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PRIORITY SETTING IN RESEARCH & TECHNOLOGY POLICY – HISTORICAL DEVELOPMENTS AND RECENT TRENDS

"INNOVATION POLICIES IN EUROPE", EDWARD ELGAR PUBLISHERS, 2007 (FORTHCOMING)

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Abstract:

Priority settings in Research & Technology Policy have changed considerably over time, mostly following paradigm changes in justification for policy. The paper describes these paradigm changes in the post-war period in their succession and co-existence and tries to elaborate important determinants for these paradigm changes.

Keywords: Research Policy, Technology Policy, Science Policy

JEL Classification: O30, O33, O38

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1 Introduction

Following Christopher Freeman (1987) we understand „technology policy“ to include all public measures that attempt to influence actors (enterprises, public institutions, households) to develop new knowledge and technologies (invention), to commercialise these new technologies (innovation) or to use them (diffusion). Technology policy as used here includes significant areas of traditional science policy aimed at promoting basic research and the production of fundamentally new knowledge (see Bernal 1937) as well as policy approaches that are today often subsumed under the heading of "innovation policy" (see Lundvall/Borrás 2005).

In advanced industrial economies, technology policy always has had a strong focus on promoting the development of specific new technologies that are expected to contribute to societal and economic policy objectives. Setting priorities in technology development was therefore a key issue in technology policy from its beginning. In this paper we try to characterise main developments in the processes of priority setting in technology policy since WWII, and to analyse recent trends, taking into account the conceptual changes in this policy area that took place within the last two decades or so, such as the innovation systems approach.

State promotion of specific technologies has a long tradition. In the pre-WWII era, the funding of research in agriculture (plant breeding, plant protection), health (vaccines), mining (geology and engineering) or navigation, transport and communication (shipbuilding, aeronautics, telecommunications) are examples of an early type of technology policy. However, the involvement (in terms of money) was quite low and the activities were often funnelled through public research institutions (see Mowery/Rosenberg 1989 and Mowery/Rosenberg 1998, 26ff for the USA; or Richter 1979 and Grupp/Icíar 2002 for Germany as an example for the European case).

World War II may be regarded as the starting point for technology policy in the modern sense. Military needs led to a co-ordinated build-up of research capabilities and specific research institutions in certain scientific disciplines and fields of technology, e.g. aeronautics, nuclear technologies, and weapons-related engineering, on a massive scale. This was the start of the era of so called 'mission oriented' technology policy. After WWII, mission-led technology policy continued by focussing on large scale R&D efforts, now mainly in two technological areas, nuclear energy and aerospace. Over time, this mission-led policy approach diversified successively into other thematic areas (e.g. ICT, materials etc.). However, this thematic diversification imposed a fundamental problem for policy makers: what technologies should be chosen and how should this decision process be organised? The answers to those questions vary considerable over time. Discussing the trends of reasoning for thematic prioritisation in technology policy and the interplay between political and economic justifications, which dominate the respective reasoning (as well as their critiques) is one main objective of the paper.

Today most industrial countries have technology policy measures geared towards specific technologies, or thematic areas, in place. A second - and related - aim of the paper is to analyse important aspects of recent trends in thematic priority setting in advanced countries. To do so, we rely on results of recent studies in which the authors have been involved (Gassler et al. 2004; Rammer et al. 2004; Weber et al. 2004). Those studies cover mainly Germany, Finland, France, U.K., Ireland, Japan, Canada, Korea, New Zealand, the Netherlands and the U.S. However we cannot give a comprehensive overview of all important trends and developments in these countries but concentrate on illustrative examples and some distinct patterns to nail down our arguments.

As usually a number of caveats apply for such a comparative approach covering a broad rage of countries with very different historical, economic and institutional backgrounds. Thus we concentrate on general patterns along four dimensions, namely the relevant institutions, the degree of centralisation of decision making processes, the role of path dependency and the role of explicit strategy formulation orientation among the involved decision makers.

2 Priority setting in technology policy – shifting paradigms

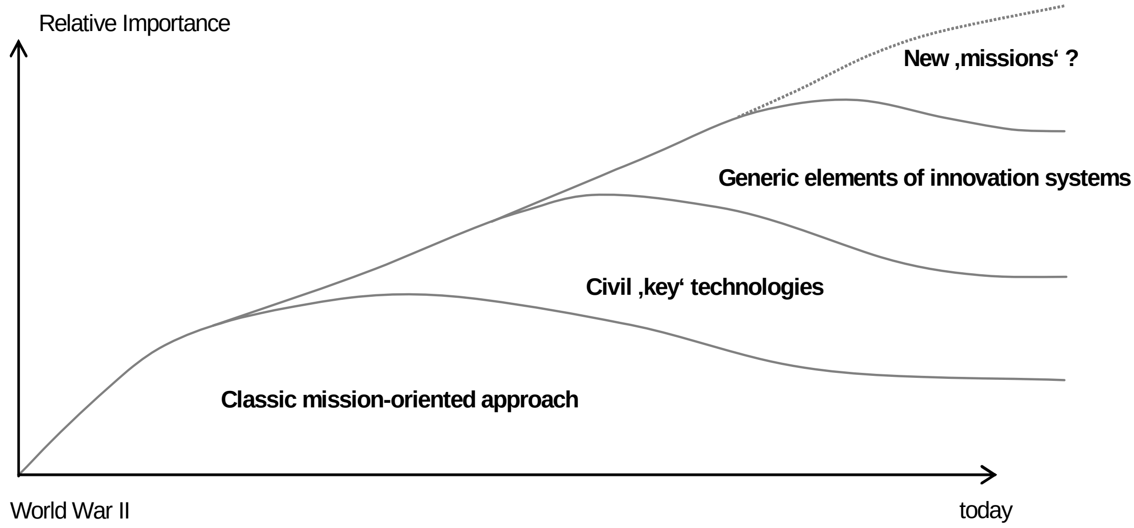
The general trends and there corresponding conceptual and theoretical framework ("paradigm") may be characterised along three dimensions as follows:

- A *thematic dimension* covers the actual priorities on which public intervention is focused on. Under priorities we understand both, specific fields of science or technology as target of technology policy as well as functional or generic areas (like technological diffusion, start-ups, academia-business linkages etc.).
- An *institutional dimension* covers the actual implementation of the process of priority setting, i.e. the very process of how priorities are chosen and fostered by policy makers and the respective institutions (including the interactions of the involved actors).
- A *legitimatory dimension* covering the arguments and the reasoning used by policy makers and actors to ‚rationalise' there actions and the resulting set of priorities.

The development since WWII has been characterised by shifting dominant paradigms concerning these three dimensions. However, these distinct paradigms did not substitute each other but added to a somewhat complex system of layered paradigmatic conceptualisations of priority-setting structures and processes (see Fier 2002). Figure 1 shows these layered system and its development over time. Four fundamental layers may be distinguished with each layer dominating a certain period of time:

- A 'traditional' mission-led approach, which evolved during the 1940s (WWII) and the 1950s (emerging ‚cold war') concentrating on key military technologies;
- an industrial policy approach, meaning the broadening of the mission-led approach towards civil industrial 'key' technologies beginning around 1960;
- a systems-oriented approach focusing functional and generic aspects beginning in the 1980s and associated with the rise of the (national) systems of innovation framework;
- a 'new' mission-led approach with an orientation towards technologies crucial for coping with new societal developments (such as demographic change and the resulting ageing, new health concerns, environmental sustainability, security).

Figure 1. Dominant trends in priority setting



Source: own draft

2.1. TRADITIONAL MISSION-LED APPROACH

The enormous demand of the military for new weapon technologies and its successful fulfilment by research institutions via new scientific and technological developments may be regarded as a major stimulus for the establishment of a technology policy on a grand scale ('big science' model) after WWII. The rapid success of the military-oriented research ambitions served as the role model for civilian research and technological development in the years after WWII. Some of the large research infrastructures developed during the war have been re-aligned to target civilian needs, such as energy production through nuclear technology, and new research initiatives aimed at further developing military-based technologies have been established, such as the EURATOM and ESA activities in Western Europe.

This so called "traditional", mission-led research and technology policy approach can be characterised as following (Soete/Arundel 1993):

- Thematic priorities are to be found in 'big science' or technological missions for which huge institutional infrastructures, long time horizons and massive financial funds were characteristic. Typical examples are nuclear energy or space exploration and weapons technologies. The goals and direction of technological research and development were defined ex-ante by a small group of experts.
- The initial demand for these projects stem from the public sector alone. The application of R&D results for the private sector and the widespread diffusion of these results play only a minor role for the definition of the mission. However arguments to enhance the technology transfer and diffusion (‚dual use', spillovers) from these missions gained importance over time.
- Usually, basic research played a crucial role for these missions. The theoretical argumentation was based mainly on a 'science-push-approach'. The number of involved actors (mainly specific public scientific institutions and selected enterprises) was relatively small and there was a defined selection process for all would-be participants. Central parts of research on new technologies were carried out at governmental laboratories founded for this very purpose.

- Identification of priorities took place within small expert panels consisting of representatives from public administration, key industrial companies, and public research institutions.
- Monitoring and control over the mission was centralised within government administration.

Traditional mission oriented policy was aimed to produce public goods in areas in which the incentives were too low and the obstacles (in terms of costs, risk, time horizon of expected results etc.) too high to expect much engagement by private sector research under normal market conditions.

In principle the traditional mission-led research and technology policy did have success (Ruttan 2006). Nuclear energy was available for commercial use in the 1950s and space exploration proceeded progressively and (initially) with enormous public attention and praise. The combination of financial funds on a massive scale, the partnership between basic research and applied technological development organised via huge public research infrastructure under clear defined thematic aims and specifications are regarded as crucial success factors for this approach.

2.2. EXPANSION TO CIVILIAN ‚KEY' TECHNOLOGIES

During the 1960ies the mission-led concept was extended towards civilian technologies (or even industries) which were regarded as crucial for economic development (‚key technologies'). Although these new thematic priorities were not constrained to public goods public intervention was argued as necessary and useful to promote the rapid appropriation and diffusion of new technological opportunities. Examples are semiconductors, ICT in general or new materials. Three factors played an important role to stimulate this expansion of technology policy:

- The success of the traditional mission-led approach set an example for the possibility of public funded and aimed technological development.
- The mere existence of research institutions initially established for the mission-led approach and their growing influence led to an expansion due to their 'natural' interests to gain importance and influence.
- Countries like Germany, France or Japan perceived a technology gap relative to the USA, and an active stimulation via technology policy seemed necessary and appropriate to initiate a sustainable catching up process (Bruder 1986; Giersch 1987; Fier 2002, 36ff; Mowery 1994, 222ff). A similar argument was used by the European Commission when initiating the EU Framework Programmes in 1985 and its predecessor research activities (see Gozzetti 1995). This catching up policy also involved elements of a sector-specific industrial policy and thus was not restricted to R&D only.

The resulting policies to foster 'key technologies' can be characterised as following:

- The spectrum of targeted technologies is quite diverse and growing over time as new scientific and technological opportunities open new fields regularly: Information and Communications technologies, production process technologies (e.g. robotics, automation etc.), biotechnology, new materials, medical technologies, renewable energy (solar and wind power). In the 1990s nanotechnology emerged as an entire new field, which is (besides the 'evergreens' ICT and biotechnology) now the new common buzz word. Interestingly, the list of selected key technologies is almost the same in most countries and the list of 'new' technologies is quite stable over time, technological fields are added to the list but seldom removed from the pool of 'new' technologies.

- Typically, the aims, instruments and financial budgets were defined in programmes lasting over a medium to long term time horizon. Often special institutions were established for administrating these programmes. Over time, this led to a complex system of technology policy since the administrative bodies of the various technology programmes started promoting their interests actively and independently.
- The access to the programmes is very broad with the explicit aim to foster participation of a large group of firms (not necessarily only big ones) and research institutions. A broad participation should guarantee a rapid application of research results and a widespread diffusion of new technologies. Sometimes the diffusion of 'new' technologies was the principle aim of these programmes (e.g. diffusion of automation techniques in manufacturing, see Polt/Pointner 2005). Large integrated, institutionalised projects often organised as 'closed clubs' of the traditional mission-led approach were substituted by a vast number of small and medium sized projects with a short to medium-term time horizon and a multitude of participants. The openness of the programmes and the principal aim to involve a large pool of potential participants led to a great thematic variety and to an ever growing list of selected technologies somewhat thwarted the aim of concentrating on few priorities.

Modern planning and monitoring techniques were developed and used to control and steer the complex processes of programme selection, development and management. Entire new disciplines and methodologies like technology assessment, technology foresight etc. evolved to tackle the selection problem of technologies.

Thus the main differences to the traditional mission-led approach are threefold: (i) the programmes are aimed at the needs of private industries (versus public needs), (ii) the degree of centralisation is much lower and (iii) degree of openness much higher with an explicit orientation towards diffusion and widespread application.

However, the new approach requires a different theoretical justification to explain the need for public intervention. Initially these arguments stem from a traditional understanding of industrial policy: the common pool of public and private resources in R&D programmes facilitates economies of scale and lead to enhanced competitiveness of the industrial sector. The rapid development and application of new technologies may lead to 'first mover' advantages and eventually to a dominant position of national 'champions' in international markets. Pooling of resources in selected growth industries (and their respective underlying technologies) may stimulate significant spillovers and externalities which set in motion a circular and cumulative growth process.

Strategic public co-ordination and active intervention in form of subsidises was regarded as crucial for realising these potential advantages. Hence the various notions like 'strategic', 'key', 'path-breaking' to characterise the technological fields and to stress the importance to foster these technologies (Soete 1991; OECD 1991; Branscomb 1994).

A second strand of argumentation stresses the importance of generic (or so called general purpose) technologies for economic development and growth. It is argued that fostering these technologies would trigger positive effects for a broad range of industries and enhance the economic competitiveness and growth dynamics of the whole country. Typical examples for such general purpose technologies are ICT. Therefore, the importance of diffusion is even much more pronounced in this approach.

2.3. SYSTEMS OF INNOVATION APPROACH

These policies of actively selecting and fostering a set of specific technologies and industrial sectorssoon attracted fierce critiques from various strands of arguments (Klodt 1987, Cohen/Noll 1991, Branscomb 1994, OECD 1998). First and foremost, the problem of selection cannot be solved satisfactorily according to the critics. Investment in R&D involves by definition uncertainties. Given the limited information available to decision makers, there is no way to guarantee that the political decision process will result in choosing the ‚right' (ex post) technologies. But choosing the 'wrong' technologies may result in vast waste of public funds, inefficient allocation of resources and eventually to market deficiencies which undermine the ultimate goal of welfare maximisation. Thematic prioritisation of specific technologies may even hinder structural change and inherits also the danger to 'lock-in' in existing structures. A too narrow prioritisation may also lead to a narrow specialisation and thus too a greater vulnerability to exogenous shocks. And last but not least, vested interests may dominate the decision-process. Over time, this approach was more and more estimated as not in line with a modern understanding of the role of market forces and the role of policy in fostering technological change.

Against this background a new concept, the so called national systems of innovation approach (NIS) emerged during the 1980s (see e.g. Freeman 1987; Lundvall 1992) and soon gained widespread acceptance as a new conceptual framework for technology policy (see e.g. OECD 2001). Instead of choosing and fostering specific thematic priorities this approach emphasises the importance of generic (or 'functional') aspects as crucial elements of a modern technology policy.

The traditional 'linear' model of innovation which assumes a discovery-invention-innovation-diffusion path of a technology is rejected in favour of a conceptualisation of innovative activities which stresses the uncertain nature of innovation projects, the intertwining of science and technology, the path dependence of technological improvements on existing technologies (so-called lock-in effects; see Arthur 1989), the role of learning procedures (learning-by-doing, learning-by-using, learning-by-trying), and the importance of an integration of R&D, production and marketing. Consequently, innovation is viewed as a selective and cumulative activity (see Dosi 1982, 1988). Furthermore, the importance of research activities for innovation is seen in a different light. Economic successful innovations are often not so much a matter of invention as they are a matter of design.

The latter, however, is far from laboratory research and cannot be deduced from R&D findings. In general, innovation activities require the use of knowledge and information which are strongly context-specific and not freely available. Channels and codes of information are required. Co-operation among institutions may facilitate the flows of knowledge necessary for carrying out innovation activities. The term *system* is used to characterise a set of institutions or institutional actors whose interactions determine the innovative performance of firms, but making no presumption that the system was consciously designed. The set of institutions may consist of (private) firms, universities, other R&D organisations, and public agencies operating within a general framework of common rules and institutions such as the specific financial and educational system etc.

Firms are regarded as the principal actors in an innovation system as they can most effectively link research, development and design activities. Transforming R&D into profits requires the integration of innovations with production and marketing which can be done most easily within a firm. However, innovating firms act in an environment strongly influenced by other actors: Universities and other R&D organisations offer different types of knowledge while the government, public agencies and other organisations (such as unions, chambers etc.) determine the institutional and political setting. The collective actions of all actors over time contribute to a specific social and cultural system with feedback on the actual behaviour of actors.

The interactions between individual actors are of crucial importance to the functioning and competitiveness of an innovation system. Technical advance in complex systems with a deep division of labour requires interactions among producers (component and raw material producers, equipment suppliers), between producers and service firms, between producers and research institutions (co-operation between R&D departments of firms, private or public R&D institutions including universities) and between firms and the government (R&D programs etc.). Interactions can take a variety of forms which may range from combinations of independent initiatives via the market to formal contracts or long-term co-operations. Interactions lead to knowledge flows within an innovation system which increases the knowledge stock of actors. Depending on the type of knowledge concerned (i.e. embodied or disembodied, codified or tacit, one-sided or interactive), specific absorption capabilities of actors are required for applying new knowledge.

In many countries policy makers quickly adopted this approach as a conceptual framework during the 1990s and developed instruments and measures addressing generic (i.e. ‚functional') aspects of their innovation systems. Examples of these policy instruments are measures to stimulate co-operation (both within the private sector as well as between private enterprises and academic institutions), the creation of (regional) networks, programmes to foster high-tech firm foundations and academic spin-offs or – more broadly – measures to stimulate the venture capital market in general. The 1990s were also a period of international 'benchmarking' and rapid policy learning between countries. Programmes which have been assessed as 'good practice' in one country have been adopted and transferred to other countries leading to intensive mutual policy learning. Examples include competence centre programmes stimulating institutionalised networking between the private business sector and academia, which – originally introduced in Australia and Sweden – attracted soon widespread attention by other countries.

The integration of different group of actors (business firms, academic institutions) into new programmes led to an increasing complexity which required new management capabilities of the funding bodies. New forms of programme administration were developed, i.e. special programme agencies which were organised outside of public sector administration and soon gained a sort of independence from the public sector. Thus, the technology policy system of most countries transformed from the original hierarchical, very centralised structure to a polycentric system with a complex system of institutions as stake-holders of technology policy (see OECD 1991; OECD 2005b).

3 Recent trends in priority-setting: thematic and procedural aspects

3.1. STRUCTURE OF PUBLIC TECHNOLOGY FUNDING - AN OVERVIEW

Today elements of all three types of technology policy paradigms discussed in chapter 2 are to be found simultaneously. Using the five largest OECD countries (in terms of GDP) USA, Japan, Germany, United Kingdom and France we try to quantify (at least in a rough manner) the relative importance of these different strands of technology policy paradigms.

The ‚mission oriented' approach with a thematic focus on defence and aerospace still receives a significant share of public money: in the five countries mentioned above about 45% of public R&D spending (without basic funding of universities) goes to defence related R&D (2003). The high significance of these classic missions is especially pronounced in the USA, where almost 60% of federal R&D spending is allocated for defence and about 8% for space research. In U.K. and in France the respective figures are 40% (for defence and space combined), whereas in Germany and Japan the share of defence and space related R&D is about 20%.[2]

Table 1: Structure of R&D subsidies in five large countries (2003, %)

Country	‚traditional' mission-led approach		'key technologies'	generic measures*
	defence	space		
USA	56	8	30	5
Japan	7	10	69	14
Germany	11	8	26	65
United Kingdom	40	2	12	46
France	30	11	17	42

** including project funding for basic research*
Note: excluding general university funding

Source: Rammer et al. (2004, 58ff) and own calculation using information provided in OECD (2005a).

The promotion of civilian ‚key technologies' differs sharply between these five countries with regard to thematic priorities, organisational structures etc. In the USA as well as in Japan usually federal ministries and agencies are responsible to foster scientific research in the respective field (e.g. the department of energy organises and funds energy related research etc.). The share of such thematic priorities is about 30% in the USA (recently with a heavy focus on life sciences, especially biotechnology) and about 70% in Japan (energy & environment; life sciences; maritime and climate research; ICT).

In Germany, France and U.K. thematic technology programmes are increasingly organised as co-operative programmes to foster integrated research networks in certain areas (Germany:

[2] Traditional mission oriented programmes play still a prominent role concerning supra-national organised R&D. Programmes like Galileo or ITER are typical examples for technological missions in the traditional sense.

"*Verbundprojekte*"; France: Research and Technological Innovation Networks - RRIT; U.K.: LINK programmes). However, their quantitative significance is with a share varying between about 10% and 25% lower than in the U.S. or in Japan. In these three large European countries generic programmes as well as unspecific measures to fund basic research (e.g. German Research Foundation in Germany; Research Councils in U.K.) play a much more prominent role. Generic measures have been gained increasing importance during the last 15 years. They encompass diverse programmes such as programmes to foster R&D in new start-ups, in small and medium sized enterprises, co-operation between academia and business, regional networks etc.

However, in recent years the focus changed again towards thematic oriented priorities. In contrast to the 1960s, 1970s and 1980s the definition of thematic priorities is based increasingly on societal needs. New technologies and the underlying research are focused on finding 'fixes' (or at least contributions to solutions) to perceived societal challenges and problems. Hence, this new approach may be summarised as 'new mission-orientation'. An important starting point for this development was the debate about the 'sustainability' of modern industrial economies in the early 1990s. This debate resulted in a broad consensus (at least in continental Europe) to foster the development of 'cleaner' technologies. Related to the problem of sustainability are themes centred on mobility, demographic change and ageing society, security and health etc. It is still open, if this new mission-orientation will emerge as a really new dominant paradigm in technology policy or simply remain a broad 'good will' concept without any real policy relevance. However, important dimensions of such a new mission-led paradigm are as follows (see Soete/Arundel 1993 and the Box below for an example from Finland):

- Identification of thematic fields is done by combining societal needs and requests and possible technological inputs to solve these needs and requests (instead of mere technological push). The argument for funding of a particular technology is based upon its contribution to solve a given problem and not based upon the technological risks and scientific uncertainties (as it was in the traditional mission-led approach).
- The process of identifying and selecting thematic areas is influenced by a large number of different actors, thus it is much more decentralised in sharp contrast to the centralised decision-making process of the older paradigm. Those actors encompass agents beyond the business world and technology policy agents including agents from other arenas such as environmental policy, health policy etc.
- A broad and quick diffusion of the research results is a central aim and is actively encouraged.
- The importance of incremental innovations is acknowledged. Again this is in sharp contrast to the emphasis on radical innovations and breakthroughs in key technologies (often labelled as 'path breaking') in the traditional mission-led paradigm.

The Tekes Strategy Focus Areas – an Example for a New Mission-led Paradigm

Tekes, the Funding Agency for Technology and Innovation of the Finnish government, is offering financial support for R&D projects performed by enterprises, universities or research institutes. Tekes has a long tradition of funding in thematic areas, the so-called technology programmes. These programmes are subject to a regular review and re-design. From the mid 1990s onward, Tekes has increasingly integrated new elements into its technology programmes such as demand orientation, market trends, global megatrends, systematic stakeholder discussions, societal values and goals, cluster approaches and the role of business competence for successful innovation. The current shape of Tekes' technology programmes may be viewed as a typical example of a new mission-led approach in technology policy.

Today, funding within technology programmes is based on so-called "Strategy Focus Areas". They combine traditional key technology areas ("technology focus areas": ICT, biotechnology, nanotechnology, materials technology) and market needs ("application focus areas": environment and energy, security and safety, work and leisure, health and well-being, services, renewing products and business concepts). Through selecting focus areas, Tekes aims at strengthening industrial clusters, developing growth areas within clusters that are customer-oriented and apply cross-technology approaches, promoting customer-driven new businesses, increasing the diffusion of ICTs, securing a stable development of generic technologies and ensuring a close interaction between R&D, market needs and business competence.

The process of defining and selecting strategic focus areas rests on extensive interaction with stakeholders. So-called "strategic discussions" with business managers and experts from enterprises, universities and research institutes as well as actors from public administration and science organisations serve as a main information source. Further sources were sectoral strategy reports and international benchmarking.

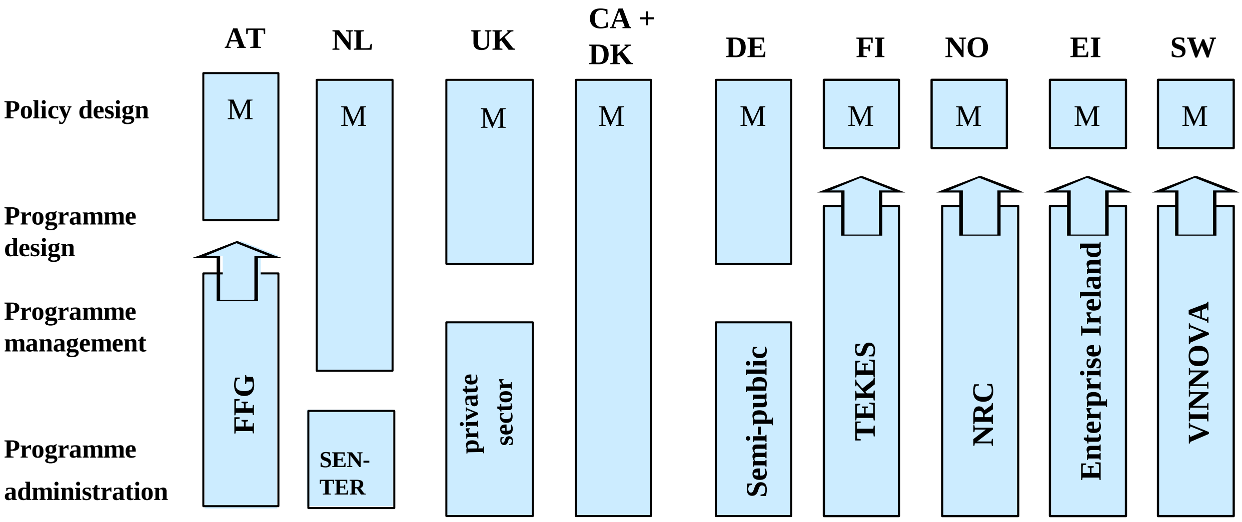
Source: Tekes (2005)

3.2. THE PROCESS OF PRIORITY SETTING – RECENT TRENDS

The last years are marked by a trend towards a similarity of theoretical background, basic aims as well as broad thematic orientation of technology policy in most of the OECD countries. Nowadays technology policy is characterised by a congruence of the different conceptual paradigms. Elements of all these paradigms can be detected in the argumentation for technology policy as well as in the rationalisation of actual policy measures. Although there is no real alternation of the paradigms, however there is clearly a shift in the dominant paradigm. Today, in most countries the systemic nature of innovation processes based upon the concept of (national) innovation systems is more or less 'officially' recognised. Thus, technology policy emphasises functional aspects like relations between various actor groups (e.g. academia, businesses etc.) in almost all countries (see Polt et al. 2001). Policy measures like special infrastructures to foster academia-business links have been established in a number of countries (e.g. competence centres in Australia, Austria and Sweden). Other measures based on the innovation system concept are intermediary institutions and technology transfer organisations, programmes to foster business establishments (especially academic start-ups) and programmes to enhance the international mobility of human capital etc. International bodies like the OECD recognise this trend stating that "*… the very concept of priorities has become broader …'functional' priorities were added to the 'thematic (technology-specific or mission-oriented)' priorities*" (OECD 1994, 21). Recently, elements of the new mission-led approach have gained importance, both at the strategic level as well as at the operative level. For example, two of the four strategic aims of technology policy of New Zealand address explicitly those 'new' missions (i.e. environmental and social aspects). These goals are not only emphasised in official 'white papers' but indeed receive certain financial resources and concrete policy measures have been developed to foster research and technological development in these areas. Such new missions are to be found in an increasing number of countries and are gaining importance since about the mid 1990s (e.g. in Austria, Belgium, Denmark, Finland, Germany, Ireland, Netherlands, United Kingdom, Sweden, Switzerland).

A particular trend with high relevance for the process of priority setting is the increasing distinction between strategic levels (i.e. ministries) and operative levels (policy measures; programmes). Usually the former is accompanied by advisory boards which are nominated by the policy levels for a certain time period but operate somewhat independently from direct political influences. The latter is increasingly outsourced from the administrative bodies to agencies which are organised more like private firms than administrative government bodies. Although this process of 'agencyfication' is to be observed in a wide range of countries, the overall degree of ‚outsourcing' and the particular division of labour between policy administration and agencies is quite different between countries (see figure 2).

Figure 2: Governance structure of technology policy in selected countries



M = responsible ministry / ministries

Source: Arnold 2004

This process has led to an increasing complexity and a multi-layered structure of the organisation of technology policy during the last decade. Today, a multitude of actors at various hierarchical layers with different but somewhat overlapping responsibilities constitute the technology policy system. Co-ordinating and balancing the somewhat different interests of these actors is a complex task and formulating common strategic aims is achieved via continuous bargaining processes.

The increasing importance of the European Union has had major influences on the various national policies within Europe and thus contributing to the aforementioned increasing complexity (Borrás 2003). The influence of EU technology policy on national policies has been twofold. First, on a paradigmatic level, national policies are increasingly shaped by conceptual discussions at the European level. Indeed, the very idea of "new missions" was promoted especially by the EU and was then adopted by various member states.

Second, EU technology policy has a direct impact on the behaviour of major research actors. The Framework Programmes (FP) have increased the intra-European cooperation in particular. They triggered the formation of sustainable research networks, an intensified cooperation on the European level, mutual publication activities etc. The thematic structure and allocation of FP funds induce a similar pattern concerning the participation in thematic areas, especially in the smaller (and the new) EU member states where the absolute amount of national funds is rather limited (Rammer et al. 2004, 171ff). The on-going ‘Europeanisation’ process of RTD policies (e.g. the establishment of the European Research Council) may ultimately lead to a convergence of conceptual approaches and thematic priorities within Europe.

This Europeanisation process is further accelerated by the perceived gap in relation to the USA, which has received increasing policy attention recently. The somewhat lacking growth performance of the European Union in the 1990s (compared to the US) led to the initiation of the Lisbon/Barcelona process in which the EU member states agreed to increase their R&D efforts. Indeed, the differences in innovation performance between the European Union and the United States are subject to an increasingly controversial dispute (see e.g. Dosi et al 2005).

To understand the process of priority setting this increasing complexity has to be taken into account: usually there is no ‘top-down’ central authority for identifying, selecting and defining thematic priorities. Instead there is a multitude of actors bargaining over which thematic priorities should be selected, how they should be defined and supported etc. These bargaining processes involve both top-down as well as bottom-up elements. Korea can be regarded as an example of a highly centralised, top-down organised governance structure of priority setting. There, delphi-oriented foresight-studies have been used to identify and select ten ‘growth industries’ (e.g. digital TV, intelligent roboters, new generation of semi conductors etc.) and the corresponding ‘key technologies’ (in this case 80 technology fields have been selected). These thematic themes are then chosen as primary targets to allocate R&D subsidies (see MOST 2003).

However, such a centralised and hierarchical organisation of technology policy is rather the exception among rich, developed countries. In most countries thematic priorities are defined at a very broad, strategic level (usually at the policy level in co-operation with the aforementioned advisory boards). Then, these strategic priorities are translated into various technology-specific thematic programmes at the level of agencies including bottom-up elements and feed-back loops. Hence, there is no stringent, one-way direction of formulating priorities at the top hierarchical level down to the R&D performers.

Priority setting via the establishment of specialised research institutions (e.g. thematic focussed institutions of ‘big science’) declines in importance. In a number of countries (e.g. Finland with VTT, Netherlands with TNO, Austria with ARCS) such research institutions underwent a process of increasing flexibility and re-orientation process focussing much more on business needs than on pre-defined scientific missions.

A major problem inherently of every priority setting process is to find a feasible methodology for the identification, selection and definition of thematic priorities or specific technologies. Methods like ‘technology assessment’ or ‘technology foresight’ which raised a lot of expectations in the 1980s and 1990s have been somewhat losing in importance. The Netherlands might act as an example for the changing role of these techniques. In the 1990s extensive foresight studies have been carried out to identify and select key technologies which might play a crucial role for economic and technological development in the Netherlands. A special designed committee (Consultative Committee on Foresight) has been established to guide these exercises (Hackmann 2003). Ten broad thematic priorities have been selected (e.g. electronic highways, ecological modernisation, integral utilisation of space, health research etc.) which should receive primary attention throughout the next ten to fifteen years. However, the results of these exercises are rather mixed and in the meantime the importance of bottom-up defined activities (*‘eigen verantwoordelijkheid’)* is much more stressed now.

Today, there is a broad consensus (at least in European and Anglo-Saxon circles) that policy should restrain from defining narrow technological priorities. Usually, free market principles are regarded as superior in selecting new technological developments and in potential successful innovations. However the restraint to broad technology areas as strategic guidelines resulted in a similar pattern of thematic priorities in most countries. Broad priorities like ICT, biotechnology, health, life sciences, new materials, nanotechnology are to be found in virtual all countries.

4 Conclusions

Priority setting is at the very centre of research and technology policy from its beginning. After WWII, several paradigms in priority setting may be distinguished: traditional mission orientation in the area of nuclear (energy), space and defence technologies; the expansion to a large number of 'key technologies' with a considerable commercial potential in many industries; the upcoming of generic measures as part of a systems of innovation approach to technology policy; and thematic priorities following societal challenges (so called 'new missions'). This paper analysed these paradigms with respect to its main characteristics and the rationale used to implement it. Table 2 summarizes the distinct properties of these paradigms along certain dimensions.

Table 2: Overview of technology policy paradigms

Technology Policy Paradigm	**Thematic dimension**	**Legitimatory dimension**	**Institutional Dimension**
'Old' Mission oriented approach	Emphasis on 'large-scale' technologies (i.e. defense, energy, transport etc.)	Production of 'public' and/or 'merit' goods	Top down definition of thematic priorities; Establishing of thematically specialised large-scale public R&D organisations (e.g. nuclear research centers)
'Industrial policy' approach ("key technologies")	ICT; Biotechnology; New Materials, Nanotechnology	Fostering competitiveness; Emphasis on static and dynamic economies of scale and specific market failures, especially spill-overs from 'generic' technologies	Emphasis on planning, technology forecasting, technology assessment; National Technology Programs;
Systemic approach	Emphasis on 'functional' aspects of the innovation system (co-operation; conditions for business start ups, regulation etc.)	"Systems failures" instead of market failures	Increasing number of actors/institutions involved in technology policy; Agencies as important players in technology policy
'New' mission oriented approach	Sustained Development; Information & Knowledge Society; Demographic Change and Aging; Mobility	Orientation towards societal needs and challenges	Integration of different societal groups; horizontal coordination of hitherto different/distinct policy areas, increasing number of actors

We have shown that paradigms did not substitute their predecessor but rather develop new features adding to the existing structure of priorities. As a result, research and technology policy today consists of a diverse set of objectives, approaches and instruments, and involve a large variety of actors. Consequently, processes of policy design have become rather complex.

However, all these different approaches (with the possible exception of systems of innovation approach) share the common problem of setting the ‘right’ thematic priorities and choosing the ‘right’ methodology for finding the most promising future technologies and research areas. At least until now, technocratic approaches using sophisticated methodologies (e.g. technology foresight, technology monitoring, SWOT-analyses) did not met the high expectations, which they received at least at some time. Almost by definition, in this area, policy is confronted with ‘true uncertainty’ i.e. the impossibility to foresee the speed and direction of future technological developments.

Hence, we conclude that technology policy should not try to define narrow ‘would-be path-breaking technologies’ and allocate resources predominantly in those themes. We do have much more confidence in the efficiency of bottom-up market forces than in top-down organised and hierarchically executed policy processes. Hence, the systems of innovation approach stressing the importance of generic functions (e.g. relations between different innovating actors etc.) within an innovation system may still be an appropriate guideline for technology policy. In addition, some thematic priorities may emerge as ‘new missions’ when new technological solutions seem necessary to address urgent societal challenges and problems (for example environmental, health and security issues).

Concerning the available tool box of instruments there has been a shift from specialised thematic-focused research institutions towards programmes open for a broader range of actors. Programmes are a much more flexible tool (i.e. they are quick to establish and quick to abandon) than institutions which, once established, usually acquire a good deal of stickiness. Today, in most countries special agencies are responsible for the organisation and management of such programmes. Thus, the organisation and governance of technology policy becomes somewhat complex due to the additional layer situated between policy actors and R&D performers. The analysis of the interrelations between the actors of these different layers of the innovation systems will be a fruitful task for further research.

5 References

Arnold, Eric (2004). Structure and Governance. Lessons from Abroad. FFF & FWF Evaluation Workshop, Vienna.

Bernal, John D. (1937). The Social Function of Science, Routledge & Kegan Paul, London.

Borrás, Susana (2003). The Innovation Policy of the European Union. From Government to Governance. Edward Elgar, Cheltenham.

Bozeman, Barry/James S. *Dietz* (2001). Research Policies Trends in the United States: Civilian Technology Programs, Defense Technology and the Deployment of the National Laboratories, in: Larédo, Philippe/Philippe Mustar (Ed.). Research and Innovation Policies in the New Global Economy. An International Comparative Analysis. Edward Elgar, Cheltenham, 47-78.

Branscomb, Lewis M. (1994). Targeting Critical Technologies, in: OECD STI Review No. 14. 34-57.

Bruder, Wolfgang (Ed.) (1986). Forschungs- und Technologiepolitik in der Bundesrepublik Deutschland. Beiträge zur sozialwissenschaftlichen Forschung, Band 94, Opladen.

Cohen, Linda R./Roger G. *Noll* (1991). The Technology Pork Barrel, Brookings Institution. Washington, D.C.

Dosi, Giovanni, Patrick *Llerena*, Mauro S. *Labini* (2005). Evaluating and Comparino the innovation performance of the United States and the European Union. European Innovation Scoreboard.

Fagerberg, Jan (1995). User-Producer Interaction, Learning and Comparative Advantage, Cambridge Journal of Economics, 19 (1): 243-256.

Fier, Andreas (2002). Staatliche Förderung industrieller Forschung in Deutschland. Eine empirische Wirkungsanalyse der direkten Programmförderung des Bundes. ZEW-Wirtschaftsanalysen, Band 62, Nomos, Baden-Baden.

Freeman, Christopher (1987). Technology Policy and Economic Performance. Lessons from Japan. Continuum International Publishing.

Gassler, Helmut/Wolfgang *Polt*/Julia *Schindler*/Matthias *Weber*, Sami *Mahroum*, Klaus *Kubeczko*, Michael *Keenan* (2004). Priorities in Science and Technology Policy – An International Comparison, InTeReg Research Report No. 39-2004. Wien, Graz.

Giersch, Herbert (Ed.) (1987). Wettlauf um die Zukunft. Technologiepolitik im internationalen Vergleich. Kieler Studien Nr. 206, Tübingen.

Guzzetti, Luca (1995). A Brief History of European Union Research Policy. Luxembourg.

Grupp, Hariolf/*Icíar* Dominguez-Lacasa/Monika *Friedrich-Nishio* (2002). Das deutsche Innovationssystem seit der Reichsgründung. Indikatoren einer nationalen Wissenschafts- und Technikgeschichte in unterschiedlichen Regierungs- und Gebietsstrukturen. Schriftenreihe des Fraunhofer-Instituts für Systemtechnik und Innovationsforschung ISI, Karlsruhe.

Hackmann, Heide (2003): National Priority-Setting and Governance of Science, Manuskript, University of Twente.

Klodt, Henning (1987). Wettlauf um die Zukunft. Technologiepolitik im internationalen Vergleich. Kieler Studien, Band 206. Poeschler, Tübingen.

Larédo, Philippe/Philippe *Mustar* (2001). General Introduction: A Focus on Research and Innovation Policies, in: Larédo, Philippe/Philippe Mustar (Ed.). Research and Innovation Policies in the New Global Economy. An International Comparative Analysis. Edward Elgar, Cheltenham, 1-14.

Lundvall, Bengt-Åke (Hg.) (1992). National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning. Pinter Publishers, London.

Lundvall, Bengt-Åke/Susana *Borrás* (2005). Science, technology, and Innovation policy, in: Fagerberg, Jan/David C. Mowery/Richard R. Nelson (Eds.). The Oxford Handbook of Innovation. Oxford University Press, Oxford, 599-631.

MOST (2003). Science and Technology in Korea. Seoul.

Mowery, David C. (1994). Science and Technology Policy in Interdependent Economies, Norwell.

Mowery, David C./Nathan *Rosenberg* (1989). Technology and the Pursuit of Economic Growth, Cambridge/New York/Port Chester/Melbourne/Sydney.

Mowery, David C./Nathan *Rosenberg* (1998). Paths of Innovation. Technological Change in 20th-Century America. Cambridge/New York/Melbourne.

OECD (1991). Choosing Priorities in Science and Technology. OECD, Paris.

OECD (1994). Science and Technology Policy Outlook. OECD, Paris.

OECD (1998). New Rationale and Approaches in Technology and Innovation Policy, STI Review No. 22, Special Issue. OECD, Paris.

OECD (2001). Innovative Clusters. Drivers of National Innovation Systems. OECD, Paris.

OECD (2005a). Main Science and Technology Indicators. OECD, Paris.

OECD (2005b). Governance of Innovation Systems: Vol. 1, Synthesis Report. OECD, Paris.

Polt, Wolfgang/Wolfgang *Pointner* (2005). Diffusionsorientierte Technologiepolitik. Eine vergleichende Wirkungsanalyse für Österreich, die Schweiz, Deutschland und die USA. Leykam, Graz.

Polt, Wolfgang/Christian *Rammer*/Helmut *Gassler*/Andreas *Schibany*/Doris *Schartinger* (2001). Benchmarking Industry-Science Relations – the Role of Framework Conditions, In: Science and Public Policy 28/4, 247-258.

Porter, Michael (1990). The Competitive Advantage of Nations. The Free Press, New York.

Rammer, Christian/Wolfgang *Polt*/Jürgen *Egeln*/Georg *Licht*/Andreas *Schibany* (2004). Internationale Trends der Forschungs- und Innovationspolitik. ZEW-Wirtschaftsanalysen vol. 73. Nomos, Baden-Baden.

Richter, Steffen (1979). Wirtschaft und Forschung. Ein historischer Überblick über die Förderung durch die Wirtschaft in Deutschland, in: Technikgeschichte 46(1), 20-44.

Ruttan, Vernon W. (2006). Is War Necessary for Economic Growth. Military Procurement and Technology Development. Oxford University Press. Oxford-New York.

Soete, Luc (1991). National Support Policies for Strategic Industries: The International Implications, in: OECD: Strategic Industries in a Global Economy: Policy Issues for the 1990s, Paris Cedex, 51-80.

Soete, Luc/Anthony *Arundel* (ed.) (1993). An Integrated Appraoch to European Innovation and Technology Diffusion Policy. A Maastrich Memorandum. Brussels/Luxembourg.

Stonemann, Paul (1987). The Economic Analysis of Technology Policy, Oxford

Tekes (2005). Building on Innovation. Priorities for the Future. Helsinki.

Weber, Matthias/Helmut *Gassler*/Wolfgang *Polt*/Bernhard *Dachs*/Gerhard *Streicher* (2004). Ansätze und Befunde zur Schwerpunktsetzung in der österreichischen Forschungs- und Technologiepolitik, Wirtschaftspolitische Blätter, 3/2004, 405-418.

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