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Abstract

The purpose of this paper is to outline the concept of technological infrastructures and to give a broad discussion of policy approaches to these infrastructures. I first outline some general features of generic technology or knowledge; the area that has been the prime focus of market failure arguments for innovation policies over the last decades.

Related to the concept of generic knowledge is the concept of technological infrastructures. These infrastructures have traditionally been described in terms of structures of national institutions providing generic knowledge in the form of RTO services. Reviewing the literature we argue that the concept may be developed to a more fruitful concept of technological infrastructures that are more closely related to the nature of the economic resources or services provided by the infrastructure. This approach unties the strong definitional links between the traditionalised concept and the institutions providing these services.

This has the rather immediate consequence of allowing a more nuanced approach to those innovation policies that address the establishment and maintenance of technological infrastructures. This allows the policy formulation process to address the economic resources more directly, but at the same time this disentangling puts more exacting demands on the capabilities of the policy maker.

I give a preliminary overview of main trends of innovation policies in the post-war period. This overview indicates how policy approaches to technological infrastructures have changed during this period, and how in particular how there has been a drift of policy thinking from institutionally based policies over the main parts of the post-war period, with supplementing functional approaches becoming evident over the last two decades.

The functional, or resource based, approach to technological infrastructures allows us to describe ongoing structural changes of these infrastructures. Through an outline of some main aspects of these structural changes, with increasing market based supply of innovation related services, and its immediate policy implications we suggest that TIP policies must fully embrace a functional approach to accommodate the impact of these changes.

Keywords: Gerneric technology; Innovation; Innovation Policy; Technological infrastructure

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Generic knowledge and technology

Generic technology and 'public good'

The Arrow-Nelson rationale (based on the 'public good' character of research-based knowledge) is discussed elsewhere. However, different justifications for public involvement emerge from a 'systems' perspective. Basically these stem from the focus on systemic innovation and the fact that technology is not infinitely socially malleable. Technology is obdurate – there are objective technical characteristics that play a fundamental role in shaping the ongoing social development of productive knowledge. The malleability/obduracy distinction is borrowed from Bijker (1995); an analysis that demonstrates the importance of obduracies in shaping technological development is Vincenti's book on the history of aeronautics (Vincenti 1990).

Related to the existence of technological obduracies, is the notion of *generic technology*: productive (hence, valuable) knowledge, general in use across a wide range of users and social, technological and geographical regions or fields. Seen as productive knowledge, technology may broadly be split into generic and specific technology, the difference of which was outlined by Richard Nelson as follows:

> On the one hand, a technology consists of a body of generic knowledge, in the form of generalizations about how things work, key variables influencing performance, the nature of currently binding constraints and approaches to pushing these back, widely applicable problem-solving heuristics etc. Dosi has called these packages of generic knowledge 'technological paradigms'. ... Much, if not all, of the *generic knowledge tends to have properties of a latent public good [and] tends to be widely applicable, and germane to a variety of users*. Access to generic knowledge may be essential if one hopes to advance further the technology ... Also, in a system where there is considerable inter-firm mobility of scientists and engineers, generic knowledge is very difficult to keep proprietary. ...
> On the other hand, a technology also comprises a collection of specific ways of doing things, or artefacts, which are known to be effective in achieving their ends *if performed or used with reasonable skill* in the appropriate context ... [A] good part of [extant techniques] is not appropriately ... characterized [as possessing latent public good properties, in the sense that certain techniques are widely applicable]. ... [A] good portion of techniques is of rather narrow application, being *tailored to the [specific] attributes of the products and processes of particular firms*. Thus the restriction of access entails little cost. (Nelson 1988): 314-15, our emphasis)

Generic technology has both obdurate and (socially) malleable dimensions: 'how things work' vs problem-solving heuristics etc., while specific knowledge is more dominated by the latter. Specific technology has use value only in a restricted, specific social context, and hence, *in extremis*, has no exchange value though it may be fully appropriable. Generic technology is in principle not (fully) appropriable and has substantial aggregate use value. We might claim as Nelson does that generic, in contrast to specific, technology has (latent) public good characteristics (i.e. it is non-rival and non-excludable) and hence (latently) no exchange value. To do this we need to bring in one further aspect.

This is usually done by recourse to a distinction between codified and tacit knowledge which is complementary to the generic/specific distinction; see e.g. David and Foray (1995). These two pairs are often interconnected. Generic technology is more likely to exist in codified forms and specific technology is dominated more by tacit forms of expression. But they are not identical. Codification of technology - a transformation of productive knowledge into information that is depersonalised, decontextualised, mobile and accessible to a wide range of unconnected potential users - usually undermines convincing threats of enforcing excludability. With low or vanishing transaction costs such information has public-good characteristics. Hence there will in general be underprovision, relative to the socially optimal level of production, of such knowledge in a market system.

Generic and specific knowledges do not operate separately. Use of one in general requires use of the other. Thus, limitations in provision of one has consequences for the generation of benefits, whether private or social, from the other. Firstly, accessing and using generic technology requires a process of 'specification'. This will usually entail a fundamental transformation and reinterpretation of generic knowledge based on extensive, often tacit, interpretative abilities. (There is a similar second-round argument for these interpretative competencies.) Substantial investment needed in building these abilities may imply strong conditions of excludability. To the extent that this generic knowledge is otherwise non-excludable, its codified forms are public goods within a subset of agents that have done this investment. This is a substantial element in the formation of durable techno-economic networks (Bell and Callon 1994).

There is also a more important dynamic interaction between generic and specific technologies. The evident complementarities of these technologies imply strong contingencies in their respective development. An underprovision of generic productive knowledge will thus have substantial impact on the development of specific technologies (and *vice versa*) and hence on the technological horizons or perceived opportunities of firms. The interaction of generic and specific technologies is an important determinant of the evolution of technological histories or trajectories of individual firms or of groups of firms, of the creation of coherence in economic growth.

Generic technology and rationales for public intervention

With the caveats outlined above we may use the term generic technology to denote that part of generic technology where 'public goods' characteristics are substantial. By implication, such generic technology is:

- Durable: Once developed it depreciates slowly;
- Multi-user: It has use value for several agents, often with
- Low transaction costs; implying that
- Ensuring appropriation by a firm or a network of firms requires setting up substantial measures (collective such as intellectual property rights, or private through joint ventures or other collusive mechanisms).

As indicated by Richard Nelson, this conceptualisation of generic technology is related to Giovanni Dosi's idea of technological paradigms, the envelope of related technological trajectories of individual firms. Similar concepts are ubiquitous in the literature on technical change, alternatively termed technological *guideposts*, *regimes* or *systems*. The idea that these concepts attempt to purvey is of a 'super-structure' of productive knowledge, enabling and enhancing the generation and utility of specific knowledge. Such paradigms have an important function. One of their important roles is to define the set of techno-economic criteria and considerations that guide firms in their choice and implementation of technically changed products, processes and organisation. There is thus a close relation between the notion of paradigms and general characteristics of market competition. Hence, paradigms or systems give character and direction to technological development or trajectories.

Approaching the concept from several angles, we thus see that such paradigms *cum* generic technology are vital ingredients of the process of innovation, technical change and economic development. At the same time the provision of such generic technology will not be socially optimal if based on private, market-based provision.

Loosely the term *knowledge infrastructure* has been used for the totality of generic knowledge or technology in an innovation system. The development and institutionalisation of such knowledge infrastructures have been prominent objectives of innovation policies in the postwar period. The production-line interpretation of the link between generation of knowledge and its (commercial) application suggests a trade off between provision of generic technology through publicly accessible infrastructure institutions (e.g. universities or advisory agencies) and subsidized generation by firms or networks of firms. The possible scope of public intervention with systemic approaches encompasses a wide range of interaction processes in the innovation system, directed also towards processes of knowledge generation, diffusion and firms' propensities and abilities to access and use generic technology. Thus the need for generation of knowledge supported by public intervention covers substantial parts of the economic environment of firms. This raises the need for improved understanding of the relations between the firm and its environment, of which a properly understood and constituted knowledge infrastructure forms a significant part.

However, 'infrastructure' is a commonly used but poorly defined concept in economic theory. A typical interpretation might be: Collectively used economic resources provided under natural or created monopolies. This issue of technological infrastructure, and policies oriented towards the 'steering' and maintenance of infrastructure, is pursued further below.

Technological infrastructures

Characteristics of technological infrastructures

The notion of knowledge or technology infrastructures has been extensively used in a small strand of innovation literatures, key references being Tassey (1991), (1992), Justman (1993), Justman and Teubal (1995) and Teubal et al (1996). We note that this suggests technology infrastructures should be regarded as vital ingredients in innovation systems, whether defined in institutional or cognitive terms. Section 1 of this paper further suggests it is a subsystem of the innovation system, but a system that has considerable generic dimensions. There is thus a potential for such infrastructures to form the main backbone of the policy response to the systemic failures. Furthermore the term itself and its use suggest potentialities for designing infrastructures through policy formulation. These are issues that will be briefly discussed in this paper.

We will suggest an approach where these and other characteristics are used as multi-dimensional features to characterise such infrastructures. An early reference to such infrastructures approaching the sense we intend for this paper is Ergas (1987). In outlining the distinction between mission-oriented and diffusion-oriented national technology policies, he pointed to technological infrastructures – the nation's 'system of education and training, its public and private research laboratories, its network of scientific and technological associations' – as a central determinant of technology policies facilitating role towards innovation performance. In that sense Ergas' outline cited above is closer to the institutional approach, describing technological infrastructures in terms that reflect institutional RTD or science infrastructures as a prominent, if not distinguishing, part.

Tassey (1991) describes these infrastructures in much wider terms, as 'science, engineering and technological knowledge available to private industry … embodied in human, institutional or facility forms'. He includes:

- Generic technologies. Tassey's use of this term is probably equivalent to 'strategic' or 'emerging' technology in 1980's technology policy debates and is narrower and has a different orientation than the sense adopted here. Tassey describes generic technology as 'core product and process technologies from which specific commercial applications are developed through subsequent applied R&D by competing firms' (Tassey 1996).
- Infratechnologies. This includes practices and techniques, basic data, measurement and test methods, etc. which support generic technology research

and its further use. He identifies four subcategories: scientific and engineering data; measurement and test methods; production practices and techniques; and interfaces that permit 'efficient physical and functional combinations of components into manufacturing and service systems'.
- Technical information.
- Research and test facilities.
- Information for strategic planning and market development.
- Forums for joint industry-government planning and collaboration, and
- Assignment of intellectual property rights.

The elements of technological infrastructures beyond generic technologies and infratechnologies are described somewhat differently in the three sources by Tassey. Compared to the specification in Tassey (1991), Tassey 1992 describes the remaining parts as *management practice* (sometimes *manufacturing* (sic!) *practice*). Tassey 1996 refers to these as 'various techniques, methods and procedures that are necessary to implement the firm's product and process strategies'. Explicit referrals are made in the latter two to concurrent engineering and TQM as major examples.

Though the first outline gives rather heterogeneous cuts of technological infrastructures, the reformulated expression of technological infrastructures as generic technologies, infratechnologies and management practice may be interpreted as comprising generic dimensions of core market competencies. The salient point of this wide definition is that it focuses the economic resources, both bodies of knowledge and the conditions and practices related to their use and development, that these infrastructures comprise.

Capabilities and infrastructures

An approach to technological infrastructures that makes the link between technological infrastructures and these economic resources explicit is suggested by Moshe Justman and Morris Teubal. Justman and Teubal identifies technological infrastructures as multi-user capabilities, that are contrasted with firm-based capabilities. They define a technological infrastructure as:

> [A] set of *collectively supplied*, *specific*, industry-relevant *capabilities*, intended for *several applications* in *two or more firms* or user organizations' (Justman & Teubal, 1995: our emphases).

In their introduction Teubal et al 1996 discuss a range of approaches to such infrastructures, ranging from more narrow approaches, as with 'science' or 'innovation' infrastructures with a more clear-cut institutional dimension, to David and Foray's structures for 'accessing and expanding' a S&T knowledge base (David and Foray 1996), arguing that some 'firm-based capabilities might have to be included in any practical definition of the growth-promoting technological infrastructure'.

The emphasis of capabilities, rather than (some notion of) a 'objectified' knowledge stock implies a closer tie to industrial practice, to economic behaviour. They explicitly note *specific* capabilities, which further points in this direction. This has two important consequences for the conceptualisation of technological infrastructures. Firstly the use of capabilities relevant for industrial purposes as the core defining term sets technological infrastructures apart from science infrastructures. Secondly it implies that technological infrastructures cannot be constructed through public policy initiatives alone; construction of a technological infrastructure in the Justman/Teubal sense requires a considerable collaboration between firms and/or industrial associations and public agencies.

However, one crucial aspect of technological infrastructures from the public policy perspective is that these capabilities complement and depend on firm-based capabilities, but their collective goods properties imply that they are not addressed by support for industrial R&D targeted at individual firms. Hence they require an explicit consideration in public policies.

Basic and advanced technological infrastructures

In their further development of the concept of technological infrastructure they distinguish between what they describe as two extreme types (implying that most fall somewhere in between), *basic* and *advanced* technological infrastructures. This reflects a differentiation in the forms of objectives variant infrastructures are expected to accomplish, responding to variations in the characteristics of the target firm populations. While basic technological infrastructures typically address the needs of SMEs in low- and medium-tech activities, advanced infrastructures are supposed to serve high-tech, leading-edge industries. Teubal (1996; 1998) further develops this perspective of an innovation policy approach to differences between firms in innovation capabilities and opportunities.

Basic technological infrastructures provide technology services such as:

- Design
- Information on new production technologies
- Testing and analysis
- Solutions to environmental or ecological problems.

to client firms. They comprise *routine or conventional* capabilities that are available, being directed towards enhancing the absorption of these capabilities by domestic firms. Given these characteristics they note in particular that these include activities that are pertinent to emergence of specialised expert consultants. This is the process of market building, referred to in the RISE proposal, which should be among the primary policy foci. The main task of basic technological infrastructures is to enhance diffusion of conventional, and hence specifiable, capabilities, through provision of technological services. Public agencies may therefore play well defined proactive roles, aiding target firms in clarification of user needs.

Hence basic infrastructures will dominantly be capability *mediating*, while advanced ones are generally focussed on capability *creation*. The diffusion orientation of basic technological infrastructures is paralleled by a *innovation* orientation by advanced infrastructures, the main task of these being to support and enhance innovation in functionally specific firms.

Economic characteristics of technological infrastructures

Smith (1997) is a significant attempt at outlining the economic characteristics and extent of knowledge infrastructures to give some order to what Teubal et al describes as the ’conceptual complexity and still-indistinct nature of the concept’. The discussion of infrastructures in general and technological infrastructures in particular in Smith (1997) will not be repeated here. Keith Smith suggests that what distinguish infrastructures from other economic resources are:

- Indivisibility.
- (Hence) technological economies of scale;
- Multiple users, often implying network externalities; and
- Generic functions.

This suggests a provisional definition of infrastructures in general:

> Economic infrastructure consists of large-scale indivisible capital goods producing products or services that enter on a multi-user basis as inputs into most or all economic activities. **(Smith 1997): p 94)**

Smith also emphasises requirement of discretionary investment decisions for its production as a further delineation of the concept. Thus he differentiates it from public institutions such as law systems. He characterises the resulting knowledge infrastructure as:

> [A] complex of public and private organizations and institutions whose role is the production, maintenance, distribution, management, and protection of knowledge. These institutions possess technical and economic characteristics that are not dissimilar to those of physical infrastructure … We could define the public knowledge infrastructure as consisting of a combination of these institutions and the flow of resources through them. **(Smith 1997): p 95-96)**

Smith's definition of the infrastructure implies a more restricted concept than Justman and Teubal. It is restricted to most or all economic activities, though the indeterminate reference to 'knowledge' without specification make the extent along these dimensions undecided. The Tassey definition is quite extensive on knowledge or capability dimensions, the extent in terms of economic functions is specified, but the context suggests a restriction similar to Smith's.

Common for all these approaches is the idea that within the area of technology policy there is a set of core functionalities for which there is a substantial argument for public provision or organisation, and that these technological infrastructure policies should be a prime focus of policy formulation. In this context the discussion of the scope of infrastructures is important as it thus relates closely to the structure and scope of objectives of public innovation7 and technology policies.

Institutions and infrastructures

A problematic point to these authors is evidently how the relation between the structured (intangible) resources and its expression in social institutions should be treated. Though Smith starts out with emphasising not to consider the institutional frameworks, but the economic resources, as outlined above the public infrastructure is defined in institutional terms. The resolution of this conceptual difficulty, which is essentially the same as the one underlying the obvious difference in approach between the organisational, a la Richard Nelson, and the competency-based, a la Lundvall, approach to innovation systems, is central for policy analysis. Policy formulation in the first three decades of the post-war period was dominated by an institutional approach to these infrastructures, viz. institution building. During the following period, c. 1970 – 1985 an approach emerged of stronger focus on the 'content' and intangible resources provided by the infrastructure. It seems to me that the last ten years have witnessed a further swing in policy attention to these infrastructures. A further consideration of the 'content' side has been accompanied by a stronger focus of requisites for the modes of institutional interaction between infrastructure institutions, as repositories of intangible infrastructure resources, and the clients or users of these.

The conceptual complexity is substantial. An approach that will be followed up during the RISE project is an attempt at delineating and detailing technological infrastructures along four dimensions:

- Economic characteristics;
- Functional modes of embodiment;
- Institutional structure; and
- Handover formats.

A significant aspect of provision of technological infrastructure services is the institutional embodiment of these infrastructures. The focus of the RISE project implies that we primarily focus the public policy perspective, with an emphasis of provision of technological infrastructures services or of TI-enabling initiatives that should be deliberate priorities of public policies. Hence we are describing provision which is:

- Organised (a subset of Justman & Teubals collective provision);
- Intended to have a sustained life-time beyond the solution of incidental technological bottle-necks;
- To be provided, maintained and developed by institutions serving multiple users, without themselves being prime users of the infrastructure resources (to avoid proprietarisation' of infrastructure resources); and
- Supported by specific policy action and funding.

This institutional framework may involve public institutions (established, owned and/or otherwise organised) by public agencies, private institutions (organised by private firms or their representatives, as industrial R&D associations, collaborative technology initiatives), or joint private-public organisations. Reflecting the variations in functional focus of technological infrastructures, even when we restrict attention to technological, in the sense of techno-economic, capabilities, the institutional framework involves a wide range of organisations, cf. the Justman and Teubal spectrum of technological infrastructure institutions:

- Industrial R&D institutions,
- Technology service institutions,
- National and regional advisory systems and 'competence centres',
- Standards organisations,
- Testing and measurement labs,
- Foresight agencies and organisations,
- Industrially oriented development and demonstration programmes with infrastructure motives (as standardisation of modes of delivery; 'handover formats'),
- Regional and national funding (both towards firms and towards infrastructure institutions) agencies with objectives focussed on industrial development/innovation.

Several recent trends in the development of public innovation and industrial policies are relevant to a technological infrastructure focus,

- In regional policies; from regional support policies to regional technology policies
- Innovation/technology policies; from strategic technology development to systems/network based approaches to interactive innovation (from technology push to concertation)
- Changes in institutional attitude; from institutional to functional approach to provision of technological infrastructure services ('privatisation', increased reliance on market-emulating relations between infrastructure institutions and client firms)
- The use of *innovation agents* in the sense of Bessant & Rush (1994, 1998), cf. also OECD (1992)

Market building and market emergence

The core RISE hypotheses includes an hypothesis of the emergence of a private-based, structure that fulfils functions partly complementary, partly substitutive to a publicly initiated/organised technological infrastructure. This is outlined in some more detail below.

Teubal (1997) argues that a catalytic, evolutionary approach is needed to the formulation of horizontal technology policies in general, and to technological infrastructure policies more specifically. Horizontal innovation policies, which aim at promoting innovation and technical change in general rather than being specifically targeted at individual industrial or functional sectors, is a functional promotion of 'socially desirable technological activities' (SDTAs). SDTAs, which involve firm level R&D and innovation activities, transfer, diffusion and adoption of technological competencies, as well as technological infrastructures, are activities that (1) have strategic value to the economy and (2) are loci of market failures. The objective of widespread and sustained use of SDTAs involve targeting institutionalisation (endogenisation) of extensive learning (e.g. ‘learning by others doing’) efforts and of ‘search’ (mapping, screening and other activities related to the identification of technological opportunities). In Teubal’s analysis, the successful promotion of SDTAs requires in addition market building; the establishment and development through policy initiatives of markets for

- SDTA support services (such as advisory, financial and technological services),
- certain types of SDTAs themselves (as providers of R&D services),
- outputs flowing from SDTAs (f.i. measurement and test services).

I agree with Teubal’s arguments that market building is an essential ingredient in horizontal technology policies, and in particular that the implementation of such policies requires a systematic approach to market building that reflects the diversity of firm and industry characteristics and technological capabilities. The economy-wide promotion of SDTAs that meets requirements of SMEs as well as LENs, of firms in prospective product areas as well as in mature industries, of innovation laggards and vanguards requires substantial institutionalisation of these. Market-building may be an efficient and important way of achieving this. In the promotion of SDTA support services, partly also in the market-built provision of SDTAs proper, we recognise Bessant and Rush’s innovation agents. In this sense the market based provision of such services following policy-implemented market building emerges as an integrated part of a wider technological infrastructure.

However, the main point I want to make here is that there is a considerable endogenous dimension to the emergence of these markets. Markets for these services have been suggested to a large extent to have grown out of market generated demands and new divisions of labour, Hauknes (1999), being reflected in the rapid growth of KIBS services in a wide range of industrialised countries. The challenge of formulation of horizontal innovation policies must then start from the existence of these processes and a consideration of the market characteristics of these emerging ‘knowledge’ or ‘competence’ markets. These processes form the major backbone of ongoing structural changes in the capability-generating and diffusing system in these economies, Bilderbeek et al (1998). den Hertog and Bilderbeek (1998) described it as the emergence of market-based ‘second knowledge infrastructures’ that supplements and transcends the public technological infrastructures that has been a main focus in postwar S&T policies.

- KIBS are developing into an informal (private) or ‘second knowledge infrastructure’ partly complementing and partly competing with the more institutionalised formal (public) or “first (public) knowledge infrastructure”.
- The boundaries between public and private knowledge-intensive (advisory) services tend to blur gradually, ultimately resulting in a more flexible capacity of external KIBS-professionals co-operating with internal KIBS professionals in providing knowledge intensive business services to clients.

The developments of these KIBS sectors opens up new opportunities policy formulations in the sense of integrating a 'second knowledge infrastructure' approach into innovation policies. This entails a market building approach to this 'private infrastructure', the EU MINT programme, as well as the UK LINK programme should be interpreted as variants of a 'market building' effort.

Nowhere is the requirements to the richness of the innovation services provided larger than towards SMEs (cf. outline of basic technological infrastructure above). In fact the market building approach may be envisaged as a policy approach where the potential scope for an integrated SME focus is much larger than for traditional technology infrastructure policies. An SME focus on such policies raises a series of issues that may be considered to be of general validity, but have more serious impact in terms of SME dimensions. These issues concern:

- The spectrum of services provided and their functional forms.
- Issues related to limited opportunities for SMEs to assess the qualities of the RTD and innovation services rendered by incorporated public and private infrastructures, as certification,
- Other aspects of the institutional framework of the associated markets, as ownership and other relations between service providers,
- Formation and development of absorption or receptive capacities of client firms and industries,
- Transferability of interaction-based experiential competencies of innovation service providers across firms and industries,
- Character of and evolution of service providing functions' core competencies,
- Appropriate roles for public infrastructure policies.

The SI4S project focussed several aspects of the endogenous emergence of 'knowledge' or KIBS markets, and qualitative aspects of the user-producer relations on these markets. The final report from the project highlighted the following conclusions concerning the increased supply and use of KIBS functions (Bilderbeek et al 1998),

- KIBS perform *par excellence* a catalyst role in knowledge-creating or innovation processes of client firms. Their role varies from adding innovative knowledge originating from the KIBS itself (KIBS as a source of innovation), originating innovative knowledge from another source to the client firm (KIBS as carrier of innovation) or helping out a client in implementing new knowledge mostly developed in house (KIBS as a facilitator of innovation).
- KIBS do play an important role in the various knowledge conversion processes. It can even be concluded that KIBS play a key role in transforming firms into learning organisations.
- The types of knowledge interactions induced and triggered by KIBS are not confined to the discrete/tangible, contractual, explicit/codified and non-human embodied forms of knowledge transfer. On the contrary, the functioning and role of KIBS can only be understood if we include process-oriented/intangible, non-contractual, tacit and human embodied forms of knowledge.
- KIBS and their clients have a sort of relationship which might be characterised as an symbiotic relationship. They – or at least the professionals they employ - profit from the interaction with the client firms and the various types of knowledge flows generated during this process of interaction as much as the client firm does. The experience gained during a given project will be used as a basis for developing new service products and approaches and will make the

involved professionals more valuable professionals towards future clients with similar problems. KIBS are by the nature of their activities in contact and co-operate with quite a number of client firms and their employees, constantly diffusing and absorbing knowledge, reprocessing it, diffusing it again, etc. Through their activities they act as bridging institutions in innovation systems (at whatever scale)and contribute considerably to the 'knowledge distribution capacity' and learning capacity of innovation systems as a whole.

A challenge for future research here is empirical and theoretical analysis of the initial formation of latent demand and of supply for these services, what the main determinants of this market emergence are, and how the rapid growth of these sectors over the last decades may be explained. Given the discussion above these are crucial issues for the future formulation of TIP policies.

The next section will briefly describe the development of innovation policies in the postwar period, where some relevant aspects of these policy developments for the evolution of technological infrastructures will be identified.

Innovation policy in the postwar period

In spite of innovation policy being a fairly recent term, industrial policies have always included objectives that focus industrial growth and generation, whether by supporting acquired comparative advantages or by facilitating new ones. In this sense innovation policy goes at least back to the industrial revolution in the UK. Though frequently used, often as here in conjunction with the term technology policies, there has been few attempts to outline in any systematic fashion what policies the term constitutes. Furthermore, in contrast to areas such as education and health policies, it is rarely identified in ministerial organisation.

Attempts to outline the forms of policies often reflect Paul Stoneman's definition (Stoneman 1987), as 'policies involving governmental intervention in the economy with the intent of affecting the process of technological innovation' or David Mowery's formulation that these are 'policies that are intended to influence the decisions of firms to develop, commercialize, or adopt new technologies' (Mowery 1992). Both these definitions emphasise the intentional aspect of the policies included; these are policies that we may term *explicit* innovation policies. As such the relevant policy initiatives are mostly included among the areas of ministerial offices responsible for industrial policies, though they often also collaterally involve science or research ministries. Typically these policies involve grant schemes and other support for industrial innovation, supporting advisory systems, training schemes, setting-up of funding agencies, etc. These explicit innovation policies includes horizontal innovation policies as defined in section 2.6, but goes beyond these to also include 'vertical' or selective innovation policies.

However, the term innovation policies is also frequently used to cover what we may term *implicit* innovation policies, policy areas where impacts on innovation performance is not among the political prerogatives, but where the policy area nevertheless has a significant impact on innovation performance. Such policy areas are usually taken to include fiscal and regulatory policies, public procurement, trade policies, etc. It is clear that these wider, implicit innovation policies then are significant determinants of the impact of explicit innovation policies.

Several attempts have been made to develop periodisations of the S&T policies in the postwar period. Though not necessarily the same as innovation policies, the strong position of economic and industrial objectives in S&T policies, besides defense related objectives, in this period implies that trends in S&T policies will be a good proxy at least for trends in explicit and S&T related innovation policies. It is clear that any such classfication run the risk of over-simplification of a process that is many-sided, where inspiration runs across different eras or periods, where national policies may be multi-layered with different layers reflecting concerns of different epochs and where national variations may be substantial. In this section we will briefly describe some attempts at periodising these policies before giving a short outline of main trends in such policies over the postwar period. In doing this we will focus broader than technology infrastructure policies, but we will note explicitly some aspects of TIP policies where it is relevant. The general trends we outline nevertheless have consequences for TIP policies in providing a more general framework within which TIP policies are shaped, whether implicitly or explicitly.

Periodisation of RTD and science policies

Stuart Blume (Blume 1985) distinguishes three phases in study of Dutch science policy after 1965, each characterised by its attitude towards science and research. The period 1965-1970 science is the ’engine of progress’, followed with a period of science as ’problem solver’ between 1970 and 1980. The last period is characterised with science as the ’source of strategic opportunities’. Harvey Brooks (Brooks 1986) emphasises World War II as a watershed, leading to the introduction of the new ’social contract’ between science and society following the impact of Bush Report (Bush 1945). With a US perspective he partitions the postwar period in three epochs:

- The Cold War period extends from 1945 to 65;
- The period of social priorities runs from 1965-78 and is followed by
- The period of emphasis in innovation policy. (The rather specific boundary date between the latter two periods (1978) relates to President Carter's initiative that year to launch a policy review of industrial innovation.)

That Harvey Brooks seems to suggest that innovation policies are a direct outgrowth of science policies, must probably be understood within a US perspective, where industrial and technology policies, in contrast to science policies, have been kept outside the federal responsibilities.

Jean-Jacques Salomon distinguishes between the childhood of science policies up to 1955, followed by a period characterised with 'pragmatism' between 1955 and the second half of the 1960s. During the latter period emphasis shifts from energy, defense and space research to industrial R&D. The period up towards the end of the

1970s, is an age of 'problematisation', while from 1977-79 onwards science policies are interlinked with policies for re-industrialisation to meet basic structural problems in national economies.

All of these point to a transition period located somewhere between 1965 and 1970, where S&T policy objectives change away from an often naïve link between scientific and welfare progress to focusing social objectives. In innovation policies this is also reflected in a transition from 'technology push' to 'market pull' strategies. In addition they also point to a shift somewhere towards the end of the 1970s and early 1980s, to strategic opportunities (Blume), industrial innovation (Brooks) or re-industrialisation (Salomon). As none of these cover the most recent period, ca. 1985 – 2000, their characterisation of their own present epoch may be influenced by myopia. However, these characterisations seem to catch some main aspects of the innovation and S&T policies that were dominant during the 1980s. The shift to strategic industrial objectives of S&T policies is accompanied by a reappraisal of market based mechanisms of technical change, a process that is concomitant with a shift in wider economic policies away from the broadly Keynesian policies of the postwar period.

Periodisation of innovation policies

The evolution of technology policy on the European scene is discussed by Rothwell and Dodgson (1992).

1950s and 1960s – separated science and industrial policies

During the 1950s and 1960s there were two main tracks of technology policies; resp. science and industrial policies with little coordination or active collaboration between policy makers from the two tracks. In some countries state intervention in industrial development was substantial. These policies were predicated on a 'science discovers, technology pushes' model of the innovation process, with a relatively clearcut division of labour between the science system and the industrial support system. Emphasis was on large firms and industrial agglomeration.

1970s – innovation policies

Rothwell and Dodgson date the emergence of innovation policy to the early 1970s with a more direct involvement of collective research intitutes in product development of individual companies. Support schemes are broadened to cover wider innovation activities that before, with increasing support in new forms to SME-based innovation.

1980s – technology policies

During the early 1980s technology policies emerges, replacing the innovation policies of the 1970s. National programmes on generic technologies, primarily IT and to a lesser extent biotechnology, and involved inter-institutional linkages focussed on collaborative pre-competitive research on the basis of increased inter-departmental collaboration. University-industry linkages were focussed, as well as strategic research in universities. Emphasis was put on NTBFs, while the availability of venture capital expanded.

We take two additional points for the last period from Rothwell and Dodgson. This period saw growing pressure for accountability, for the research system to account for its resource use in terms of its societal impact, accompanied by increased evaluation of RTD policy initiatives and RTD institutions. After 1980 regional policies shifted from largely exogenous, formulated by national authorities. They characterise the regional policies of the 1980s as strongly endogenous, focussing mobilisation of regional industrial and technology resources. The creation and enhancement of regional technology/transfer infrastructures, involving innovation centres, technopoles etc., is perhaps the most marked trend,

Rothwell (1992) has outlined a generational taxonomy of (policy) approaches to innovation. Though it is not directly linked to a periodisation, the use of a generational model suggests a reflection of historical shifts of emphasis. He identifies five generations, of which the last is an idealized model of future development of integrated approaches to innovation:

- First generation - R&D-based technology push, in a sequential process (1950s and early 1960s).
- Second generation - need-pull with R&D as reactive to market trends and needs, in a sequential process (1970s).
- Third generation - coupling mode of integration of R&D and marketing, in a sequential process with feedback (1980s).
- Fourth generation - integrated mode, with parallel and integrated development, based on strong user-producer links, non-sequential processes (late 1980s and 1990s).
- Fifth generation - systems integration and networking model (1995-2000 - ?).

We have supplemented these generations with suggestions of which periods each was dominant. This generational model thus represents itself a sequential process of sophistication of innovation models, leading from simple production line, or socalled 'linear', models to developed 'innovation systems' approaches to innovation and innovation policies.

A brief sketch of innovation policies in the postwar period

In giving a brief sketch of postwar developments we will not directly use these periodisations. But the outline will reflect several of the concerns reflected in the schemes. For our purposes here, we focus explicit innovation policies. This is necessarily a limited perspective, but even a schematic outline of wider implicit innovation policies would go far beyond the RISE project. Since our main focus is technological infrastructures this focus of explicit innovation policies is probably sufficient as a basis for the further refinement of this sketch into a historical analysis of policy learning in the area of TIP policies.

During the postwar period these policies in Europe grew out of the political concern of reconstruction and the building of a new European industry after the war. A distinctive event at the beginning of this period was the publication of the Bush Report, Bush (1945), which laid the ground for the development of US science policies and led to the establishment of the National Science Foundation in 1950. From a European perspective it is probably an exaggeration to claim that the Bush Report was a decisive event. It is noteworthy for two reasons. Firstly it was to a large extent based on the experiences of the allied countries efforts into science-based development of defense technologies. Here the report summed up several ideas and experiences that shaped science and innovation policy making in several countries. Secondly the re-interpretation of the Bush Report that followed its publication provided arguments that were widely used also in European countries. This re-interpretation is best captured by the argument of a ‘social contract’ between the science system and society.

Broadly the noted concern took two forms, the emergence of new S&T policies with the establishment of new or reorganised S&T agencies, and emphasis of state-owned, -managed or -organised industrial enterprises. The first led to institutions as NSF in the US, while Clement Atlee's nationalisation of UK core industries in 1948 may illustrate the second.

Though the so-called 'Sputnik shock' was interpreted in its time as a signal of the failure of Western industrial policies to generate unparalleled industrial growth and technological leadership, the period 1950-1970 has since been characterised as the 'golden era' with a substantially higher income and production growth in the OECD area than anytime before or after. Nevertheless the Sputnik shock lead to an intense development of S&T policies, first in the US, later through the organisation created on the basis of the Marshall Aid and OEEC, the OECD. An indicative event here is the development of the first versions of what became known as the Frascati-manual, as well as the background report OECD 1963.

This period, which Salomon notes is a period of pragmatism, is a period where evidently some of the naïvetes of the previous belief in the welfare generating potential of the science effort were questioned. It is in this period the Arrow-Nelson rationale was developed, but it is also the period in which the growth accounting residual (Abramowitz 1956, Solow 1957) was noted widely for the first time with its claim that technical change is an almost totally dominant source of economic growth. What was later denoted the Minerva debate, after the journal in which most contributions were published (later published in Shils 1968), shows substantial questioning of contemporary S&T objectives. In this period the establishment of an institutional infrastructure aiding national industries was prominent in national S&T policies, many of the institutional characteristics of the national systems of S&T institutions, as R&D institutions, structures of HEIs, technological service institutions etc., reflect policy developments in this period.

For economic development after 1970, it is common to point to the OPEC crises of 1973-4 and 1978-9 as events that had dominant effects on future growth. Also important for the orientation of S&T and innovation policies was the shift in focus to social priorities and market needs, as noted above. In 1971 the Rotschild report, establishing the customer-contractor principle, was published as a UK Green Paper. When Richard Nixon was elected in 1968 he was elected on a programme that featured social priorities prominently (Averch 1985), one of his first S&T policy initiatives was the launching of the War on Cancer in 1969. A symptomatic landmark of the onset of this period is the OECD Brooks Report, published in 1971 (OECD 1971). Environmental concerns, as well as issues of social reform, were factors that shaped the profiles of S&T policies, as well as the portfolios of policy instruments. Program-organised, targetted research becomes a strong mode of organising research priorities.

It is in this period that the international policy debate starts using the term ’innovation policies’, by 1980 the term is used as a wellknown term in OECD fora, see eg OECD 1982. What is happening in this period is a specialisation of S&T policies, with emerging policy focus of the need to direct attention to other issues than the former S&T dominated policies, relying heavily on scientific research as the main vehicle. At the end of the decade focus is widely attended to giving priority to ’strategic research’, to (technological) research areas that are potentially widely applicable, later often claimed to be generic in applicability, but which require substantial scientific research and development to reach a stage where it is commercially applicable. The first document that identifies strategic research priorities is the UK Dainton Report, published together with the Rotschild report in HMSO (1971), but in full disconcord with its conclusions.

In the period after 1980 the area of innovation policy debate involves an increased focus on regional competition of technological hegemony. Contributing to this was the increased awareness of the productivity slowdown after 1973 and the idea of a ’new economic and social context’ that science and technology policies had to meet, as argued in the OECD Delapalme Report, OECD 1980. The increased perception of a ’Japanese challenge’ in Europe and the US was accompanied by the idea of Fortress Europe in US. International debate was increasingly formulated in terms of the Triad; the perceived triangular technology competition between Europe, US and Japan. When Japan launched its fifth generation programme for development of information technologies towards 2000 in the footsteps of the highly succesful VLSI project, it was quickly followed by IT and other technology initiatives in US and the European countries (Rothwell and Dodgson 1992). Based on the notion of generic technology, mainly meaning information and materials technology and microbiology based biotechnology, a dominant trend in many countries was the implementation of large scale policy initiatives to build up the national and regional capabilities that were perceived as necessary to compete and survive in sunrise industries of tomorrow.

Not surprisingly there were many responses in the area of information and communication technologies. The French Nora-Minc report, Nora and Minc (1980), published in French in 1978, also contributed to set the pace for a subsequent focus of *informatique* and *telematique*. During the mid-1980s the initiatives to establish national programmes of ICT proliferated. In the UK the Alvey programme was initiated in 1985, in Sweden the IT4 programme was launched in 1986-87, while the Norwegian IT 'target area' was introduced in 1986. On the European scene this period was accompanied by the establishment of ESPRIT, the EU large scale IT RTD programme, in 1982 and later the first Framework Programme in 1984, as well as President Mitterand's intitiative that led to the establishment of EUREKA in 1985. In this period funding agencies and R&D institutions that had been a central part of S&T policies in the postwar period incresingly came under scrutiny. The main aspect of the criticisms that were raised were addressed to agencies lacking ability to address the long term issues of building up national capabilities in these generic technologies, processes that eventually led to reorganisation of funding agencies in many countries.

Towards the end of this decade and into the 1990s it was frequently argued that fundamental changes in research and science-based innovation policies were emerging, there were "many signs that we amy be looking at the end of an era, with the possiblity of a much greater discontinuity on science policy than … transitions in the mid-60s and late 70s … it is possible that we face … a 'sea-change' in the role of science and technology comparable to what took place after World War II" (Brooks (1990, p 19). The S&T system in the new era must fulfill stronger demands of societal steering (Yoxen 1988), accountability and collectively organised research, with 'science in a steady state' of public funding (Ziman 1987). During the 1980s the use of assessments and evaluations exploded. In parallel the literature on research and policy evaluation, on evaluation methodologies, practice and indicators boomed. To what extent this was paralleled by a systematic use of evaluation efforts for building a policy oriented knowledge base was widely discussed at the time and is still unclear.

A signpost for the developments of innovation policies in the 1990s was the publication of the OECD Sundqvist Report in 1988 (OECD 1988). The main message was the need of a 'socio-economic strategy' for technological change, the report argued that traditional approaches to the relevant policies had been to narrow in neglecting the interdependence of technical, economic and social change. The policy objectives of technology policies should feature 'the effectiveness of social systems which generate and diffuse technical innovations' prominently. With the first indications of an emerging system approach to technological innovation the report reflected ongoing changes of emphasis in member countries. Policy attention was increasingly directed at the powers to mediate and diffuse innovation capabilities in national systems.

The Sundqvist Report was a direct precursor for establishment of the OECD Technology and Economy Programme, a substantial effort to synthesise recent research into innovation processes and formation of innovation capabilities, OECD 1991 and OECD 1992. The period after 1990 has substantiated these systems and network approaches to innovation further, together with a significant increase in the use of innovation analysis and research as input to policy making processes. With the third and fourth framework programmes the profile of EU S&T policies has shifted to include specific socio-economic objectives and related research. This process has further been developed in the new structure that was introduced into the fifth framework programme.

These most recent developments in innovation policies highlights changes in the roles of the traditional organisations being parts of national S&T systems. The use by several national authorities of 'innovation agents', such as in the UK Link, the EU MINT and the Norwegian BUNT programmes, involve attempts to build markets for innovation services that have been within the realm of S&T institutions. It would seem, though this needs substantiating further, that in parallel to the policy developments there is a shift in policy emphasis from S&T institutional infrastructures to provision of infrastructural function or services.

Distributed knowledge generation and the capabilities of firms

Structural change in knowledge generation and distribution

The enhanced role of knowledge and information as productive resources has lead to increased demand for productive knowledge, as well as for analytic capabilities in selecting, refining, transforming and using it. These tendencies have reinforced the processes of professionalising business practice, of the growth of managerial capitalism, in the Chandler sense. The increased strategic importance of access to and capability to use information and knowledge inputs rapidly, emphasise the importance of abilities to identify, transform and regenerate these inputs to enable direct and indirect implementation and use of these information inputs. These bridging functions between flows and repositories of information and knowledge external to a firm and internal use of (regenerated) information and knowledge is vital to achieve accomplish effective dissemination and use of these inputs.

The underlying resourcebased view of the firm, with capabilities and competencies as a central dimension of what constitutes a firm, implies that competencies and capabilities and hence learning processes are localised or specific, rather than global and general. The indicated trends have facilitated a process that has involved the emergence of *knowledge markets*, and a concomitant growth of a class of functions that have been described broadly as 'knowledge intensive business services'. These processes have lead to specialisation in bridging functions and professionalisation of expertise. Increasingly these bridging functions have therefore been encapsulated in new bridging institutions within the 'learning' economy. The knowledge intensive service firms play a role in national innovation systems that supplements and broadens the generative and distributive functions that traditionally have been the responsibility of the public S&T infrastructures, R&D institutions, advisory and extension services etc.

The growing importance of bridging between external repositories and flows of knowledge, the sourcing of external capabilities and expertise and internal competencies and capabilities clearly increases further the needs of tapping into these flows. Knowledge intensive services as bridging institutions are evidently at the core of these processes, also themselves promoting a process of cumulative causation that may possibly affect the general division of labour in knowledge production. The bridging function is essentially the creation and adaptation of channels of communication between external and internal repositories of knowledge. However, these flows are not ’energy’ flows that are sufficient capacities for action by firms tapping into them. The essential feature of such bridging functions is that they require genuine transformation and regeneration into the specific circumstances of any firm, it requires bridging between generally accessible knowledge and information and localised capabilities and competencies. Hence the importance of specialised appreciative transformation capabilities on the hand of bridging entrepreneurs.

The generation and diffusion of innovations and information about them rely more and more upon knowledge which is generated not only by learning processes implemented by internal research and development laboratories but also and to a growing extent, by the daily interaction, communication and trading of information of learning firms among themselves and with other scientific institutions. The knowledge intensive business service firms play a major role in this context as qualified interfacing bridging institutions.

The intensified role of such processes indeed make the label of a knowledge intensive or learning economy apt. Obvious characteristics of the emerging knowledge markets and bridging functions and institutions is then (i) suppliers with specialised functional and intermediary expertise and skills, and (ii) interactive learning between suppliers and clients that impacts clients’ production capabilities and competencies. The latter point implies that the bridging institutions are producers of intermediate inputs, their clients are other firms and organisations, both within the private and public sectors. The criteria for identifying knowledge intensive business service suppliers as new bridging institutions are:

- The constituent role of suppliers' specialised expertise, usually integrated with professional knowledge.
- They supply intermediate inputs, rather than output for final consumption. Their 'products' may both be bundled with or supplied independently of other tangible or intangible input factors.
- The 'products' are intended intermediate inputs into clients' capability generating and processing processes.

Implications of structural change

The new patterns of knowledge generation and distribution involve more than a direct extension of the existing system. The phenomenon of emerging knowledge markets and of a new form of bridging institutions is both a symptom of and will in itself reinforce processes of qualitative change in innovation systems.

We are now witnessing an emerging mode of organisation of knowledge production, towards a progressive unbundling of the production of knowledge, through expertise specialisation and institutional creation of knowledge markets. Production of knowledge becomes the core activity of specialised firms whose product consists in new technological and scientific information which can be sold in the market place. Reorganisation of knowledge production is associated with increasing appropriability of expertise and localised knowledge. Distributed production of knowledge generates forms of knowledge that are integrated composites of tacit and explicit expertise generated within differentiated contexts that are oriented towards and even constituted by application areas. Variants of this mode of knowledge production have been suggested earlier. Aspects of it is evident in Roy Rothwell's 'fifth generation' innovation model (Rothwell 1992), as well as in the Mode 2 production of knowledge described by Michael Gibbons and collaborators (Gibbons et al 1992). Michel Callon has outlined a somewhat different variant, in his version it has been described as a 'privatising' capturing of knowledge production by techno-economic networks (Callon 1994).

It is nothing new that the modes of production of knowledge involve joint production and use of tacit and explicit, or articulated, knowledge. The new mode leads us to emphasise is that in modern economies the following apply in substantial parts of knowledge production:

i) Knowledge production and distribution is distributed and involves distributed and localised contexts of application.
ii) The production structure evolves towards more distributed structures and institutions.
iii) However, enhanced information and network technologies may expand the sphere of influence, or 'market extension', of each producer.
iv) A closer alignment of specialised production and supply with expanding and differentiate demand patterns of potential client with opportunity, capability and willingness to buy.
v) With such knowledge production and its frontiers being shaped by this market interaction in a fundamental way, significant elements of distributed knowledge production are generated in the interaction process of clients and providers; it is generated 'on the market place'.
vi) Hence this mode involves new incentive structures and new agendas of knowledge production, and implies rather different processes of quality control and cumulation of knowledge.
vii) Lastly, it involves a diversity of new forms, new codification patterns, and bundling into other product markets of knowledge transmission or interaction, alongside with traditional modes of transmission/interaction.

Innovation policies with distributed knowledge generation

Until now, the economic importance of generic scientific knowledge as the unique result of formal R&D conducted in-house by firms and scientific activities conducted by universities, has been exaggerated. R&D expenditure as an adequate indicator of a firm's productivity performance is equally misguided. As a consequence too much emphasis has been put upon R&D policies and more generally science policies as the basic tools to sustain the rates of accumulation of new knowledge. Tacit knowledge, acquired by localised personal experience and individual learning processes, is also a major source of technological knowledge. In fact, many small firms generate significant innovations based mainly on tacit localised knowledge; and many larger firms actually fail in the diffusion of innovative initiatives in unrelated activities because of a lack of tacit-learning appropriation opportunities. There is thus a basic need for an economic environment which encourages the accumulation of such tacit knowledge and enables its interaction with the codified counterparts.

In the generation of new technological innovations, firms rely on external knowledge acquired by means of informal interactions between themselves, sharing learning opportunities and experience, and with other, established sources of knowledge and information and more formal processes of technological co-operation. Outsourcing of research activities and the procurement of knowledge intensive business services also plays an increasing role in assessing the innovative capabilities of each firm. The levels of outsourcing of knowledge intensive business services should be accounted for when assessing the amount of inputs invested in the process of research and learning. The outsourcing of knowledge-intensive services could become an important recipient for policy interventions.

The innovative characteristics of the firm and the topology of the economic spaces into which it is embedded dictate the terms of communication and information exchange between firms, ultimately determining their innovative capabilities. We can identify three such 'architectural' factors in particular: the individual resources designated to the internal accumulation and implementation of tacit and codified knowledge; the receptivity to outside technological knowledge; and the connectivity and distribution network, in terms of knowledge, between firms. The quality of and accessibility to the information and communication technology infrastructure is also a significant indicator of an economy's innovative potential.

The topology of innovation systems and the quality of their communication networks can be greatly enhanced by the new key-sectors such as the knowledge intensive business services industries. The conditions of communication, dissemination, distribution, access and the quality of knowledge-intensive business service have important effects on the economic system in terms of innovative capacity. Countries with an advanced supply of knowledge intensive business services are likely to have stronger communication capability in terms of connectivity and receptivity levels and hence higher innovation capabilities. The services of consultants and advisers improve connectivity between agents, sharing learning experiences and creating learning opportunities, thus also enhancing receptivity. Similarly, advanced business services, in terms of distribution, competence and access, improve the interaction between tacit and codified knowledge, helping to introduce increasingly individual technological and organisational innovations. Such a dynamic situation can be of particular benefit to small- and medium-sized firms, compensating for the high costs of in-house R&D and the technological knowledge it helps generate.

More generally, traditional innovation policies based upon incentive schemes mainly designed to increase the levels of R&D could be reoriented in order to take into account the communication properties of innovation systems. Policies enhancing technological co-operation between firms and between firms and universities and specifically technological outsourcing are important in this context. Technological outsourcing may be pushed by active demand and supply policy specifically designed to favour the specialisation of firms in well defined technological niches and the implementation of technological cooperation aimed at internalising rent technological externalities and increasing spatial stochastic interactions probability.

Advanced countries with well designed innovation systems are likely, over time, to experience a continual increase in innovative capability levels provided that positive feed-backs take place either 'spontaneously' or as a result of technology policies and strategies. Successful agents rooted within innovation systems can learn to communicate, in terms of both connectivity and receptivity, as soon as they realise that their innovation capability is positively influenced by the communication network and subsequently take advantage of increasing returns and positive feedbacks in learning both internal and external to each firm.

This entails a rather fundamental shift in the basis and rationales for innovation and technology policies. The dominant mode of policy formulation has been in terms of design supply functions, where the main challenge of policy formulation has been to identify key areas for the development of strategic technology inputs to business sectors. The ongoing reorganisation of knowledge generation to a distributed production system around markets for knowledge makes challenges for public policy simpler, and more difficult. They get simpler in that they allow an emancipation from the market failure rationales of innovation and R&D policies, with their conflation of the objectives of public policies with a fictitious benchmark of perfectly functioning markets. They contribute with a clearer demarcation of public and private objectives of innovation policies.

On the other hand these challenges make policy formulation more difficult. The innovation policy challenges that are raised, are clearly much more indirectly related to the actual unfolding of industrial innovation. Policy objectives will be more open-ended and framework enabling than oriented towards specific technological or economic objectives, with three core areas of policy formulation.

First, public policy should ensure the distributive capacities of broader innovation systems, both in terms of material and immaterial infrastructures and in terms of counteracting tendencies to locking in of knowledge markets on specific techno-economic objectives. This also includes facilitating extension and entry of these production and distribution systems into economic areas outside those 'high tech' areas that dominate the present developments.

Furthermore, an essential element of the new production mode is the building up of systematic absorption capacities on client firms. Public policy has an obvious role in enabling this process of professionalising potential users that face barriers cost or attention barriers, notably for firms and sectors where conditions for linking up with the new production system is weakly developed. This would seem in particular relevant for certain categories of SMEs. This regards development of in-house capabilities to utilise the distributed production system, as well as capabilities to assess and evaluate services that are offered on the market.

A pertinent issue here is needs of formal and informal standardisation, certification etc. It will be required that public policy includes an aspect of regulation, in some cases it may still be necessary for public regulation and certification, through educational requirements and otherwise. In other cases a more appropriate role is to enable development and proficiency of industrial and professional networks and organisations.

Thirdly, a core area is ensuring flexible interaction of the distributed system of knowledge producers and the public system of universities and other scientific institutions, institutions of higher education and so on, that allows a sound division of labour. This does not imply a tightening of the requirements of user orientation and industrial needs of academic institutions. Such responsiveness is well developed in a few industrial areas, with well forged links between academia and industry, most notably in the pharmaceutical industry and micro biology based production, as well as between the geo-physical sciences and geological surveying and petroleum exploration. The point is that there are several specific factors of each of these areas that aligns institutions; these are not role models that can be applied generally for academia-industry links.

Rather the implication is to emphasise the mutual and reinforcing advantages in allowing a complementary rather than a collateral division of labour emerge. Though conditions would vary, a measure that would enrich interactions as well as enhance the benefits and network building effects from the education objectives of academic institutions is dual and mixed careers.

A further case may be raised in the role of public policy and policy agencies as market makers and mediators. This role has been taken up to some measure in the use of 'innovation agents' in public innovation policy programmes, see Bessant and Rush 1994, 1998. However, we may also envisage a wider role given the accepted legitimacy and independence of public agencies, in terms of advising, mediating and 'broking' between KIBS producers and users.

In terms of institutional sectors, the challenges these trends raise are probably largest for public or semi-public R&D infrastructures that are organised or substantially funded from public sources to serve industrial innovation. Examples here are the

Dutch TNO and the Finnish VTT organisations, Norwegian industrial R&D institutes, as well as to some extent the German Fraunhofer institutions and French/Italian style research council based organisations. These institutions may increasingly find themselves in a situation where they may be criticised for subsidised activity in competition with the new market actors. For several organisations as these a rational alternative will probably be to enforce the institution's role in developing a general scientific knowledge infrastructure, on par with the role of academic institutions. On the other hand institutions as these are large enough to be able to shape the knowledge 'industries' and markets themselves. It is obvious that the responsibilities this implies for public policies in surveying and assessment, are many and complex.

We do not envisage a wholesale shift in restructuring of public policies, this will probably be a gradual process. Furthermore, as with the former shifts in emphasis of innovation policies, there will be layers of sedimentation with new and former approaches and modes of knowledge production will coexist. However, even a partial development along the lines we have suggested here implies the need for a rethinking of rationales and implementation strategies for public innovation policies.

References

Abramowitz M. (1956), *American Economic Review*, vol. 46, p. 5-23

Averch H. A. (1985), **A strategic analysis of science and technology policy**, John Hopkins University Press, Baltimore 1985

Bell G. and M. Callon (1994), *STI Review*, vol. 14, p. 59-118, OECD, Paris 1994

Bessant J. and H. Rush (1995), *Research Policy*, vol. 24, p. 97-114

Bessant J. and H. Rush (1999), *Innovation agents and technology transfer*, *in* M. Boden and I. Miles (eds), **Services, innovation and the knowledge based economy**, Pinter (forthcoming)

Bijker W. (1995), **Of bicycles, bakelites, and bulbs – Toward a theory of sociotechnical change**, MIT Press, Cambridge (US) 1995

Bilderbeek R., P. den Hertog, G. Marklund and I. Miles (1998), *Services in innovation: Knowledge intensive business bervices (KIBS) as co-producers of innovation*, SI4S Synthesis Report 3, STEP Group 1998

Blume S. (1985), *The development of Dutch science policy in international perspective 1965-1985*, RAWB Achtergrondstudies no. 14, Amsterdam 1985

Brooks H. (1986), *National science policy and technological innovation*, *in* R. Landau and N. Rosenberg (ed), **The positive sum strategy – Harnessing technology for economic growth**, National Academic Press, Washington DC 1986

Brooks H. (1990), *The future: Steady state or new challenges?*, *in* S. Cozzens et al (eds), **The research system in transition**, Kluwer Academic Publishers, Dordrecht 1990

Bush V. (1945), *Science – The endless frontier, A report to the President on a program for postwar scientific research*, Washington July 1945

Callon M. (1994), *Science, Technology & Human Values*, vol. 19, p. 395-424

David P. and D. Foray (1995), *STI Review*, vol. 16, p. 14-25, OECD, Paris 1995

Dosi G. (1988), *Journal of Economic Literature*, vol. 26, p. 1120-1171

Edquist C. (1997) (ed), **Systems of innovation – Technologies, institutions and organizations**, Pinter, London 1997

Ergas H. (1987), *Does Technology Policy Matter?*, *in* B.R. Guile and H. Brooks (eds), **Technology and Global Industry – Companies and nations in the world economy**, National Academy Press, Washington DC 1987

Gibbons M. et al (1994), **The new production of knowledge – The dynamics of science and research in contemporary societies**, Sage, London 1994

Hauknes J. (1999), *Dynamical innovation systems – Do services have a role to play?*, in M. Boden and I. Miles (eds), **Services, innovation and the knowledge based economy**, Pinter (forthcoming)

Hertog P. den and R. Bilderbeek (1998), *Conceptualising (service) innovation and the knowledge flows between KIBS and their clients*, SI4S Topical Paper 11, STEP Group, Oslo 1998

Mowery D. (1994), **Science and technology policy in interdependent economies**, Kluwer Academic Publishers, Boston 1994

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

Nora S. and A. Minc (1980), **The computerization of society**, MIT Press, Cambridge (US) 1980

OECD (1963), **Science, economic growth and government policy**, OECD, Paris 1963

OECD (1971), **Science, growth and society – A new perspective**, (*the Brooks Report*), OECD, Paris 1971

OECD (1980), **Technical change and economic policy**, (*the Delapalme Report*), OECD, Paris 1980

OECD (1981), **Science and technology policy for the 1980s**, OECD, Paris 1981

OECD (1982), **Innovation policy – Trends and perspectives**, OECD, Paris 1982

OECD (1988), **New technologies in the 1990s – A socio-economic strategy**, (*the Sundqvist Report*), OECD, Paris 1988

OECD (1991), **Technology in a changing world** (*the TEP Synthesis Report*), OECD, Paris 1991

OECD (1992), **Technology and the economy – The key relationships** (*the TEP Background Report*), OECD, Paris 1992

OECD (1995), **Boosting businesses – Advisory services**, OECD, Paris 1995

Rip A. and R. Hagendijk (1988), *Implementation of science policy priorities*, SPSG Concept Paper no. 2, SPSG, London 1988

Rothwell R. (1992), *R&D Management*, vol. 22, p. 221-39

Rothwell R. and M. Dodgson (1992), *Technovation*, vol. 12, p. 223-238

Salomon J.J. (1977), *Science policy studies and the development of science policy*, *in* I. Spiegel-Rösling and D. deSolla Praice (eds), **Science, technology and society**, Sage, London 1977

Senker J. (1991), *Research Policy*, vol. 20, p. 29-43

Shils E. (1968), **Criteria for scientific development: Public policy and national goals**, MIT Press, Cambridge (US) 1968

Smith K. (1997), *Economic Infrastructures and Innovation Systems*, *in* Edquist (1997)

Solow R. (1957), *Review of Economics and Statistics*, vol. 39, p. 312 – 320

Stoneman P. (1987), **The economic analysis of technology policy**, Clarendon Press, Oxford 1987

Tassey G. (1991), *Research Policy*, vol. 20, p. 345-361

Tassey G. (1992), **Technology Infrastructure and Competitive Position**, Kluwer Academic Publishers, Norwell 1992

Tassey G. (1996), *Infratechnologies and Economic Growth*, *in* Teubal et al (1996)

Teubal M. (1997), *Research Policy*, vol. 25, p. 1161-1188

Teubal M. (1998), *STI Review*, no. 22, p. 138-168

Justman M. and M. Teubal (1995), *Research Policy*, vol. 24, p. 259-281

Teubal M. et al (1996) (eds), **Technological Infrastructure Policy – An International Perspective**, Kluwer Academic Publishers, Dordrecht 1996

Vincenti W. G. (1990), **What engineers know and how they know it: Analytical studies from aeronautical history**, John Hopkins University Press, Baltimore 1990

Yoxen E. (1988), *Public concern and the steering of science*, SPSG Concept Paper no. 7, SPSG, London 1988

Ziman J. (1987), *Science in a "steady state" – The research system in transions*, SPSG Concept Paper no. 1, SPSG, London 1987

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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.