økonomisk analyse av tjenestenæringer: Utfordringer til datagrunnlaget

A-02-1999
Svend Otto Remøe
Rushing to REGINN: The evolution of a semi-institutional approach

A-03-1999
Svend Otto Remøe
TEFT: Diffusing technology from research institutes to SMEs

A-04-1999
Finn Ørstavik
The historical evolution of innovation and technology policy in Norway

A-05-1999
Svein Olav Nås og Johan Hauknes
Den digitale økonomi: Faglige og politiske utfordringer

A-06-1999
Thor Egil Braadland, Anders Ekeland og Andreas Wulff
Norske IT-kompetanse miljøer

A-07-1999
Eric J. Iversen
A patent share and citation analysis of knowledge bases and interactions in the Norwegian innovation system

A-08-1999
Thor Egil Braadland
Knowledge infrastructure in the Norwegian pulp and paper industry

A-09-1999
Anders Ekeland og Thor Egil Braadland
Staten og IT-kompetansen: Offer eller aktivist?

1998

A-01-1998
Finn Ørstavik and Svein Olav Nås
Institutional mapping of the Norwegian national system of innovation

A-02-1998
Arne Isaksen og Nils Henrik Solum
Innovasjonsstrategier for Aust-Agder. Innspill til Strategisk Næringsplan

A-03-1998
Erland Skogli
Knowledge Intensive Business Services: A Second National Knowledge Infra-structure?

A-04-1998
Erland Skogli
Offshore engineering consulting and innovation

A-05-1998
Svein Olav Nås, Anders Ekeland og Johan Hauknes
Formell kompetanse i norsk arbeidsliv 1986-1994: Noen foreløpige resultater fra analyser av de norske sysselsettingsfilene

A-06-1998
Trond Einar Pedersen
Machine tool services and innovation

A-07-1998
Roar Samuelsen
Geographic Information Technology Services and their Role in Customer Innovation

A-08-1998
Nils Henrik Solum
FoU-aktivitet i Oslo: En presentasjon av noen sentrale FoU-data

A-09-1998
Thor Egil Braadland
Innovation capabilities in southern and northern Norway

A-10-1998
Finn Ørstavik and Svein Olav Nås
The Norwegian Innovation-Collaboration Survey

1997

1/97
Johan Hauknes, Pim den Hertog and Ian Miles
Services in the learning economy - implications for technology policy

2/97
Johan Hauknes and Cristiano Antonelli
Knowledge intensive services - what is their role?

3/97
Hans C. Christensen
Andrew Van de Vens innovasjonsstudier og Minnesota-programmet

1996

1/96
Tore Sandven
Acquisition of technology in small firms

2/96
Johan Hauknes
R&D in Norway 1970 – 1993: An overview of the grand sectors

1995

1/95
Johan Hauknes
En sammenholdt teknologipolitikk?

2/95
Hans C. Christensen
Forskningsprosjekter i industriell regi i Kjemisk komite i NTNF i 60- og 70-årene

3/95
Anders Ekeland
Bruk av EVENT ved evaluering av SKAP-tiltak

4/95
Terje Nord/Trond Einar Pedersen
Telekommunikasjon: Offentlig politikk og sosiale aspekter for distributive forhold

5/95
Eric Iversen
Immatrielle rettigheter og norsk næringspolitikk: Et kommentert referat til NOE seminaret

Arbeidsrapportene 6/95 til og med 15/95 består av empiriske analyser av blant annet innovasjonsaktivitet i nøkkelbransjer i Norge

6/95
Innovation performance at industry level in Norway: Pulp and paper

7/95
Innovation performance at industry level in Norway: Basic metals

8/95
Innovation performance at industry level in Norway: Chemicals

9/95
Innovation performance at industry level in Norway: Boxes, containers etc

10/95
Innovation performance at industry level in Norway: Metal products

11/95
Innovation performance at industry level in Norway: Machinery

12/95
Innovation performance at industry level in Norway: Electrical apparatus

13/95
Innovation performance at industry level in Norway: IT

14/95
Innovation performance at industry level in Norway: Textile

15/95
Innovation performance at industry level in Norway: Food, beverages and tobacco

16/95
Keith Smith, Espen Dietrichs and Svein Olav Nås

The Norwegian National Innovation System: A study of knowledge creation, distribution and use

17/95
Eric Iversen og Trond Einar Pedersen med hjelp av Erland Skogli og Keith Smith
Postens stilling i det globale informasjonssamfunnet i et eksplorativt studium

1994

1/94
Hans C. Christensen
Målformulering i NTNF i Majors tid

2/94
Hans C. Christensen
Basisteknologienes rolle i innovasjonsprosessen

3/94
Erik S. Reinert
Konkurransedyktige bedrifter og økonomisk teori - mot en ny forståelse

4/94
Johan Hauknes
Forskning om tjenesteyting 1985-1993

5/94
Johan Hauknes
Forskning om tjenesteyting: Utfordringer for kunnskapsgrunnlaget

Storgaten 1, N-0155 Oslo, Norway
Telephone +47 2247 7310
Fax: +47 2242 9533
Web: http://www.step.no/

STEP group

STEP-gruppen ble etablert i 1991 for å forsyne beslutningstakere med forskning knyttet til alle sider ved innovasjon og teknologisk endring, med særlig vekt på forholdet mellom innovasjon, økonomisk vekst og de samfunnsmessige omgivelser. Basis for gruppens arbeid er erkjennelsen av at utviklingen innen vitenskap og teknologi er fundamental for økonomisk vekst. Det gjenstår likevel mange uløste problemer omkring hvordan prosessen med vitenskapelig og teknologisk endring forløper, og hvordan denne prosessen får samfunnsmessige og økonomiske konsekvenser. Forståelse av denne prosessen er av stor betydning for utformingen og iverksettelsen av forsknings-, teknologi- og innovasjonspolitikken. Forskningen i STEP-gruppen er derfor sentrert omkring historiske, økonomiske, sosiologiske og organisatoriske spørsmål som er relevante for de brede feltene innovasjonspolitikk og økonomisk vekst.

The STEP-group was established in 1991 to support policy-makers with research on all aspects of innovation and technological change, with particular emphasis on the relationships between innovation, economic growth and the social context. The basis of the group's work is the recognition that science, technology and innovation are fundamental to economic growth; yet there remain many unresolved problems about how the processes of scientific and technological change actually occur, and about how they have social and economic impacts. Resolving such problems is central to the formation and implementation of science, technology and innovation policy. The research of the STEP group centres on historical, economic, social and organisational issues relevant for broad fields of innovation policy and economic growth.