ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

MANAGING NATIONAL INNOVATION SYSTEMS

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Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

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– to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

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GÉRER LES SYSTÈMES NATIONAUX D’INNOVATION

FOREWORD

Knowledge has become the driving force of economic growth, social development and job creation and the primary source of competitiveness in the world market. As a result, the OECD countries are in a process of transition from resource-based to knowledge-based economies. This transition has raised a great deal of interest in the international research community and created new challenges for governments to adjust their policies accordingly. For more than ten years, the OECD has been active in analysing these developments and in increasing our understanding of the characteristics of the transition. It has become obvious that we are facing fundamental changes in both our conventional thinking and in our living and working environment. The term "knowledge-based economy" is not a catchword; it reflects a genuine change in the overall conditions in which economic and social activities take place and, therefore, calls for a renewed policy agenda for governments not only in the OECD area but also worldwide.

The process of moving from knowledge generation through diffusion and exploitation to new businesses and jobs is very complex. A systemic approach based on the notion of the national innovation system has provided an appropriate framework for coping with such complexity. The OECD Working Group on Technology and Innovation Policy (TIP), under the aegis of the Committee for Scientific and Technological Policy, has completed a four-year study on the policy relevance of this approach. Some of the empirical findings of this study are presented in earlier OECD studies, such as the 1998 publication, *Technology, Productivity and Job Creation: Best Policy Practices*. The present publication gives additional results and draws attention, for the first time, to the policy implications of the systemic approach.

The work draws heavily on earlier scientific work. In particular, it owes a great deal to Paul David and Dominique Foray for their original work on the distribution power of the national system of innovation. Keith Smith has helped convert many theoretical considerations into operational concepts which are applicable in empirical work. At the OECD, Jean Guinet and Wolfgang Polt were in charge of the exercise. Their commitment and competence were invaluable to the success of the project. The NIS study was also a new type of activity for the OECD. Many countries volunteered to lead the work in the various focus groups; their significant financial and intellectual resources made the exercise possible. It is important to note that this work was a collective effort of the whole TIP Working Group. Therefore, I wish to extend my thanks to all my colleagues in the group. Finally, it is appropriate to thank all the researchers who contributed to the study through the focus groups.

It has been a great pleasure and honour to lead the study. I have learnt a great deal. I am convinced that the work will continue. We are still at the beginning. Much more work is required to obtain full understanding of the characteristics of the emerging knowledge-based economy and of appropriate government responses to facilitate the transition.

Erkki Ormala
Chairman of the Working Group
on Technology and Innovation Policy

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SUMMARY

The current wave of scientific discoveries and technical advances provides OECD countries with unparalleled opportunities for economic growth and improved social well-being. But the rapid increase in new scientific and technological knowledge only provides economic and social benefits when it is effectively exploited and leads to innovation. Innovation is a key driver of long-term economic growth, the primary basis for competitiveness in world markets and part of the response to many societal challenges. While public expectations from technological innovation are evolving in line with social concerns (*e.g.* unemployment, sustainable development, ageing populations), the innovation process itself is undergoing profound changes. Public policies must adapt effectively to such changes. Governments face the task of strengthening innovation systems in order to take greater advantage of globalisation and the move to a knowledge-based economy.

This report summarises the main findings of the Committee for Scientific and Technological Policy's (CSTP) work on national innovation systems – and related work in the context of the project on Technology, Productivity and Job Creation – which aimed to: *i)* characterise the current transformation of the innovation process; *ii)* identify the main country-specific and other factors that determine innovation patterns and performance; and *iii)* determine the implications for government policy to promote innovation.

The changing climate and conditions for innovation

In essence, innovation is the ability to manage knowledge creatively in response to market-articulated demands and other social needs. Enterprises are the main source of innovation; their performance depends on incentives provided by the economic and regulatory environment, their access to critical inputs (via factor markets or through interactions in networks and clusters of knowledge-based organisations) and their internal capacity to seize market and technological opportunities. Several trends combine to change the conditions for successful innovation:

- *Innovation increasingly relies on effective interaction between the science base and the business sector.* In all sectors, the innovative process is increasingly characterised by feedback between the science base and the different stages of technology development and commercialisation. In fields such as biotechnology, scientific research is the main source of innovation, blurring the distinction between science and technology. A greater part of the scientific research agenda is driven by problems identified during the course of technological development in the business sector.
- *More competitive markets and the accelerating pace of scientific and technological change force firms to innovate more rapidly.* Together with the expanding range of technologies which firms must manage or master, this situation is exerting pressure on business R&D and may be squeezing out private investment in long-term applied research. This is occurring in a context where budget constraints and cuts in defence-related R&D have generally led to stagnation in spending on public sector research and development. There may be implications for long-term innovative capacity.
- *Networking and collaboration among firms are now more important than in the past and increasingly involve knowledge-intensive services.* Competition provides incentives to innovate, but networking and collaboration at local, national and international levels are often necessary to build the capabilities to do so. Clusters of innovative firms and other private and public knowledge-based organisations are emerging as drivers of growth and employment. Two-thirds of OECD production and 70% of

jobs are in services, where innovation is generally less driven by direct R&D expenditure and is more dependent on acquired technology and the quality of human resources. Moreover, innovative manufacturing firms are increasingly interacting with knowledge-intensive services.

- *Small and medium-sized enterprises (SMEs), especially new technology-based firms, have a more important role in the development and diffusion of new technologies.* Small enterprises, especially new technology-based firms, play a distinctive and increasing role in innovation systems. Beyond their direct contribution to the creation and diffusion of new goods and services, new technology-based firms help instil a culture of innovation, encourage investment in skills and improve economy-wide dynamic allocative efficiency. However, the conditions for their creation and growth are still far from optimal in most countries and the innovation capacities of most SMEs are still limited.

- *The globalisation of economies is making countries' innovation systems more interdependent.* Trade in technology is growing, as are international alliances among firms and cross-border purchases of patents and licences. Investment in foreign research facilities is also on the rise, particularly by firms based in smaller countries. In this environment, the competitiveness of firms depends more and more on their ability to link to international innovation networks. However, globalisation is not leading to a homogenisation of national innovation patterns. Countries still differ greatly owing to differing starting points, technological and industrial specialisation, institutions, policies and attitudes to change.

In sum, innovation performance depends not only on how specific actors (*e.g.* enterprises, research institutes, universities) perform, but on how they interact with one another as elements of an innovation system, at local, national and international levels.

A new role for governments

For the most part, governments address current challenges with administrative structures and policy instruments that have been shaped by responses to past problems. Traditionally, they have intervened in the technology arena to address market failures. They should also address systemic failures that block the functioning of innovation systems, hinder the flow of knowledge and technology and, consequently, reduce the overall efficiency of R&D efforts. Such systemic failures can emerge from mismatches between the different components of an innovation system, such as conflicting incentives for market and non-market institutions (*e.g.* enterprises and the public research sector), or from institutional rigidities based on narrow specialisation, asymmetric information and communication gaps, and lack of networking or mobility of personnel.

Governments need to play an integrating role in managing knowledge on an economy-wide basis by making technology and innovation policy an integral part of overall economic policy. This requires co-ordinated contributions from a variety of policies in order to:

- Secure framework conditions that are conducive to innovation, such as a stable macroeconomic environment, a supportive tax and regulatory environment, and appropriate infrastructure and education and training policies.

- Remove more specific barriers to innovation in the business sector and increase synergies between public and private investment in innovation.

A new agenda for technology and innovation policy

Technology and innovation policy should complement broader structural reforms in many fields (*e.g.* competition, education and training, financial and labour markets), by focusing on the following key objectives:

- *Building an innovation culture.* Overcoming the inability of many firms to cope with technical progress owing to inappropriate work organisation, poor management practices and underdeveloped techniques and incentives for incorporating new knowledge and technology requires strategies on the part of firms and governments. Governments should also address the specific factors that restrain the number of technology-based start-ups and reduce their growth potential.
- *Enhancing technology diffusion.* Governments need to look carefully at the balance between support to the "high-technology" part of the manufacturing sector, and support aimed at fostering innovation and technology diffusion throughout the economy. They should direct their diffusion efforts across a wide range of firms, from the technologically advanced to those with lesser capabilities, from firms in traditional sectors to those in emerging industries, and to firms at different stages in their life cycle and in the services sectors.
- *Promoting networking and clustering.* Technology and innovation policy should not focus on single firms in isolation but rather on their ability to interact with other enterprises and organisations. Governments should reduce obstacles that prevent the formation of networks and ensure that the public research infrastructure works in close collaboration with business. They can also nurture the development of innovative clusters through schemes to stimulate knowledge exchange, reduce information failures and strengthen co-operation among firms.
- *Leveraging research and development.* In general, there is a need for new approaches to stimulating innovation that provide greater scope and incentives to private initiative and are less dependent on direct government financial support. Governments should help the science system adjust to the emerging entrepreneurial model of knowledge generation and use, while ensuring the continued pursuit of curiosity-driven research. In order to increase the leverage of government support programmes on private sector funding, foster co-operation among actors in innovation systems, and enhance synergy between market-driven R&D and that directed to government missions (*e.g.* defence, health, environment), governments should consider making greater use of public/private research partnerships and should foster commercialisation of research through patents, licences and spin-off firms.
- *Responding to globalisation.* Policies are needed which capture the benefits associated with both inward and outward R&D investments and other global technological alliances, provided that opportunities and incentives for mutual gain depend on sound and predictable rules of the game. Countries should generally build on the globalisation process through openness to international flows of goods, investment, people and ideas. They can increase their ability to absorb science and technology from around the world and make themselves attractive locations for innovation by upgrading the indigenous technology base, stimulating the growth of localised innovative clusters or competence centres, and enhancing international co-operation in R&D.

Although OECD countries may be facing substantially similar challenges, national policies will always have significantly different contexts. Policy responses are therefore to some degree country-specific and dependent on historical heritage and on features of the economic and innovation systems. There are also important differences among countries in the capacities and traditions of their science and technology policy institutions. However, based on a common understanding of the mechanisms of innovation and technology diffusion in a knowledge-based economy, there is room for improved mutual learning from successes and failures in addressing common objectives.

INTRODUCTION

This report summarises the main analytical findings of the OECD's work on national innovation systems (NIS) (Box 1), and draws the implications for government technology and innovation policy. It characterises the current transformation of the innovation process, identifies the main country-specific and other factors that determine innovation patterns and performance, and provides guidelines for government promotion of innovation, with examples of countries' good policy practices.

Box 1. **The NIS project**

The OECD project on national innovation systems (NIS) has evolved along two tracks: *i)* general analysis involving all countries; and *ii)* more in-depth analysis of specific aspects within focus groups.

The **general analysis** comprised:

- A comparison of national innovation systems based on a standardised set of quantitative indicators and information on countries' institutional profiles.
- The production of country reports on national patterns of knowledge flows and related aspects of innovation processes.

Work within **focus groups** involved countries with advanced methodologies, data sets, or special research/policy interests co-operating in the following six areas:

- ***Innovative firms*** (lead countries: Canada, France). This focus group aimed at defining characteristics of firms that favour (or hamper) innovative activities, with a view to determining how government policy can directly or indirectly help increase the stock of innovative firms.
- ***Innovative firm networks**** (lead country: Denmark). This focus group analysed and compared the networking activities of innovative firms in participating countries through a co-ordinated firm-level survey based on a new methodology.
- ***Clusters**** (lead country: Netherlands). This focus group addressed two main questions: To what extent and in which respects do clusters differ in their innovation performance and mechanisms of knowledge transfer? What policy recommendations can be derived from a "cluster approach" to technology and innovation policy?
- ***Mobility of human resources**** (lead countries: Norway, Sweden). This focus group examined the role of the mobility of human resources in the circulation of knowledge within an NIS. Their work involved the production of comparable stock and mobility data for three countries (Finland, Norway and Sweden) which have access to labour-registry data, with special emphasis on the highly educated in natural sciences and engineering.
- ***Organisational mapping**** (lead country: Belgium). This focus group carried out a qualitative comparison of NIS institutional profiles and a quantitative comparison of networks of R&D collaboration at international level, based on existing databases.
- ***Catching-up economies*** (lead country: Korea). This focus group examined the specific features of national innovation systems in what are termed "catching-up economies", especially the need to build up an indigenous science and technology base.

* A summary of the work of these focus groups is presented in Annex 2.

INNOVATION AND ECONOMIC PERFORMANCE IN A KNOWLEDGE-BASED ECONOMY

Innovation in a knowledge-based economy

The process of innovation and technology diffusion is undergoing substantial change. The main driving forces are increasing market pressures (stemming from globalisation, deregulation, changing patterns of demand and new societal needs) that lead to a closer integration of technology in commercial strategies, as well as scientific and technological developments (*e.g.* increasing multidisciplinarity in the production of new knowledge, diminishing cost of access to and processing of information). The production of goods and services is becoming more and more knowledge-intensive – more science-intensive via the better use of existing stocks of scientific knowledge, more technology-intensive via the diffusion of advanced equipment, as well as more skills-intensive in terms of managing the increasingly complex knowledge base related to productive activities. Technology diffusion now involves much more than the mere purchase of advanced equipment. It often requires organisational and managerial innovation if the potential of new technologies is to be fully exploited. This is most visible in the implementation of information and communication technologies (ICTs).

Innovation is a creative and interactive process involving market and non-market institutions. Innovation consists of the creative use of various forms of knowledge when responding to market-articulated demands and other social needs. Technical knowledge can be *"codified"* (in the form of publications, patents, blueprints, etc.) or "*tacit*" (embedded in the "know-how" and dexterity of individuals, in organisational routines and the like). It can be *"scientific"* (stemming from either basic or applied research) or it can be *"production and engineering"* knowledge (*e.g.* derived from hands-on experience with production processes or from testing and experimenting).

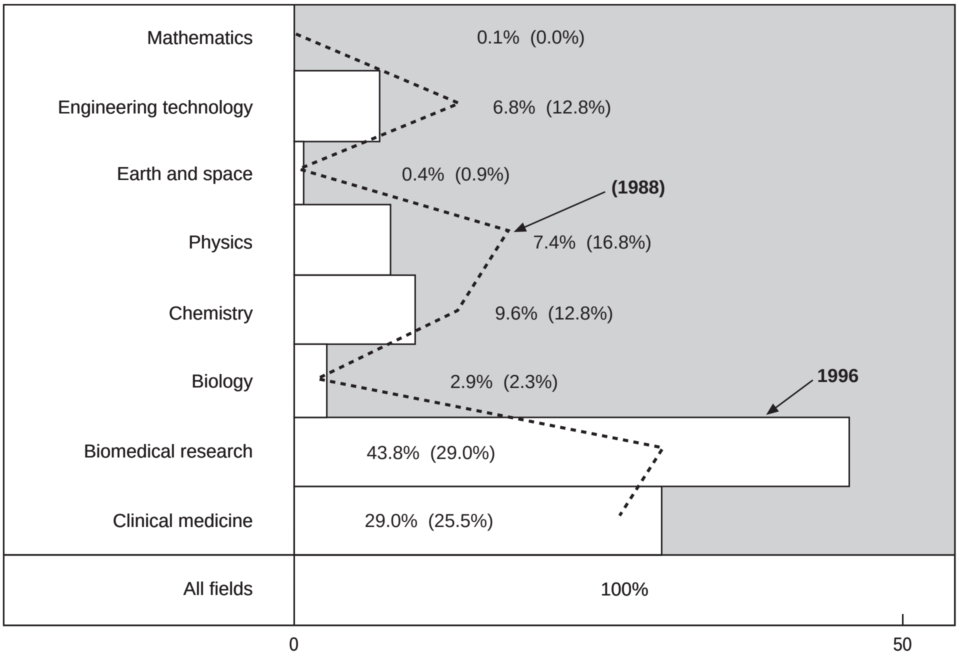
Technical knowledge becomes economically useful only when its production and use is efficiently managed by some form of organisation (firms, laboratories, universities, etc.) which channels individual creativity towards collective goals, that is, when it is merged with managerial and organisational knowledge. It yields economic benefits, and therefore justifies private investment in its production and assimilation, only when it is embodied in traded goods and services, that is when creativity can be valued and rewarded by price mechanisms in the product, labour and financial markets.

Complementarity between the market and the organisation of innovation processes is crucial for determining the economic and social benefits to be gained from advances in knowledge. When markets do not operate properly, firms have fewer and/or distorted incentives to compete by adding to the stock of public (socially useful) knowledge. If non-market knowledge-producing organisations are denied the resources needed to push their investigations beyond what markets can see, there is a parallel risk of a long-term erosion of the stock of knowledge. If market and non-market institutions do not interact well, technological change will slow down and its contribution to economic growth and welfare will diminish.

Innovation depends on scientific progress. The scientific content of innovation is increasing and the scientific roots of innovation are diversifying and changing in relative importance (Figure 1). There is, in particular, a growing role for biomedical and clinical research. This reflects both movements on the scientific front, demand-side effects (ageing, environmental concerns, etc.) and technology fusion (*e.g.* bio-informatics).

In an interactive model of innovation, intersectoral knowledge spillovers multiply opportunities for innovating through creative recombination of scientific inputs. Whereas institutional and cultural barriers

Figure 1. **The changing scientific roots of innovation**
Citations in US industry patents of US articles (main scientific disciplines)
Distribution in %, 1988 and 1996



Source: US National Science Foundation, 1998.

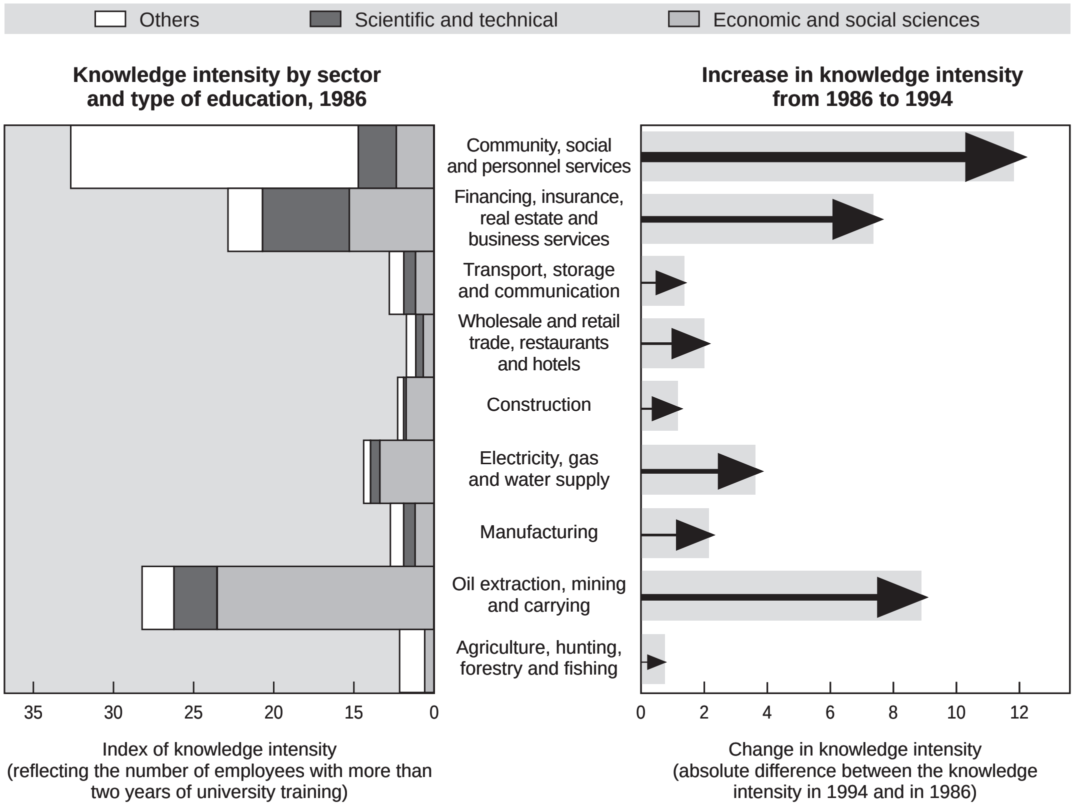
to fruitful co-operation between the science system and the business sector pose problems in most countries, five trends may help overcome some of them: *i)* regional agglomeration of knowledge-based activities (the most successful regions are often centred around major basic research institutions); *ii)* increased recognition that "low technology" and "high technology" may share a common science base; *iii)* pressures on the science system to increase its self-financing capabilities through patenting and contract research; *iv)* new forms of technological entrepreneurship and improved support from the financial system and public programmes (science-intensive new firms, venture capital, dual use technology); and *v)* easier communication and mutual understanding through the increasing use of common research tools (*e.g.* information technologies).

Innovation requires more than R&D. The emergence of a knowledge-based economy is often associated with the growing share of R&D-intensive industries and with the increasing use of advanced knowledge in hitherto "low-technology" industries. This view is far too narrow. The production of goods and services is becoming more knowledge-intensive but not necessarily more R&D-intensive (Figure 2). Many rapidly growing new service activities (*e.g.* software, venture capital funds, etc.) employ highly qualified labour and are highly intensive in immaterial investment but not in formal R&D. They belong to the most innovative activities, are based on technical progress (especially in information technology), but do not appear among the "high-tech" sectors.

Following intensified price competition, employment has fallen in some high-technology industries in many OECD countries in the early 1990s, but it has consistently risen in "knowledge-intensive" sectors where competition based on product differentiation leads to both market creation and expansion.

A too narrow focus on R&D overlooks the importance of other types of innovative efforts such as design or market analysis (Table 1) and the variations in the R&D content of innovation and in the

Figure 2. **Cumulative increase in the knowledge intensity of economic activities, Norway**



Source: Smith, 1996.

innovative performance of sectors (Figure 3). Many firms in low-technology industries make substantial innovation-related efforts. In addition, firm-level analysis and surveys reveal that variance in innovativeness is greater at the firm than at the sectoral level, especially in traditional activities where small firms predominate.

Firms are the central actors but do not act alone. Firms are the main vectors of technological innovation. Their capacity to innovate is partly determined by their own capabilities, partly by their capacity to adopt and apply knowledge produced elsewhere. The increasing complexity, costs and risks involved in innovation enhance the value of networking and collaboration to reduce moral hazard and transaction costs. This has spurred the creation of a multitude of partnerships between firms with complementary assets in addition to traditional market-mediated relations (*e.g.* purchase of equipment, licensing of technology). Firms exchange information and engage in mutual learning in their roles as customers, suppliers and subcontractors. Interactions among firms and a number of other institutions involved in the innovation process are also intensifying: universities and other institutions of higher education, private and public research labs, providers of consultancy and technical services, regulatory bodies, etc.

Technology, innovation and productivity

Technological change and innovation are among the main determinants of productivity growth. Productivity is the key to increasing real income and competitiveness and is one of the most important yardsticks of industrial performance. Economic analysis generally finds that productivity growth is attributable to firms' investments

Table 1. **Breakdown of innovation expenditures**

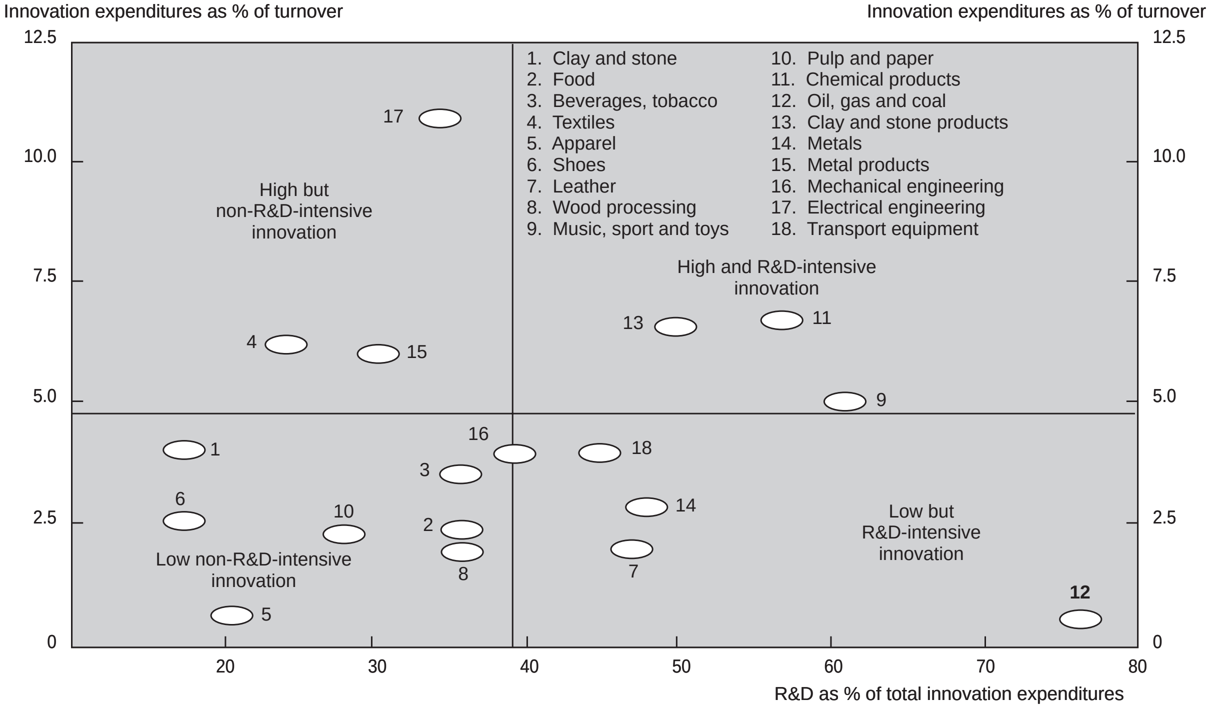
Percentage share

	R&D	Patents and licences	Product design	Market analysis	External spending
Australia	35.1	4.1	..	7.6	..
Belgium	44.7	1.5	11.3	6.6	21.2
Denmark	40.1	5.3	15.8	8.2	9.0
Germany	27.1	3.4	27.8	6.1	29.2
Greece	50.6	6.4	..	13.2	11.7
Ireland	22.2	4.3	22.0	38.5	20.4
Italy[1]	35.8	1.2	7.4	1.6	47.2
Luxembourg	29.3	8.9	8.4	4.3	26.4
Netherlands	45.6	6.1	7.6	19.8	20.2
Norway	32.8	4.2	14.2	5.5	17.6
Portugal	22.9	4.1	24.5	5.4	16.8
Spain	36.4	8.0	..	8.8	6.3
United Kingdom	32.6	2.7	28.4	8.9	15.9
Average	**33.5**	**4.6**	**24.0**	**6.6**	**22.4**

1. Adjusted according to ISTAT. Data do not total 100%, as "other expenditures" are not included in the table.

Source: Bosworth *et al.,* 1996; Community Innovation Survey Data; ISTAT, 1995; Australian Bureau of Statistics, 1994.

Figure 3. **R&D and innovation expenditures in Austria, 1990**



Source: CIS data.

in physical capital, training and technology, and may also be aided by public investment in education, research and infrastructure. Moreover, a more recent strand of microeconomic work suggests that the process of creative destruction and the exit and entry of firms may also provide an important contribution to productivity growth (OECD, 1998*a*). Finally, firm-specific factors, including management and workplace arrangements, also affect productivity growth in important ways.

The growing body of empirical evidence on the determinants of productivity at the firm level suggests that *aggregate productivity patterns may give a misleading picture*. There is a large variation in behaviour and characteristics among firms within industries, including with respect to the development and use of technology. The recent availability of establishment- or firm-level data in a number of OECD countries has made it possible to explore technology-productivity relationships at the micro level. Such firm-level research shows that developing or adopting new technology spurs higher productivity, but that a number of other factors, such as worker training, organisational structures and managerial ability, are crucial.

Technological change and productivity gains are generally accompanied by *changes in skill requirements*. Industries that have invested more in research and perform more innovative activity also tend to acquire more human capital. Firm-level studies also provide evidence of technological advances and skills upgrading. A study for the United States demonstrated strong links between new work practices and the incidence of training, and suggested that investments in human capital had positive effects on productivity (Lynch and Black, 1995).

Organisational change is also important to enabling productivity gains (OECD, 1998*b*). The successful introduction of new technologies often depends on new work practices, such as the adoption of work teams, multiskilling and job rotation, quality circles, just-in-time production practices, increased autonomy and responsibility of work groups, and flatter hierarchies. For example, the "lean system" in the motor vehicle industry involves many new work practices, including multiskilling and increased training. Organisational change is, in some cases, a prerequisite for adopting advanced technology. Industrial enterprises that reorganise their production process often adopt advanced manufacturing technology, while organisational change, such as the introduction of horizontal management structures, worker autonomy and just-in-time delivery, is closely linked to the introduction of advanced technologies. Organisational change also often involves the use of information technology (IT). A recent study analysing the relationship between organisational practices, IT use and productivity for 273 large firms found that greater IT use is associated with greater use of self-management teams, more investment in human capital, and increased use of worker incentives.

Technological change alone, therefore, can only bring limited productivity gains. However, when it is accompanied by organisational change, training, and upgrading of skills, *i.e.* when the new technologies are thoroughly "learned", it can contribute to significant productivity gains. A better understanding of *firm-level behaviour, i.e.* why some firms do well and why others fail, remains needed, however. Work in the OECD NIS project on innovative firms and on firm networks contributes to this understanding and thus helps to improve knowledge of the drivers of productivity growth.

NIS work also contributes in other ways to the analysis of productivity growth, as it looks into the role of knowledge flows among firms. Economic analysis demonstrates that *technology diffusion* is just as important as R&D and innovation to productivity growth. At the economy-wide level, it is less the invention of new products and processes and their initial commercial exploitation that generate major economic benefits than their diffusion and use. Innovating firms do not fully appropriate the productivity benefits of successful innovations. Rather, these become embodied in goods and ultimately contribute to higher productivity for the economy as a whole. For many industries (especially outside manufacturing), buying and assimilating technologically sophisticated machinery and equipment, often ICTs, is the main way of acquiring technology. Together with training, such capital-embodied technology raises the technological level of an industry's capital stock and improves productivity.

The importance of such embodied technology for total factor productivity (TFP) was explored in a recent OECD study (Sakurai *et al.*, 1996). A formal breakdown of economy-wide TFP growth in the 1970s and 1980s based on estimates of the impact of R&D and of technology diffusion showed that for the ten OECD countries covered by the analysis: *i)* technology diffusion contributed substantially to TFP growth, often accounting for more than half of productivity growth in a given period; *ii)* its contribution typically exceeded that of direct R&D efforts; and *iii)* technology diffusion had a much greater impact on TFP growth in the 1980s than in the 1970s. The impact of technology diffusion is felt most strongly in the services, which are increasingly active as developers and users of new technologies, in particular in the ICT segment of services. In addition, productivity growth is increasingly dependent on international technology diffusion.

COUNTRY-SPECIFIC INNOVATION PATTERNS

The characteristics of innovation processes described in the previous section are common to OECD countries. However, their translation into concrete innovative activities differs among countries depending on industrial specialisation, specific institutional settings, policy priorities, and so on (Patel and Pavitt, 1994). Historical experience shows that such differences persist even when countries deal with the same technological and economic developments (Vertova, 1997). Countries thus have a tendency to develop along certain "technological trajectories", shaped by past and present patterns of knowledge accumulation and use.

National innovation systems

A systemic approach to innovation: the theoretical foundations

The standard "market failure" argument was already articulated in the 1960s, in the framework of neo-classical welfare economics, and has since been the basic justification for most science and technology policies. Market failure, which may arise due to imperfect appropriability conditions or risk, implies that the private rate of return to R&D is lower than its social return. The attractiveness of the market failure argument lies in its clarity. It suggests a simple criterion for judging the appropriateness of government intervention to promote technological development and innovation. However, theoretical advances in the understanding of innovation processes and their contribution to economic growth have pointed to a need to revisit the rationale of science, technology and innovation policies (OECD, 1998*d*).

- *New growth theory* challenges some of the main hypotheses underlying the neo-classical view of the contribution of technological change to economic development (Romer, 1990; Aghion and Howitt, 1998). It stresses the importance of increasing returns to knowledge accumulation from investment in new technologies and human capital.

- *Evolutionary and industrial economics* demonstrates that this accumulation process is path-dependent (following "technological trajectories" which show some inertia), non-linear (involving interactions between the different stages of research and innovation) and shaped by the interplay of market and non-market organisations and by various institutions (social norms, regulations, etc.) (Metcalfe, 1995).

- *Institutional economics* addresses issues related to the design and co-ordination of institutions and procedures involved in handling more complex interdependencies, as growth leads to the increasing specialisation of tasks and productive tools (North, 1995).

Together, these different streams of economic thinking provide the eclectic theoretical foundations of *systemic analysis* of technological development and innovation. Such analysis helps define the tasks of governments in promoting innovation-led growth, by emphasising that:

- Competitive markets are a necessary but not sufficient condition for stimulating innovation and deriving the benefits from knowledge accumulation at the level of firms and individuals. Firms are not "simple algorithms to optimise production functions", but learning organisations whose efficiency depends on numerous and often country-specific institutional, infrastructural and cultural conditions regarding relationships among the science, education and business sectors, conflict resolution, accounting practices, corporate governance structures, labour relations, etc.

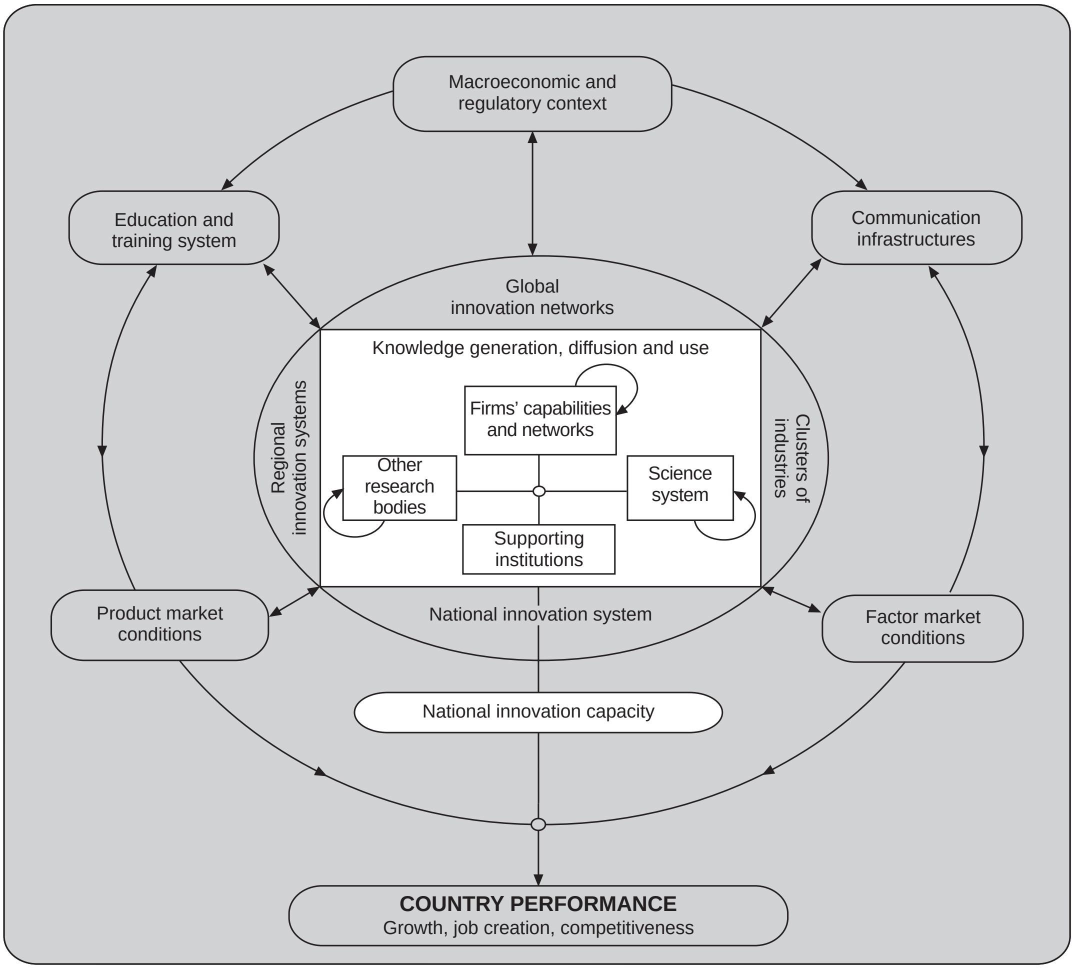
- Agglomeration economies at the regional level, network externalities and dynamic economies of scale in clusters of technologically related activities are important sources of increasing returns to private and public investment in R&D.
- In addition to correcting market failures [provision of public goods, intellectual property rights (IPRs), subsidisation of R&D], governments have a responsibility for improving the institutional framework for knowledge exchange among firms and between market and non-market organisations.

The sources of diversity

A first source of diversity is *country size and level of development*. Large and highly developed countries offer markets with advanced customers and opportunities to reap economies of scale while maintaining diversity in R&D activities. Innovators in smaller high-income countries generally have to internationalise more rapidly and concentrate on a narrower range of fields to reap these benefits (*e.g.* mobile communications in Finland and Sweden). They will profit most from free flows of technology across borders and their innovation systems are often focused on capturing the benefits of inflows of technology. Smaller countries face proportionally higher costs for maintaining institutions (*e.g.* in education and science) that cover a broader range of subjects than can be taken up by their industries. On the other hand, technological change in ICTs, combined with deregulation and globalisation, may reduce the scale advantages of large countries. Most OECD Member countries have developed the knowledge base and technological capabilities needed to sustain a high standard of living. For them, the present challenge is to “forge ahead” or, at least, not to “fall behind”. But one group of Member countries faces a different challenge, that of “catching up” with the most advanced economies (see below).

A second source relates to the *respective roles of the main actors* in innovation processes (firms, public and private research organisations, and government and other public institutions), and the *forms, quality, and intensity of their interactions* (Figure 4) These actors are influenced by a variety of factors that exhibit some degree of country specificity: the financial system and corporate governance, legal and regulatory frameworks, the level of education and skills, the degree of personnel mobility, labour relations, prevailing management practices, etc. The variable role of government is partly reflected in the levels and structures of public R&D financing. In “catch-up” countries (Greece, Hungary, Mexico, Poland, Portugal, Turkey), government R&D expenditure accounts for a higher share of total R&D than in more advanced economies. These countries often still need to build a scientific and technological infrastructure and their business sectors tend to have only weak technological capabilities. At the other end of the spectrum are countries in which the business sector provides the bulk of R&D funding (Belgium, Ireland, Japan, Sweden, United States). Countries also differ in the orientation of publicly funded R&D. For instance, despite a common trend away from the “traditional” missions of the post-war period (defence, energy) and towards new societal demands, such as ageing populations, the environment and competitiveness, the defence cluster still plays an important role in some countries, notably France, Sweden, the United Kingdom and the United States. The variable role of the higher education sector (universities, etc.) serves as an indication of the relationship between the science system and the rest of the innovation system. The share of expenditure on R&D in the higher education sector (HERD) financed by government is declining in the majority of OECD countries, but remains very high in some (*e.g.* Austria). In others, the enterprise sector is a significant financial contributor to universities.

Figure 4. **Actors and linkages in the innovation system**



Source: OECD.

NIS as a tool for policy analysis

The market and non-market institutions in a country that influence the direction and speed of innovation and technology diffusion can be said to constitute a *national innovation system*. Innovation systems also exist at other levels, *e.g.* there are world-wide, regional or local networks of firms and clusters of industries. These systems may or may not be confined within a country's borders, but national characteristics and frameworks always play a role in shaping them. This also holds true with regard to the internationalisation of innovative activities, which to a large extent reflects foreign investors' perception of the relative strengths of national innovation systems (*e.g.* the existence of scientific centres of excellence, or the supply of skilled scientists, engineers and competitive suppliers). The concept of an NIS (Box 2) provides a tool for analysing country specificities in the innovation process in a globalised economy, as well as a guide for policy formulation (Box 3). It highlights interactions and interfaces between various actors and the workings of the system as a whole rather than the performance of its individual components (Lundvall, 1992).The following sections review the main distinctive attributes of NIS: *i)* patterns of scientific, technological and industrial specialisation, including in catching-up economies; *ii)* institutional profiles; *iii)* structures of knowledge interactions.

Box 2. **The concept of a national innovation system (NIS)**

National innovation systems are defined as the "... set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provide the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies". (Metcalfe, 1995)

From this perspective, the innovative performance of an economy depends not only on how the individual institutions (*e.g.* firms, research institutes, universities) perform in isolation, but on "how they interact with each other as elements of a collective system of knowledge creation and use, and on their interplay with social institutions (such as values, norms, legal frameworks)". (Smith, 1996)

Box 3. **Levels of NIS analysis**

NIS analysis embraces several complementary approaches.

At the micro level, it focuses on the internal capabilities of the firm and on the links surrounding one or a few firms, and examines their knowledge relationships with other firms and with non-market institutions in the innovation system, with a view to identifying unsatisfactory links in the value chain. Such analysis is most relevant to subject firms and is usually carried out by consulting firms, but it can also enrich policy makers' understanding when its findings are adequately related to broader issues.

At the meso level, it examines knowledge links among interacting firms with common characteristics, using three main clustering approaches: sectoral, spatial and functional. A ***sectoral (or industrial) cluster*** includes suppliers, research and training institutes, markets, transportation, and specialised government agencies, finance or insurance that are organised around a common knowledge base. Analysis of ***regional clusters*** emphasises local factors behind highly competitive geographic agglomerations of knowledge-intensive activities. ***Functional cluster*** analysis uses statistical techniques to identify groups of firms that share certain characteristics (*e.g.* a common innovation style or specific type of external linkages).

At the macro level, it uses two approaches: macro-clustering and functional analysis of knowledge flows. ***Macro-clustering*** sees the economy as a network of interlinked sectoral clusters. ***Functional analysis*** sees the economy as networks of institutions and maps knowledge interactions among and between them. This involves the measurement of five types of knowledge flows: *i)* interactions among enterprises; *ii)* interactions among enterprises, universities and public research institutes, including joint research, co-patenting, co-publications and more informal linkages; *iii)* other innovation supporting institutional interactions, such as innovation funding, technical training, research and engineering facilities, market services, etc.; *iv)* technology diffusion, including industry adoption rates for new technologies and diffusion through machinery and equipment; *v)* personnel mobility, focusing on the movement of technical personnel within and between the public and private sectors.

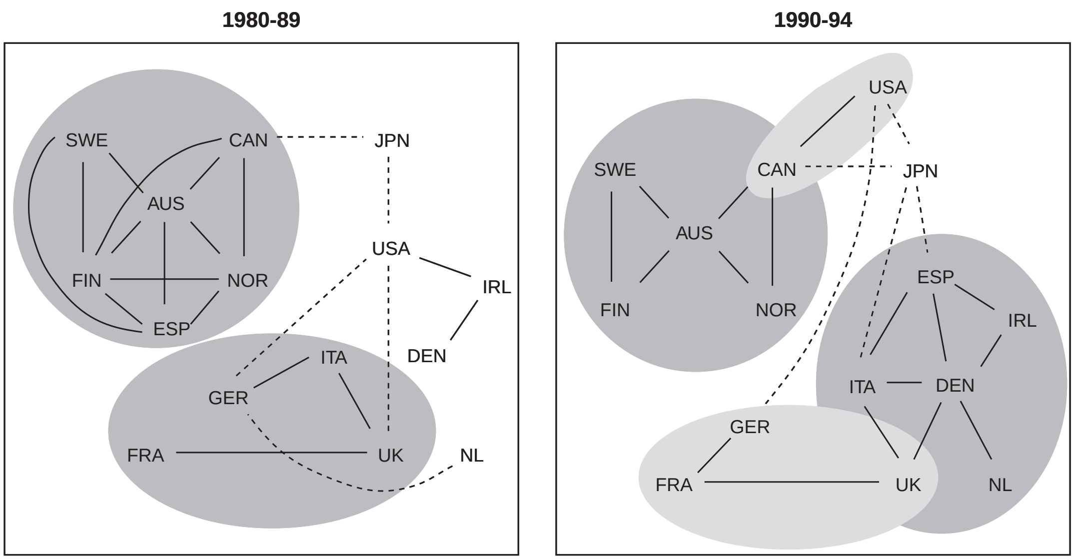
Specialisation in national innovation systems

The analysis of specialisation patterns is constrained by the scope and quality of existing data and cannot cover an NIS comprehensively. Indicators of scientific specialisation measure (in terms of publications) the relative weight of certain scientific disciplines in each country's science system, while two measures of technological change (patenting activity and R&D intensity) can show technological specialisation. Indicators of export performance demonstrate relative trade specialisation, and productivity patterns show differences in specialisation among OECD Member countries. The catching-up economies have specific features and adjustment problems.

Scientific specialisation

The scientific specialisations of NIS are quite different, even when only looking at fields that are likely to have the greatest impact on technological development (Table 2). Specialisation patterns were quite stable in the period 1981-93, but, owing to recent developments, they look more dissimilar in the 1990s than in the 1980s. Dissimilarities can partly be explained by country size *(e.g.* the broader science base of the United States), standard of living (*e.g.* the high shares of clinical medicine and biomedical research in countries that spend more on health care) and industrial specialisation (*e.g.* the specialisation of Germany and Japan in engineering sciences).

Figure 5. **Technological (dis)similarities among groups of countries**[1]
Based on patenting



1. Dotted lines indicate a significant negative correlation (dissimilarity) between the patterns of revealed technological advantage (RTA) of countries; straight lines indicate significant correlation (strong similarity) (at a 5% significance level).

Source: OECD.

On the other hand, certain countries display considerable similarities. Germany and Japan have a common specialisation in engineering, technology, chemistry and physics; France, Germany and Italy are all specialised in chemistry, physics and mathematics. The scientific efforts of United States are more evenly spread; this explains the pronounced difference with most other countries. Austria, the Netherlands, the Nordic countries and the United Kingdom are all relatively specialised in clinical medicine, a focus that has increased in the United Kingdom in the 1990s. Despite this pronounced specialisation, citation shares indicate that the UK science base – like that of the United States – appears to be fairly strong over a broad range of fields.

Technological specialisation

National innovation systems also differ in their patterns of technological specialisation. An examination of long-term historical developments (Vertova, 1997), as well as of more recent trends (Patel and Pavitt, 1996), points to the following features:

- A limited number of countries show strong similarities; there are no overall signs of convergence (Figure 5).

Table 2. **Specialisation patterns in science, selected scientific fields, 1981 and 1995**

	United States	Japan	Germany	France	Italy	United Kingdom	Canada	Australia	Austria	Denmark	Finland	Netherlands	Norway	Sweden	Switzerland
1981															
Biology	104	89	85	68	54	106	158	206	58	75	61	95	121	59	46
Biomedical research	108	89	73	102	93	100	102	83	54	96	93	121	101	115	92
Chemistry	65	187	141	137	149	93	92	90	106	55	61	110	72	68	108
Clinical medicine	105	68	92	95	101	107	80	91	142	153	154	92	138	153	116
Earth and space sciences	121	35	71	92	99	104	136	144	50	61	59	80	98	45	65
Engineering and technology	111	133	106	65	65	99	106	67	73	35	63	73	43	61	88
Mathematics	106	63	156	111	63	73	129	87	131	82	93	84	61	49	53
Physics	89	135	122	130	133	85	84	69	100	85	70	121	47	56	139
1995															
Biology	97	82	76	67	59	101	172	231	65	127	111	119	158	99	65
Biomedical research	113	89	76	129	83	100	98	83	70	98	79	100	78	97	101
Chemistry	73	137	148	116	111	88	84	74	100	65	67	77	73	72	104
Clinical medicine	106	87	87	80	106	115	88	102	135	128	144	120	129	133	106
Earth and space sciences	121	45	72	88	86	104	158	122	66	106	87	92	160	74	71
Engineering and technology	108	115	92	80	89	96	125	90	66	46	78	70	69	68	60
Mathematics	109	37	101	182	112	77	114	79	101	90	51	77	86	66	74
Physics	83	140	143	118	128	79	70	66	102	77	68	82	46	82	133
Differences between periods															
Biology	–6.1	–6.7	–9.3	–1.2	5.0	–5.4	14.3	25.6	6.3	51.6	49.8	24.5	37.3	40.3	19.4
Biomedical research	4.6	–0.6	3.3	27.5	–10.2	0.0	–3.9	–0.8	15.8	2.4	–13.9	–20.4	–22.9	–17.8	8.5
Chemistry	7.8	–50.3	6.7	–20.7	–38.0	–5.4	–7.5	–16.4	–5.9	9.8	5.5	–33.6	1.6	4.4	–4.2
Clinical medicine	0.9	19.0	–4.8	–15.1	4.9	8.2	7.5	10.5	–6.2	–25.2	–9.8	28.0	–8.8	–20.0	–10.7
Earth and space sciences	–0.1	10.5	1.0	–4.3	–12.5	0.0	21.9	–21.7	16.2	45.3	28.0	12.4	62.1	28.5	6.1
Engineering and technology	–3.0	–17.3	–14.5	15.3	24.3	–3.7	18.3	23.6	–6.9	11.0	14.8	–3.1	25.7	6.2	–28.1
Mathematics	3.4	–26.0	–55.4	71.2	49.5	4.8	–15.5	–8.1	–30.7	7.8	–41.8	–7.3	25.5	16.4	21.1
Physics	–6.6	4.7	20.0	–11.8	–4.9	–6.2	–13.9	–2.4	2.2	–7.9	–1.4	–38.9	–0.8	25.9	–5.8
Correlation between years	0.954	0.898	0.734	0.594	0.637	0.913	0.929	0.948	0.929	0.700	0.598	0.123	0.768	0.863	0.866

Note: For a given country (region) and field, this indicator is defined as the share of publications in that scientific field in relation to the total number of publications by that country (region), divided by the share of that field in total world publications × 100. Values greater than 100 indicate relative specialisation.
Source: National Science Foundation, *Science and Engineering Indicators 1998;* OECD calculations.

- For most countries, there is a significant positive correlation between past and present patterns, an indication that technological capabilities accumulate over time and that development is strongly path-dependent. This does not exclude rapid structural change in some countries, but even then the coefficient of correlation with previous periods is positive.

"Clustering" of countries with similar technological specialisation shows strong similarities between smaller, mainly resource-based economies (although to a lesser degree in the 1990s than in the 1980s) as well as some similarities among the larger European countries. It also reveals the unique specialisation patterns of Japan and the United States. At the same time, structural change is reflected in the changing composition of country "clusters" over time. Important structural changes can be observed for Denmark and Spain, and for Finland and Ireland.

Empirical analysis based on patents granted at the US Patent and Trademarks Office (USPTO) also reveals certain specialisation patterns (Table 3). Compared with the OECD average (the data cover all 29 OECD economies), Australia, Belgium, Denmark and the Netherlands show relatively strong innovative activity in agro-food; Belgium, Denmark, France, Germany, Italy, Switzerland and the United Kingdom have strong patenting activity in the health area (mainly due to patenting of pharmaceutical products); Germany and Sweden have strong performance in mechanical engineering; Finland and Sweden in paper; and Japan, Korea and the Netherlands are strong innovative performers in computing and information goods. Although some of these patterns are quite stable over time, as indicated by high correlation coefficients over the two periods, there are also some dynamic patterns. The relative patenting performance of Japan in the transport segment over the period 1990-96, for instance, is much weaker than its performance over the period 1980-89. Because of the large weight of the United States in the patents granted by USPTO, no clear patterns can be perceived, while the low number of patents granted to firms in small OECD economies limits the scope for identifying their technological strengths.

Export specialisation

The differences in the scientific and technological specialisation of OECD economies are partly reflected in patterns of export specialisation (Table 4). Although science and technology are not equally important to all sectors of the economy, strong technological performance may be reflected in strong export performance. The strong patent performance of Australia, Denmark and the Netherlands in food products is reflected in their export performance, the strong innovative performance of Belgium, Denmark and Switzerland in pharmaceuticals, and the relatively strong patent performance of Japan, the Netherlands, the United Kingdom and the United States in office and computing equipment. These patterns do not always hold, however, and more detailed work – for instance, in the form of cluster analysis – is required to substantiate these findings.

Patterns of productivity growth

Patterns of productivity growth also indicate specialisation in OECD economies. Recent statistical analysis at the OECD indicates major differences in productivity growth rates in different industries.[1] This implies that country-specific factors, which apply uniformly across industries, such as broad macro-economic conditions, are unlikely to be major determinants of labour productivity growth. Industry-specific factors play a more significant role, as different firms within an industry are, by definition, engaged in similar activities and operate in the same markets. They therefore use similar types of input configurations, benefit from the same knowledge about technologies and undergo similar shocks.

The key role played by specialisation is observable in country/industry-specific effects, the dominant feature of productivity growth rates. The stronger the trend towards specialisation based on specific national competencies in particular industries, the less it is likely that productivity growth will evolve along similar lines, even within the same industry. It is likely that international trade and openness are instrumental in this process. They stimulate competition and the transfer of knowledge and thus lead to similar productivity growth patterns in industries. At the same time, trade reinforces international specialisation, as it puts a premium on accumulated experience and know-how specific to certain industries in certain countries.

Table 3. **Specialisation patterns in patenting activity, selected areas**

	Australia	Austria	Belgium	Canada	Denmark	Finland	France	Germany	Italy	Japan	Netherlands	Korea	Sweden	Switzerland	United Kingdom	United States
1980-89																
Agro-food	220	61	197	148	228	74	83	85	101	58	172	74	88	144	115	110
Health	55	65	132	52	130	45	120	140	178	82	103	75	32	219	136	93
Construction	327	289	88	237	142	151	100	77	103	34	105	129	148	87	90	116
Mechanical engineering	101	112	34	77	135	89	119	135	99	116	54	76	133	72	116	89
Paper	88	169	166	303	85	3 367	82	114	72	36	14	0	880	56	117	83
Transport	111	124	27	108	41	95	115	130	101	141	48	106	117	49	111	83
Chemistry	62	63	167	60	88	59	117	134	134	82	114	68	38	175	123	97
Computing equipment	40	40	59	73	39	32	106	64	67	152	170	130	52	53	90	94
Total number of patents	3 422	3 087	2 643	13 149	1 632	1 823	23 743	66 551	9 343	122 494	7 622	523	7 923	12 332	24 700	392 809
Share in OECD-16	0.5	0.4	0.4	1.9	0.2	0.3	3.4	9.6	1.3	17.7	1.1	0.1	1.1	1.8	3.6	56.6
1990-96																
Agro-food	192	82	214	145	285	94	85	87	94	52	204	50	106	120	131	115
Health	88	88	172	71	257	76	148	156	180	73	113	53	65	218	162	95
Construction	280	314	77	291	141	118	88	80	103	32	72	39	128	102	92	121
Mechanical engineering	137	125	40	91	103	71	117	161	101	104	57	57	148	91	118	90
Paper	47	109	96	253	132	3 170	104	159	51	27	16	15	848	29	95	92
Transport	129	117	31	107	41	62	105	159	81	112	41	57	124	43	97	91
Chemistry	63	78	197	69	153	74	144	160	160	82	131	48	62	180	147	93
Computing equipment	43	35	52	58	26	70	88	50	52	154	136	248	64	42	85	89
Total number of patents	3 068	2 410	2 564	14 114	1 408	2 398	20 130	49 386	8 493	150 672	6 089	5 539	5 114	8 324	17 523	378 257
Share in OECD-16	0.5	0.4	0.4	2.1	0.2	0.4	3.0	7.3	1.3	22.3	0.9	0.8	0.8	1.2	2.6	56.0
Differences																
Agro-food	28	21	17	3	57	21	1	2	6	5	32	25	18	24	16	5
Health	33	23	40	19	127	30	28	16	3	9	10	22	32	0	26	2
Construction	47	25	11	54	0	33	12	2	0	1	33	90	20	15	2	5
Mechanical engineering	37	12	5	14	33	18	2	26	2	13	3	19	15	19	2	1
Paper	41	60	70	49	47	197	21	46	21	9	2	15	32	27	22	9
Transport	18	6	4	1	1	33	10	28	20	29	7	50	6	6	15	8
Chemistry	1	16	29	9	64	16	28	27	26	0	18	20	24	5	24	4
Computing equipment	3	6	7	15	13	38	18	14	15	2	35	118	12	11	5	5
Change in share in OECD-16	0.0	0.1	0.0	0.2	0.0	0.1	0.4	2.3	0.1	4.6	0.2	0.7	0.4	0.5	1.0	0.6
Correlation between periods	0.95	0.94	0.89	0.95	0.84	1.00	0.67	0.96	0.97	0.98	0.93	0.56	1.00	0.97	0.84	0.92

Note: For each country and cluster, this indicator shows the share of patents of a country in a cluster, relative to the share of that cluster in total patents. Values over 100 indicate relative specialisation.
Source: OECD calculations on the basis of data from CHI Research.

Table 4. **Export specialisation by manufacturing industry, 1980-94**[1]

	Food, beverages and tobacco ISIC 31		Textiles, apparel and leather ISIC 32		Wood products and furniture ISIC 33		Paper, paper products and printing ISIC 34		Chemicals ISIC 35		Pharmaceuticals ISIC 3522		Non-metallic mineral products ISIC 36	
	1980	1994	1980	1994	1980	1994	1980	1994	1980	1994	1980	1994	1980	1994
United States	94	98	73	63	69	78	92	98	94	95	98	71	53	54
Canada	78	64	20	25	379	456	432	294	73	68	17	17	35	56
Japan	14	7	66	31	9	6	22	18	51	60	19	20	81	71
Australia	522	390	78	158	100	88	25	46	44	76	47	103	25	53
New Zealand	728	703	236	174	146	242	164	177	24	50	20	23	31	24
Austria	43	44	185	135	371	248	176	197	74	83	101	117	228	178
Belgium	97	129	124	125	91	84	63	71	136	149	102	136	132	154
Denmark	406	369	94	99	220	312	55	66	76	93	182	246	102	96
Finland	39	36	125	40	707	432	814	747	62	61	33	27	60	76
France	141	161	106	107	57	62	63	85	114	119	126	134	118	122
Germany[2]	63	67	80	86	69	62	62	86	103	108	103	100	101	93
Greece	232	287	376	531	28	46	35	29	152	111	45	48	344	338
Iceland	947	1 057	92	26	0	2	3	5	3	3	0	2	1	7
Ireland	447	287	144	58	28	21	46	28	99	148	193	287	106	52
Italy	60	72	259	314	154	175	46	60	92	77	80	78	246	248
Netherlands	228	270	75	85	44	55	71	93	209	161	87	114	63	72
Norway	150	169	37	30	105	141	245	213	102	133	19	29	48	61
Portugal	145	90	479	640	493	279	170	168	70	65	77	24	165	281
Spain	141	129	153	129	101	74	115	86	89	88	91	79	264	243
Sweden	22	29	45	31	328	304	406	338	63	84	90	211	64	54
Switzerland	42	43	101	74	35	46	60	69	119	163	482	451	39	52
Turkey	234	216	711	730	33	28	8	20	68	57	24	23	378	195
United Kingdom	85	93	89	89	32	29	60	87	114	123	145	158	90	79
Share in total OECD manufacturing exports	8.1	7.4	6.5	5.7	2.1	2.1	3.8	3.7	18.8	17.1	1.1	1.9	1.9	1.6

	Basic metals ISIC 37		Metal products, machinery and equipm. ISIC 38		Office and computing equipment ISIC 3825		Radio, TV and communication equipment ISIC 3832		Aircraft ISIC 3845		Motor vehicles ISIC 3843	
	1980	1994	1980	1994	1980	1994	1980	1994	1980	1994	1980	1994
United States	55	43	121	115	222	154	100	139	328	273	82	82
Canada	136	143	85	97	78	63	52	56	70	78	173	221
Japan	147	90	142	144	83	166	290	217	3	8	182	153
Australia	291	317	28	50	20	96	12	41	35	61	15	28
New Zealand	54	123	12	19	1	4	6	12	2	6	6	4
Austria	132	146	79	89	24	24	90	85	4	9	38	78
Belgium	177	169	60	62	25	26	68	40	24	13	97	121
Denmark	36	42	72	68	27	57	66	57	21	24	18	15
Finland	79	168	47	68	15	66	46	110	3	5	16	24
France	107	111	91	87	81	62	62	61	65	211	114	93
Germany[2]	97	101	115	107	78	50	84	65	58	82	137	127
Greece	140	189	14	20	0	5	14	14	0	32	6	5
Iceland	166	265	3	10	0	14	0	0	14	62	0	0
Ireland	10	24	59	82	331	425	76	167	12	20	21	4
Italy	66	90	89	82	105	50	44	38	30	43	70	54
Netherlands	66	87	54	66	54	143	110	81	48	46	24	28
Norway	271	401	60	54	43	39	41	39	4	18	14	16
Portugal	27	21	40	48	42	5	97	56	38	20	24	43
Spain	155	133	74	93	47	39	25	42	19	75	109	190
Sweden	106	152	105	97	111	30	111	116	5	36	111	105
Switzerland	64	67	106	90	36	27	48	36	33	15	7	9
Turkey	45	277	20	23	0	2	10	20	0	10	42	19
United Kingdom	75	94	104	96	123	166	71	103	238	129	74	64
Share in total OECD manufacturing exports	9.2	5.1	47.3	55.2	2.2	4.6	4.0	7.3	2.7	3.0	11.6	14.1

1. The indicator is defined as the share of an industry's exports in the country's total manufacturing exports, divided by the industry's OECD-wide share in total manufacturing exports.
2. Figures for Germany for 1994 refer to unified Germany.

Source: OECD, STAN database, April 1997.

Innovation in catching-up economies

Catching-up economies face a somewhat different specialisation pattern from most other OECD economies. Catch-up theory argues that countries at low income levels may be able to grow faster than those at high income levels since they can use the technology already developed by the latter. Catching up may benefit from late development, but there is no guarantee that it will. Economic theory suggests that it depends primarily on two factors, namely social capability and technological congruence (Abramowitz, 1990). Social capability involves the availability of an appropriate institutional framework, the role of government, primarily its capability for economic policy making and the population's technological and skills level. Technological congruence refers to the suitability of technology from high-income countries for use in follower countries.

An important difference between catching-up and other economies is the initial availability of a substantially larger stock of advanced technology to draw on. While catching-up economies may experience rapid economic growth and structural change for an extended period, their catch-up potential will eventually be exhausted. They will then need to expand their indigenous science and technology base. The NIS Focus Group on Catching-up Economies addressed the following issues:

- Conditions under which less advanced economies can catch up with more advanced economies.
- Time at which their latecomer advantage will be exhausted.
- Current problems faced by catching-up economies confronted with rapid globalisation and the revolution in information and communications technology.
- Moving from imitative to an innovative economies.

How does the NIS of a catching-up economy differ from that of a high-income OECD economy? A number of differences stand out. First, the R&D intensity of these economies is relatively low, often below 1% of GDP, while the share of researchers in the labour force is also quite low, and these countries provide a relatively limited contribution to scientific activity (Table 5). The low R&D intensity is due to low government and private spending on R&D, although the public sector tends to play a larger role in total R&D expenditure than the private sector, as the country still needs to develop its national science and technology base and the private sector is often relatively weak in technological terms.[2] The economic structure of these countries is often more geared towards low- and medium-technology industries, and this contributes to relatively low private R&D spending. Second, these countries' innovative activity, as measured by an index of technological strength, also tends to be quite low compared to higher-income economies. Their technology balance of payments often shows a negative balance, which indicates that they are highly dependent on technology imports. Third, as the transfer and adoption of technology plays a very large role in these countries, their NIS system has a strong focus on technology transfer, adoption and diffusion.

The differences between the catching-up and other OECD economies should not be exaggerated, however. OECD countries have different strengths and weaknesses and can learn from each other in many areas. The variation in sectoral productivity performance across the OECD area also suggests that there is still scope for catch-up even among high-income countries (OECD, 1998*a)*. In addition, the globalisation of science and R&D and the growing international networking of firms imply that technology adoption from abroad is of increasing importance to all OECD economies, whether they are catching-up economies or not.

Institutional profiles

Innovation processes have many common characteristics and are influenced by several common trends. Countries differ, however, in their translation of these factors into innovation and, ultimately, into new products and services. The institutional structure of countries' national innovation systems helps explain such international differences. The weight and relative focus of the public and private sectors in funding and performing R&D (Figure 6), the objectives and instruments of government support for industrial technology (Table 6), the role of different government ministries, and the scientific, technological and industrial specialisation of OECD

Table 5. **Income and technological performance, 1995**[1]

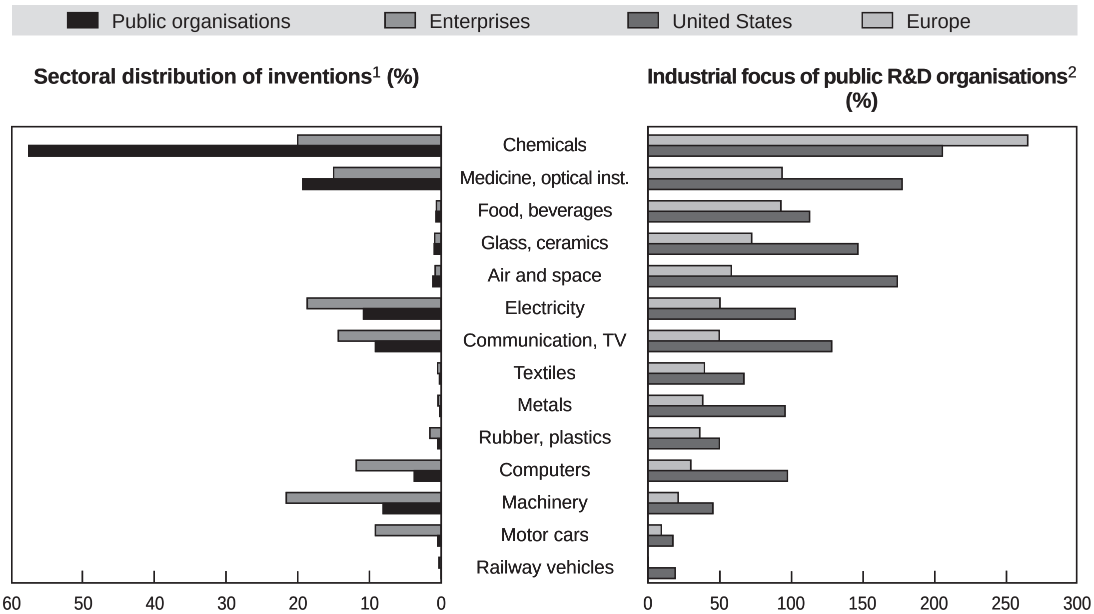
	Income level, 1996	Indicators of scientific and technological performance							
	GDP per head of population as a % of OECD average	Gross domestic expenditure on R&D as a % of GDP, 1995	Researchers per 10 000 labour force, 1995	Scientific and technical articles per unit of GDP, 1995[2]	Government financed R&D as a % of GDP, 1995	Government financing of R&D as a % of total R&D, 1995	Business expenditure on R&D as a % of business GDP, 1995	Technological strength per US$ of R&D, 1995[3]	Technological intensity, 1995[4]
United States	140	2.6	74	20	0.9	34.6	2.1	410	10.4
Norway	128	1.7	73	21	0.8	43.5	1.4	..	..
Switzerland	126	2.7	46	37	0.8	28.4	2.2	..	..
Japan	121	2.8	83	15	0.6	20.9	2.2	354	10.6
Iceland	118	1.5	72	23	0.9	62.9	0.8		..
Denmark	117	1.8	57	31	0.7	39.2	1.7	87	1.6
Canada	114	1.7	53	25	0.6	33.7	1.4	203	3.3
Belgium	112	1.6	53	20	0.5	26.4	1.4	111	1.8
Austria	111	1.5	34	18	0.8	47.6	1.1	125	1.9
Australia	107	1.6	64	24	0.8	47.5	0.9		..
Germany	107	2.3	58	21	0.8	37.0	1.9	215	5.0
Netherlands	106	2.0	46	31	0.9	42.1	1.3	170	3.5
France	103	2.3	60	20	1.0	42.3	1.9	115	2.7
Italy	102	1.1	33	13	0.5	46.2	0.8	101	1.0
Sweden	100	3.6	68	41	1.0	33.0	3.9	147	5.3
United Kingdom	98	2.1	52	29	0.7	33.3	1.8	160	3.2
Finland	96	2.3	61	35	0.9	35.1	2.2	114	2.7
Ireland	92	1.4	59	16	0.3	22.6	1.4	69	1.0
New Zealand	88	1.0	35	29	0.6	52.3	0.3	..	..
Spain	77	0.9	30	16	0.4	43.6	0.5	21	0.2
Korea	72	2.7	48	5	..	19.0	2.3	25	0.7
Portugal	70	0.6	24	7	0.4	65.2	0.2	8	0.0
Greece	67	0.5	20	16	0.2	46.9	0.2	..	..
Czech Republic	64	1.2	23	15	0.4	35.5	0.9	..	..
Hungary	47	0.8	26	20	0.4	47.9	0.4	115	0.7
Mexico	36	0.3	6	2	0.2	66.2	0.1	15	0.0
Poland	35	0.7	29	17	..	64.7	0.4	..	..
Turkey	30	0.4	7	4	0.2	64.5	0.1	..	..

1. Or latest available year.
2. Scientific and technological articles per billion US$ of GDP. See National Science Foundation (1998).
3. Technological strength is determined by multiplying the number of patents with an index of their impact. This index measures how frequently a country's recent patents are cited by all of a current year's patents. The patents refer those granted at the US Patent Office. Data are from CHI research.
4. Technology intensity compares the technological strength of a country with its GDP expressed in PPP$. See OECD, *Science, Technology and Industry Outlook 1998* for details.

Source: OECD calculations on the basis of the MSTI database, CHI Research, National Science Foundation (1998), and OECD, *Science, Technology and Industry Outlook 1998.*

economies all affect countries' institutional arrangements. The NIS Focus Group on Organisational Mapping has produced useful insights into the role of institutions in the innovation process.

Figure 6. **Industrial focus of public *vs.* private research**



1. Originating in Europe, Japan and the United States, and for which a patent has been applied for in at least two countries between 1991 and 1996.
2. Ratio of the number of public inventions to business inventions.

Source: European Commission, *The Competitiveness of European Industry*, 1998. (Data from EPIDOS and IFO Patent Statistics.)

In terms of their ***main functions***, a distinction can be made between institutions that formulate or co-ordinate policy, those that finance R&D, those that fund R&D, those that perform a bridging role and those that deal with related functions (technology transfer and diffusion, promotion of technology-based firms, human resource mobility). The most important of these institutions are governments (local, regional, national and international, with different weights by country) that play the key role in setting broad policy directions; bridging institutions, such as research councils and research associations, which act as intermediaries between governments and the performers of research; private enterprises and the research institutes they finance; universities and related institutions that provide key knowledge and skills; and other public and private organisations that play a role in the national innovation system (public laboratories, technology transfer organisations, joint research institutes, patent offices, training organisations and so on).

Examples of the complex institutional arrangements in place across the OECD area are provided in Figure 7, which shows R&D financing and performance in France, and in Figure 8, which shows an institutional map of the Norwegian system of public support to innovation. The Norwegian system consists of six layers with different functions, with many institutions present in several layers. The top layer consists of the general policy-making bodies; the second formulates and implements technology and innovation policies; the third consists of institutions that facilitate and give direction to R&D and innovation; the fourth contains the R&D-performing institutions; the fifth has institutions that facilitate technology diffusion; and the sixth contains private and public business operations. Figure 9 shows – in a slightly different manner – how various institutions participate in the Australian NIS. Similar institutional maps are

Table 6. **Government support for industrial technology by type, 1995**

	Australia 1994	Canada 1995	Finland 1996	France 1995	Germany 1993	Japan 1995	Mexico 1995	Netherlands 1996	United Kingdom 1995	United States 1995
Fiscal incentives										
Fiscal incentives	38.9	46.9	0.0	8.8	0.0	1.8	0.0	25.0	0.0	6.2
Grants and forgiven loans	14.1	9.7	42.7	14.6	28.0	1.2	2.3	12.0	4.9	15.5
Other	0.0	0.4	2.7	0.0	0.0	1.3	0.0	0.0	0.0	0.0
Total	**53.0**	**57.0**	**45.4**	**23.4**	**28.0**	**4.3**	**2.3**	**37.0**	**4.9**	**21.6**
Mission-oriented contracts and procurement										
Defence	9.7	4.7	0.0	35.6	19.5	8.3	..	7.4	61.2	58.8
Space	0.2	9.8	7.4	19.4	11.2	7.5	..	12.3	4.5	8.7
Other	0.0	14.8	0.0	4.3	1.8	10.9	..	1.7	7.3	9.4
Total	**10.0**	**29.3**	**7.4**	**59.4**	**32.5**	**26.6**	**..**	**21.3**	**73.1**	**76.9**
S&T Infrastructure										
Technology institutes, etc.	28.8	5.6	34.7	0.9	13.7	21.6	14.3	11.0	2.6	0.5
Academic engineering	0.2	0.0	0.0	0.0	1.6	0.0	..	0.9	6.3	0.0
Other	8.0	8.1	12.5	16.4	24.3	47.5	83.4	29.7	13.2	0.9
Total	**37.0**	**13.7**	**47.2**	**17.2**	**39.5**	**69.1**	**97.7**	**41.7**	**22.1**	**1.4**
GRAND TOTAL	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: OECD calculations based on R&D database, PSI database and information supplied by Member countries, March 1998.

available for other OECD economies (Austria, Belgium, Finland, Germany, Spain, Sweden, Switzerland, United Kingdom – see Annex 3).

The institutional arrangements shown in Figures 7, 8 and 9 are only partly captured in aggregate R&D data which indicate that OECD countries differ substantially in terms of the weight of the public and private sector in financing R&D; in terms of the role of foreign financing in total R&D expenditure; and in terms of the main performers of R&D (OECD, 1998*a*). While the data only cover R&D outlays, they suggest considerable institutional diversity, which may have an important bearing on innovative performance. For instance, in Belgium, Sweden and Switzerland, the business sector is clearly the dominant source of R&D financing, whereas government funding is about as important as business funding in Australia, Austria, Norway and Spain. Aggregate data also suggest that there are important differences in performing sectors. In Australia and Spain, the government sector performs a large share of R&D, but it plays only a minor role in Austria, Belgium, Sweden and Switzerland.

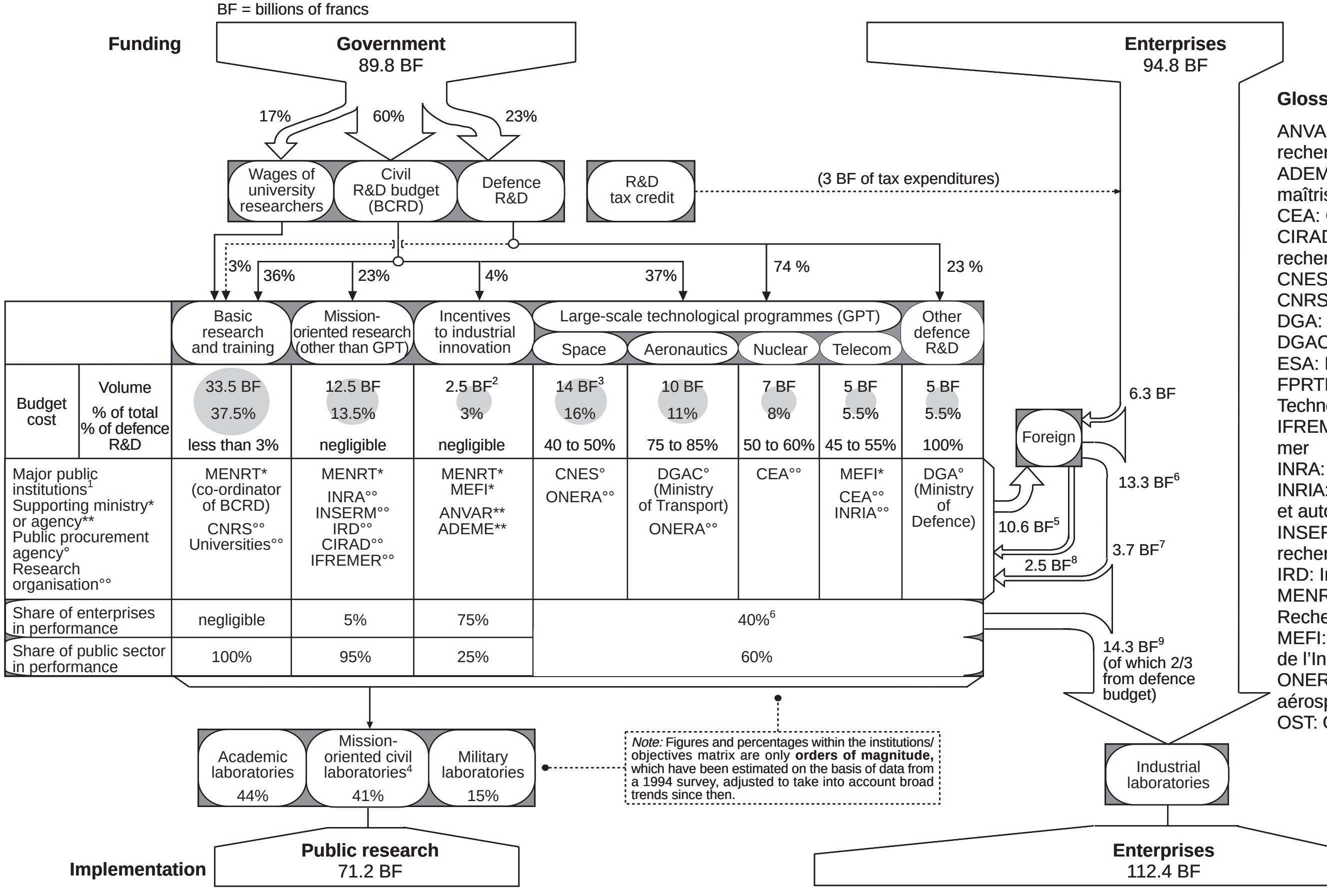
Institutional mapping allows *looking beyond aggregate statistics* at the main funders and providers of different types of research (basic, pre-competitive, applied and experimental); the degree of (formalised) policy integration and co-ordination; the degree of centralisation of funding; whether governments play a direct role or act mainly through intermediary institutions; the role of technology transfer institutions; etc. Institutional mapping, although it is not yet standardised, is now available for 11 countries and highlights important *institutional differences* which complement the aggregate data. For instance, according to the aggregate data, the role of the public and private sectors in funding and performing R&D is almost identical in Sweden and Switzerland, but these countries differ markedly in how R&D is organised and performed. In Switzerland, regional authorities (cantons) contribute significantly (37% in 1992) to university funding, whereas the bulk of federal support is indirect and channelled through the Federal Institutes of Technology and associated research institutes. In Sweden, in contrast, more than 55% of university funding comes directly from the Ministry of Education, about 17% is channelled from the Ministry of Education through the research councils and the remainder is funded by R&D agencies from specialised ministries. In addition, the Swedish government plays a substantially more important role than the Swiss government in financing private sector R&D, mainly owing to funding provided by the Ministry of Defence.

Apart from giving better information about a country's specific institutional arrangements, institutional mapping also provides useful policy insights. It can help to *identify mismatches*, overlaps and deficiencies in support programmes. Although the Focus Group on Institutional Mapping has not yet completed its work, some results are already available. For Belgium, there appear to be considerable differences between the Flemish and the Walloon innovation system. In Flanders, firms have strong links with other firms (both national and international) and are heavily engaged in European research projects (such as EUREKA), while firms in Wallonia primarily co-operate with universities and have fewer links with industry and European research programmes. It is important to take such regional differences into account in international policy discussions. They can also serve as a useful learning tool for best-practice policies.

Institutions matter. Proper institutional arrangements can help to improve policy co-ordination, enhance transparency and information flows within the economy, improve the efficiency of government action, and reduce systemic mismatches. Achieving consistency and credibility in science and innovation policy depends on the extent to which co-ordination between ministries can be ensured and whether various stakeholders can be involved in policy formulation. Policy-making arrangements in OECD countries differ considerably, however (Box 4), and further analysis is needed to know whether they are all able to improve the distribution power of innovation systems and increase their contribution to economic performance.

Institutional mapping is especially useful to trace ***flows of disembodied, tacit knowledge*** which take place in non-market-mediated, joint R&D projects in the pre-competitive or near-market stage. As these flows may be difficult to capture in other types of NIS-related analysis, institutional mapping may therefore be regarded as an important complement to other work on knowledge flows in national innovation systems, such as cluster analysis (see below). Detailed institutional analysis also makes it possible to

Figure 7. **Funding and implementation of R&D in France, 1997**



Glossary

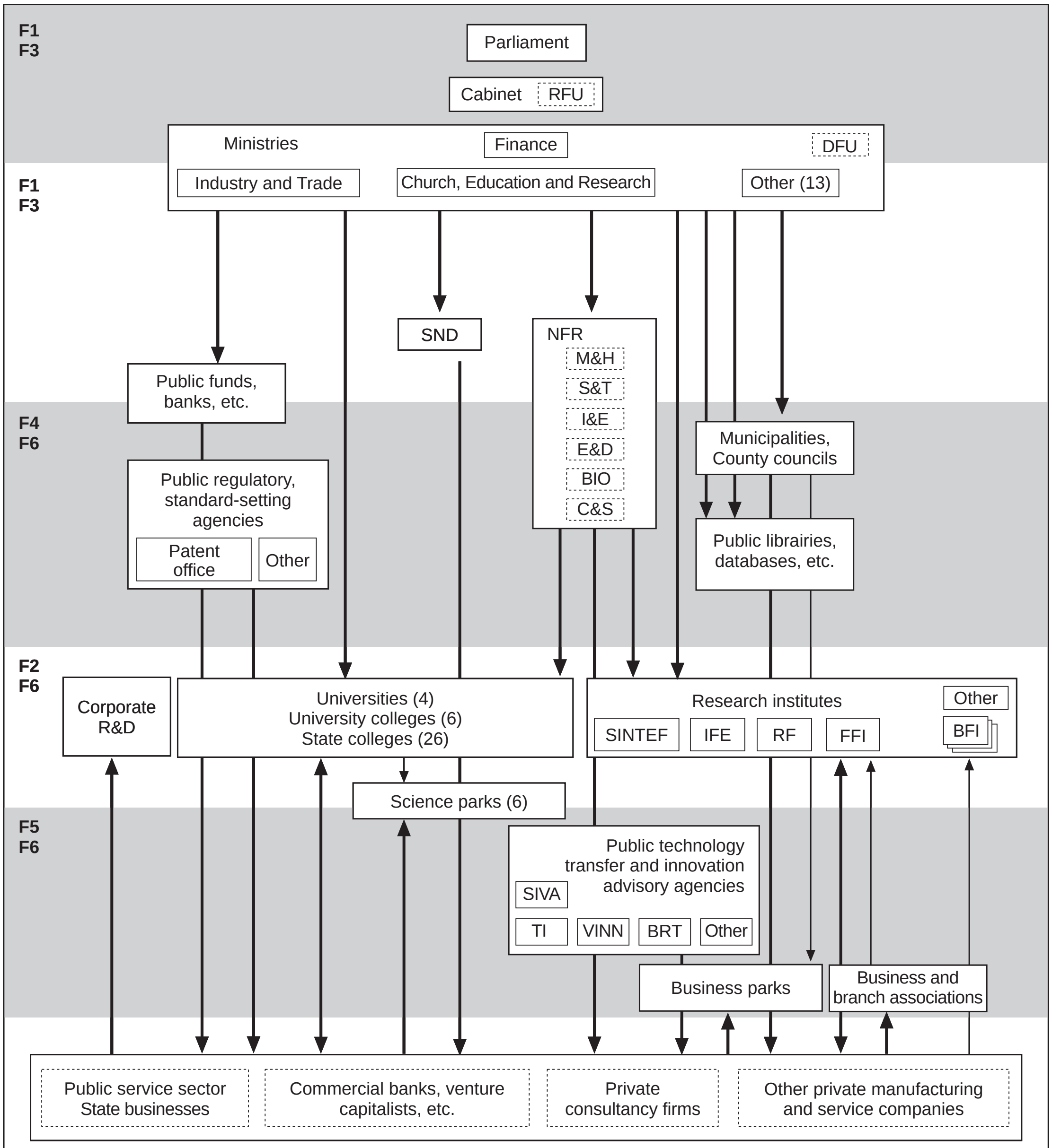
ANVAR: Agence nationale de valorisation de la recherche
ADEME: Agence de l'environnement et de la maîtrise de l'énergie
CEA: Commissariat à l'énergie atomique
CIRAD: Centre de coopération internationale en recherche agronomique pour le développement
CNES: Centre national d'études spatiales
CNRS: Centre national de la recherche scientifique
DGA: Délégation générale à l'armement
DGAC: Direction générale de l'aviation civile
ESA: European Space Agency
FPRTD: Framework Programme for Research and Technological Development of the European Union
IFREMER: Institut français pour l'exploitation de la mer
INRA: Institut national de la recherche agronomique
INRIA: Institut national de recherche en informatique et automatique
INSERM: Institut national de la santé et de la recherche médicale
IRD: Institut de recherche pour le développement
MENRT: Ministère de l'Éducation nationale, de la Recherche et de la Technologie
MEFI: Ministère de l'Économie, des Finances et de l'Industrie
ONERA: Office national d'études et de recherches aérospatiales
OST: Observatoire des sciences et des techniques

1. Each institution is characterised according to its main mission, which does not exclude its involvement in others.
2. Excluding the R&D tax credit and the European FPRTD.
3. Including the French contribution to the European Space Agency.
4. Including international public laboratories.

Source: OECD from budget data (projet de loi de finance 1999), MENRT statistics, and OST indicators.

5. French participation in international research organisations (including the contribution to the research budget of the European Union).
6. Including R&D procurement from enterprises by international organisations (*e.g.* FPRTD, ESA).
7. R&D procurement from enterprises by French public organisations.
8. R&D procurement from French public organisations by international organisations (including FPRTD).
9. Excluding R&D procurement from enterprises by international organisations (*e.g.* FPRTD, ESA).

Figure 8. **The Norvegian system of innovation – organisational structure**



Functions in institutional matrix

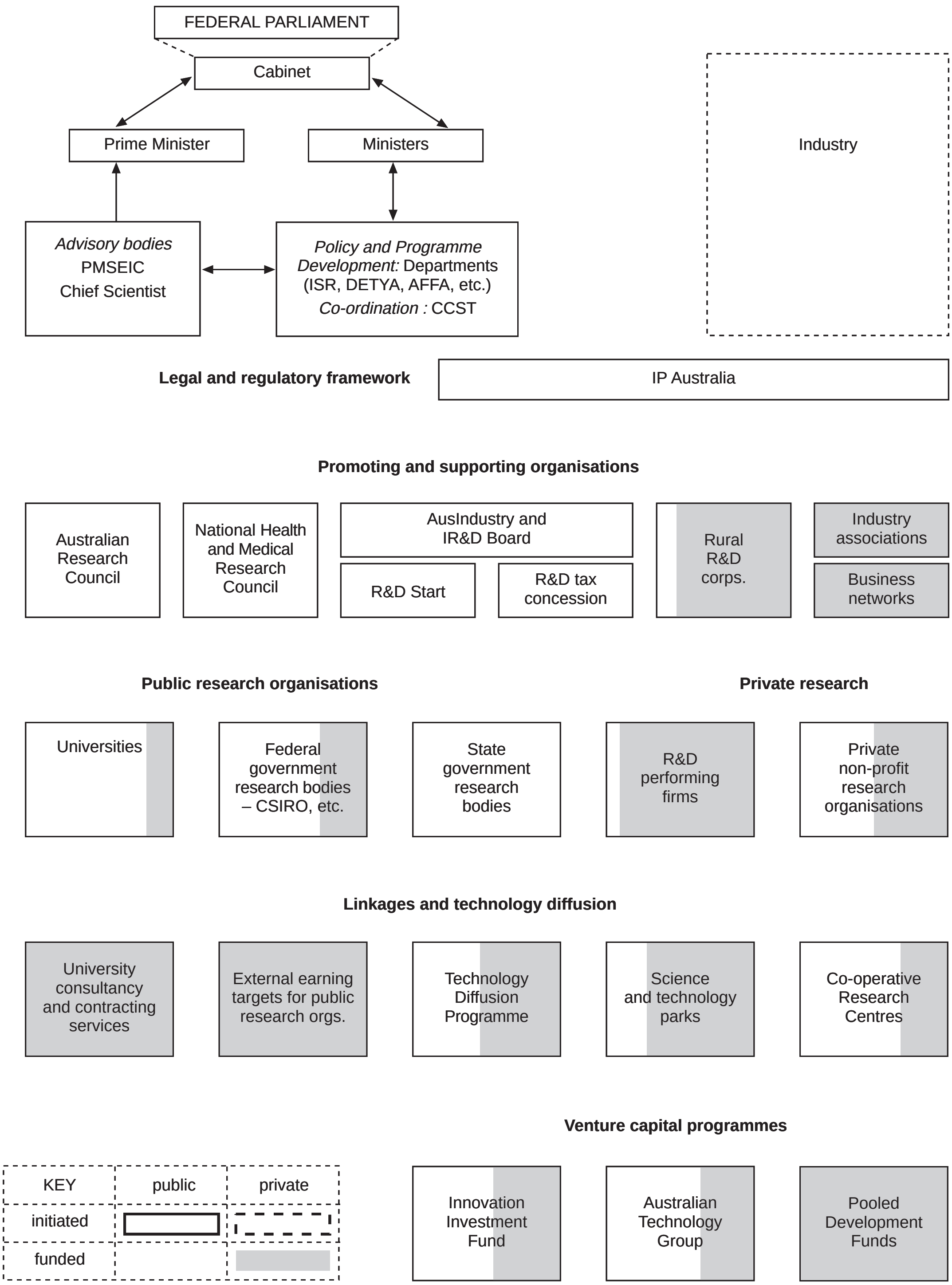
F1: Policy formulation, co-ordination, supervision and assessment
F2: Performing R&D (basic, pre-competitive, applied)
F3: Financing R&D
F4 : Promotion of human resource development and mobility
F5 : Technology diffusion
F6 : Promotion of technological entrepreneurship

RFU - The Government's Research Policy Board
DFU - The Interministerial Committee on Research Policy
SND - The Norwegian Industrial and Regional Development Fund
NFR - The Research Council of Norway
M&H - Medicine and Health
S&T - Science and Technology
I&E - Industry and Energy
E&D - Environment and Development
BIO - Bioproduction
C&S - Culture and Society

TI - National Institute of Technology
VINN - Advisory Office for Northern Norway
BRT - Regional advisory services for private businesses
BFI - Industry joint-owned research institutes; for instance the paper industry research institute
SINTEF - Foundation for Scientific and Industrial Research
IFE - Institute for Energy Technology
FFI - Norwegian Defence Research Establishment
RF - Rogaland Research

Source: STEP Group, 1997.

Figure 9. **The Australian system of innovation – organisational structure**



Source: Australian Department of Industry, Science and Resources, 1999.

Box 4. **The main policy-making institutions in national innovation systems**

Government ministries are the main institutions responsible for policy making. However, ministerial responsibilities, in terms both of policy making and of funding, differ considerably among OECD countries. In some, such as Germany and Norway, the Ministry of Education (which funds the universities) is responsible for more than half of the government funds committed to R&D. In Sweden, about 45% of all government funding originates from the Ministry of Education and about 24% from the Ministry of Defence. More typically, as in Australia and Finland, two-thirds or more of funds come from the Ministry of Education and an S&T or Trade and Industry ministry. In countries such as Canada, R&D funding decisions are spread over many ministries and agencies; the National Research Council, the largest spender, is responsible for only 14% of the total.

Although policy making is the shared responsibility of several ministries in most OECD countries, co-ordination mechanisms exist in several. For instance, the aim of Australia's Coordination Committee on Science and Technology, the UK Office for Science and Technology, and the Spanish Interministerial Commission for Science and Technology (CICYT) is to co-ordinate policy formulation across ministries. In Spain, the National R&D Plan creates the primary framework for such co-ordination. In a number of countries (*e.g.* Australia and Finland), policy making on science and technology issues involves the highest levels of government. For instance, Finland's Science and Technology Policy Council advises the government on science, technology and innovation policies; it is chaired by the Prime Minister and consists of five other ministers and ten high-level expert members. Most countries also have advisory institutions that help to formulate science and technology policy, such as the Swiss Science Council which advises the Federal Council on all questions related to science policy.

Other policy-making bodies are important as well. Regional (state and local) governments are particularly important in countries with a federal government (*e.g.* Australia, Belgium and Germany). In Belgium, the three regions (Brussels Capital Region, Flemish Region, Walloon Region) have many responsibilities for science and technology policy – particularly for funding for institutions of higher education). In Germany, the Science Council helps to co-ordinate state and federal support to innovation.

address more specific policy questions, such as whether co-operative arrangements among different actors (firms, universities and so on) at the pre-competitive level also lead to co-operation at the near-market or commercial level, or whether countries and technologies differ in this respect.

Linkages within and between national innovation systems

Links within the science system

The production of scientific knowledge is undergoing a major transformation (Gibbons et al., 1994). It increasingly cuts across disciplines, institutions and countries. The advancement of science is no longer the sole concern of universities and specialised research bodies, but involves a widening range, both national and international, of other institutions (corporate R&D labs, hospitals, etc.). Further, scientific knowledge is increasingly produced with an eye to its application.

Growing *international scientific collaboration* is a major characteristic of the changing science system. At the beginning of the 1990s, co-authored articles represented more than 50% of all scientific articles, with internationally co-authored articles accounting for more than 20% (Table 7). The share of co-authored articles involving at least one researcher based in another country has increased, but in most countries by less than national (or intra-regional) collaboration. Also, the accelerated development of science systems in some countries has led to a decline in their degree of internationalisation (*e.g.* China, the East Asian and Pacific countries, South and Central America). The United States is still the centre of international scientific collaboration. A little under one-quarter of all internationally co-authored articles involve US researchers – far more than those of any other country. Nevertheless, as the overall US share of scientific publishing is even greater (one-third of the total), its degree of internationalisation is lower than that of most other countries.

Table 7. **Patterns of international collaboration in science and engineering research, 1991-95**

Number of scientific articles and percentage shares

Source country/region	Total (in thousands)	Share of multi-authored (%)	Internat. co-authored (%)	Share of all articles	Share of total internat. co-authored	Degree of internationalisation[1]
United States	773.7	56	16	31.7	21.3	0.67
United Kingdom	186.2	52	26	7.6	8.1	1.06
Germany	174.6	50	30	7.2	8.9	1.24
France	132.2	61	32	5.4	7.1	1.31
Italy	76.9	70	33	3.2	4.3	1.35
Other Southern Europe	74.0	56	32	3.0	4.0	1.33
Nordic countries	96.3	65	36	3.9	5.8	1.47
Other Western Europe	136.2	61	38	5.6	8.8	1.57
Japan	200.6	50	13	8.2	4.3	0.52
Canada	103.9	57	28	4.3	5.0	1.17
Former USSR	134.6	29	17	5.5	3.9	0.70
Eastern Europe	58.1	56	41	2.4	4.0	1.68
Israel	25.6	66	37	1.1	1.6	1.51
Near East/N. Africa	17.6	55	37	0.7	1.1	1.52
Other Africa	21.3	60	39	0.9	1.4	1.60
Australia, New Zealand	62.6	51	25	2.6	2.6	1.03
India	43.8	33	13	1.8	1.0	0.55
Central America	9.6	65	46	0.4	0.7	1.89
South America	32.7	62	40		2.2	
China	30.8	52	29	1.3	1.5	1.18
Asian NIEs[2]	37.5	53	24	1.5	1.5	1.00
Other Asia/Pacific	9.2	70	57	0.4	0.9	2.32
Total	**2 438.0**	**54**	**24**	**100.0**	**100.0**	**1.00**

1. Share of internationally co-authored/share of all articles.
2. NIE = Newly industrialised economies.

Source: National Science Foundation, *Science and Engineering Indicators 1998;* OECD calculations.

The *openness of countries' science systems* differs. The size of the scientific base cannot explain the low degree of internationalisation, and thus the less open science system, of some countries (*e.g.* India, Japan and the former USSR). Other countries (*e.g.* Australia, Germany, the United Kingdom) with comparable numbers of publications show a much higher propensity to collaborate internationally. While researchers from the United States still participate in the bulk of internationally co-authored papers, other poles of collaboration are emerging among European countries and between East Asian countries and China. On the other hand, links among eastern European countries have eroded considerably as a result of the collapse of their science systems. Overall, the data indicate that scientific collaboration is increasing, although more at the national or regional than at the international level. This suggests that the national science system and immediate neighbours continue to matter in the "global research village", even as openness to cross-disciplinary and cross-country scientific co-operation is gaining in importance.

Links between science and technology

The interface in an NIS between the science system and the enterprise sector is an important one. However, industries and countries with different industrial specialisation patterns differ greatly in their *reliance on the science base*, and few (*e.g.* pharmaceuticals, organic and food chemistry, biotechnology and semiconductors) have strong direct links with basic research. Except in such industries, scientific knowledge stemming from basic research is rarely a direct input into technological innovation. However, it is an essential indirect input into the process of technological innovation in many industries (Martin and Salter, 1996). It can be accessed and used by innovating firms in various ways and forms (*e.g.* in published information, embedded in new instruments and methodologies, via personal contacts and participation in scientific networks, embodied in the skills and abilities of graduates, or through spin-off firms, joint R&D ventures and projects, etc.). Many of these flows have recently intensified – the sign of the increased "scientific content" of technological innovation.

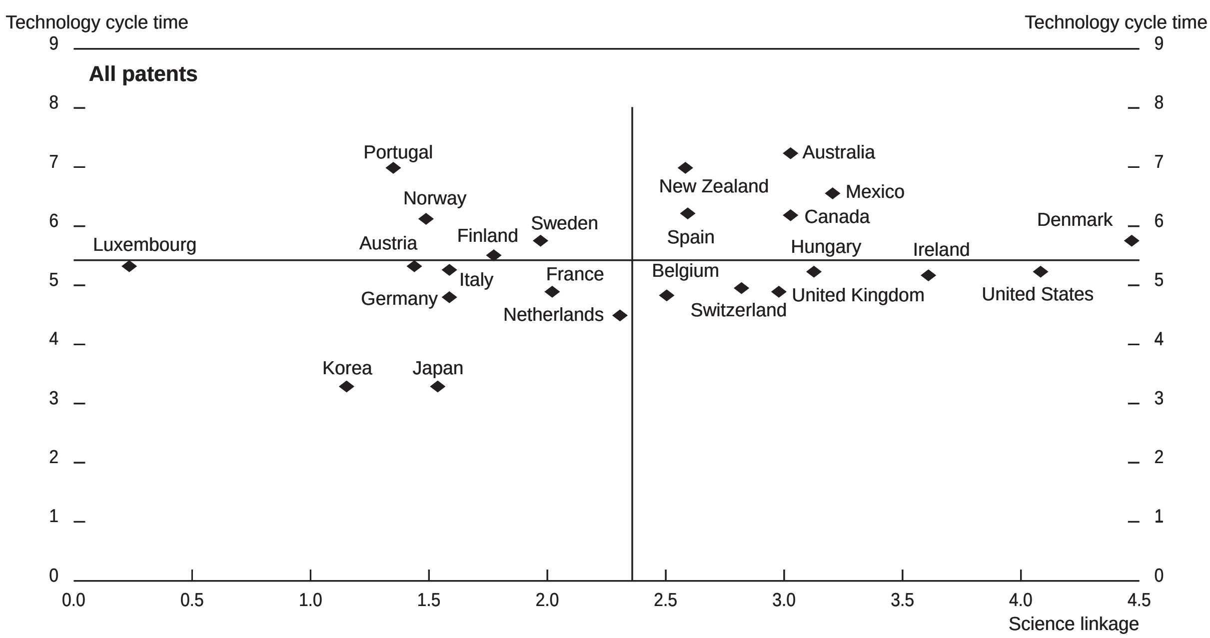
For instance, a recent study of references cited in US patents (Narin *et al.*, 1997) reveals that patents increasingly rely on basic, publicly supported research. *Patent-science links* tripled from 17 000 in 1987-88 to 50 000 in 1993-94. Among the papers cited in US patents in 1993-94, almost 75% draw on publicly supported science at academic, governmental and other public institutions (both in the United States and abroad). In the case of the pharmaceuticals industry, almost 80% of the science citations are based on publicly funded science. This study also shows that the links have a strong national component and that the papers cited are published in mainstream, basic scientific research journals.

The importance of the "science link" differs from one country to another according to industrial specialisation and to the strength of the interaction (including incentives for researchers and enterprises) between the science system and the enterprise sector. Some innovation systems show strong links between science and industrial innovation (*e.g.* Canada, Denmark, Ireland, the United Kingdom and the United States).[3] In countries like Germany, Japan and Korea, but also to a lesser extent in Austria and Italy, innovation has been geared more towards engineering excellence and the rapid adoption and adaptation of technological innovation as reflected in rapid "technological cycle times" (Figure 10).

Data on the science linkage of European patents over the 1992-94 period also suggest considerable differences across countries (European Commission, 1997*a*). They indicate that, in their European patents, the United States and Japan have closer links to science than do the European countries. Among the latter, Belgium, Denmark and the United Kingdom have the strongest links to science, a reflection of their strong innovative activity in optics and polymers, chemistry, and microelectronics. Austria, Germany, Italy, Spain and Sweden have weaker science specialisation, in accordance with their specialisation in mechanical and engineering technologies.

Although there continues to be scope for competitive advantages that are not based on tight links between scientific knowledge and technological innovation, the interplay between industry and the science

Figure 10. **Science and technology linkages and innovation**[1]



1. Technology cycle time indicates the median age of patents cited in industrial patents. The lower the median, the quicker the "take-up" of technological invention by firms. The science link indicates the average number of scientific publications in industrial patents. The data used are straight averages over 1980-95 for the technology cycle time, and 1985-95 for the science linkage. Both values were normalised by the sample standard deviations. The lines represent the unweighted average for the sample of countries.

Source: TP-2 database (CHI Research), OECD calculations, March 1998.

base is of increasing importance for technical progress and economic performance and is thus an important target for technology and innovation policy.

The respective role of firms, universities and public research institutions in knowledge generation differs greatly from one country to another. Everywhere, however, increasing their interplay is a priority so as to ensure that there will be technological opportunities over the long term and to improve the public research sector's responsiveness to economic and social needs. More flexible funding arrangements, including a greater share of contract-based resources, would contribute to achieving these goals. Strengthening university/industry co-operation in research should be another policy aim. In general, greater use of public/private research partnerships can increase synergies between market-driven R&D and R&D directed to government missions in defence, health, environment and other areas.

Labour mobility

Labour mobility among research organisations (universities and other research institutions) and the business sector, as well as among firms, together with informal contacts within innovation networks (see below), is the most powerful mechanism for transmitting tacit knowledge. It concerns scientists, technicians, engineers, and skilled workers but also business executives, since their mobility is a very effective way of propagating best managerial practices.

Analysis of the impact of labour market allocation and mobility on countries' innovation capacity is severely constrained by the lack of appropriate data. Nordic countries are unique in their access to labour-registry data and have pioneered research on linkages related to human resources in innovation systems:

- A study by Sweden's NUTEK on the employment patterns of graduates in natural sciences and engineering showed that the qualifications and allocation of human resources provide a better explanation of a country's technological strength than R&D expenditure statistics.
- The same study concluded that mobility of PhDs was a very weak means of knowledge transfer. Universities are the largest employers of PhDs in engineering and natural sciences, and the PhDs tend to remain in universities (in Sweden, within a seven-year period only 16% moved to another type of institution).
- A study by Norway's STEP showed that the *business services sector* is a strategic "hub" in an NIS, in that it both recruits and supplies skilled manpower from a much wider range of sectors/branches than any other sector/branch.
- Another NUTEK study on international movements of scientists and engineers showed that firm strategies regarding international sourcing of qualified labour differ significantly among European countries, an indication of the significance of cultural factors.

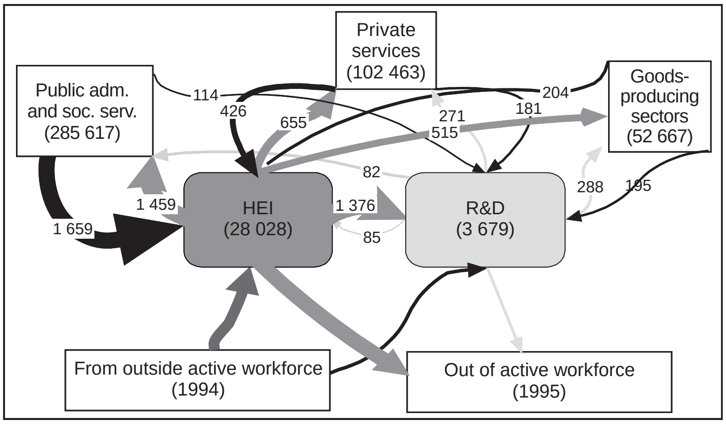
The work of the Focus Group on Mobility of Human Resources (see summary in Annex 2) represents a first attempt to compare Nordic statistics on the distribution and flows of human resources, with a view to providing a benchmark for further national and international efforts (*e.g.* in the OECD "Blue Sky" project) based on available data sources. Its preliminary results can be summarised as follows:

- Over a two-year period, around 20-25% of the employed population either changed jobs or left the active workforce. The "stable" workforce accounted for only around 60% after three years, and for as little as 20% in Sweden after six years and 30% in Norway after seven.
- In the countries studied (Finland, Norway, Sweden), mobility from research institutes or universities to enterprises is rather low (less than 1% of the enterprises are concerned), and its direct impact on technology diffusion is even lower, given that most researchers switch to other activities when entering the business sector. When recruiting scientists and engineers, firms draw mainly on new graduates and on mobility from other enterprises.

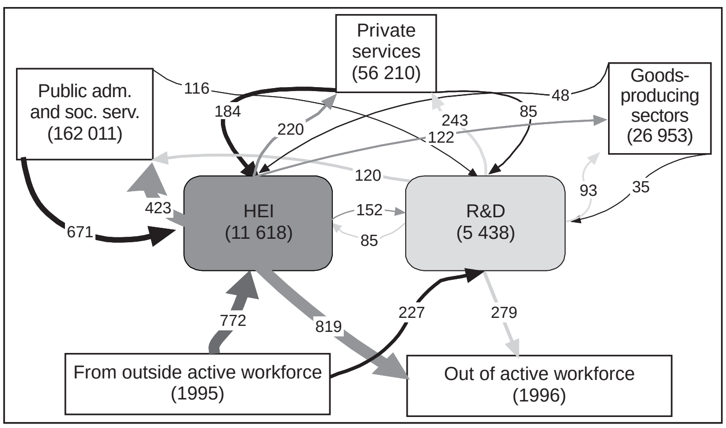
The main differences between these countries with regard to the stocks and flows of human resources (Figure 11) .

Figure 11. **Mobility of employees with higher education degrees by providing and receiving sectors (absolute numbers)**

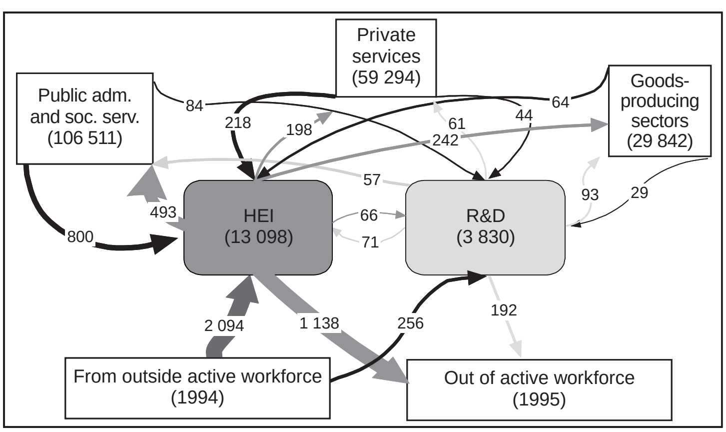
Sweden (1994-95)



Norway (1994-95)



Finland (1995-96)



HEI: Higher education institutions.
Source: Report of the Focus Group on Mobility of Human Resources, 1998.

- reflect industrial specialisation (a cumulative increase in knowledge intensity enhances the demand for graduates in the already skill-intensive sectors, *e.g.* the oil industry in Norway); general labour market conditions (flows in and out of the active workforce); and institutional profiles (in Sweden an important share of industrial research takes place in universities, in contrast with Norway and Finland where specialised research institutes play a more important role).

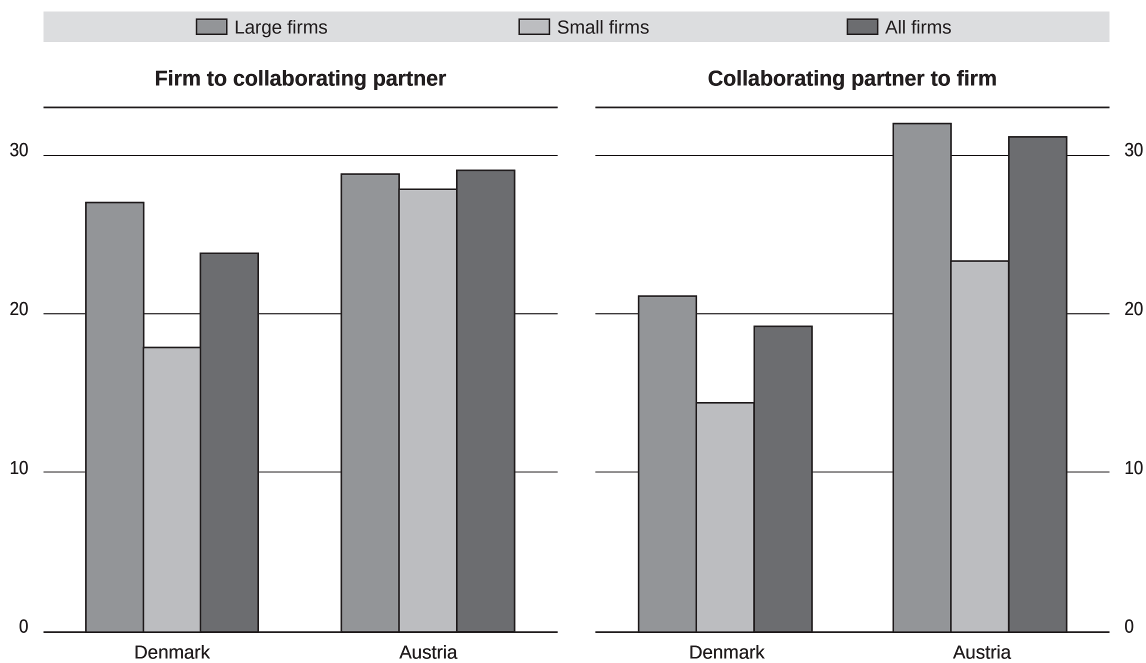
- In Sweden, both the higher education sector and the R&D sector display greater "human resource" interactions with the manufacturing sector than do their counterparts in Finland and Norway. The interactions between the R&D sector and the services sector are weaker in Finland than in Sweden and Norway. The flows from the higher education sector to the R&D sector are much stronger in Sweden than in the other two countries, whereas the reverse flows are the strongest in Norway.

- International differences in industry recruitment patterns and in interactions between firms and the R&D infrastructure are more pronounced at a very disaggregated level (42-sector classification). This suggests that reliance on only macroeconomic studies of the impact of labour markets on the innovation processes can be misleading.

Survey data can be used both as a substitute for and as an important complement to register data (*e.g.* Figure 12 which depicts labour mobility between collaborating firms). A number of sources (*e.g.* recruitment patterns from trade organisations, unions, universities, etc.) provide relevant information. Combining these sources could provide a basis for extending the comparative analysis beyond the Nordic countries. One purpose of the OECD "Blue Sky" project is precisely to develop the indicators which would allow an OECD-wide benchmarking of labour mobility patterns.

Figure 12. **Exchange of personnel between collaborating firms, 1997**

% of firms involved in the exchange of personnel with collaborating partners



Source: Report of the Focus Group on Innovative Firm Networks, 1998.

Embodied technology and knowledge flows

Knowledge can flow in various ways within and between NIS: embodied in capital goods and personnel, disembodied in patents and licences, in codified form (publications, blueprints) or in tacit form (informal networks, skills). Practically all forms of knowledge flows have intensified in recent years, contributing to an overall increase in the knowledge intensity of all economic activities. The following sections examine two major carriers of embodied technology and knowledge flows: purchases of equipment and intermediary products, and foreign investment.

Technology embodied in equipment and intermediary products

Several studies (including innovation surveys) underline the important role of flows of *technology embodied in equipment and intermediary products*. The analysis of input-output flows provides additional insight into the importance of "indirect" R&D. Total R&D intensity (as measured by the sum of direct R&D and all types of indirect flows – intermediary goods and investment from both home and abroad) is considerably higher than direct R&D, the latter accounting for only 40-60% of the total.

The importance of indirect R&D in overall manufacturing has increased in most countries (Figure 13). Countries differ considerably, nevertheless, with respect to the importance of the different channels. In larger economies such as the United States and Japan, "imported technology" is just a small, albeit growing, fraction, of total R&D intensity. In smaller countries, technology acquired through imports accounts for 40-50% of the totalTechnology is largely supplied by a few high-technology industries, while the use of embodied technology is widespread and considerably increases the "technology content" of industries categorised as low- or medium-technology, if only their own R&D efforts are counted (OECD, 1996*a*).

Although the technology content of trade flows has generally increased, a few sectors are the main "gateways" for technology flows in most countries – *e.g.* chemicals in Denmark and the Netherlands, aerospace in the United Kingdom, motor vehicles in Germany. This pattern reflects the differentiated national patterns of technological specialisation.

Foreign investment

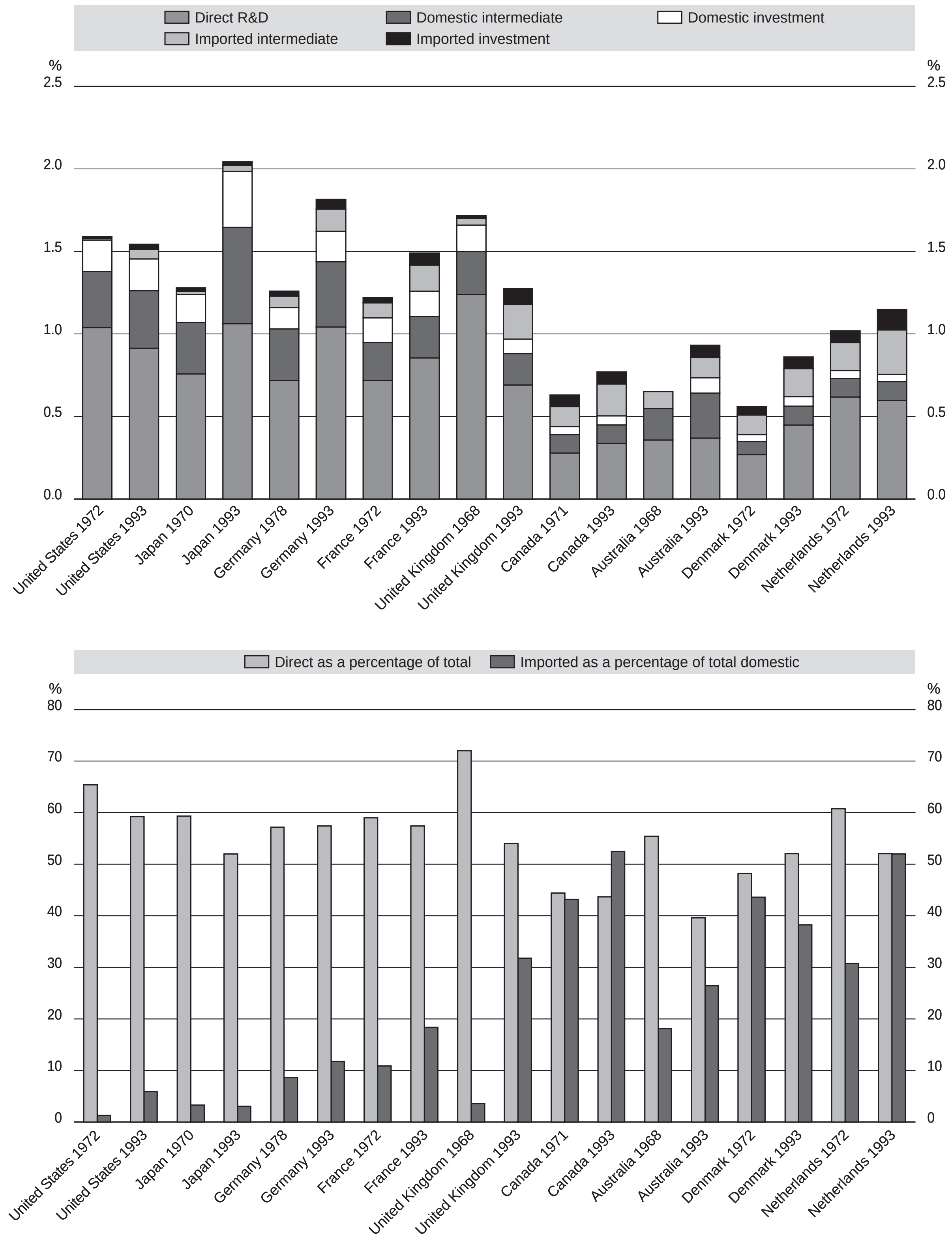
Foreign investment is another important international source of technology and innovation capabilities. The innovative behaviour of foreign subsidiaries gives some indication of how national characteristics shape the globalisation process.

Corporate innovation activity as measured by patents is still predominantly located close to the firm's headquarters (Table 8), especially for large countries like France, Germany, Italy, Japan and the United States. However, there is a tendency towards internationalisation, especially for firms from smaller countries (Belgium, the Netherlands, Switzerland) and for the United Kingdom, which hosts a number of companies with globally dispersed activities. In 1994, the R&D carried out by foreign subsidiaries represented only 11% of the total R&D of 12 major OECD countries.

Foreign R&D is mainly established by acquiring existing firms and research facilities, but there is also a tendency for firms with strong technology of their own to rely on greenfield operations (Andersson and Svensson, 1994). In some cases, R&D is shifting away from addressing local market needs to establishing competence centres which carry out R&D for the whole corporation. While, in general, the R&D intensity of domestic firms is higher than that of foreign subsidiaries (Figure 14), the relationship between a company and its foreign subsidiaries is influenced by the country of origin's and the host country's relative technological positions, as well as by industry- and firm-specific factors (Table 9).

Thus, in most OECD countries (*e.g.* Canada, France, Germany, the Netherlands, Sweden, the United Kingdom), domestic firms are much more R&D-intensive than foreign affiliates. However, in a few (Finland, Japan, the United States), R&D intensity is roughly balanced, while in others (Australia, Ireland) it is higher in foreign affiliates. Again, this reflects the varying features of the respective national innovation systems. Foreign R&D in the United States is attracted by the quality of research institutions, while

Figure 13. **Direct and indirect R&D intensity**



Source: OECD, calculation from Input-Output and ANBERD databases.

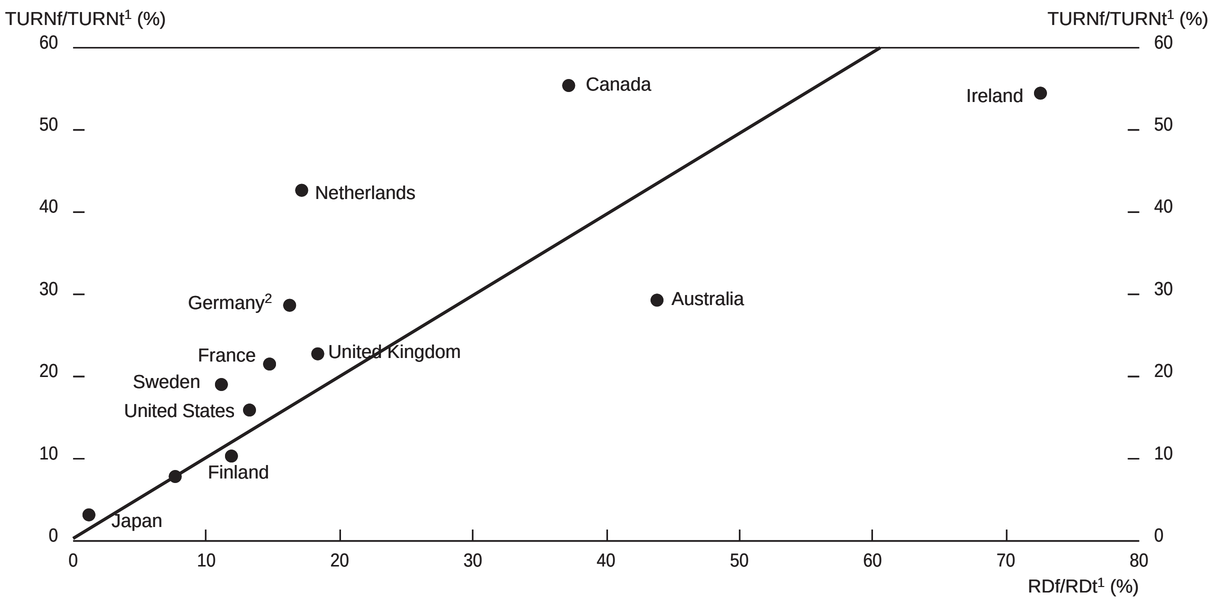
Table 8. **Geographic location of large firms' patenting activities in the United States, 1985-90**

Percentages

	No. of firms	Home	Abroad	*of which:* United States	Europe	Japan	Other
Japan	139	99.0	1.0	0.8	0.2	..	0.0
United States	243	92.2	7.8	..	6.0	0.5	1.3
Italy	7	88.2	11.8	5.3	6.2	0.0	0.3
France	25	85.7	14.3	4.8	8.7	0.3	0.6
Germany	42	85.1	14.9	10.4	3.9	0.2	0.4
Finland	7	82.0	18.0	1.6	11.5	0.0	4.9
Norway	3	67.9	32.1	12.7	19.4	0.0	0.0
Canada	16	67.0	33.0	24.9	7.3	0.3	0.5
Sweden	13	60.8	39.2	12.6	25.6	0.2	0.8
United Kingdom	54	57.9	42.1	31.9	7.1	0.2	3.0
Switzerland	8	53.3	46.7	19.6	26.0	0.6	0.5
Netherlands	8	42.2	57.8	26.1	30.6	0.5	0.6
Belgium	4	37.2	62.8	22.2	39.9	0.0	0.6
All firms	**569**	**89.1**	**10.9**	**4.1**	**5.6**	**0.3**	**0.8**

Source: Patel, 1997.

Figure 14. **Share of foreign affiliates' R&D and turnover (or production) in total manufacturing R&D**



1. TURNf/TURNt: foreign affiliates' turnover/total firms' turnover; RDf/RDt: foreign affiliates' R&D/total firms' R&D.
2. Sample of the 500 most R&D-intensive firms.

Source: OECD, AFA, STAN and ANBERD databases, November 1997.

Table 9. **Nature of R&D activities of foreign affiliates in countries of destination**

Parent company's Technological position	Affiliate's technological position[1] in destination country		
	High	Medium	Low
High	Development of new technology. In close link with universities and other local laboratories.	Laboratory of production support. Specialised laboratory. Technology transfers from the parent company.	Laboratory of production support. Technology transfers from the parent company.
Medium	Technology "watch". R&D effort more important than the parent company's.	Specialised laboratory.	Laboratory support. Technology transfers from the parent company.
Low	Technology "watch".	Technology "watch".	

1. The technological position reflects various quantitative and qualitative measures: the R&D effort, patents, scientific publications, high-technology exports, links between universities and industries, structure and quality of scientific and technological personnel.
Source: OECD.

locating R&D in Ireland is motivated more by the need to upgrade and adapt products and processes. From the perspective of the United States, foreign R&D expands already intensive knowledge interactions, but is also a source of knowledge outflows. In Ireland, foreign R&D is a major driving force in the technological catch-up process. From the perspective of the home country, the internationalisation of R&D reduces the concentration of R&D by domestic firms at home, and risks dismantling some of the home country's innovative capacity. Such risks may loom particularly large for small countries whose R&D base is strongly dominated by a small number of large multinational firms (Krugman, 1991). On the other hand, foreign R&D strengthens the ability of firms to increase their sales abroad, expand their overall resources and investment and absorb foreign technology more effectively.

INNOVATIVE FIRMS, NETWORKS AND CLUSTERS

The OECD report, *Technology, Productivity and Job Creation*, found that "firms that innovate more consistently and rapidly, employ more workers, demand higher skill levels, pay higher wages, and offer more stable prospects for their workforce" (OECD, 1996*b*). The report also noted that "innovative firms are not superior algorithms to maximise production functions, but efficient learning organisations that seize technological and market opportunities creatively in order to expand production frontiers". The innovativeness of firms depends on the incentives they face, their own competencies, and the efficiency of their external linkages with other firms and institutions (networks and clusters).

The innovative firm

The importance of framework conditions

Firms innovate when they are motivated to do so and can afford the required investment. The business environment influences them in many ways. If markets are not competitive or contestable enough, firms can derive monopoly rents from safer investment and will have fewer reasons to take the risk of innovating. All factors that discourage investment in general (*e.g.* high interest rates, inflation, volatility of exchange rates, etc.) will have a negative effect on innovation and technology diffusion. Compared to alternative business strategies, other factors reduce the attractiveness and feasibility of innovation: a financial sector unable to assess innovative projects, weak protection of intellectual property which reduces the rewards for creativity, regulations which increase risks and costs of commercialisation of innovative products or processes, etc.

Innovation capacities

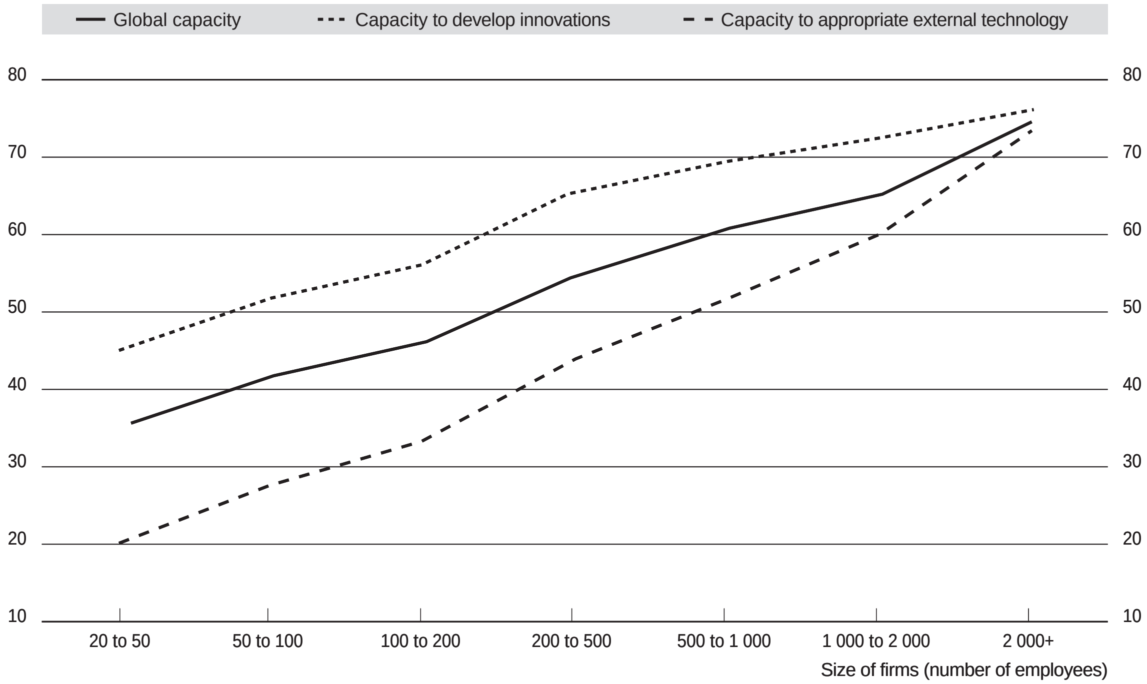
There is increasing evidence that the innovation capacities of most firms, especially SMEs, are limited (Clark and Quévreux, 1998). This is in part due to market and systemic failures, which lead to the following weaknesses:

- The "low capability trap". Until a firm has learnt something, it cannot properly specify what it needs to learn. More generally, many firms lack certain competencies to manage innovation, especially when it involves developing and mastering external linkages (Figure 15).
- Organisational inadequacies, inadequate availability of information, and/or deficiencies in managerial skills. These prevent sound self-diagnosis of needs and reduce the perceived value of organisational change and external (*e.g.* consulting) market services.

Not only do many firms not innovate, innovative firms also vary in their level of competence. A key policy challenge is to help non-innovative firms acquire basic capabilities and more competent firms to increase their level of innovativeness. In broad terms, one can distinguish four levels of innovativeness, irrespective of firm size and activity (Figure 16):

- Level 0 – *The static firm* innovates seldom or not at all, but may have a stable market position under existing conditions.
- Level 1 – *The innovating firm* has the capability to manage a continuous innovation process in a stable competitive and technological environment.

Figure 15. **Innovation capacity of French manufacturing firms, 1997**
(Index)



Source: French Ministry of Industry, SESSI, 1997.

- Level 2 – *The learning firm* has, in addition, the capability to adapt to a changing environment.
- Level 3 – *The self-regenerating firm* is able to use its core technological capabilities to reposition itself on different markets and/or create new ones.

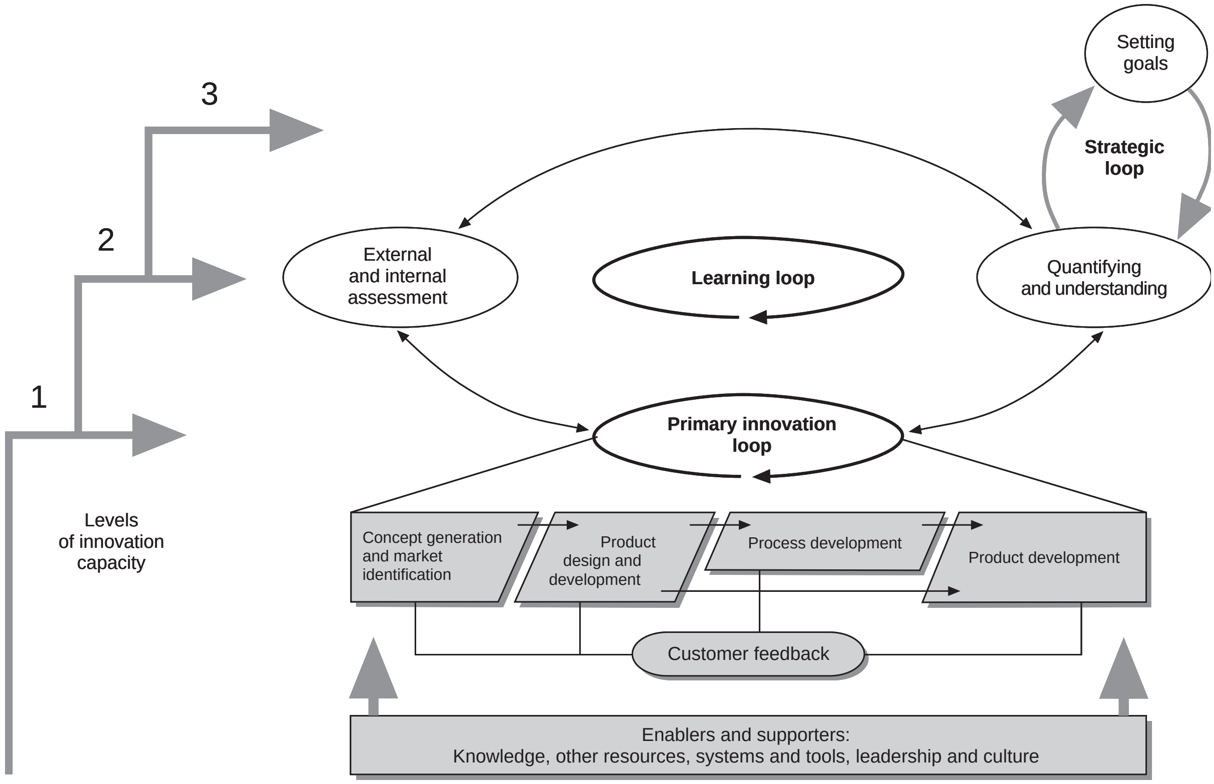
The new technology-based firms (NTBFs), which play an increasingly important role in innovation systems, illustrate well the existence of these "competence thresholds" and the implications for government policy. Whereas some NTBFs are condemned to a short life span because of a defective business plan, many others will not achieve a sustained growth trajectory because of the absence of a corporate governance structure able to adjust to changing conditions. A successful NTBF requires superior governance and management capabilities, including comprehensive understanding of product technology, manufacturing technology, market research, financial planning, accounting, legal aspects, contracts and networking, as well as a supportive environment of relevant business services (OECD, 1998*b*).

Governments can indirectly help spur management and innovation capabilities by supplementing or catalysing private initiatives in three ways: development of "infrastructure" to correct information imperfections in the business services market; public provision of innovation management tools or benchmarking services; promotion of the development, diffusion and adoption of management know-how.

Evaluation of existing policies to promote innovation management capabilities demonstrates that there is much scope for improving policy responses in this area. This requires, however, better understanding of the main capacities underlying firms' innovative behaviour. For a long time, studies on innovation management have been predominantly:

- Project-oriented. They have neglected to relate firm attributes to more generic abilities to manage technical change.
- Focused on industry. They have neglected the increasing importance of innovation in the services sector.

Figure 16. **Levels of firms' innovation capacity**



Source: Adapted from Arnold and Thuriaux, 1997; Brown, 1997.

- Dominated by high-technology sectors. They have neglected innovation in low-technogy-intensive sectors.
- Modelled on the experience of large firms.

On the basis of a review of more recent thinking on innovation research and best business practices, the Focus Group on Innovative Firm Networks identified six main groups of capacities which underlie innovation in all types of firms and sectors (Arthur D. Little, 1998): managing the competence base, vision and strategy, creativity and idea management, intelligence, organisation and process, culture and climate.

Types of firms and gaps in innovation capacities

When identifying barriers to greater innovativeness, it is necessary to take into account that: *i)* small firms differ from large ones in the skills and professional training of their managers and in the profile of their innovation capacities; and *ii)* SMEs form a very diverse population.

Large and smaller innovative firms have important common needs (Arthur D. Little, 1998): commitment from the top (in the case of an SME, often the owner); an integrated view of innovation strategy and business strategy; a clear idea of the firm's distinctive competencies; an openness to constructive ideas and contributions from all staff; a structured way of watching and responding to changes and opportunities in the business environment.

However, smaller firms tend to have more limited financial and human resources, less ready access to information, and shorter time horizons. In addition, they are generally more risk-averse and reluctant to engage outside help, except for very specific short-term needs. Overall, the scope for improving innovativeness is greater for small firms than for large ones.

While this justifies a policy focus on SMEs, concrete action to upgrade firm innovation capacities (*e.g.* by supporting the development and diffusion of benchmarking and diagnostic tools) must be tailored to the specific needs of the different types of SMEs (Tables 10 and 11).

Table 10. **A typology of SMEs**

Type	Definition
Type 1: New technology-based SMEs	Firms successfully pursuing technological advance in specific areas of new, fast-developing technologies.
Type 2: Niche market differenciators	Firms successfully exploiting value-added niches in traditional markets.
Type 3: Technological leaders	Firms which have succeeded in becoming industrial leaders with their own products and technologies.
Type 4: Joint developers	Firms working as subcontractors and having a role in co-designing or developing products.
Type 5: Efficient classical subcontractors	Classical subcontractors with no, or hardly any, products of their own.
Type 6: Resilient SMEs	Firms having recently successfully reacted after suffering serious adverse market conditions.
Type 7: Would-be reactive SMEs	As yet unsuccessful Type-6 firms.
Type 8: Quietly passive SMEs	Firms following established tracks without much growth and change.
Type 9: Barely surviving SMEs	Firms threatened in their very existence.

Source: Arthur D., Little, 1998.

Table 11. **Possible priorities[1] for innovation support in SMEs**

Type	Level of need	Managing the competency base	Vision and strategy	Creativity and idea management	Intelligence	Organisation and process	Culture and climate
1	Medium				light	light	
2	Medium	light	light	dark	light	dark	
3	Low				light		
4	Medium	light	light		dark	light	
5	Medium	light	light			dark	light
6	Medium	light	dark	light	light	light	light
7	High		dark	dark	light		dark
8	Medium		dark	light			dark
9	Low		dark				dark

1. Dark shading: priority needs. Light shading: other needs.
Source: Arthur D. Little, 1998.

Innovative firm networks

Firms rarely innovate alone

Competitiveness is becoming more dependent upon the ability to apply new knowledge and technology in products and production processes. However, with growing competition and globalisation and the rapid advancement of knowledge, new technologies and innovative concepts have a wider variety of sources, most of them outside the direct control of firms. Firms have become more specialised and increasingly focus on their core competencies. For complementary knowledge and know-how, they increasingly rely on interaction with a variety of actors (*e.g.* equipment and component suppliers, users, competitors and non-market research institutions such as universities or government laboratories). Inter-firm collaboration is by far the most important channel of knowledge sharing and exchange (Table 12). Creating appropriate conditions for such collaboration thus poses a key policy challenge.

Table 12. **Relative importance[1] of technology transfer channels**

	Australia	Belgium	Denmark	France	Germany	Ireland	Italy[2]	Luxembourg	Norway	United Kingdom
Use of others' inventions	4	4	3	2	5	2	5	4	2	2
Contracting out of R&D	8	5	6	5	6	3	6	5	5	6
Use of consultancy services	5	3	4	4	3	5	3	5	3	4
Purchase of other enterprises	7	7	7	7	7	6	8	8	6	7
Purchase of equipment	1	6	2	3	4	4	1	3	8	5
Communication services from other enterprises	2	2	1	1	1	1	2	1	1	1
Hiring of skilled personnel	3	1	5	6	2	7	4	2	4	3
Other	6	8	8	. .	8	8	7	7	7	8

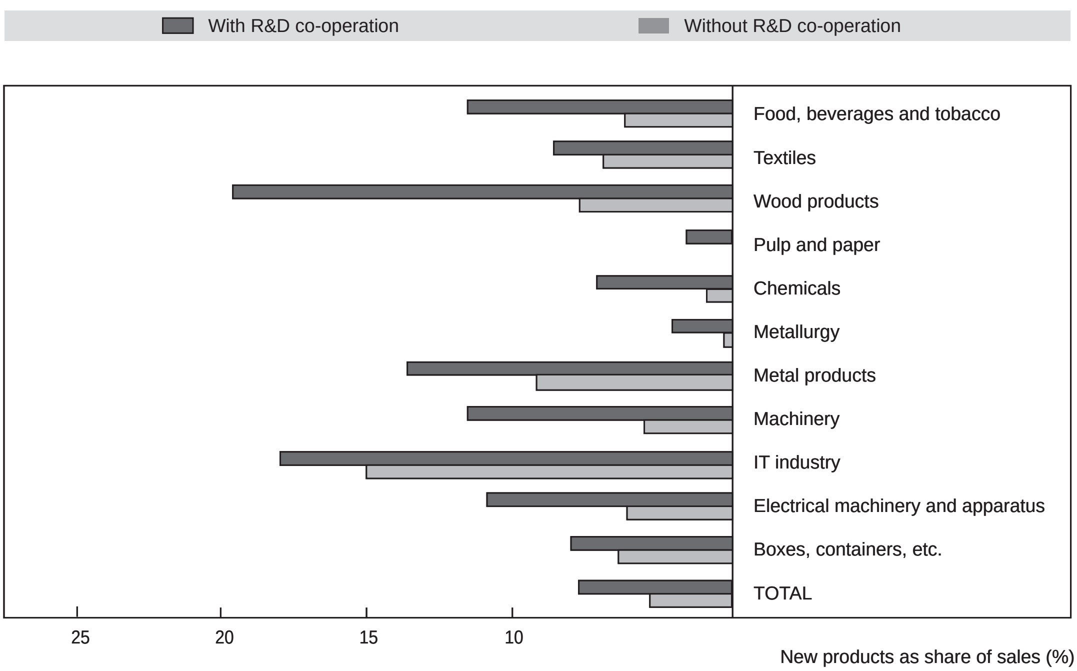
1. Importance was ranked from 1 (highest) to 8 (lowest).
2. Adjusted according to ISTAT. "Other" includes "purchase of projects". The table does not allow for direct comparison, as the response rates differ considerably between countries.

Source: Bosworth *et al.*, 1996; CIS data; ABS, 1994.

Networking has in fact become an effective innovation technique in its own right. Empirical studies have confirmed that collaborating firms are more innovative than non-collaborating ones (Figure 17). The preliminary results of the survey carried out by the Focus Group on Innovative Firm Networks (see Annex 2) confirm the findings of previous surveys such as the Community Innovation Surveys (CIS). In Austria, 62% of innovating firms collaborated with one or more partners. The corresponding share was 75%

Figure 17. **Firms collaborating on R&D are more innovative**

New products as share of sales by industry in Norway, 1992

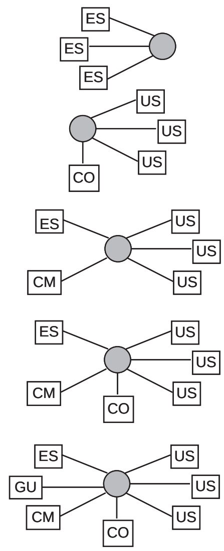


Source: STEP Group, 1996.

in Norway and 83% in Spain, and in Denmark it was as high as 97%. Moreover, innovating firms generally interact with several partners rather than a single one (Figure 18). Even the minority non-collaborating firms do not work in isolation, but purchase embedded technologies, consultancy services and intellectual property and seek ideas from a variety of sources.

Figure 18. **Types of firm networks**

Type of network (survey of eight European countries)[1]	% share
Weak or no network linkages	12.9
Equipment supplier (ES) dominated networks	14.4
Marketing-oriented networks: users (US) and competitors (CO)	16.0
Marketing-oriented networks: equipment and component (CM) suppliers and users	15.8
Marketing-oriented networks: equipment and component suppliers, users and competitors	21.9
Complete innovation networks, including government laboratories and universities (GU)	19.1



1. Belgium, Denmark, France, Germany, Ireland, Italy, Netherlands, Norway.
Source: DeBresson *et al.,* 1997.

General and country-specific networking patterns

Relationships are selective, durable and trust-based. Firms tend to establish selective relationships which are relatively stable in the medium- to long-term. Network building is a slow process which relies on affinity and builds loyalty. For instance, a Danish survey reveals that only a small minority of collaborative agreements recorded over a period of two years involved new partners. In Austria, more than 70% and in Denmark around 60% of collaborating firms consider trust and confidentiality as a necessary basis for co-operation. But only 24% of such firms in Austria, and 22% in Denmark, consider a trial period with the partner before committing substantial resources to a collaborative venture as important. This indicates the importance of *ex ante* trust, based on experience and reputation.

The growing importance of knowledge-intensive services. The services sector plays an increasingly important role in the innovation process. One aspect is the collaboration between manufacturing and knowledge-intensive service firms. The survey carried out by the Focus Group on Innovative Firm Networks and the CIS surveys concur in estimating that between 30% and 50% of innovative firms are involved in such interaction.

Internationalisation goes hand in hand with strengthened domestic networks. Inter-firm collaboration is still predominantly inward-oriented. However, foreign firms, especially suppliers of materials and components, and private customers play a significant and growing role within national innovation networks (Table 13 and 14; Figure 19). A Danish survey suggests that the internationalisation of inno-

Table 13. **Propensity of innovative firms to engage in international exchange of technology**

Percentages

	Belgium	Denmark	France	Germany	Italy	Netherlands	Norway
Acquiring technology	74.5	76.6	56.1	24.7	40.4	26.3	43.2
Exporting technology	82.5	77.3	52.7	31.7	49.7	17.8	28.5

Source: DeBresson *et al.,* 1997.

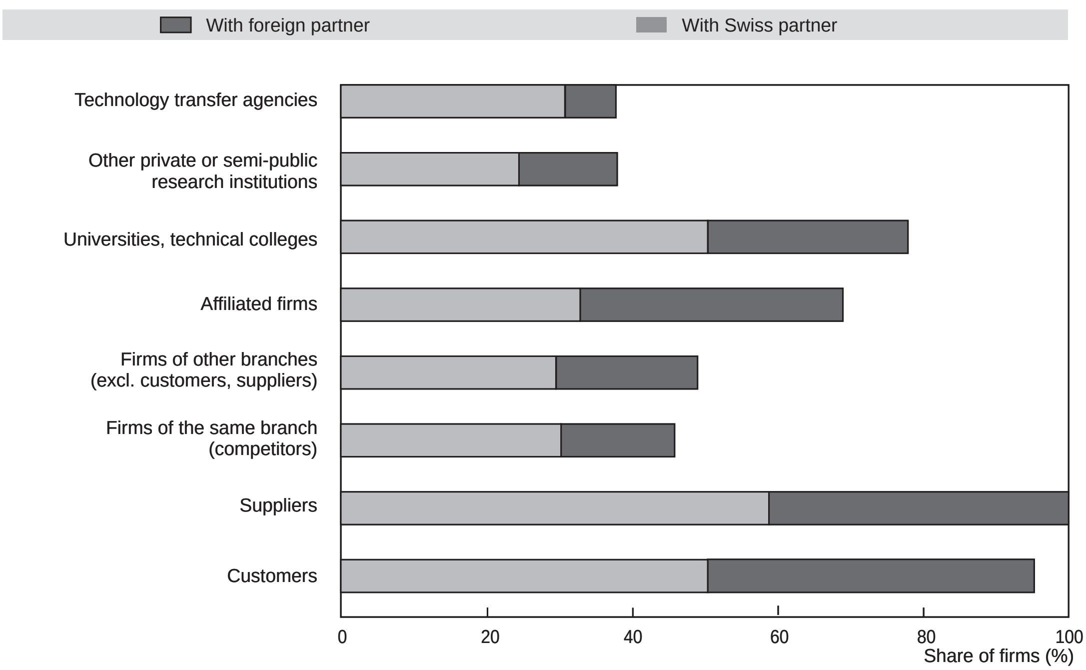
Table 14. **Distribution of foreign and domestic collaborating partners, 1997**

Partner	Co-operation with domestic partners (%)			Co-operation with foreign partners (%)		
	Austria	Denmark	Spain	Austria	Denmark	Spain
Customers (governmental)	n.a.	20	24	14	9	9
Customers (private)	n.a.	62	41	37	41	29
Suppliers of materials and components	n.a.	64	48	42	41	35
Suppliers of equipment	n.a.	37	40	22	20	28
Suppliers of technological services	n.a.	39	n.a.	18	14	n.a.
Other private technical consultants	n.a.	17	48	n.a.	6	20
Marketing and management consultants	n.a.	30	28	7	8	6
Competitors	n.a.	9	9	11	5	6
Universities and research centres	n.a.	15	55	11	6	14
Parent company or subsidiaries	n.a.	21	19	24	16	22
Others	n.a.	32	4	n.a.	17	8

Source: Report of the Focus Group on Innovative Firm Networks, 1998.

Figure 19. **Domestic and foreign partners in R&D collaboration in Switzerland**

Manufacturing, 1994-96



Source: Vock, 1998.

vation networks does not necessarily weaken domestic linkages. Increased international competition appears to have strengthened Danish networks while opening them to international customers and suppliers.

International strategic technology alliances, such as R&D joint ventures, research corporations, joint R&D agreements and minority holdings, are another important way for firms to co-operate in developing major new technologies. Strategic technology alliances have grown rapidly over the past decade. Figure 20 shows the growth of new alliances, within and between the main economic blocs. Between the main blocs, growth has been particularly rapid in alliances between European and US firms. Most of the growth has been among firms in biotechnology and information technology. Within the economic blocs, growth in new strategic alliances has tapered off in Europe and Japan in the 1990s, following a boom during the late 1980s. However, new strategic alliances continue to spread rapidly in the United States, with information technology alliances providing the main impetus to growth.

National innovation systems are characterised by different patterns of interaction. Countries differ with regard to the extent, nature and motives of inter-firm collaboration, as well as the degree of internationalisation of inter-firm linkages. The work of the Focus Group on Innovative Firm Networks shows, for instance, that Spanish and Danish innovating firms collaborate more frequently with suppliers of machinery and production equipment than do their counterparts in Austria and Norway, and that, compared with collaboration with a parent or subsidiary, collaboration with competitors is infrequent except among Norwegian firms. Interactions between firms and the technology infrastructure are even more country-specific, reflecting differences in institutional frameworks and the orientation of public policies. For instance, universities and research institutes are more frequent partners of firms in Spain and Austria than in Denmark and Norway. The propensity to collaborate with foreign actors is influenced by country size and industrial specialisation, the location and strategies of multinational firms and public policies. For instance, in Europe, large programmes build on existing networks to promote cross-border R&D collaboration (the European Union Framework Programme, EUREKA). Work by the Focus Group on Organisational Mapping (see Annex 2) confirms that firms in small countries are significantly more inclined to partner with foreign actors than those in large countries; they rely on networking to compensate for insufficient resources and the lack of appropriate partners in their home country. This work also demonstrates that such subsidised R&D collaboration is still dominated by a small group of actors (often large multinationals).

The role of clusters in national innovation systems

Clusters are networks of interdependent firms, knowledge-producing institutions (universities, research institutes, technology-providing firms), bridging institutions (*e.g.* providers of technical or consultancy services) and customers, linked in a production chain which creates added value. The concept of cluster goes beyond that of firm networking, as it captures all forms of knowledge sharing and exchange. The analysis of clusters also goes beyond traditional sectoral analysis, as it takes into account the links to firms outside traditional sectoral boundaries. As the Focus Group on Cluster Analysis and Cluster-based Policy has shown (see Annex 2), cluster analysis is regarded in several OECD countries as an important tool for providing a sound basis for industrial and technology policy. In this respect, cluster analysis is one of the core elements of the work on national innovation systems.

Co-operation in clusters is increasingly required for firms to be successful. Moreover, it offers a direct way to improve economic performance and reduce costs. Co-operation can lower costs if firms acquire knowledge and thus meet their needs more cheaply than by producing that knowledge in-house. It also creates greater opportunities for learning, an essential requirement for productivity improvement; it may make possible economies of scale and scope, enable the sharing of risks and R&D costs, and allow greater flexibility. It also may help to reduce the time to market for new products and processes. Analysis of several mature OECD-area industries (textiles, steel and automobiles) suggests that co-operation with suppliers and customers, in increasingly stable arrangements (clusters), has significantly helped these industries to revitalise and regain competitive strength (OECD, 1998*a*).

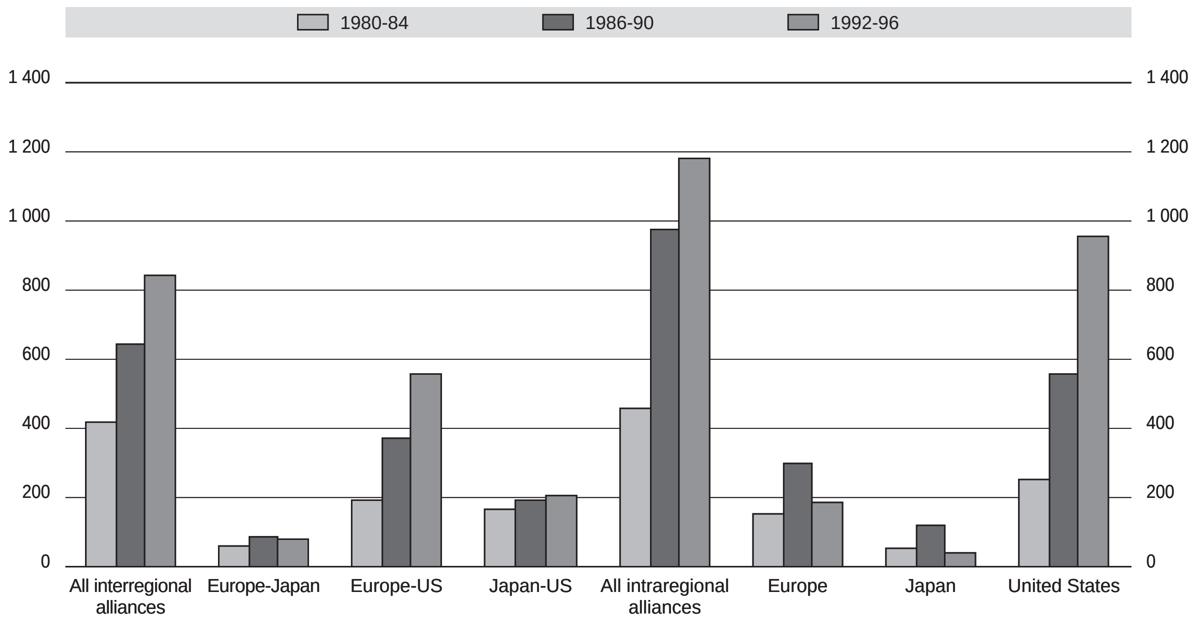
Networking within clusters is also increasingly required if firms want to satisfy consumer needs. today's more demanding consumers play an important role in guiding innovation in clusters that produce consumer goods and services. Feedback from retailers to producers plays an increasing role in determining the direction of innovative efforts in the clothing industry; links with distributors play a key role in guiding technological change in the automobile industry; and large and demanding clients have triggered innovation in the construction industry. The influence of demand, changes in fashion and lifestyles is less marked in more basic industries, however. Most manufacturing-related clusters in Sweden, for instance, produce goods with long life cycles.

Cluster analysis indicates that a cluster's knowledge base is the source of a great diversity in innovation practices. Some clusters are closely linked to the science system and their innovation depends heavily on scientific discovery (pharmaceuticals, semiconductors and biotechnology, for instance). Others act as intermediaries between science and other clusters (*e.g.* information technology), and still others are quite independent of the science system (*e.g.* mechanical engineering). This diversity indicates the need for a variety of approaches to analysis and policy.

Cluster analysis

Several factors help clusters emerge. Many successful clusters have historical roots, sometimes linked to available natural resources. The emergence of clusters, including the establishment of links with customers and other firms, takes time, however. For Finland, a number of factors were considered critical to the emergence of innovative clusters, namely: a critical mass of firms to enable economies of scale and scope, sufficient cases of successful entrepreneurship, demanding (often international) customers, a good mix of rivalry and co-operation, advanced supplier firms, flexible organisation and management, continuous upgrading of knowledge, and attractiveness of the industry for talented people. These critical factors are among the areas where governments may aid cluster formation.

Figure 20. **Interregional and intraregional strategic technology alliances**
(1980-84 and 1992-96, by economic area)



Source: National Science Foundation, 1998 ; based on data from J. Hagedoorn, MERIT.

Clusters can be identified at various levels of analysis. Micro-level analysis focuses on inter-firm linkages, industry- (meso-) level analysis on inter- and intra-industry linkages in a production chain, and macro-level analysis on how industry groups constitute the broader economic structure. Cluster analysis can also be applied at the regional level. Regional clusters are often based on certain local strengths, such as a strong knowledge infrastructure (possibly linked to the strengths of a local university or research institute), the geographical location or infrastructure (such as the proximity of a major port or airport) or the presence of a major firm.

At the aggregate level, most OECD countries for which cluster studies have been made identify certain successful clusters in which these countries possess a strong competitive advantage (Box 5).

Box 5. **Selected clusters in OECD countries**

Australia: Commercial services, agro-food, metals/electrical, transport and communication, biomedical, ICT.

Austria: Construction, chemicals, media, metals/electrical, transport and communication, ICT, wood and paper.

Belgium: Energy, ICT, biotechnology, materials.

Denmark: Construction, energy, health, agro-food, shipping, technical, pharmaceuticals/bio-technology and medical technology, mink.

Finland: Construction, chemicals, energy, health, forestry, basic metals, telecommunications, environment.

Netherlands: Construction, chemicals, commercial services, agro-food, energy, health, paper, media, transport and communication, metal/electrical.

Sweden: Construction, agro-food, energy, metals/electrical, ICT, wood and paper, materials, machinery, transport equipment.

United States: Construction, chemicals, energy, agro-food, media, metal/electrical, ICT, wood and paper, biotechnology, transport equipment, aerospace.

Cluster analysis relies on various techniques (input-output analysis, innovation interaction matrices, graph theory, correspondence analysis, case studies), depending on the questions to be addressed. Using these techniques, it is possible to trace the interdependence of firms, which is sometimes based on trade linkages, sometimes on innovation linkages, sometimes on knowledge flow linkages and sometimes on a common knowledge base or common factor conditions. More generally, such studies rely on the idea that innovation is basically an interactive learning process which demands knowledge exchange, interaction and co-operation between various actors in a network of production or value chain.

Cluster analysis allows for a better understanding of interactions among different parts of the economy and for tracing deficiencies and mismatches. The following are examples from national studies:

- Studies for ***Norway*** indicate the critical importance of scientific research (sonar, medicine, nutrition) for its aquaculture cluster and help to identify pertinent scientific research needs.
- Input/output analysis for ***Australia*** indicates a lack of inter-industry linkages. Many firms are unable to find partners to develop innovative products and processes. Reasons for the lack of networking include the low-technology nature of most economic activity and the high degree of concentration. Industrial activity essentially takes place in vertically integrated large businesses (most of them overseas multinationals); as a consequence, innovation takes place in hierarchies rather than in flexible networks or clusters. This creates a situation where production and knowledge flow links are not embedded in education, training and research institutions, thereby creating gaps in the innovation networks on which innovative firms depend.

- A study of the ***Netherlands*** identifies a need for demanding customers in the construction sector if this sector is to improve performance and points to a possible role of government procurement in this area.
- A study for ***Switzerland*** shows that in the areas of process technology and appliances Swiss industry masters the core mechanical technologies but is unable to make the transition to electronic technologies. Insufficient links to electrical engineering and information technology producers are considered to be among the causes of this problem.
- A study for ***Spain*** shows the inadequacy of bridging institutions to facilitate technology diffusion across the economy. A lack of specialisation and overlap and rivalry between various institutions are regarded as causes of this problem. The study also indicates that innovative firms in Spain are very isolated and mainly depend on internal sources of knowledge.

In the Netherlands, cluster studies have played several roles. Initially, they served mainly as analytical tools to provide strategic advice on how to improve competitiveness and enhance co-operation and knowledge flows. Nowadays, they serve as an important input at the macro level on ways to improve the mismatch between science (research institutes and institutes of higher education) and industry. At the micro level, they provide a way to target government efforts more precisely and focus them on areas where problems (systemic failures) have been identified. Science-based clusters, for instance, might benefit most from measures to strength the interaction between science and industry and to promote basic research. Process-oriented clusters, applying technologies developed elsewhere, might benefit more from diffusion-oriented programmes.

Cluster analysis offers other benefits (Roelandt and Den Hertog, 1999):

- It offers a new way of thinking about the economy and helps overcome the limitations of traditional sectoral analysis.
- It captures important linkages in terms of technology, skills, information, marketing and customer needs, which are increasingly regarded as fundamental to competition and to the direction and pace of innovation.
- It provides ways to redefine the role of the private and public sector and that of other institutions and can provide a starting point for a constructive business-government dialogue.

Cluster-based policy making

Cluster analysis serves the policy-making process in several ways. In larger OECD economies, such as the United States and the United Kingdom, or in federal states, cluster analysis often serves as an important tool for regional development. In such cases, it focuses mainly on the location of certain sectors and the need for physical and social proximity for effective cluster formation. In the United States, for instance, cluster studies have been used in "focus groups" as a tool to organise dialogue and interaction among firms in different sectors and to help focus scarce resources for local development. In North Carolina, cluster studies were used to focus acquisition efforts for new firms, establish formal networks, target local training programmes and focus industrial extension programmes. In the United Kingdom, cluster studies have identified actors and development opportunities for regions, which can then be used by regional development agencies, such as the Welsh Development Agency and Scottish Enterprise. Regional cluster initiatives have been taken by several German *Länder* (states) many states in the United States and many regions in Europe.

In smaller OECD economies, cluster approaches help to focus R&D support and scientific research on priority needs, as they permit better understanding of the strengths and weaknesses of national economies. For instance, Finland has focused a significant proportion of its support for technological development on its telecommunication cluster, which is believed to be one of the future cornerstones of the Finnish economy. Several countries, *e.g.* Belgium and Denmark, focus their support for centres of excellence on areas identified in cluster studies. A government's implicit acknowledgement that a certain area of the economy is important for future economic development may also help to generate more private investment. Technology foresight studies may also be used in the context of cluster analysis, as they allow governments, scientists and the business sector to establish a common long-term perspective.

Care should be taken so that policies pertaining to clusters do not become an alternative to traditional public support, nor should governments try to create clusters. Rather, governments should only complement the market-led formation of clusters and focus their efforts on features of successful clusters, including: a critical mass of similar or related enterprises; specialised services and infrastructure; accessible and rapid exchange of information and knowledge; a skilled workforce; vigorous competition to spur improvements in performance; high rates of business formation; and an appropriate social infrastructure.

Most countries that apply a cluster approach in policy making have integrated this approach with attempts to improve the dynamic functioning of their markets by strengthening competition policy and removing barriers to competition. Cluster policies can conflict with competition policy, as co-operative arrangements and alliances may restrict competition. This may not be a problem in practice, however. Most competition occurs between clusters and co-operation at the pre-competitive stage should not necessarily impede the functioning of competitive markets. The increasing globalisation and deregulation of OECD economies may also help to promote competition, while governments can also guarantee competition by an effective policy framework.:

The reduced role in industrial and technology policy of direct government support suggests that governments will mainly play a *role as catalysts and brokers* in strengthening cluster formation. Apart from broad framework policies, a number of policies are generally considered suitable to cluster-based approaches (Table 15):

Table 15. **Systemic and market failures and cluster-based policy responses**

Systemic and market failures	Policy response	Countries' focus in cluster-based policy making
• Inefficient functioning of markets.	• Competition policy and regulatory reform.	• Most countries.
• Informational failures.	• Technology foresight. • Strategic market information and strategic cluster studies.	• Netherlands, Sweden. • Canada, Denmark, Finland, Netherlands, United States.
• Limited interaction between actors in innovation systems.	• Broker and networking agencies and schemes. • Provision of platforms for constructive dialogue. • Facilitating co-operation in networks (cluster development schemes).	• Australia, Denmark, Netherlands. • Austria, Denmark, Finland, Germany, Netherlands, Sweden, United Kingdom, United States. • Belgium, Finland, Netherlands, United Kingdom, United States.
• Institutional mismatches between (public) knowledge infrastructure and market needs.	• Joint industry-research centres of excellence. • Facilitating joint industry-research co-operation. • Human capital development. • Technology transfer programmes.	• Belgium, Denmark, Finland, Netherlands, Spain, Sweden, Switzerland. • Finland, Spain, Sweden. • Denmark, Sweden. • Spain, Switzerland.
• Missing demanding customer.	• Public procurement policy.	• Austria, Denmark, Netherlands, Sweden.
• Government failure.	• Privatisation. • Rationalise business. • Horizontal policy making. • Public consultancy. • Reduce government interference.	• Most countries. • Canada. • Canada, Denmark, Finland. • Canada, Netherlands. • Canada, United Kingdom, United States.

Source: Roelandt *et al.*, 1999.

- *Stimulating knowledge exchange* between actors in various clusters and supplying strategic information to reduce information failures. Technology foresight activities, broadly based cluster studies, the establishment of discussion platforms, or the establishment of Internet Web sites by governments are possible initiatives in this area.
- *Using direct intervention* – for instance in the form of R&D support – when there are clear market or systemic failures in view, when the private sector alone can not undertake the task, or when there are strong social benefits to government effort. The creation of centres of excellence and technology transfer programmes, in close co-operation with the private sector in the form of public-private partnerships, or support for basic and pre-competitive research in cluster-related areas such as the environment or information technology, are examples of this approach.
- *Acting as a demanding customer* in the area of public needs. In many parts of the economy, such as education, health, infrastructure, energy and defence, governments are major customers for goods and services and can use their buying power to promote innovative behaviour and the clustering of activities.
- *Strengthening co-operation between science and industry*, an area where many policy initiatives have been taken across the OECD area, and where cluster analysis provides scope for more informed policy action.
- *Reducing or removing legislative barriers* that prevent co-operation or act as a barrier to innovation.

If governments are to act as brokers and catalysts, it is essential that networks or discussion platforms meet clear business needs and that governments or intermediary institutions are well informed about the cluster and its specific needs. A top-down approach rarely works. Cluster policies also reinforce the need for a horizontal approach to policy making, a point recognised in earlier OECD work, and thus a need for modernisation of government policy making. They are also a way for governments to improve the efficiency of public spending on R&D and technology, as cluster approaches can increase the dissemination of technologies across the economy and the economic rate of return to government efforts.

POLICY IMPLICATIONS

The current wave of scientific discoveries and technical advances provides OECD countries with unparalleled opportunities for economic growth and improved social well-being. While public expectations are evolving with social concerns (*e.g.* unemployment, sustainable development, ageing populations, etc.), the innovation process itself is undergoing profound changes. To realise the full potential of new technologies for growth and jobs, OECD governments must respond effectively to such changes. They face the common task of strengthening innovation systems in order to take greater advantage of globalisation and the move to a knowledge-based economy.

The OECD's analysis of national innovation systems – and related work in the context of the Technology, Productivity and Job Creation project – demonstrates that policy challenges and responses may differ significantly among countries, depending on their size and level of development, their industrial, scientific and technological specialisation, as well as their institutional structure, which affects domestic patterns of knowledge interactions. However, it also suggests some guiding principles for good practice policies (Annex 1 provides selected country examples) which can help countries learn from the experience of others.

A new role for governments

Traditionally, governments have intervened in the technology arena to address market failures, for example when firms under-invest in R&D due to the existence of "spillovers" which limit their ability to fully appropriate returns or due to the uncertainty associated with innovation. They have used measures aimed at increasing the volume of R&D, without giving enough consideration to improving the effectiveness and efficiency of existing R&D.

The new role for governments requires them also to address systemic failures which block the functioning of the innovation system, hinder the flow of knowledge and technology and, consequently, reduce the overall efficiency of national R&D efforts. Such systemic failures can arise from mismatches between different components of an innovation system, such as conflicting incentives for market and non-market institutions, *e.g.* enterprises and the public research sector. Other market and systemic failures may result from institutional rigidities based on narrow specialisation, asymmetric information and communication gaps, and lack of networking or mobility of personnel.

Governments need to play an integrating role in managing knowledge on an economy-wide basis by making technology and innovation policy an integral part of overall economic policy. This involves:

- *Refocusing specific objectives and adapting the instruments of technology and innovation policy.* Policies to promote research collaboration, facilitate firm networking and clustering, encourage institutional ties, diffuse technology and increase personnel mobility take on new significance. Governments must also ensure that long-term technological opportunities are safeguarded through adequate support to basic and pre-competitive research. New approaches may be required to increase national benefits from the globalisation of production and research.
- *Securing framework conditions that are conducive to innovation.* Science, technology and innovation policies need to operate in a stable macroeconomic environment and complement broad reforms in other fields. These include competition policies to increase innovation-driving competition but also facilitate collaborative research; education and training policies to develop the necessary human capital (Austria and Finland, see Annex 1); regulatory reform policies to lessen administrative bur-

dens and institutional rigidities; financial and fiscal policies to ease the flow of capital to small firms (Hungary, see Annex 1); labour market policies to increase the mobility of personnel and strengthen tacit knowledge flows; communications policies to maximise the dissemination of information and enable the growth of electronic networks; foreign investment and trade policies to strengthen technology diffusion worldwide; and regional policies to improve complementarity between different levels of government initiatives.

New approaches or institutional arrangements, including public/private partnerships, may be needed to co-ordinate the formulation and implementation of these policies (Korea, see Annex 1). In many countries, better techniques and institutional mechanisms for evaluation are needed to improve decision making across traditional administrative competencies and can spur innovation in government (Switzerland and United Kingdom, see Annex 1).

In practice, many science and technology policies remain piecemeal, with insufficient attention given to fostering interactions and spillovers at national and international levels. Although situations vary, this presents OECD policy makers with a number of common challenges when addressing issues ranging from innovation culture through technology diffusion to the creation of knowledge.

Building an innovation culture

Overcoming the inability of firms to cope with technical progress owing to inappropriate work organisation, poor management practices and underdeveloped techniques and incentives for incorporating new knowledge and technology requires strategies on the part of firms and government. The extent to which governments can help business to be innovative may be limited. Still, governments can:

- *Create favourable framework conditions for business*, research and education and *encourage businesses, both large and small, to adopt best practices in innovation and business management.* Governments can help where market shortcomings or the system hinder adoption of best practices, as in the case of infrastructure gaps and information asymmetries (Canada, see Annex 1). They can also be more direct facilitators or catalysers of innovative firm behaviour through policy initiatives that encourage flexible management structures, organisational change and training.

- *Extend the scope of technology diffusion programmes to include elements that promote firm-level capabilities for identifying, accessing and incorporating new knowledge and techniques* (Norway and Spain, see Annex 1). Management improvement programmes that incorporate business diagnostics, technology awareness, strategic planning, networking and staff training can promote an "innovation culture" among a wider range of enterprises. Smaller firms should be the main targets of such measures.

New technology-based firms deserve special attention since, beyond their direct contribution to the creation and diffusion of new goods and services, they help instil a culture of innovation, encourage investment in skills and improve economy-wide dynamic allocative efficiency. Governments should address the specific factors that restrain the number of valuable entrepreneurial technology-based projects, raise obstacles to their transformation into business start-ups, and weaken subsequent market selection processes to the detriment of firms with high growth potential. This involves in particular:

- Removing regulatory barriers to entry when appropriate.

- Encouraging the development of private venture capital (United States, see Annex 1).

- Reforming regulations which unduly inhibit entrepreneurship on the part of researchers in the public and private sectors (Japan, see Annex 1).

- Removing other obstacles to risk taking (*e.g.* bankruptcy laws which excessively penalise failure, or limitations on the stock options that can improve the risk/reward ratio for highly qualified staff).

Enhancing technology diffusion

Governments should look carefully at the balance between support to the "high technology" part of the manufacturing sector, and support aimed at fostering innovation and technology diffusion throughout the economy. Technology policy has paid insufficient attention to the growth and needs of the knowledge-intensive services sectors. In the OECD area, two-thirds of production and 70% of jobs are in services, where the nature of innovation is somewhat different than in manufacturing. It is less driven by direct R&D expenditure and more dependent on acquired technology, organisational change and the quality of human resources. Strengthening technology diffusion mechanisms should be a key policy priority, and governments should direct their efforts towards a wide range of firms, from the technologically advanced to those with lesser capabilities, from firms in traditional sectors to those in emerging industries, and towards firms at different stages in their life cycle and in the services sectors.

- *Manufacturing extension services, information networks, demonstration and benchmarking schemes, and technical assistance* are important channels for disseminating technology and codified knowledge (Norway, see Annex 1).
- *Better designed and integrated public schemes that include an element of industry cost-sharing*, can increase the ability of firms to access and exploit new technologies (Spain, see Annex 1).
- A *different approach may be needed to increase the innovative performance of the services sector*, with emphasis on regulatory reform, services-relevant R&D, small firm schemes, information technology and competitive public procurement to promote new growth areas.

Governments must encourage human as well as institutional linkages. The tacit knowledge embodied in people can be multiplied through interaction and transfer of expertise.

- As a basis, *education policy* must emphasise multidisciplinary and lifelong learning. It must also focus on new skill requirements such as working in teams, maintaining interpersonal relationships, communicating effectively, networking and adapting to change.
- *Flexible labour markets*, as recommended by the *OECD Jobs Study*, can facilitate the transfer of skills between enterprises and within the innovation system.
- Technology diffusion policies should focus on incentives for *worker training* and on easing the *mobility of personnel* within and between the public and private sectors.

Promoting networking and clustering

Increasingly, the innovation process stems from interactions within networks of firms and knowedge-based organisations. This is part of a general shift, fuelled by advances in information technologies, towards more networked business interactions. These networks also reflect the increasing interdisciplinarity that is at the core of today's technical change. Strategic research and technology development alliances among firms are multiplying as R&D costs increase and no single enterprise, no matter how large, has all the necessary knowledge and expertise in-house or within its home country. Firms rely more on their relations with suppliers, customers and even competitors for complementary competencies in the innovation process. And importantly, manufacturing firms are increasingly interacting with knowedge-intensive services.

Technology and innovation policy should not focus on single firms in isolation but rather on their ability to interact with other enterprises and organisations by:

- *Joining with regulatory and competition policy to remove unnecessary barriers to co-operation and alliances and to reduce obstacles that prevent the formation of networks.* Competition laws should ensure sufficient levels of competition, while not hindering the co-operative development of new technologies. Regulations should not unduly impede inter-firm collaboration, and regulatory reforms can reduce burdens on firms and promote innovation in many fields.
- *Easing the access of firms to knowledge-intensive services* which can aid their organisational and technical transformation.

- *Ensuring that the public research infrastructure works in close collaboration with business.* Government can promote interaction with public research through partnership schemes, co-operative research and matching funding (France, see Annex 1). More efforts should be made to involve less actively collaborating actors, such as SMEs, including through a shift in the subsidies for R&D collaboration from a focus on the short-term competitiveness of highly innovative firms to the more long-term strengthening of the competencies of less innovative firms.

In many countries, clusters of innovative firms are emerging as drivers of growth and employment. Innovative clusters of economic activity are becoming magnets for new technology, skilled personnel and investment in research. These groups of enterprises tend to be well established and stable, innovating through strong backward and forward linkages with suppliers and customers. They emerge most often where critical masses of firms allow economies of scale and scope, and where there is a strong science and technology base and a culture conducive to innovation and entrepreneurship. Clusters might also be based on factors such as natural resources or geographical advantages. For governments, cluster analysis and policies can:

- Create a platform for dialogue with the business sector (Netherlands, see Annex 1).
- Provide insights into identifying economic strengths and weaknesses, gaps in innovation networks, development opportunities for regions, infrastructure needs and targets for enhanced investment in science and knowledge.

However, clusters differ both in and between countries, with varying implications for innovation policy. How they emerge or how they prompt firms to innovate is still imperfectly understood. Governments primarily nurture the development of innovative clusters through regional and local policies and development programmes and by providing appropriate policy frameworks in areas such as education, finance, competition and regulation. Also valuable are schemes to stimulate knowledge exchange, reduce information failures and strengthen co-operation among firms. But more direct policy tools can be used to encourage cluster formation, such as:

- Focused R&D schemes, innovative public procurement, investment incentives and the creation of "centres of excellence" (Sweden, see Annex 1).
- Competition for government funding to provide incentives for networks to organise themselves on a regional basis (Germany, see Annex 1).

Leveraging research and development

To stimulate innovation, new approaches are needed which provide private initiative greater scope and more incentives and which are less dependent on direct government financial support. The stagnation of research spending may have implications for long-term innovative capacity in some economies. Governments must respond by preventing under-investment in research and innovation. Some governments have been able to increase public investment in R&D (Finland, Japan); others have increased the efficiency of public support by emphasising leveraging and linkages in place of targeted programmes. At the same time, these responses need not be mutually exclusive: greater public investment may be combined with efforts to increase the efficiency of support.

Market-led innovative processes should rest on a sound knowledge base, which is found primarily in the "*science system*" – the scientific research performed in academic and public research institutions and supported largely by government. Public science contributes to health, environment and national security as well as to general advances in knowledge and to quality of life. Scientific advances are also the wellspring of technical innovation. Industry uses university and government research to a large degree, either directly through joint research or acquisition of patents and licenses or indirectly through public research results. Firms also rely on the science base for trained personnel and access to methods and techniques. A growing number of industrial patents refer to basic science literature as a source of knowledge. In some fields such as biotechnology, scientific research is the main source of innovation, so that the distinction between science and technology is blurred. In all sectors, the innovative process is increasingly characterised by feedback between the science base and the different stages of technology development and commercialisation.

Policies need to help the science system adjust to the emerging entrepreneurial model of knowledge generation and use, while securing the continued pursuit of curiosity-driven research.

- *Government funding for long-term research in universities and publicly funded laboratories and institutes must be assured.* It is important that generic, exploratory research is kept at a level which sustains technological opportunities in the long run (Finland, Japan, Korea, see Annex 1).
- *Rigidities in the public research sector in many countries need to be corrected* to increase linkages to other parts of the economy and improve responsiveness to economic and social needs, *e.g.* through technology foresight studies (New Zealand, see Annex 1). More flexible funding arrangements, including a greater share of contract-based resources, would contribute to this goal. Strengthening university/industry co-operation in research should be another policy aim (Austria, see Annex 1). Heightened mobility of university and government researchers, which may require adjustments to regulatory frameworks, would further open up the public research sector (Japan, see Annex 1).

Virtually all OECD governments also support pre-commercial research and development in order to correct for under-investment by firms and to obtain public benefit. In order to increase the leverage of government support programmes on private sector funding, foster co-operation among actors in innovation systems, and increase synergy between market-driven R&D and R&D directed to government missions (*e.g.* defence, health, environment), governments should consider:

- *Increasing the efficiency of existing financial support programmes.*
- *Making greater use of public/private research partnerships* (Australia, see Annex 1). Compared with traditional R&D support, such partnerships entail a more competitive selection process and greater private sector participation in project selection, funding and management. However, their design must minimise the potential risks of capture by private sector participants or displacement of industry research spending.
- *Fostering commercialisation.* Innovators and society will also gain from greater commercialisation of research, including through patents, licenses and spin-off firms. The experience of the United States and other countries shows that royalties and licensing fees from patents and technology can yield significant income. An emphasis on commercialisation also helps move technology into the marketplace. Researchers and professors can start spin-off firms which contribute to innovation and employment on the basis of licensed research results. However, fostering commercialisation and high-technology start-ups requires institutional flexibility and appropriate intellectual property rights rules and other regulations.

Responding to globalisation

Firms and countries vary considerably in the degree to which they interact with partners at national or international level. While there are clear benefits to firms that set up facilities abroad or form alliances, some governments worry about the "hollowing out" of their research capabilities and the effects on long-term innovative capacity. Conversely, governments that host a great deal of foreign research are concerned about potential outflows of knowledge and technology and problems in adjusting to heightened competition in local markets.

Policies are needed that capture the benefits associated with both inward and outward R&D investments and other global technological alliances, provided that the opportunities and incentives for mutual gain depend on sound and predictable rules of the game. Countries should generally encourage *openness to international flows of goods, investments, people and ideas.* They can increase their ability to absorb science and technology from around the world and make themselves attractive locations for innovation. To benefit fully from the internationalisation of trade, investment and knowledge, policy makers, especially in small countries, need to encourage greater interplay between absorptive and innovative capacity by:

- *Upgrading the indigenous technology base and improving linkages within national economies* to obtain spillovers from research, wherever it is conducted (Ireland, see Annex 1).
- *Stimulating the growth of localised innovative clusters or competence centres* which attract foreign R&D investments and personnel (Netherlands, see Annex 1).
- *Enhancing international co-operation in R&D.*

Learning from best practices

Although the situation in OECD countries may be substantially similar for some problems, the context in which national policies are set is significantly different. Policy challenges and responses are therefore, to some degree, country-specific and depend on historical heritage as well as on features of economic and innovation systems. Countries also differ markedly in the capacities and traditions of their science and technology policy institutions; the division of responsibilities between central and sub-central levels of government; the role and power of different ministries; the nature of government/ industry relationships; and the scope for public/private partnerships. The priority tasks of technological and innovation policy are somewhat different. For example, some countries (*e.g.* Japan) place greater emphasis on strengthening the science base, while others (*e.g.* the United States) concentrate on leveraging mission-oriented public R&D, and others (*e.g.* several European countries) try to build a more innovative culture, especially among smaller firms.

The "path-dependency" of technology policy increases the risk of inefficient government initiatives but can also lead to unique strengths in innovative ability. National technology policy institutions have developed specialised skills and corresponding toolkits which may help or hinder accomplishing policy aims. For the most part, governments address current challenges with administrative structures and policy instruments that have been shaped by responses to past problems. These distinctive national features are both constraints on policy choices in the short term and possible targets for policy reform in the longer term. They form the national policy context in which policy options must be analysed and spending prioritised.

Newer Member countries face a greater challenge, since they have to build a national innovation system, in some cases (*e.g.* Eastern European countries) from elements of a no longer functioning system. They may also have to complete the framework institutions needed for building efficient national innovation systems (Mexico, see Annex 1). They need to acquire a range of skills, *e.g.* training, networking management. A main problem may be the inability of domestic enterprises to articulate their technology requirements, as they face the challenge of moving from imitation to innovation (*e.g.* Mexico, Korea). However, these countries may be able to use latecomer advantages – including acquired technology and know-how and learning from the experience of others – to catch up to more advanced countries. Yet imported technology is no substitute for a sound science base and domestic innovative capacity when determining long-run technological performance. The emphasis must be on assimilation of know-how through learning by doing and learning by research.

The OECD is an important forum for analysing the principal changes in the nature and role of scientific and technological progress, including the growing impact of globalisation; for identifying the ways in which these changes can best be harnessed to promote economic growth while responding to major social challenges; for helping Member countries to develop appropriate policies in these areas; and for assisting countries to exploit the full potential of international co-operation. However, countries will generally assess and devise policies and programmes in the context of their own innovation systems and their policy implementation capability.

Annex 1

EXAMPLES OF GOOD POLICY PRACTICES

This annex provides examples of good policy practices that are in line with the main policy recommendations of the report (Box A1). It attempts to strike a balance between coverage of policy areas and of Member countries. Examples should therefore not be viewed as the single best practice in a given policy area, but rather as illustrations of possible good responses to a *generic* policy challenge in a specific national context.

Box A1. **Typology of good policy practices**

Theme	Policy aim	Means	Country example
Securing appropriate framework conditions	To develop human resources in S&T.	Reforms to post-secondary education.	Austria – *Fachhochschulen study courses.*
		Increased government and industry support to professional education.	Finland – *Public/private partnership programme.*
	To close market gaps in the financing of innovation.	Establishment of a legal framework for venture capital.	Hungary – *Venture Capital Act.*
Building an innovation culture	To reduce asymmetry in information.	Internet-based business information network.	Canada – *Strategis Initiative.*
	To diffuse best practices in innovation management.	Funding greater use of benchmarking and diagnostic tools.	Norway – *BUNT programme.* Spain – *MINER scheme.*
	To promote the creation of innovative firms.	Public investment in venture capital.	United States – *SBIC programme.*
Enhancing technology diffusion	To increase firms' absorptive capacity.	Co-financing of consultants to upgrade firms' organisational ability.	Norway – *BUNT programme.*
	To improve linkages between SMEs and public research.	Co-financing of technology uptake via public/private partnerships.	Spain – *CDTI Centre.*
Promoting networking and clustering	To stimulate the formation of innovative clusters of firms.	Brokering and procurement policies.	Netherlands – *Clustering policies.*
		Competition among regions for funding of cluster initiatives.	Germany – *BioRegio Initiative.*
	To ensure a better match between the S&T infrastructure and industry needs.	Co-funding of centres of excellence to facilitate university-industry interactions.	Sweden – *NUTEK Competence Centre Programme.*
		Building networks between public research actors and firms.	France – *Réseaux Nationaux de la Recherche (RNS).*
Leveraging research and development	To sustain technological opportunities in the long run.	Increased government spending on basic R&D.	Japan, Korea.
		Increased public support to R&D.	Finland.
	To increase economic return from public research.	Public/private partnerships.	Australia – *CRC Programme.* Austria – *CD Society and Laboratories.*
		Technology foresight for policy setting.	New Zealand.
		Regulatory reform (university-industry interface).	Japan.
Responding to globalisation	To increase linkages between domestic and foreign-owned firms.	Building networks of competitive domestic firms.	Ireland – *National Linkage Programme.*
	To increase country's attractiveness as a location for knowledge-based activities.	Building innovative clusters (see above).	See above.
		Systemic upgrading of the S&T infrastructure.	Mexico.
Improving policy making	To enhance policy co-ordination.	Raising the co-ordination function to the highest policy level.	Korea – *Science and Technology Council.*
	To improve policy evaluation.	Making evaluation obligatory.	United Kingdom – *ROAME-F model.*
		Developing new methodologies.	Switzerland.

AUSTRALIA

Theme: **Leveraging research and development**

Specific programme/initiative: **Co-operative Research Centre (CRC) programme**

The Co-operative Research Centre (CRC) programme aims to strengthen long-term collaboration between public research actors and industrial firms so as to increase the innovative capacity of Australian firms and generate spillovers throughout the economy. Since 1990, the programme has launched 67 interdisciplinary science and technology centres that bring together integrated research teams involving public research institutes (*e.g.* universities, government research organisations) and users of their research (*e.g.* government departments, public utilities, industry associations, private companies). The main sectors targeted are manufacturing, information and communication technology, mining, energy, health and pharmaceuticals, environment and agro-business. A CRC is structured like a small company and has three main activities: research (short-term research and strategic research); education (*i.e.* postgraduate research) and training (*i.e.* promoting awareness of users and transfer of knowledge). The CRC programme funds between 16% and 49% of a CRC while public/private partners provide cash and in-kind contributions. Participants provide most of the physical infrastructure of a CRC. The responsible government agency administers the programme, but grants the CRCs considerable flexibility in planning and management. What makes the CRCs effective is the contractual agreement among core participants and between them and the Commonwealth government. All partners, especially small firms, must have a clear understanding of the liabilities and expectations from participation. Given the limited R&D capability of domestic firms and the small market for technological applications, the CRCs have reached out to multinationals and foreign-based firms. At the same time, capturing benefits for Australia (*e.g.* in terms of jobs) is a concern and explains the preference for licensing rather than selling the technology emerging from the CRCs.

AUSTRIA

Theme: **Leveraging research and development/Securing appropriate framework conditions**

Specific programme/initiative: **Christian Doppler Society and Laboratories/Reforms to Post-secondary Education**

The Christian Doppler (CD) Society and Laboratories were founded in 1988 in order to ensure better links between university research and industrial research. The CD Society comprises firms that are willing to invest in long-term basic research. It supports the establishment of CD laboratories and secures their long-term financial basis. There are currently 14 CD laboratories in selected universities; they are managed by internationally recognised scientists, according to the following main criteria: an Austrian firm's specific need for industry-oriented basic research; the firm's willingness to contribute financially to the CD Society; the existence of an university with excellent scientific potential to host the laboratory. The annual budget of the CD laboratories is currently about ATS 40 million, of which ATS 16 million is provided by the public sector.

While the share of Austrian university graduates in natural sciences and engineering has increased from around 17% in 1985 to around 23% in 1995, the formal education system has been slow to respond to industry demand for technical skills. The introduction in 1994 of the *Fachhochschulen* study courses, as a supplement and alternative to university studies, aims to fill this gap. To facilitate mobility between universities and *Fachhochschulen,* students in both systems have equal status. This means that *Fachhochschul* students are eligible for grants or scholarships for overseas studies and can complete doctoral studies at any university. Demand for *Fachhochschul* studies has increased from ten study courses to 40 in 1998, and they now involve nearly 6 000 students, of which 20% are women. While the national government is responsible for setting admission standards, the organisation of the courses is devolved to the provinces, communities and private bodies, thus ensuring education programmes that are adapted to local needs.

CANADA

Theme: **Building an innovation culture**

Specific programme/initiative: **Strategis Initiative**

Supply-side diffusion programmes in Canada have become more user-driven and are oriented towards building innovation capacity in firms. Canada's Strategis is the largest Internet-based business data network in Canada. It provides access to business and market information, links to potential partners, alliances, access to new technologies or processes, assistance in assessing the risks of new ventures, and benchmarking tools. Examples include the distCovery database which provides access to more than 35 000 licensable technologies from Canada and around the world; the Canadian Technology Gateway which lists S&T activities and capabilities in Canada; and Trans-Forum, a technology transfer tool for universities and colleges. The success of the programme depends on a client-oriented approach to the provision of information and the one-stop concept. To avoid potential pitfalls from such electronic clearinghouse services, information must be up to date and accurate and the structure of the offerings should have a common interface. Clearly defined "ownership" responsibilities within Industry Canada keep the information up to date and authoritative.

FINLAND

Theme: **Leveraging research and development/Securing appropriate framework conditions**

Specific programme/initiative: **Increase in support for R&D/Public/private partnership programme to develop human capital**

In order to sustain the economic and employment benefits from investment in technology and innovation, the Finnish government has taken steps to increase R&D spending while launching public/private partnerships to increase the supply of workers with information technology skills. By increasing the amount of public support to R&D and providing incentives to sustain growth in private R&D spending, the Finnish government aims to increase total spending on R&D in Finland from 2.5% to 2.9% of GDP by the end of 1999.

While growth in information technologies (especially telecommunications and computing services and software) contributes to the revival of the Finnish economy (and now accounts for some 10% of GDP and between 120 000 to 190 000 jobs), there is evidence that the supply of new graduates is lagging behind demand from firms. Addressing this through traditional education policy is difficult given the time lag associated with educating new graduates (*i.e.* six years for university graduates and four years for polytechnic graduates). In response, the government adopted in 1998 a public/private partnership programme that includes both *ad hoc* measures to promote know-how and increase the number of graduates in the near future, and permanent increases in the provision of university and non-university professional education. Industry will contribute by putting equipment and experts at the disposal of educational institutions, offering internships and encouraging their interns to graduate. The programme will concern over 20 000 students between 1998 and 2002 and is expected to increase the number of degrees by one-third from 1999 to 2006. The programme will also require a sufficient number of qualified students and teachers. To increase the pool of potential students, an additional programme is being launched to strengthen education in mathematics and science. Measures are also being taken to find ways to attract more female students to the fields and alleviate the shortage of qualified teachers. The *ad hoc* measures included in the programme will require a total of FIM 80 million (US$ 14 million) in public funding between 1999 and 2002. The expenditure of the permanent increases in educational provision will amount to FIM 440 million (US$ 81 million) by 2006.

FRANCE

Theme: **Promoting networking and clustering**

Specific programme/initiative: **Réseaux nationaux de la recherche (RNR)**

Increasing social returns on investment in the large public research sector is a priority in France. One means is public/private research partnerships that promote the participation of SMEs between public laboratories and industry in selected broad technological areas. To this end, national research networks (*réseaux nationaux de la recherche*) are being developed under the auspices of the Ministry for Education, Research and Technology. The first of these networks, devoted to telecommunications (RNRT) was launched at the end of 1997. It involves several public research institutions and requires 50-75% financial contribution from private participants, with a preferential treatment granted to SMEs.

GERMANY

Theme: **Promoting networking and clustering**

Specific programme/initiative: **BioRegio initiative**

In order to promote networking and clustering in the biotechnology sector, the German government has integrated competition for funding via the "BioRegio" initiative launched in 1996. The initiative requires regions to submit ideas for the development of biotechnology on a regional basis and awards financial and other special support to the selected regions. A main criterion for the selection of a region is the existence of collaboration between all the parties concerned (*i.e.* universities, industries and the public administration) in the competing regions. This is a systemic approach to providing incentives for regions to organise their networks and clusters in the biotechnology field and promote the development of an integrated biotechnology industry. In particular, the fund aims to promote the transfer of scientific knowledge in biotechnology from universities to German industry, thus speeding the commercialisation of biotechnology research into products and processes.

HUNGARY

Theme: **Securing appropriate framework conditions**

Specific programme/initiative: **Venture Capital Act**

The development of new technologies and products can lead to new industries that help broaden the industrial base. Venture capital plays a crucial role in this process by providing entrepreneurs and new firms with opportunities for expansion. In Hungary, over 90% of the stock of venture capital is foreign. The Hungarian government passed legislation in March 1998 which is designed to encourage the development of domestic venture capital funds. Although the law does not distinguish between seed and equity capital, its aim is to boost the supply of venture capital for early-stage financing. It states that funds may only be in the form of closed-end funds for a period of no less than six full calendar years. The initial capital of a venture capital company or fund may not be less than HUF 500 million. As regards investment rules, the equity investment of registered capital should reach 30% within 24 months, 50% on average during the first six calendar years, and 70% on average during any three-year period. The State Supervisory Commission for Money and Capital Markets provides regulatory oversight for venture capital companies, venture capital funds and fund managers.

IRELAND

Theme: **Responding to globalisation**

Special programme/initiative: **National Linkage Programme**

In Ireland, where innovative capacity depends largely on foreign investment in high technology, there has been concern that national firms are insufficiently integrated into networks with multinational firms. In response, the National Linkage Programme (NLP) aims to increase the supply of goods and services from national to foreign firms based in Ireland. The NLP links groups of domestic firms to help them interact more coherently and cohesively with foreign firms, which are becoming more selective and demanding of local partners and suppliers.

JAPAN

Theme: **Leveraging research and development**

Special programme/initiative: **Increase in basic R&D/Regulatory reform**

Aware that structural reform of the economy is crucial for me creating new industries and ensuring their stable growth, the Japanese government announced in 1997 a Program for Economic Structural Reform and an accompanying Action Plan. In the latter, the government identified four areas – innovation financing, human resource development, technology, and highly advanced information telecommunications – as key areas requiring more sophistication to sustain new business activities. Within the human resources and technology areas, university-industry co-operation has been emphasised as a means to support structural reform. The government is undertaking regulatory reforms to create a flexible and competitive environment for university-industry co-operation. The main focus of the reforms is the rules governing the public research institutions and publicly funded research. The government is preparing to amend laws that presently restrict research activities in private companies by professors in national universities in order to make it possible, or easier, for industry to hire university professors for a fixed term to carry out joint research. Another legislative measure aims to pave the way for closer university-industry co-operation by promoting technology transfer from universities to industry through technology licensing organisations (TLOs). By fostering spin-offs and new industries, TLOs aim to improve the contribution of universities to industry and society.

KOREA

Theme: **Leveraging research and development/Improving policy making**

Specific programme/initiative: **Increase basic R&D/S&T policy co-ordination**

In the long term, innovation cannot be guaranteed by imitation alone. Recent policy measures stress the potential of Korea's resources in science and technology, particularly in terms of human capital, to contribute to a recovery from the current crisis. To this end, the government has transferred the co-ordination of S&T policy to the Science and Technology Council, which is to be chaired by the president of Korea. The legislation governing S&T policies is also in the process of amendment. Among the expected outcomes will be greater resources for basic R&D (funding is expected to rise by 20% by 2002), the promotion of young scientists, and the establishment of centres of excellence in Korean universities.

MEXICO

Theme: **Responding to globalisation**

Specific programme/initiative: **Systemic upgrading of the S&T infrastructure**

Mexico has long grappled with a dual economy, characterised by export-oriented multinationals and inward-oriented, low-technology small firms which lack links to international and national sources of knowledge and technology. New measures now aim to strengthen the S&T infrastructure. These include the establishment of an R&D tax credit, the lowering of import duties for research materials, and support for a government-funded but privately managed venture capital scheme. The CONACYT's 20 research centres are being reorganised with a view to gradually reducing public support while increasing funding from industry. Knowledge and Innovation is a new programme planned to foster networking, technology diffusion, and the development of new markets for technological services. Mexico is also using technology foresight studies to better focus research and policy actions.

NEW ZEALAND

Theme: **Leveraging research and development**

Specific programme/initiative: **Technology Foresight Project**

In New Zealand, a country with limited R&D resources and a small industrial base, the use of technology foresight has become an integral aspect of technology and innovation policy. The Foresight Project is a consultation-based mechanism for reviewing and prioritising science and technology objectives in order to maximise public benefits. The latest Foresight Project, started in 1997, is to set S&T budget priorities for the period 2000-02. The project has four phases. The first develops the best possible assumptions about the future for S&T. The assumptions are used to create a national view of required competencies and a strategy for setting priorities. Phase two focuses on knowledge foresight, sector foresight and economic evaluation of previous public investments in science and technology. Priority setting and budget allocation are decided in phase three and implemented in the phase four. This process requires broad participation from the science and technology community to share information and understanding. For sector foresight, in particular, all sectors of society and the economy are encouraged to develop their own foresight exercises (*i.e.* their vision and goals for 2010) and to indicate how these could be achieved through science and technology. The advantage of consultation-based foresight exercises is the involvement of a broad number of actors in an interactive process. Consultation-based exercises, however, require significant outreach efforts and costs on the part of government. Still, they also help create networks between public and private actors and can strengthen longer-term co-operation in science and technology.

NETHERLANDS

Theme: **Promoting networking and clustering**

Specific programme/initiative: **Brokering and procurement policies**

In recent years, Dutch innovation policy has focused increasingly on "clustering policies", which encourage strategic co-operation between high-technology companies and the public research system. R&D support from the government has therefore been shifting towards clusters of firms and research institutes and away from individual firms or institutes. The Dutch government strategy for stimulating the formation of innovative clusters in a market economy is based on three main tenets: framework, brokering and procurement policies. Brokering policies prepare a meeting ground between firms and research institutes. Specifically, they facilitate collaborative projects to upgrade specific clusters at the pre-competitive stage (*e.g.* life science research in the medical and agro-food cluster) through public grants and consultancy support. In some cases, firms and research institutes are brought together in "focus groups" to identify opportunities in a specific emerging market, such as information and environmental technologies. These policies also facilitate the establishment of research centres of excellence (*Top instituten*) in specific areas, in order to stimulate co-operation between industry and public research institutes. Brainport is a complementary initiative which concentrates on R&D activities in transport, communication and distribution. Programmes for and/or co-financed by private firms provide incentives for the public research sector to match research activities to private needs.

NORWAY

Theme: **Building an innovation culture/Increasing technology diffusion**

Specific programme/initiative: **BUNT Programme**

Norway's BUNT (Business Development Using New Technologies) programme illustrates the shift towards demand-driven technology diffusion measures, which has also taken place in many other OECD countries. The BUNT programme focuses on developing the problem-solving capacities of firms and their organisational ability to incorporate technology. The BUNT provides funding for consultants to help firms undertake a general evaluation, followed by the development of a strategic plan for technology use and company development. Experience from the BUNT programme suggests that organisational change is often a precondition for the introduction and efficient use of new technology. An important part of the BUNT programme, and a reason for its success, has been the continuous evaluation of the programme, which has provided programme management with regular input on the evolution of different aspects of the programme, making it possible to adjust the programme to emerging best practices. Difficulties have generally been encountered in the final phase, notably after the implementation of the first or second priority action plans. This raises the question of whether support should be withdrawn or maintained. *Ex post* evaluations of approximately 50 former BUNT companies showed that they still needed some consultant assistance, an indication of a persisting failure to build internal innovative capacity.

SPAIN

Theme: **Building an innovation culture/Improving technology diffusion**

Specific programme/initiative: **CDTI Centre/MINER Schemes**

Spain's industrial base is characterised by low R&D intensity in firms, especially in mature manufacturing industries. Rather than targeting the development of high-technology sectors, technology and innovation policy in Spain focuses primarily on diffusing new and existing technologies to mature industries such as textiles, shoes, wood products and food processing. Through the Centre for Industrial Technology Development (CDTI), this policy has concentrated on promoting SMEs' participation with public research in public/private partnerships. A key focus of the CDTI is the financing of technology uptake partnerships involving SMEs that lack access to other sources of innovation financing. Evaluations note the need to ensure against opportunistic behaviour by firms, particularly larger ones. In addition, the government (MINER) has implemented a series of programmes to promote technology uptake in SMEs. Examples include the promotion of diagnostics for helping SMEs assess technological needs and capacity, databases for accessing patents and licensing offices, and training schemes for research management.

SWEDEN

Theme: **Promoting networking and clustering**

Specific programme/initiative: **The NUTEK Competence Centre Programme**

In Sweden, innovation and technology policies are moving away from the linear innovation model and associated support schemes. This change is illustrated by the Competence Centre Programme, launched by NUTEK in 1993. The competence centres aim to enhance university-industry interactions and structure them around poles of excellence with a critical mass of resources, thus ensuring a better match between the S&T infrastructure and industry needs. In order to ensure that the proposed centres respond to both the needs of industry and the long-term priorities of universities, part of the centre's funding must come from the university's internal funds, and the industrial contribution must include the commitment of staff seconded to the centre. Under these conditions, NUTEK issued an open call for joint university/industry proposals and the centres were selected through a competitive process out of 100 initial proposals. Swedish industry has shown a great interest in the competence centres from the very beginning of the programme and has played an active role in their build-up. To date about 160 firms are participating in 28 competence centres.

SWITZERLAND

Theme: **Improving policy making**

Specific programme/initiative: **New approaches to evaluating S&T support programmes**

Support to technology diffusion remains a main policy concern in Switzerland, as large investments in R&D are insufficiently translated into commercial products and processes, particularly among SMEs. Until recently, an effective means of evaluating the efficiency of diffusion programmes was lacking, thus limiting the scope for programme and policy improvement. Conventional evaluation methods do not generally assess the net economic effects of the public support programmes for technology diffusion, as they concentrate on performance in the context of the programme and do not analyse the effects of environmental factors by using a statistical control group (*i.e.* non-participants to the programme). A recent econometric approach uses micro-level data to see whether support programmes actually result in rapid and broader technology diffusion. It also tries to identify the relative effectiveness of the main elements of a given support programme (*e.g.* training, consultancy, R&D support, etc.). It uses an econometric model to estimate the relation between policy intervention and the resulting additional technology diffusion. The model includes environmental variables (*e.g.* firm size, potential for the application of technology, intensity of the use of technology, technology market conditions, etc.) and policy variables (*e.g.* the number of projects, the amount involved, etc.), and explains the interaction between these variables. Both direct and indirect effects of a promotion programme can be captured by this econometric analysis which, coupled with more qualitative evaluations (*e.g.* based on interviews), provides an improved basis for policy making.

UNITED KINGDOM

Theme: **Improving policy making**

Specific programme/initiative: **ROAME-F evaluation model**

In the area of S&T policy evaluation, the UK ROAME-F model ensures that all technology and innovation policies are soundly based and provides a structure for measuring the success of programmes. It requires a formalised, obligatory statement on the rationale, objectives, appraisal, monitoring, evaluation and feedback of each proposal for new programme expenditure. One of the most important aspects of the ROAME-F model is a standardised framework that clearly specifies both the "rationale" and the "objectives" of government intervention on the basis of the concept of market failure. Another important element is the fact that "appraisal", "monitoring" and "evaluation" are all formally incorporated into the programme and that the methodologies are also specified from the start. In addition, the ROAME-F model places a formal obligation on policy makers to react to "feedback" from the results of evaluations. Through this feedback mechanism, evaluation is systematically embedded in the policy-making process and its follow-up in the form of redesigning or reforming existing or future policies is secured.

UNITED STATES

Theme: **Building an innovation culture**

Specific programme/initiative: **SBIC Programme**

While the emergence of new technology-based firms (NTBFs) in the United States is due largely to appropriate framework conditions for business and entrepreneurship, government policy has nevertheless been instrumental in helping small innovative firms to access the financial and managerial capital necessary to expand. Entrepreneurs looking for seed capital to launch a small business often have difficulties finding institutional resources. In order to solve this problem and promote businesses with innovation potential, the Small Business Investment Company (SBIC) programme has operated in the United States since 1958. SBICs are licensed and regulated by the Small Business Administration (SBA) and supply equity capital, long-term loans and management assistance to qualifying small businesses. These SMEs are able to receive financial and/or management assistance, and venture capitalists participating in the programme can supplement their own private investment capital with funds borrowed at favourable rates and backed by a SBA guarantee. As SBICs are privately organised and privately managed investment firms, they are in effect profit-seeking organisations. Therefore, SBICs have an incentive to seek out small businesses with innovative products or services with strong growth potential. In terms of the efficiency of the programme, tax revenue generated each year from successful SBIC investments more than covers the cost of the programme.

Annex 2

SUMMARY OF FOCUS GROUP REPORTS

Innovative Firm Networks[4]
A pilot study of Austria, Denmark, Norway and Spain (EuroDISKO)

Introduction

Innovation results from complex interactions between research, design, production and marketing that take place in a web of interactive learning within and among firms and other knowledge organisations (Lundvall, 1992). Organisational and institutional features (rules, norms and habits) of firms'environment that shape such innovation networks vary across countries and regions. The specific patterns of interaction between users and producers of innovations are at the very core of what defines national (regional) innovation systems (Freeman, 1991; Nelson, 1993; Edquist, 1997) and are an essential aspect of their internationalisation.

Despite their importance in explaining innovation performance, international differences in the patterns of inter-firm linkages, including cross-border collaboration, are still poorly understood owing to the lack of comparable data.[5] The objective of the Focus Group on Innovative Firm Networks was to address this issue by carrying out co-ordinated pilot surveys in four countries, Austria, Denmark, Norway and Spain, with the aim to identify similarities and differences regarding:

- The extent, nature and motives of inter-firm collaboration in the process of product innovation (new or improved tangible products).
- The degree of internationalisation of inter-firm linkages.

The pilot surveys were carried out according to a common methodology, derived from the Danish DISKO (Danish Innovation System in a Comparative Perspective) project and involved the use of the CATI (Computer Aided Telephone Interviewing) technique to gather information on:

- Type of partnership (including both formal and informal collaborative arrangements).
- Reason for and importance of collaboration with the specific type of partner.
- Duration and intensity of collaboration.
- Mobility of labour during collaboration.
- Services related to product development.

Innovative firms were defined as those that had developed one or more new products within the last two years (three in the case of Spain). They represented 44% of the 1 006 firms surveyed in Austria, compared to 56% of the sample (1 022 firms) in Denmark, 75% of the sample (797 firms) in Norway, and 78% of the sample (398 firms) in Spain.

Main findings

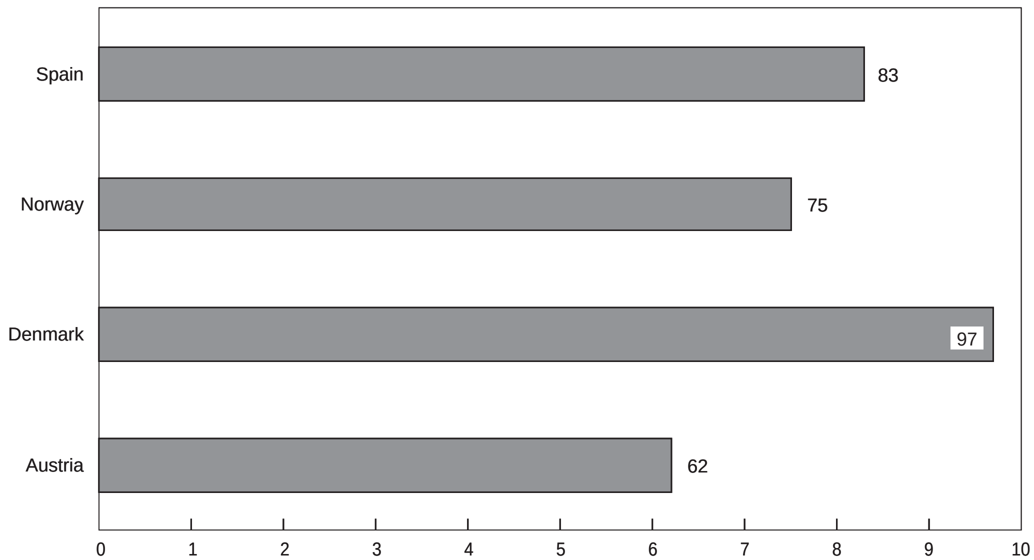
Propensity to collaborate

EuroDISKO confirms the findings of previous surveys (*e.g.* CIS) which show that firms rarely innovate alone (Figure A1) and that the propensity to collaborate in innovation increases with firm size, especially in Spain and, to a lesser extent, in Austria and Norway (Figure A2). In Denmark, almost all innovative firms are involved in some form of collaboration. Another distinguishing feature of Spain is the relatively even and low propensity of both medium-sized and large firms to collaborate.

Types of partners

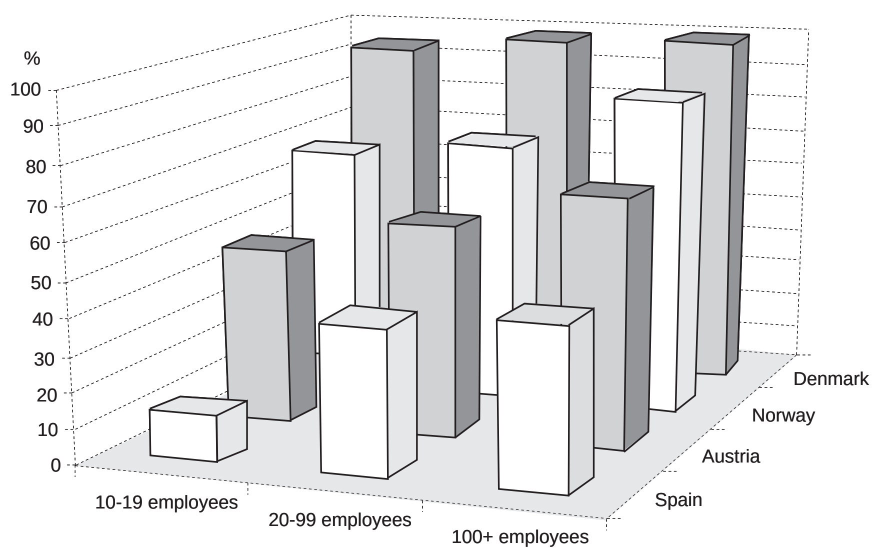
There is considerable variation across countries with regard to the types of partners of firms (Figure A3). For example, universities and research institutes are frequent partners for Spanish firms (60%), but less so for Austrian firms (33%), for Danish firms (17%), and for Norwegian firms (23% for universities, and 41% for research institutes).

Figure A1. **Share of innovative firms with one or more partners, 1997**



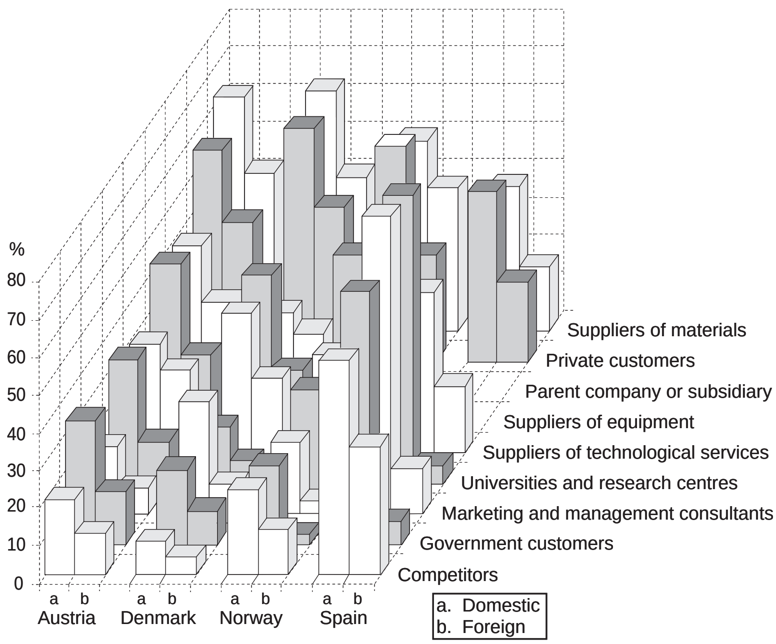
Source: Report of the Focus Group on Innovative Firm Networks, 1998.

Figure A2. **Collaboration and firm size, 1997**



Source: Report of the Focus Group on Innovative Firm Networks, 1998.

Figure A3. **Types of partners of firms, 1997**



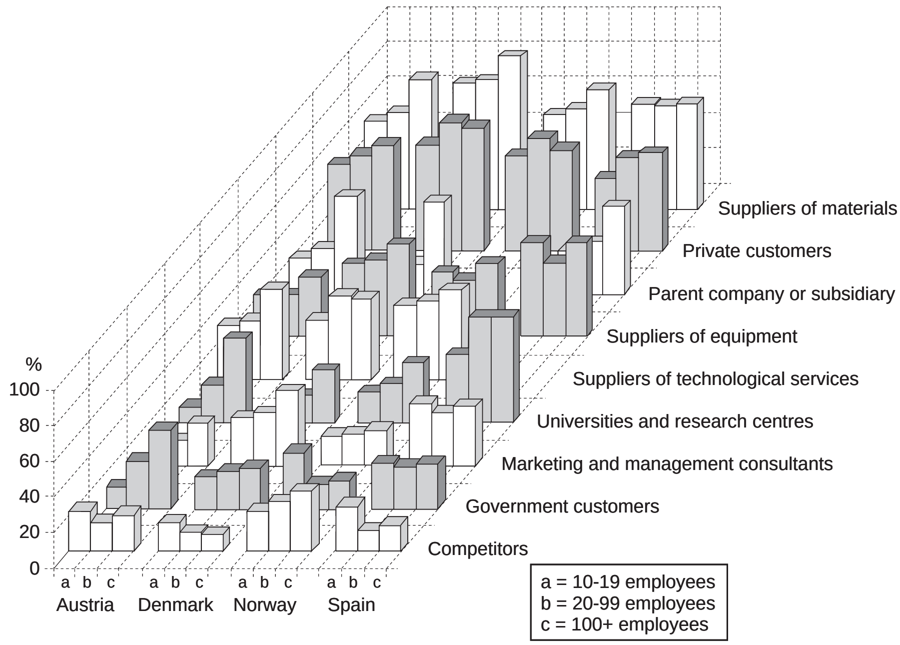
Source: Report of the Focus Group on Innovative Firm Networks, 1998.

This reflects differences in institutional frameworks and the orientation of public policies. For example, in Denmark, the broad range of services offered by intermediary organisations that are part of the GTS system (Approved Technological Service System) reduces the need for collaboration with universities and research centres. In Spain, public policies strongly support, through subsidies, collaboration between public institutions and firms (around two-thirds of the firms involved in product development have received public support for what they identify as their most important project).

Figure A3 confirms the importance of supplier-buyer chains and intra-group relationships in innovation systems. Private customers are more frequent partners than government customers in all four countries (however, the discrepancy between the frequency of collaboration with private and with government customers is larger for Denmark than for the other countries). Customers and suppliers of materials and components are the most frequent partners of innovative firms in Denmark, Norway and Austria. Spanish and Danish innovating firms, however, collaborate more frequently with suppliers of machinery and production equipment than do their counterparts in Austria and Norway. Compared with collaboration with a parent or subsidiary, collaboration with competitors is infrequent except among Norwegian firms.

Figure A4 shows that the frequency of collaboration with different types of partners varies also with firm size. Generally, the smaller the firm, the lower the probability of collaboration with universities and research centres (except in Spain), marketing and consultants, and with a parent and subsidiary company. Small firms interact more frequently with competitors than do large firms, except in Norway. For the other types of partners, patterns are more complex and country-specific. For example, in Austria, size makes less difference for collaboration with competitors, contract research organisations, marketing and management consultants and suppliers of machinery and production equipment. In Denmark, size is less a factor in collaboration with competitors, government customers, suppliers of machinery and production equipment, suppliers of technological services, testing, control and marketing and management consultants. In Norway, the negative correlation between firm size and collaboration with government customers is most striking (32% of small firms report collaboration with government customers, compared to only 16% for firms with 100 employees and more). This can be seen as an indirect measure of the success of a government policy (the so-called OFU contracts) aimed at engaging SMEs in collaborations with the public sector.

Figure A4. **Types of partners according to firm size, 1997**



Source: Report of the Focus Group on Innovative Firm Networks, 1998.

Collaboration between manufacturing firms and knowledge-intensive service firms deserves special attention, given its role in increasing innovation capabilities throughout the economy. EuroDISKO (Figure A5) and CIS-type data concur in estimating that between 30% and 50% of the firms surveyed had established a co-operative link with consultants, technological service firms, etc.

Domestic and foreign collaboration

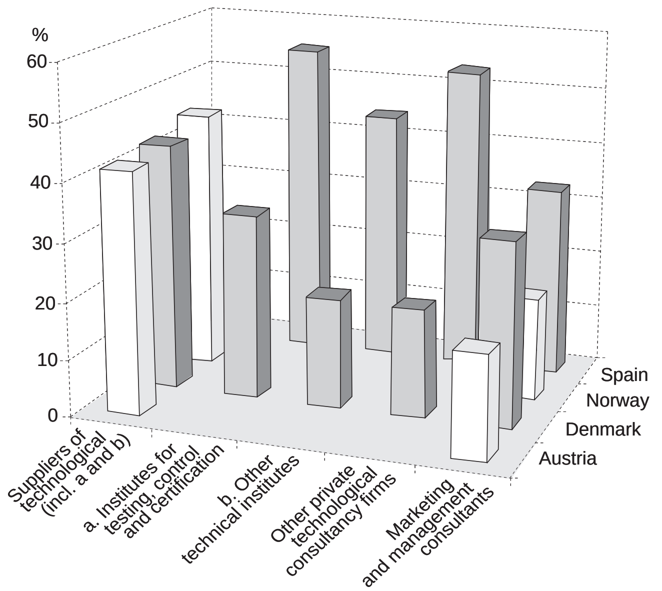
Figure A6 shows that collaboration *within* the country is still most important for product innovation. Co-operation with foreign firms already plays a significant role, however, especially when it involves suppliers of materials and components and private customers, but the DISKO survey reveals that, in Denmark, increased collaboration with foreign firms has been accompanied by intensified collaboration with domestic partners. In contrast, in Spain, collaboration with consultants and providers of technological services, as well as with competitors, is more inward-oriented than in the other countries.

Overall, the propensity to collaborate with foreign partners is very similar in Austria, Denmark and Norway. It is slightly lower in Spain, but this may be due to the size of the country since, other things being equal, large economies may be expected to have a greater variety of technical competencies within the national boundaries than smaller ones. However, this hypothesis would need to be tested against comparable data for other medium-sized countries.

The importance of informal network relationships based on trust

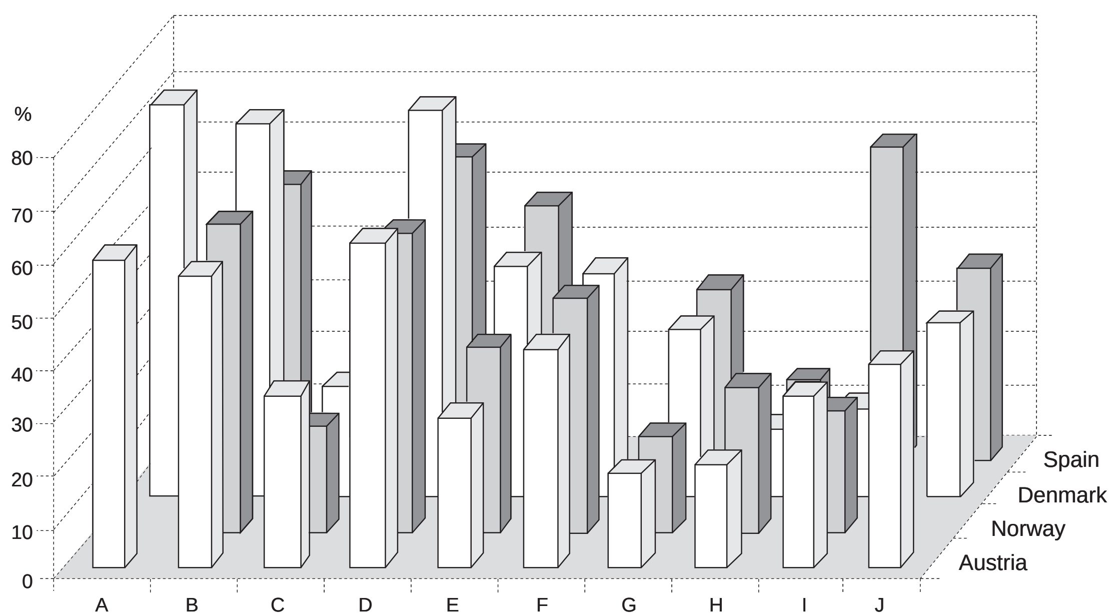
Knowledge is often embodied as much in people as in organisations. Informal information exchange and co-operation gain in importance in a context where innovation rests on an increasingly complex and rapidly evolving knowledge base. Co-operation requires a basis in affinity and loyalty, since the quality of relationships among partners inevitably affects the outcomes of the co-operation. The most important determinants of these relationships are trust and confidentiality, reputation of the partner and fairness. As Freeman (1991) argues, "personal relationships of trust and confidence (and sometimes of fear and obligation) are important both at the formal and informal level… For this reason, cultural factors such as language, educational background, regional loyalties, shared ideologies and

Figure A5. **Collaboration with knowledge-intensive services, 1997**



Source: Report of the Focus Group on Innovative Firm Networks, 1998.

Figure A6. **Domestic and foreign collaboration, 1997**



A. Customers
B. Private customers
C. Government customers
D. Suppliers of materials
E. Suppliers of equipment
F. Suppliers of technological services
G. Management and marketing consultants
H. Competitors
I. Universities and research centres
J. Parent company or subsidiary

Source: Report of the Focus Group on Innovative Firm Networks, 1998.

experiences and even common leisure interests continue to play an important role in networking". EuroDISKO provides some information about the role of trust and confidentiality in network building for Austria and Denmark. In Austria, more than 70% and in Denmark around 60% of all co-operating firms consider that trust and confidentiality are important prerequisites for co-operation. But only 24% of Austrian co-operating firms and 22% of Danish co-operating firms consider as important a trial period with the partner before committing substantial resources to a collaborative venture. This indicates the importance of *ex ante* trust, based on experience and reputation in determining co-operation patterns.

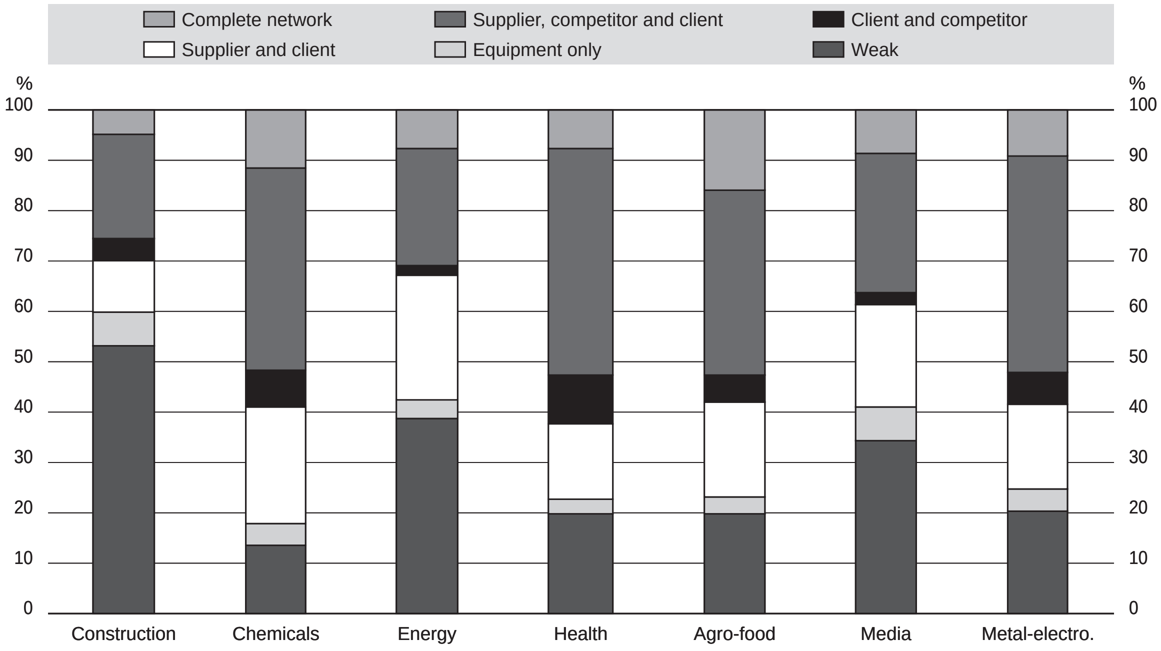
Cluster Analysis and Cluster-based Policy[6]

Introduction

The national innovation system concept is one of a much larger family of "systems of innovation" approaches. All have system analysis as their common starting point, but differ in the object and level of analysis (*e.g.* supranational, regional, technological, sectoral, clusters) (Edquist, 1997). The work of the Focus Group on Cluster Analysis and Cluster-based Policy (CACP) demonstrates that the cluster approach provides unique insights into innovation processes and that it can contribute to innovation policy making at both national and regional levels.

The focus group has defined economic clusters as networks of production of strongly interdependent firms (including specialised suppliers) linked to each other in a value-adding production chain. In some cases, clusters also encompass strategic alliances with universities, research institutes, knowledge-intensive business services, bridging institutions (brokers, consultants) and customers. The cluster concept goes beyond "simple" horizontal networks in which firms, operating on the same market for final products and belonging to the same industry group, co-operate in certain areas (*e.g.* joint R&D, demonstration programmes, collective marketing or joint purchasing policy). Clusters are most often cross-sectoral (vertical and/or lateral) networks and encompass complementary firms specialised around a specific link or knowledge base in the value chain.[7] Figure A7. illustrates the importance and variability of network relations in innovation clusters

Figure A7. **Networks of innovation in clusters in the Netherlands, 1992**



Source: Van den Hove *et al.*, 1998.

The key incentives for cluster formation[8] are diverse: *i)* to gain access to new and complementary technology; *ii)* to capture economies of scope; *iii)* to spread risks; *iv)* to promote joint R&D efforts with suppliers and users; *v)* to obtain reciprocal benefits from the combined use of complementary assets and knowledge; *vi)* to speed up learning processes; *vii)* to lower transaction costs; and *viii)* to overcome (or create) barriers to market entry.

Table A1 summarises the main differences between the traditional sectoral approach and the cluster-based approach. By specifying strict boundaries for industries or sectors (mostly based on some statistical convention), the traditional sectoral approach fails to take into account the importance of interconnections and knowledge flows within a network of production (Rouvinen and Ylä-Antilla, 1999). The cluster concept is more in line with the modern interactive model of innovation since it captures vertical relationships between dissimilar firms and symbiotic knowledge inter-dependence in the value chain (Dunning, 1997). The main goal of the focus group was to gain a better understanding of successful innovative behaviour in various clusters, based on some common starting points (Box A2).[9]

Table A1. **Traditional sectoral approach *vs.* cluster approach**

Sectoral approach	Cluster approach
• Groups with similar network positions.	• Strategic groups with mostly complementary and dissimilar network positions.
• Focus on end-product industries.	• Includes customers, suppliers, service providers and specialised institutions.
• Focus on competitors.	• Incorporates the array of interrelated industries sharing common technology, skills, information, inputs, customers.
• Hesitancy to co-operate with rivals.	• Most participants are not direct competitors but share common needs and constraints.
• Dialogue with government often focuses on subsidies and protection.	• Wider scope for a constructive and efficient business-government dialogue.
• Looks for diversity in existing trajectories.	• Looks for synergy and new trajectories.

Source: Adapted from Porter, 1997.

Box A2. **Starting points of the Focus Group on Cluster Analysis and Cluster-based Policy**

- Firms usually innovate in networks of production and rarely in isolation. Most innovative activities involve multiple actors and stem from the combination of complementary and specialised competencies and the knowledge of various actors.
- The synergy that arises from the combination of complementary knowledge of dissimilar firms and knowledge organisations and the need for firms to cope with increasing uncertainties in their environment are the driving force for the emergence of innovative collaborative agreements and clusters.
- Important innovations stem from "new" combinations of complementary knowledge and competencies.
- Different types of networks and markets require a variety of innovation styles.
- Cluster initiatives originate from a trend towards governance based on networks and partnerships. This coincides with a trend in policy making from direct intervention towards indirect policies to facilitate technology diffusion and innovation.

The scope of cluster analysis

Most of the participating countries' cluster studies have as their objective to characterise networks of strongly interdependent firms or industrial activities, although they may have a different focus:

- Trade linkages (Hauknes, 1999; Roelandt *et al.*, 1999; Bergman and Feser, 1999).

- Innovation linkages (DeBresson and Hu, 1999).
- Knowledge linkages (Vuori, 1995; Poti, 1997; Roelandt *et al.*, 1999; Van den Hove, 1998).
- Common knowledge base or common factor conditions (Drejer *et al.*, 1999).

Most cluster analyses use a combination of techniques at different levels of aggregation to answer different questions and provide different information (Table A2).

The value added of cluster analysis

The focus group's assessment of the various countries'studies points to the following main advantages of the cluster approach:[10]

- It offers a new way of thinking about economic and industrial structures and is a useful alternative to the traditional sectoral analysis.
- It captures the changing nature of competition in a knowledge-based economy where innovation determines competitive advantage, and uncovers important non-firm-specific microeconomic determinants of the direction and pace of technological development.
- It contributes to the understanding of innovation systems at a reduced scale, and provides insights into policy responses to systemic imperfections.
- It has been used successfully as a tool for policy making in some countries, and as a tool for strategic business development in both industrialised and developing countries (Ceglie, 1999).
- It helps to redefine the role of and forms of co-operation between the private sector, government, trade associations and educational and research institutions in a time of rapid change that cuts across traditional industrial and technological boundaries.
- It helps to identify untapped opportunities for complementary public and private investment.

Countries' approaches in cluster-based policy

Clustering is a bottom-up, market-induced and market-led process. This does not, however, imply that governments should only ensure that co-operation in clusters does not lead to collusive behaviour that restricts competition. Cluster studies demonstrate that governments also have a role as facilitator of networking, as catalyst of private efforts to create dynamic comparative advantage, and as institution-builder to establish an efficient incentive structure and infrastructure.

Four rationales for government promotion of innovation can be identified in the participating countries' studies: *i)* creating favourable framework conditions for an efficient functioning of markets; *ii)* correcting externalities associated with investment in knowledge; *iii)* ensuring that government is a competent customer, and *iv)* reducing other systemic imperfections. The last has long been neglected but is now increasingly recognised as the key to further improvement of public policies.

In response to systemic imperfections, cluster-based policy initiatives should operate in favourable framework conditions and aim at: *i)* stimulating interaction and knowledge exchange among the various actors in systems of innovation; *ii)* removing information failures by providing strategic information; *iii)* removing institutional mismatches and organisational failures in innovation systems, especially mismatches between the (public) knowledge infrastructure and private demand, including the lack of a demanding customer in the value chain; *iv)* removing government failures and government regulations that hinder the process of clustering and innovation.

In practice, cluster policy approaches differ across countries.[11] Some are bottom-up, focusing on the removal of market imperfections to facilitate market-induced initiatives without setting national priorities (as in the United States and the Netherlands). Some are more top-down, where government (in consultation with industry and research agencies) sets national priorities, formulates a challenging view for the future, and selects actors to engage in cluster-based dialogue groups which subsequently operate without much government interference (as in some Nordic countries).

In general, the clustering process is initiated by establishing forums or other platforms for dialogue among firms and organisations involved in relevant clusters. Strategic information (such as technology foresight studies and strategic cluster studies) is often among the inputs to this dialogue. The actual organisation differs, depending on countries' national traditions and culture in policy making, their institutional profile, and their economic size and industrial specialisation.

Table A2. **Level of analysis, cluster technique and cluster concept adopted in various countries**

Country	Level of analysis			Cluster technique					Cluster concept
	Micro	Meso	Macro	I/O	Graph	Corresp.	Case	Other	
Australia		X	X	X		X	X		Networks of production, of innovation, and of interaction.
Austria		X	X				X	Patent data and trade performance.	Industrial districts.
Belgium	X				X			Scientometrics.	Networks or chains of production, innovation and co-operation.
Canada		X	X	X			X		Systems of innovation.
Denmark	X	X		X	X		X		Resource areas.
Finland	X	X					X		Clusters as unique combinations of firms tied together by knowledge.
Germany	X	X		X		X			Similar firms and innovation styles.
Italy		X		X					Inter-industry knowledge flows.
Mexico		X	X				X		Systems of innovation.
Netherlands		X	X	X			X		Value chains and networks of production.
Spain		X		X			X		Systems of innovation.
Sweden		X					X		Systems of interdependent firms in different industries.
Switzerland	X	X				X	X	Patent data.	Networks of innovation.
United Kingdom	X	X					X		Regional systems of innovation.
United States		X		X			X		Chains and networks of production.

Source: OECD.

OECD countries' experience points to some pitfalls in cluster-based policy making. A number of key policy principles can be derived from this experience:[12]

- The creation of clusters should not be a government-driven effort, but should result from market-induced and market-led initiatives.
- Cluster policy should not be a disguise for outdated industrial policy based on subsidies and protection from competition.
- Government policy should shift from direct intervention to indirect inducement. Government involvement is only justified if there is a clearly identified market or systemic failure, and if there are strong reasons to believe that government intervention can improve the situation.
- Governments should not take the lead in cluster initiatives, but rather act as catalyst and broker for bringing actors together and supplier of supporting structures and incentives to facilitate the clustering and innovation process.
- Cluster policy should not ignore small and emerging clusters.
- Governments should not attempt to create clusters "from scratch" in declining markets and industries.

Reviewing the various policy initiatives in the participating countries reveals the following main components of cluster-based policy in OECD countries:

- A vigorous competition and regulatory reform policy (almost all countries).
- Provision of strategic information by technology foresight studies (*e.g.* Netherlands, Sweden), cluster studies (*e.g.* Austria, Denmark, Finland, Italy, Netherlands, Sweden, United Kingdom, United States,), special research groups (*e.g.* Denmark, the Austrian TIP research programme, the German Delphi report), or special Web sites (*e.g.* Strategis in Canada).
- Broker and networking agencies and schemes (*e.g.* the Danish Network Programme, the Dutch Innovation Centres).
- Cluster development programmes (*e.g.* cluster programmes in Finland and the Netherlands, regional development agencies in Germany, the United Kingdom, the United States and the Flemish R&D support to clusters).
- Joint industry-research centres of excellence (*e.g.* Belgium, Denmark, Finland, Germany, the Netherlands, Spain, Sweden and Switzerland).
- Public procurement policy (*e.g.* Austria, Denmark, the Netherlands).
- Institutional renewal in industrial policy making (*e.g.* Canada, Finland).
- Platforms for constructive dialogue (*e.g.* the US focus groups, the Danish reference groups, the proposed Swedish industrial system approach, the UK regional development agencies, the Dutch brokering policy, the Finnish national industrial strategy, the German Council for Research, Technology and Innovation).

In conclusion, cluster studies not only provide an analytical tool for increasing understanding of innovation processes, they can also be used as a tool to bring government technology and innovation policy and strategic business development into a common framework. Many countries use the cluster approach as part of a market-led economic development strategy aimed at stimulating dialogue and fostering knowledge exchange among the various actors in their systems of innovation. But cluster approaches pose a challenge to governments'ability to render policy-making processes and institutions more apt to pursue "horizontal policies". Cluster policies require co-ordinated contributions from a variety of government agencies and ministries (*e.g.* those responsible for education, science, trade, competition, technology, public works, fiscal policy and so on) (Ormala, 1998; Sulzenko, 1998; Roelandt *et al.*, 1999).

Knowledge Transfer Through Labour Mobility[13] A Pilot Study on Nordic Countries[14]

Introduction

The mobility of highly educated labour is an important mechanism for knowledge transfer, and relevant indicators are a necessary complement to other measures (*e.g.* R&D statistics, innovation surveys, knowledge flows embodied in machinery and equipment) for mapping key linkages in innovation systems. They are also necessary to create a more solid common basis for policy analysis in the fields of innovation, education and labour markets. However, their development is impaired by a number of methodological problems and, in many countries, by the lack of suitable data.

Nordic countries are privileged in having register data on employees which can be used to study the stocks and flows of personnel from the perspective of national innovation systems. The registers contain information on each employee, including age, education and employment at any particular time.

The aim of the Focus Group on Mobility was to demonstrate how such information can be used to compare national patterns of human resource mobility in innovation systems, with a view to contributing to the development of indicators in other countries. The pilot study explored mostly uncharted territory, since it exploited data (register data) that has only recently been available[15] and could not build much on previous studies on mobility, which were based on *ad hoc* surveys and were only partly relevant.[16]

Methodology

A basic assumption underlying the pilot study is that the mobility of personnel between organisations entails some transfer of knowledge. The degree to which this holds true depends on factors for which information is available (*e.g.* employment tenure and educational level), but also on others (*e.g.* each person's ability and opportunity to learn and his/her exact position or occupation in the organisation).

In this study, the indicator for knowledge is the level and field of formal education. An alternative might have been occupational classification, but not all OECD countries collect such data, and classifications differ (Elias, 1996). It is much more difficult to assess the impact and extent of knowledge transfer associated with experienced personnel. In the future, an indicator combining education and the aspects of a person's career may be constructed.

Strict comparability of data from different countries is very difficult to achieve. A thorough understanding of the institutional conditions of individual countries is needed. Discrepancies in institutional and educational systems necessarily reduce the value of direct comparisons. The focus group's work shows that even when comparing three countries that are similar in many respects, contextual work is required to make quantitative comparisons analytically meaningful.

The study of stocks and flows of employees with higher education was carried out according to the following terms:

- An individual was considered as "employed" if he/she held a job during at least one of the years during the period under review.
- Mobility was defined as a change of workplace (establishment), and not of organisation or of sector, since a relatively low level of sectoral breakdown would have entailed serious distortions of measured mobility patterns. International mobility, even between the Nordic countries, was not taken into account.[17] Such limitations should be overcome in follow-up work.
- A breakdown into eleven sectors was chosen, to reflect the main characteristics of each country's national innovation system while allowing cross-country comparisons: the higher education sector, the R&D sector (including the industrial research institutes) and nine industrial or public sectors.[18]
- For practical reasons, stocks and flows were measured for the latest available years in each country (1994-95 for Finland and Sweden, and 1995-96 for Norway), despite the fact that mobility patterns show great variation even over short periods of time, depending heavily on the economic climate. In follow-up work, the stability of mobility rates over time will be tested.

Main findings

Mobility rates

Employee mobility is not a marginal phenomenon. Between a quarter and a fifth of employees were recorded as having left their employer one year later (Table A3). The majority changed jobs (*i.e.* did not leave the active labour force). Mobility rates are roughly the same for the highly educated as for other employees, with a somewhat higher mobility in Finland and Sweden than in Norway.[19]

Table A3. **Mobility rates**

Percentage of total employment, first year

Type of employees	Type of mobility rate[1]	Finland	Norway	Sweden[2]
All employees	Wide	23.3	20.1	24.0
All employees	Narrow	11.5	12.4	16.2
All higher educated employees	Wide	23.9	18.6	23.4
All higher educated employees	Narrow	17.9	12.8	19.5
Natural sciences and engineering	Wide	23.3	19.9	22.4
Natural sciences and engineering	Narrow	17.8	14.6	19.0
Medical fields of science	Wide	26.7	21.4	25.1
Medical fields of science	Narrow	21.2	14.7	21.9
Social sciences, humanities and other fields of science	Wide	23.6	17.4	23.3
Social sciences, humanities and other fields of science	Narrow	17.4	11.7	19.2

1. Wide type of mobility: Includes persons leaving the active workforce. Narrow type of mobility: Excludes those leaving the active workforce.
2. For Sweden, only persons working in establishments with valid NACE codes for both years are included.

Source: OECD.

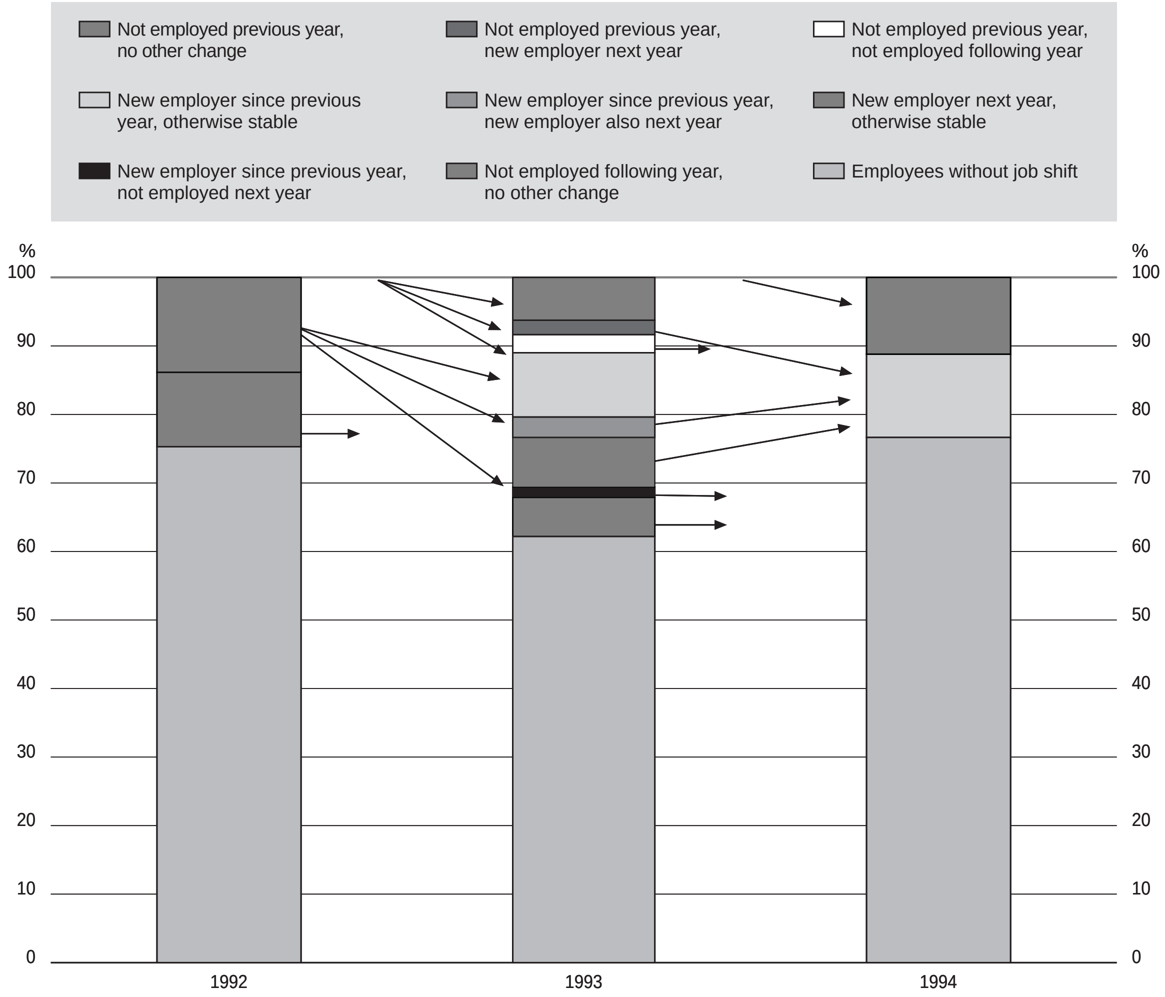
With mobility rates at this level, if everyone had the same propensity to change jobs, the total staff of each enterprise would change in four to five years. There are of course large differences between individuals and groups. There are "stayers" and "movers". In addition, an important source of measured mobility is the entry and exit of enterprises. A large share of mobility results from enterprises going out of business or being restructured in such a way that they change their identity number in the registers used to measure mobility. To what extent this is "real" mobility depends on the definition of the "birth" and "death" of a firm, *i.e.* on business demography.[20]

Mobility rates have so far been calculated for two consecutive years. Adding one year makes it possible to take both inflows and outflows into account. The overall mobility rate increases to around 40% over a two-year period in both Finland and Norway, and nine main types of mobility can be identified (Figure A8).

Most mobility concerns those who change status from one year to the next, and then become stable. Among these are employees who continue to work for the same employer in the following year. This group encompasses those who have accumulated experience working for one employer and may be viewed as a valuable recruit for the subsequent employer. Employees with accumulated work experience with one employer before starting work with a new employer account for 7-8% of employment (Norway, Finland). In addition, there is a small group of "experienced workers" who are employed in each of the three years, but change employer each year. These "experienced nomads" represent around 3% of employment (Norway, Finland). An even smaller group of "nomads" (around 2% of employment) includes those who were not employed in the first year, work for an employer the following year, but change employer again the subsequent year. Such "inexperienced nomads" are, probably to a large extent, newly educated workers looking for a suitable job.

Two distinct groups emerge from the mobility patterns: those who were not employed by the same establishment in the previous year ("new employees"), and those who were ("stable workers"). Their mobility rates in the following year differ (Figure A9): about 17-18% (Norway, Finland) for "stable workers", compared to as much as 37-45% (Norway, Finland) for "new employees". From the employer's perspective, the loss of experienced workers is more serious than the loss of new recruits. The high mobility rate of new employees should probably be interpreted as a kind of trial and error process, for both employers and employees.

Figure A8. **Types of mobility, Norway 1992-94**



Source: Nås *et al.*, 1998.

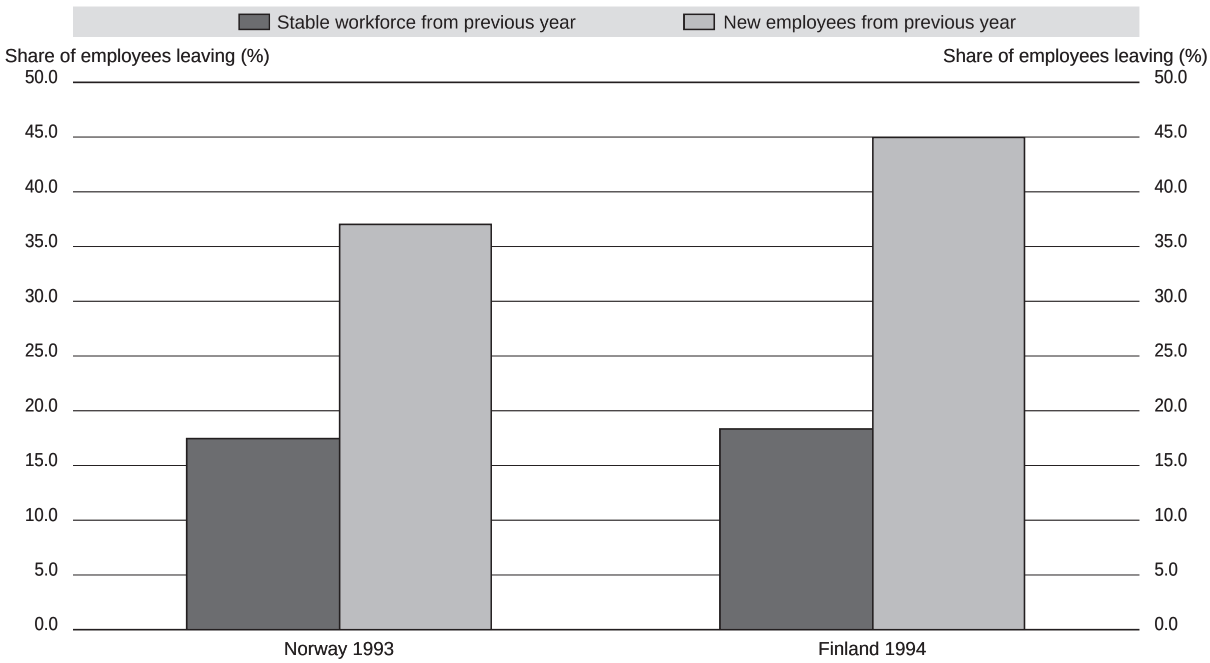
Sectoral flows of personnel with higher education

Table A4 shows that the three countries exhibit similarities and differences with respect to knowledge flows, in terms of labour mobility between sectors, including the higher education sector and the R&D institutes (referred to below as the NIS institutions).

As a common feature, the higher education sector (HE) is the main hub among NIS institutions, owing to its large size as compared to the R&D institutes. There is a strong link between the public sector and HE, and the net direction of flows is from the public sector to HE. The flows between NIS institutions and the goods producers and private services are modest.[21] The links between R&D institutes and HE are in general also relatively weak, except for Sweden where a number of people move from HE to R&D institutes, whereas in Norway and Finland the net flows are in the opposite direction.

There are more interactions between manufacturing and the NIS institutions in Sweden and Finland than in Norway, where NIS institutions have instead stronger links with private services, particularly business services. A comparison of the "degree of connectedness" of NIS institutions (the difference between total mobility and mobility within NIS institutions) reveals that R&D institutes interact with other sectors to a higher degree than HE in Sweden

Figure A9. **Mobility rates of "stable" and "new" employees**



Source: Nås *et al.*, 1998.

and Norway. In Finland, HE appears to be more "connected", in part because of a high level of mobility between R&D institutes. Lastly, the flows in and out the active workforce are relatively high in Finland.

The three countries show very similar patterns when considering the allocation of personnel with higher education in the industrial sectors, with two caveats: the higher share of highly educated in the primary sectors in Norway owing to the importance of the petroleum industry; and the wider sectoral distribution of scientists and engineers in the relatively large Swedish manufacturing sector.

Differences in national patterns of labour mobility, which are greater when measured at a more disaggregated level (42 sector classification), should be interpreted against the background of variable economic conditions and institutional profiles.

During the period under review, the general economic climate, which has been more favourable in Norway than in Sweden and Finland, has influenced mobility rates, especially the flows in and out of the active workforce. In Sweden, a great deal of industrial research takes place in universities whereas in Norway and Finland, large industrial research institutes (in particular, SINTEF and VTT, respectively) play a dominant role in the industrial research infrastructure. Such differences also leave their mark on the flows between the R&D institutes, HE and industry. Moreover, HE differs in terms of academic orientation and duration of degree (affecting the relative proportions of PhDs), although these differences seem to lessen over time.

Concluding remarks

The focus group has concentrated thus far on only one type of mobility, by considering the stocks and flows of individuals, ignoring the stocks of firms or organisations and, in most cases, the number of organisations concerned by mobility. Further work should be carried at a greater level of disaggregation, especially with regard to the types of NIS institutions, mobility of the population outside the labour market (*e.g.* newly graduated, unemployed, immigrants, emigrants, etc.), the impact of the mobility of organisations themselves, and international mobility, in particular temporary flows, as for instance within large multinational firms.

Table A4. **Mobility of employees with higher education by delivering and receiving sectors**

FINLAND

Receiving sectors (1995)	Delivering sectors (1994)														
	Primary sectors, mining, oil %	Manu-facturing %	Utilities and construc-tion %	Trade, hotels, restaurants %	Transport, storage, commu-nication %	Financial services, real estate %	Business services %	R&D institutes %	Higher education insti-tutions %	Public adminis-tration and defence, health and social work %	Other non-public services %	Out of active workforce %	No. persons moving	No. persons employed	Mobility rate in %
Primary sectors, mining, oil	17.0	0.3	0.4	0.5	0.2	0.1	0.5	1.5	0.1	0.1	0.6	1.0	377	2 211	17.1
Manufacturing	5.8	56.8	11.4	11.7	5.4	2.3	10.7	9.9	5.3	1.2	5.4	14.7	8 061	23 576	34.2
Utilities and construction	0.3	1.5	34.5	0.7	1.5	0.2	1.9	0.5	0.1	0.1	0.3	2.0	888	2 924	30.4
Trade, hotels, restaurants	3.5	5.9	2.8	37.6	3.7	1.6	4.1	1.4	0.9	0.5	2.6	7.0	3 357	11 992	28.0
Transport, storage, communication	1.0	1.4	1.0	2.2	47.7	0.7	1.9	0.4	0.2	0.2	0.7	2.3	1 244	4 588	27.1
Financial services, real estate	0.0	0.5	0.4	0.7	0.2	65.2	2.2	0.3	0.2	0.3	0.7	1.2	2 087	6 599	31.6
Business services	4.5	5.9	10.1	7.2	5.7	7.6	38.3	4.8	3.3	1.5	4.5	12.2	5 777	20 812	27.8
R&D institutes	0.6	0.4	0.1	0.2	0.1	0.2	0.5	39.2	1.6	0.3	0.3	1.3	794	3 625	21.9
Higher education institutions	1.3	0.9	1.0	1.5	0.3	0.5	1.3	8.5	34.5	2.9	4.1	10.8	4 787	11 508	41.6
Public administration, health, social	6.7	5.1	5.5	6.5	4.1	2.9	7.5	7.3	11.4	67.2	14.9	38.0	28 582	100 638	28.4
Other non-public services	2.9	1.1	0.6	1.2	1.6	1.0	1.7	1.0	0.0	0.0	0.0	4.9	1 184	11 687	10.1
Out of active workforce	56.1	19.8	30.7	28.7	28.1	17.5	28.3	24.7	26.3	17.2	55.4	0.0	12 229	19 300	63.4
Total[1]	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**			
No. persons moving (= 100)	312	5 944	690	2 813	955	2 416	4 643	778	4 327	27 251	2 447	19 300			
No. persons employed	2 374	24 395	3 073	12 838	4 556	7 012	21 931	3 830	13 098	106 511	12 957	19 300			
Mobility rate out (%)	13.1	24.4	22.5	21.9	21.0	34.5	21.2	20.3	33.0	25.6	18.9	100.0			

1. Total includes a residual category consisting of members of the workforce that were active in unclassified NACE groupings in 1995. The value for this residual varies between 0.3 and 8.7 (Other non-public services) for each category represented in the table.

Source: OECD.

Table A4. **Mobility of employees with higher education by delivering and receiving sectors** *(cont.)*

NORWAY

	Delivering sectors (1995)														
Receiving sectors (1996)	Primary sectors, mining, oil %	Manu- facturing %	Utilities and construc- tion %	Trade, hotels, restaurants %	Transport, storage, commu- nication %	Financial services, real estate %	Business services %	R&D institutes %	Higher education insti- tutions %	Public adminis- tration and defence, health and social work %	Other non-public services %	Out of active workforce %	No. persons moving	No. persons employed	Mobility rate in %
Primary sectors, mining, oil	27.4	1.5	1.1	1.2	0.7	0.7	1.7	3.2	1.0	0.4	0.7	0.3	963	5 977	16.1
Manufacturing	3.7	38.4	9.2	6.9	4.4	3.3	6.6	4.8	4.2	1.2	3.2	1.4	3 551	15 911	22.3
Utilities and construction	0.5	1.9	28.5	1.6	1.7	1.5	2.1	0.9	0.5	0.6	1.2	0.4	1 050	5 181	20.3
Trade, hotels, restaurants	19.8	7.3	4.5	28.8	5.7	3.6	6.9	3.1	1.5	1.9	3.0	1.5	3 655	13 127	27.8
Transport, storage, communication	3.0	3.8	2.0	2.8	30.6	1.9	4.1	0.6	0.4	0.6	1.0	0.7	1 580	6 280	25.2
Financial services, real estate	0.6	0.7	1.3	1.7	1.4	31.7	2.2	1.3	1.0	0.3	0.7	0.3	930	6 050	15.4
Business services	6.0	12.1	11.8	14.9	10.9	14.6	36.5	17.2	4.5	2.6	6.6	2.8	6 355	23 669	26.8
R&D institutes	1.0	0.6	0.3	0.5	0.5	0.4	0.7	14.0	3.8	0.4	1.1	0.3	710	5 110	13.9
Higher education institutions	0.6	1.1	0.6	1.1	1.2	1.5	1.1	14.6	22.4	2.5	3.4	1.2	2 318	11 781	19.7
Public administration, health, social	6.9	4.2	11.8	12.5	12.5	5.3	8.6	11.6	19.6	55.5	22.5	11.8	25 165	160 168	15.7
Other non-public services	0.5	1.3	1.3	1.6	1.7	1.0	1.7	1.2	2.8	1.6	22.0	1.0	1 804	8 663	20.8
Out of active workforce	29.6	26.5	27.0	26.0	27.7	33.0	26.7	26.9	38.0	32.0	34.2	78.1	65 949	65 949	200.0
Total[1]	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**			
No. persons moving (= 100)	1 296	3 232	958	3 412	1 381	972	5 232	1 038	2 155	27 008	1 748	14 308			
No. persons employed	6 516	15 592	5 089	12 884	6 081	6 092	22 546	5 438	11 618	162 011	8 607	14 308			
Mobility rate out (%)	19.9	20.7	18.8	26.5	22.7	16.0	23.2	19.1	18.5	16.7	20.3	100.0			

1. Total includes a very small residual category consisting of members of the workforce that were active in unclassified NACE groupings in 1995. The value for this residual varies between 0.3 and 1.3 for each category represented in the table.

Source: OECD.

Table A4. **Mobility of employees with higher education by delivering and receiving sectors** *(cont.)*

SWEDEN

Receiving sectors (1995)	Delivering sectors (1994)														
	Primary sectors, mining, oil %	Manu-facturing %	Utilities and construc-tion %	Trade, hotels, restaurants %	Transport, storage, commu-nication %	Financial services, real estate %	Business services %	R&D institutes %	Higher education insti-tutions %	Public adminis-tration and defence, health and social work %	Other non-public services %	Out of active workforce %	No. persons moving	No. persons employed	Mobility rate in %
Primary sectors, mining, oil	8.9	0.4	0.4	0.3	0.1	0.3	0.4	0.1	0.1	0.3	0.6	0.6	444	2 252	19.7
Manufacturing	9.1	38.8	9.3	11.9	7.2	4.1	11.9	23.5	6.8	2.1	3.6	10.7	8 989	46 126	19.5
Utilities and construction	1.4	1.2	11.3	0.8	1.3	0.5	2.4	0.8	0.4	0.6	0.4	1.4	847	5 560	15.2
Trade, hotels, restaurants	2.6	6.9	8.1	21.2	4.2	3.9	6.5	4.0	1.3	1.7	2.7	6.7	4 969	21 536	23.1
Transport, storage, communication	1.8	2.0	1.8	2.8	19.9	3.0	3.3	7.1	0.6	0.7	1.4	3.1	2 132	12 534	17.0
Financial services, real estate	0.4	0.9	0.9	1.8	1.7	28.8	3.9	0.7	0.5	0.5	0.5	1.9	1 775	12 397	14.3
Business services	12.1	16.3	21.7	17.0	15.9	22.1	25.5	12.4	6.6	5.7	6.8	13.6	11 289	51 511	21.9
R&D institutes	0.0	2.2	1.0	0.7	0.8	0.6	1.1	13.8	22.8	0.4	0.6	1.2	2 027	4 861	41.7
Higher education institutions	3.0	1.7	0.8	1.3	1.1	1.5	2.0	12.4	16.8	4.2	3.9	6.2	4 637	26 547	17.5
Public administration, health, social	17.4	5.4	16.6	12.5	11.6	10.5	12.4	7.9	18.3	36.4	23.2	42.7	41 376	284 093	14.6
Other non-public services	10.7	1.9	2.0	2.4	3.2	2.2	4.1	1.3	3.1	3.7	19.7	5.9	2 002	6 374	31.4
Out of active workforce	26.9	21.1	22.6	25.2	30.5	20.8	23.6	14.7	20.7	30.4	31.3	0.0	3 492	14 325	24.4
Total[1]	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**			
No. persons moving (= 100)	475	7 605	929	5 143	2 001	1 907	9 604	845	6 118	42 900	1 623	3 734			
No. persons employed	2 283	44 742	5 642	21 710	12 403	12 529	49 826	3 679	28 028	285 617	5 995	14 567			
Mobility rate out (%)	20.8	17.0	16.5	23.7	16.1	15.2	19.3	23.0	21.8	15.0	27.1	25.6			

1. Total includes a residual category consisting of members of the workforce that were active in unclassified NACE groupings in 1994. The value for this residual varies between 0.0 and 13.3 (Public administration), with an average of around 4 for each category represented in the table.

Source: OECD.

Organisational Mapping of R&D Collaboration[22]
A Pilot Analysis of European Networks

Introduction

Innovation networks involve different types of organisations (*e.g.* firms, universities, and private and public research institutes) and increasingly transcend national borders. Comparing their national features, including the degree and forms of internationalisation, requires two complementary efforts: collection of new data (*e.g.* the survey by the Focus Group on Innovative Firm Networks) and better exploitation of existing data. The aim of the Focus on Organisational Mapping[23] was to contribute to the latter effort by using the techniques of social network analysis to characterise national patterns of (subsidised) joint R&D projects between firms, research laboratories, universities and government agencies, and of (private) R&D agreements between firms.

This approach allows for an analysis at different levels of aggregation. Data are collected at the micro level of inter-firm collaboration and collaboration between firms and other types of organisations. But the analysis can also be performed at the sectoral level, revealing patterns of intra- and intersectoral knowledge flows. Further aggregation makes possible the analysis of international knowledge flows.

Methodology

The graph-theoretical technique of social network analysis (Berkowitz, 1982; Scott, 1991) provided the basic analytical tool. Data on the relations between different entities can be used to create a graph that makes it possible to detect linkages in different types of networks and the impact these network relations may have on the behaviour of participants (Sprenger and Stokman, 1989). Three types of data were analysed:

- Data on participation in R&D projects within the Framework Programmes (FWP) of the European Union, as recorded in the CORDIS database (European Commission, 1997*b*). These projects concern “pre-competitive” R&D collaboration in the early stage of R&D.
- Data on EUREKA projects, which promote “near-market” R&D collaboration (EUREKA, 1998).
- Data on some 13 000 private co-operative projects, established up to 1996, that relate to technology transfer or joint research, as recorded in the MERIT-CATI data bank (MERIT, 1998).

Only links (established from 1990 onwards) between actors in a given country and foreign partners were considered. Links among the foreign partners were disregarded, as were “pre-competitive” R&D projects that only involved non-firm partners. The criterion was whether two actors collaborated in an R&D project (FWP, EUREKA) or had established a co-operative agreement. Lines are defined as “directed” if they run from the prime contractor to a partner and as “undirected” if they run between partners of equal status. The graph consisting of nodes and lines, together with additional information, is defined as a network (Box A3).[24]

Main findings[25]

Relative specialisation

Table A5 shows the relative specialisation indices (RSIs) that have been calculated in order to determine the technological domains in which countries are relatively specialised with regard to R&D collaboration and technology alliances.[26] RSIs relate the number of projects of a given country in a given area to the overall weight of the given area in the whole group of countries.

There are some remarkable differences between the specialisation profiles in different types of networks, especially when comparing FWP (Table A5) and private technological alliances (Hagendoorn and Narula, 1996). While Belgium has a high RSI for electronics in the FWP, it has a rather low number of technology alliances in this field. On

Box A3. **Basic concepts of graph-theoretical analysis**

Components

A component C of a graph can be defined as a maximally connected subgraph, *i.e.* every node of C is connected with at least one other node of C, and there exists no node outside C which is connected to at least one node of C. The number and size of components in a graph reveals the degree of interdependence of the different actors. The density of a component relates the number of actual links to the number of potential links within the group and thus measures its degree of connectivity.

Cliques

N-cliques can be defined as subgraphs of which all points are linked with one another through a path with maximal length equal to n in a way such that no point outside the subgraph has the same quality. Cliques, defined at a certain level of multiplicity, can be seen as clusters of actors that collaborate frequently with one another. By merging the detected cliques, the core of the R&D network can be detected and its density can be measured.

the contrary, it has a relatively high number of alliances in biotechnology for which it has a RSI below unity in the FWP. Spain has a RSI below unity for telecommunications for which it has a high number of alliances compared to the average. For Switzerland, there seems to be a better matching of specialisation in FWP and alliance specialisation (*e.g.* the high RSI for biotechnology and the high number of private alliances with Swiss partners in this field).

Table A5. **Relative specialisation indices for ongoing projects of the EU Framework Programmes, 1997**

	Biotechnology	(Micro-) electronics	Environmental protection	Energy saving/ renewable energy resources	Information processing	Materials technology	Telecom-munications	Medicine	Aerospace
Belgium	0.70	1.12	0.72	0.88	1.12	1.08	1.20	1.16	0.85
Denmark	1.42	0.78	0.95	2.53	0.73	0.64	0.56	1.61	1.15
Finland	0.89	0.93	0.75	1.38	0.80	1.32	0.58	1.09	1.26
France	1.04	1.05	0.93	0.81	1.01	0.93	1.03	1.29	1.09
Germany	0.66	0.99	0.84	1.08	0.98	1.29	0.91	0.75	1.08
Greece	0.22	1.17	0.86	2.09	1.33	0.55	1.40	0.40	0.85
Ireland	0.79	1.35	1.04	0.66	1.52	0.35	2.05	0.16	0.75
Italy	0.70	1.30	0.77	0.80	1.17	1.12	0.84	0.70	0.90
Luxembourg	0.00	0.50	0.00	0.00	1.16	2.96	2.16	0.00	0.00
Netherlands	1.34	0.54	1.45	1.26	0.74	1.00	1.03	1.06	1.14
Portugal	0.00	0.72	0.96	2.56	0.83	1.12	1.02	0.34	1.39
Spain	0.35	1.33	0.66	0.82	1.26	1.26	0.79	0.48	0.92
Sweden	2.38	0.41	0.89	0.56	0.50	1.56	0.70	1.97	1.08
Switzerland	1.81	1.03	1.55	0.65	0.95	0.46	1.34	0.80	1.00
United Kingdom	1.25	0.87	1.25	1.02	0.94	0.85	0.95	1.38	0.91

Source: OECD calculations based on European Commission, 1997*a*.

Components and cliques

The number of components and the size and density of the largest component at different levels of multiplicity are recorded in Table A6. Due to the relatively low participation of Swiss actors in FWP projects, the size of the largest component decreases rapidly for Switzerland. For Belgium and Spain, at a multiplicity level of 8, the largest component still contains over 40 actors. This means that there is a group of more than 40 actors in which each actor

Table A6. **Number of components, size and density of the largest component**

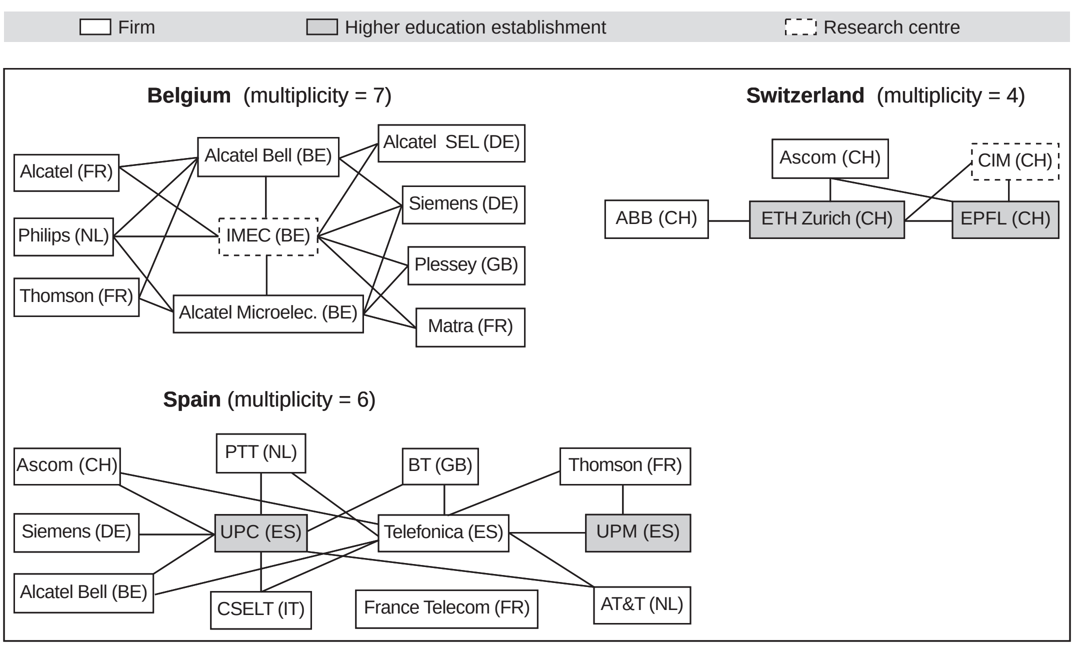
	Belgium			Spain			Switzerland		
	No. of components	Size of largest component	Density of largest component	No. of components	Size of largest component	Density of largest component	No. of components	Size of largest component	Density of largest component
Multiplicity 2	12	359	0.01	16	533	0.01	7	349	0.01
Multiplicity 3	3	144	0.03	10	222	0.01	3	119	0.02
Multiplicity 4	2	95	0.05	8	136	0.03	4	62	0.04
Multiplicity 5	1	67	0.07	5	99	0.03	1	38	0.07
Multiplicity 6	1	53	0.08	3	76	0.04	1	26	0.08
Multiplicity 7	1	46	0.08	1	57	0.05	1	17	0.13
Multiplicity 8	1	41	0.08	1	47	0.06	1	10	0.20

Source: OECD calculations based on European Commission, 1997*a*.

collaborates eight times or more with at least another actor of the component. These "high multiplicity components" represent the small groups of actors that frequently participate and collaborate in FWP, as opposed to the large group of organisations that only participate occasionally.

Each project or alliance with three or more partners can be regarded as a clique. By combining the cliques that can be detected at a certain level of multiplicity, the core network of most actively collaborating partners (*i.e.* the core of the components at high levels of multiplicity) can be identified. The interlinking of detected cliques is shown in Figure A10, which reflects the importance of information and communication technologies (ICTs) in FWP and the dominance of multinationals and national telecommunications operators in these areas. For Belgium, the central actor is the Interuniversity Microelectronics Centre (IMEC), which was established in 1984 by the government of the Flemish Community.

Figure A10. **Cliques in the complete graphs**



Source: OECD calculations based on European Commission, 1997*a*.

Despite the fact that Spain has an RSI below unity in telecommunications, there is a rather dense network around the Spanish telecommunications operator, Telefónica, which matches the relative high number of private alliances with Spanish partners in this field. However, Telefónica is the only Spanish firm in the core. This shows the high dependence on the monopolist at the time, given the absence in Spain of own or foreign multinationals in this field.

For Switzerland, even at a multiplicity level of 4, only cliques without any foreign partners can be detected. EPFL and ETH Zurich are two Swiss polytechnic institutes with a tradition of collaboration. Ascom and ABB are known to be inclined to form partnerships with education establishments. The CIM is an initiative, launched five years ago and initially sponsored by federal funds, to form "competence" centres to combine training and research. The most central actor in the Swiss FWP graph is, not surprisingly, the Swiss telecommunications multinational Ascom. Swiss pharmaceutical firms, which are very active in private technological collaboration, do not occupy a central position in the networks of subsidised collaboration.

Revealed comparative preference

Table A7 presents the revealed comparative preference (RCP) of 17 European countries, based on the number of collaborative links in the fourth FWP. A RCP greater than unity reveals a relative preference of actors of two given countries to collaborate. In general, neighbouring countries have RCPs above unity, and firms in small and large countries tend to prefer collaboration with partners from large countries. There is a very significant relation between country size and the share of collaborative links between actors of the same country. The correlation between the share of links between actors of the same country and the 1997 population is 0.91 (Table A8).

Table A7. **Revealed comparative preference in the Fourth EU Framework Programme, 1994-96**

	BE	DK	DE	GR	ES	FR	IE	IT	LU	NL	AU	PT	UK	NO	FI	CH	SE
BE	1.00																
DK	0.82	1.73															
DE	1.04	0.96	0.74														
GR	0.86	0.97	0.94	1.38													
ES	0.99	0.75	0.91	0.98	1.13												
FR	1.13	0.71	1.18	0.89	1.20	0.77											
IE	0.91	1.16	0.79	1.10	0.96	0.88	1.54										
IT	0.89	0.76	1.05	1.24	1.23	1.13	0.76	0.85									
LU	3.18	1.09	1.00	1.02	0.48	1.18	1.19	0.71	19.5								
NL	1.24	1.32	1.09	0.80	0.81	0.91	1.07	0.77	0.73	1.07							
AU	0.88	0.77	1.42	0.97	0.96	0.89	1.04	1.04	1.11	0.78	2.17						
PT	1.06	1.02	0.84	1.22	1.39	0.86	1.22	0.92	0.88	0.86	0.57	2.22					
UK	0.96	1.12	1.07	1.04	0.92	1.11	1.32	0.97	0.52	1.20	0.80	0.99	0.73				
NO	0.82	1.82	0.83	0.92	0.69	0.87	1.06	0.78	1.21	0.98	0.77	0.84	1.22	2.86			
FI	0.90	1.30	0.94	0.93	0.77	0.71	1.24	1.21	1.49	1.03	1.23	0.89	0.91	1.29	1.51		
CH	1.28	0.84	1.18	0.80	0.76	1.06	0.78	1.03	0.81	1.02	1.18	0.70	0.94	1.21	0.87	1.55	
SE	0.78	1.43	1.07	0.91	0.80	0.90	0.90	0.87	0.51	1.05	0.79	0.97	1.06	1.14	1.57	0.82	1.27

BE: Belgium; DK: Denmark; DE: Germany; GR: Greece; ES: Spain; FR: France; IE: Ireland; IT: Italy; LU: Luxembourg; NL: Netherlands; AU: Austria; PT: Portugal; UK: United Kingdom; NO: Norway; FI: Finland; CH: Switzerland; SE: Sweden.
Source: OECD calculations based on European Commission, 1997*a*.

FWP collaboration with actors of foreign countries is more important to small than to large countries. This also holds for the share of national alliances in the total of technology alliances of a given country established in the period 1992-95 (correlation equals 0.65).

In Table A9, RCP is calculated for collaboration in ongoing EUREKA projects. There is a greater variance in RCP in EUREKA (as well as for private partnerships; see European Commission, 1997*a)* than for collaboration in FWP. Once again, RCP is on average higher for neighbouring countries. Apparently, the closer to the market, the greater the preference for specific (mostly neighbouring) countries.

Table A8. **Share of national links and country size**

	% Framework Programme	% technological alliances	1997 population thousands
Germany	10.75	11	82 190
France	11.10	12	58 543
United Kingdom	10.38	11	58 201
Italy	8.97	5	57 236
Spain	8.73	7	39 718
Netherlands	7.04	4	15 661
Greece	6.83	0	10 522
Belgium	4.37	4	10 188
Portugal	6.71	0	9 803
Sweden	6.03	8	8 844
Austria	4.68	n.a.	8 161
Switzerland	3.04	n.a.	7 277
Denmark	5.08	0	5 248
Finland	5.11	7	5 142
Norway	5.65	n.a.	4 364
Ireland	3.45	8	3 559
Luxembourg	3.72	n.a.	41

Source: OECD calculations based on European Commission, 1997*a*.

Table A9. **Revealed comparative preference in EUREKA**

Ongoing projects as of 30 June 1996

	BE	DK	DE	GR	ES	FR	IE	IT	LU	NL	AU	PT	UK	NO	FI	CH
DK	0.93															
DE	1.04	0.92														
GR	0.64	0.64	0.61													
ES	1.00	0.74	0.99	1.52												
FR	1.59	0.82	1.03	1.23	1.49											
IE	0.94	1.57	0.74	0.00	0.75	0.76										
IT	1.05	1.20	0.89	1.99	1.43	1.67	0.84									
LU	0.00	0.00	2.83	0.00	0.00	0.00	0.00	0.00								
NL	1.86	1.16	1.32	0.57	1.08	1.10	1.12	0.81	3.55							
AU	0.76	0.57	2.18	0.36	0.68	0.65	0.71	1.02	0.00	0.80						
PT	0.76	1.21	0.86	2.86	2.28	1.39	1.13	0.94	0.00	0.72	0.51					
GB	0.82	1.59	1.12	0.58	1.18	1.21	1.33	1.19	3.62	1.22	1.04	0.92				
NO	0.72	1.09	0.69	1.83	0.67	0.99	0.90	0.64	0.00	0.94	0.55	0.87	0.88			
FI	0.68	1.46	0.88	1.84	0.85	1.03	2.53	1.04	0.00	0.64	0.77	1.05	1.00	1.53		
CH	0.82	0.67	1.77	0.56	0.53	1.15	1.11	0.66	0.00	1.38	2.28	0.40	0.90	0.64	0.86	
SE	0.78	1.49	1.11	0.98	1.03	0.72	0.72	0.69	0.00	0.89	1.03	0.81	0.94	3.24	1.79	0.91

BE: Belgium; DK: Denmark; DE: Germany; GR: Greece; ES: Spain; FR: France; IE: Ireland; IT: Italy; LU: Luxembourg; NL: Netherlands; AU: Austria; PT: Portugal; UK: United Kingdom; NO: Norway; FI: Finland; CH: Switzerland; SE: Sweden.
Source: OECD calculations based on EUREKA, 1998 and European Commission, 1997*a*.

Coincidence

Table A10 reports the coincidence of lines in FWP, EUREKA and private alliances. Spain and Belgium have a similar pattern of coincidence with some 3% of links in FWP coinciding with more than 10% of EUREKA links.

As regards the sequence, out of 73 coinciding pairs in the Belgian graph, 41 collaborations took place in FWP prior to collaboration in EUREKA. In contrast, out of the 97 coinciding pairs in the Spanish graph, this "right" sequence (*i.e.* in accordance with the pipeline model) emerges in only 23. For Switzerland, this "right" sequence emerges for less than half of the coinciding pairs. The coincidence between FWP and private alliances is low.

Table A10. **Coincidence of lines and pairs of actors in Framework Programmes, EUREKA and private alliances**

	FWP-EUREKA	FWP-Private alliances	EUREKA-Private alliances
Coinciding lines			
Belgium	267 (3.2%) – 80 (10.6%)	1 (0.01%) – 1 (3.12%)	0 – 0
Spain	313 (2.9%) – 112 (10.7%)	2 (0.02%) – 1 (1.32%)	0 – 0
Switzerland	102 (4.1%) – 26 (1.0%)	12 (0.49%) – 7 (3.10%)	1 (0.04%) – 1 (0.44%)
Coinciding pairs (sequence)			
Belgium	73 (41 FWP > EUREKA)	1 (Alliance > FWP)	
Spain	97 (23 FWP > EUREKA)	1 (FWP > Alliance)	
Switzerland	56 (27 FWP > EUREKA)	4 (3 FWP > Alliance)	1 (Alliance > EUREKA)

Source: OECD calculations based on EUREKA, 1998 and European Commission, 1997*a*.

Conclusions

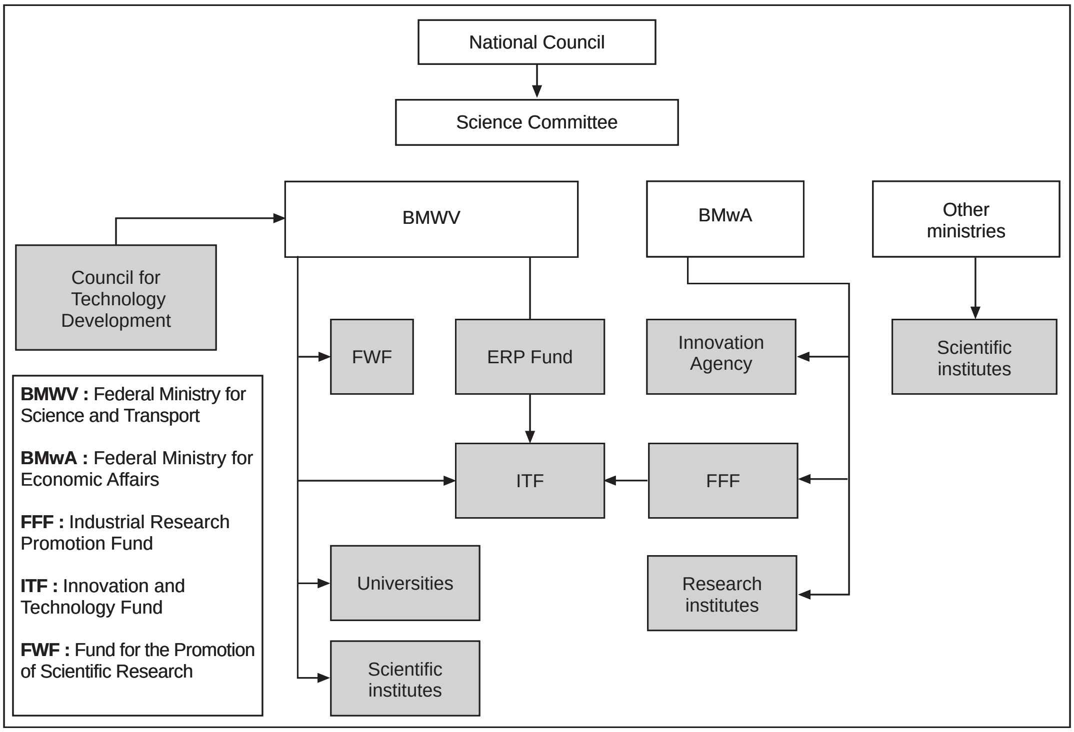
There are important differences among actors, sectors and countries with regard to the occurrence, magnitude and motives of collaboration in basic and applied research and the development of new products and processes. The pilot study by the Focus Group on Organisational Mapping demonstrates that:

- Firms in small countries are significantly more inclined to become partners of foreign actors than firms in large countries and to rely on networking to compensate for insufficient resources and lack of appropriate partners at home.
- Subsidised R&D collaboration is still highly dominated by a small group of actors (often large multinationals). More effort should be made to involve less collaborating actors, like SMEs, including by reorienting subsidies for R&D collaboration from a focus on the short-term competitiveness of innovative firms to the more long-term effects of strengthening the competencies of less innovative firms.
- Countries with few domestic multinationals, like Belgium, are relatively active in basic research but less so in near-market collaboration and private technology alliances. This indicates insufficient valorisation of national R&D potential. The high participation in EUREKA and private alliances of a small country with a considerable number of domestic multinationals, like Switzerland, supports this view.
- A comparison of specialisation patterns reveals a certain mismatch between technological activities and economic performance, which is more significant for Belgium and Spain than for Switzerland.
- Countries are generally still somewhat inclined to collaborate with neighbouring or culturally close countries, and both small and large countries tend to prefer collaboration with partners from large countries.
- There is little, if any, evidence to support the pipeline model of a sequence in which co-operation in pre-competitive research prepares actors for collaboration in near-market R&D activities.

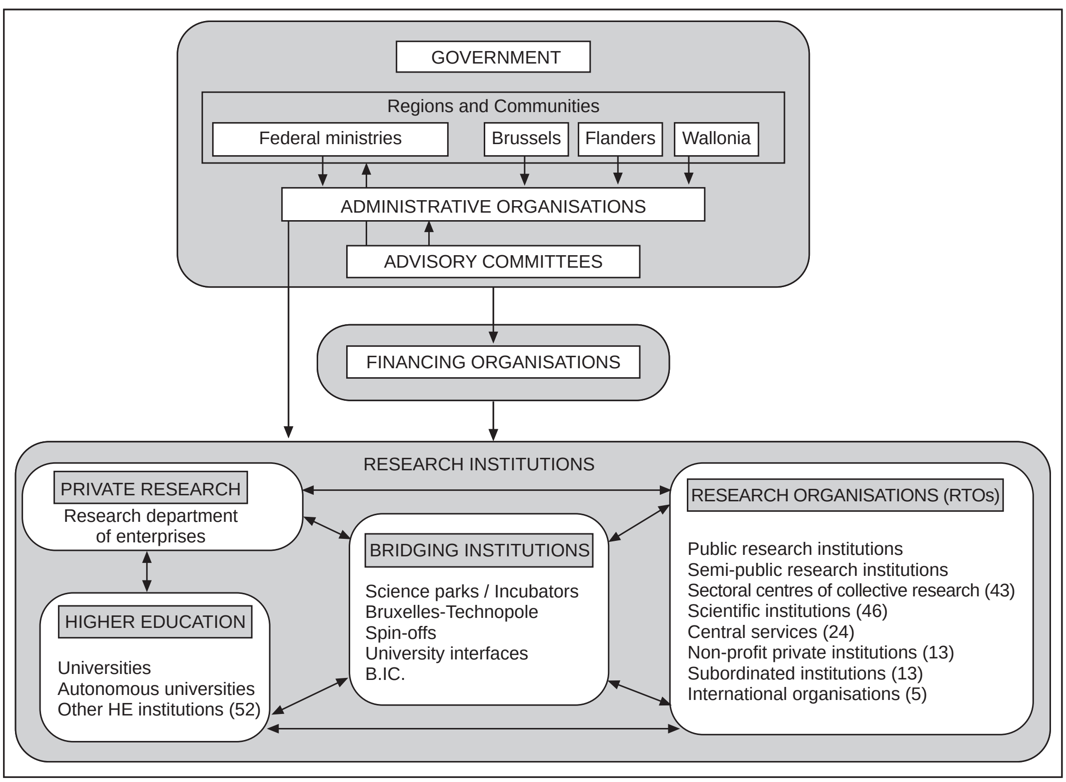
Annex 3

INSTITUTIONAL PROFILES OF NATIONAL INNOVATION SYSTEMS[27]

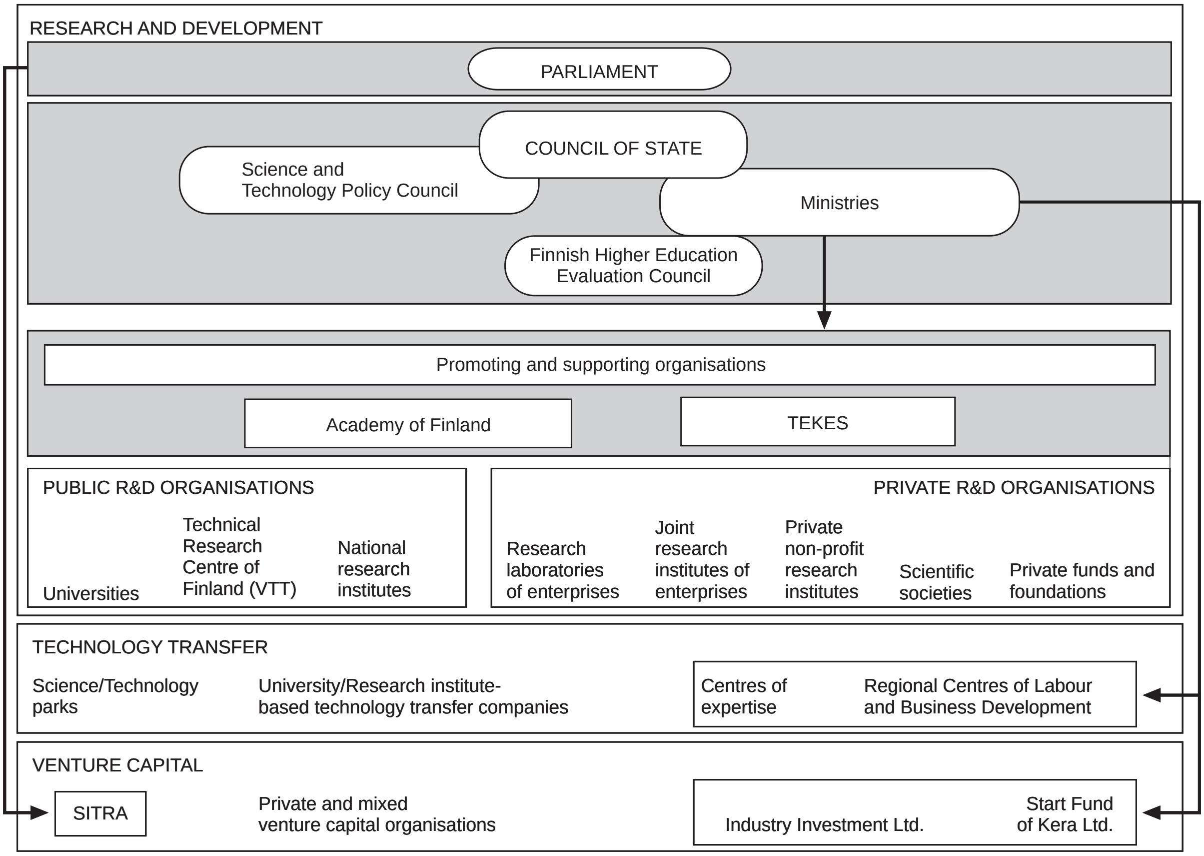
AUSTRIA — The organisation of technology and innovation policy



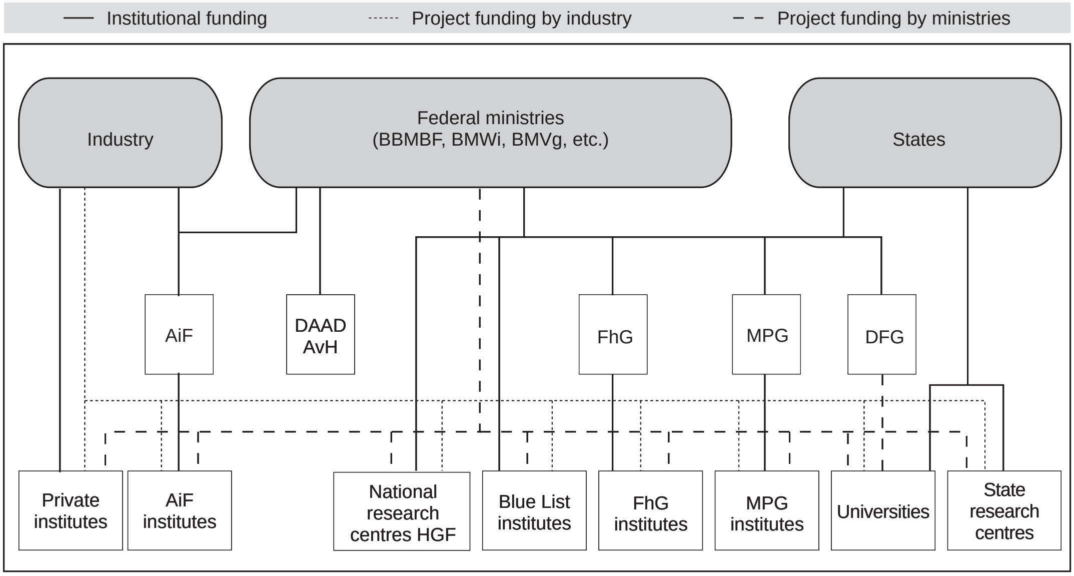
BELGIUM — Institutional profile of the NIS



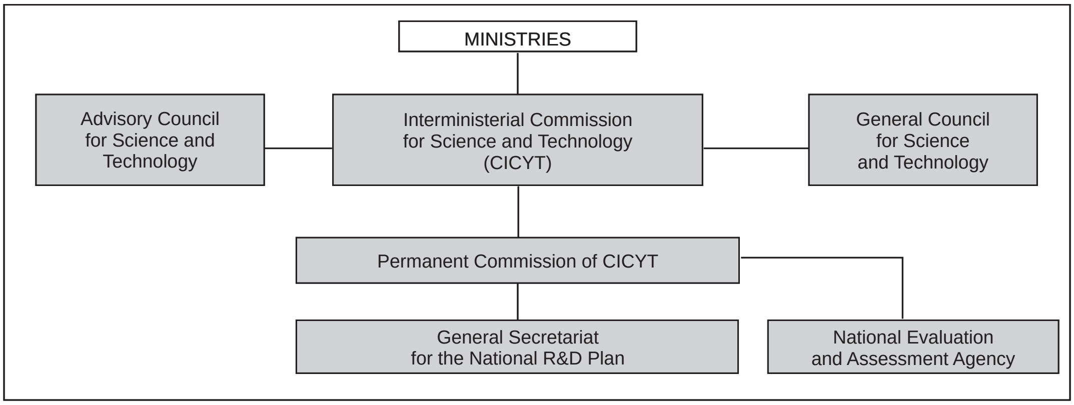
FINLAND — Institutional profile of the NIS



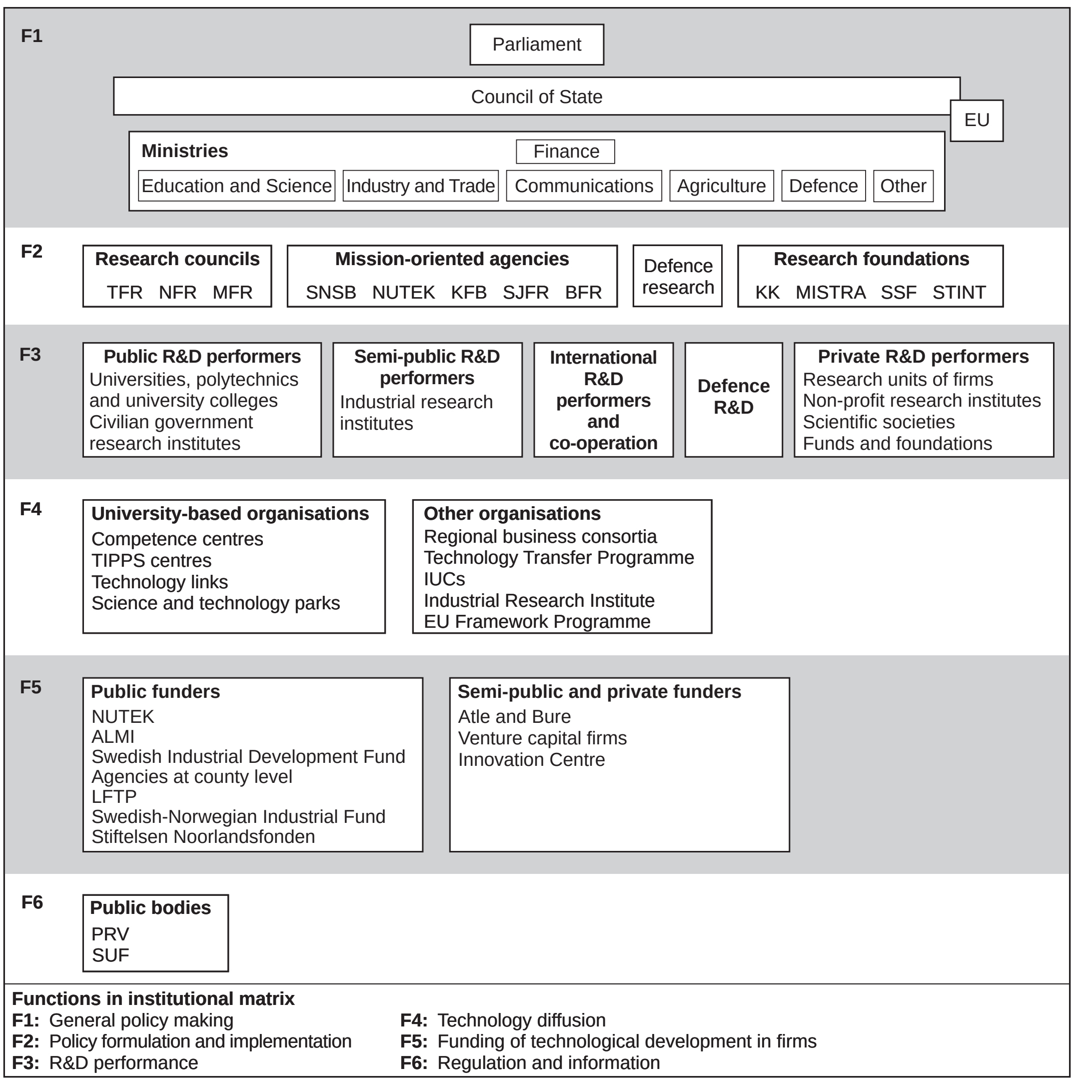
GERMANY — Institutional profile of the NIS



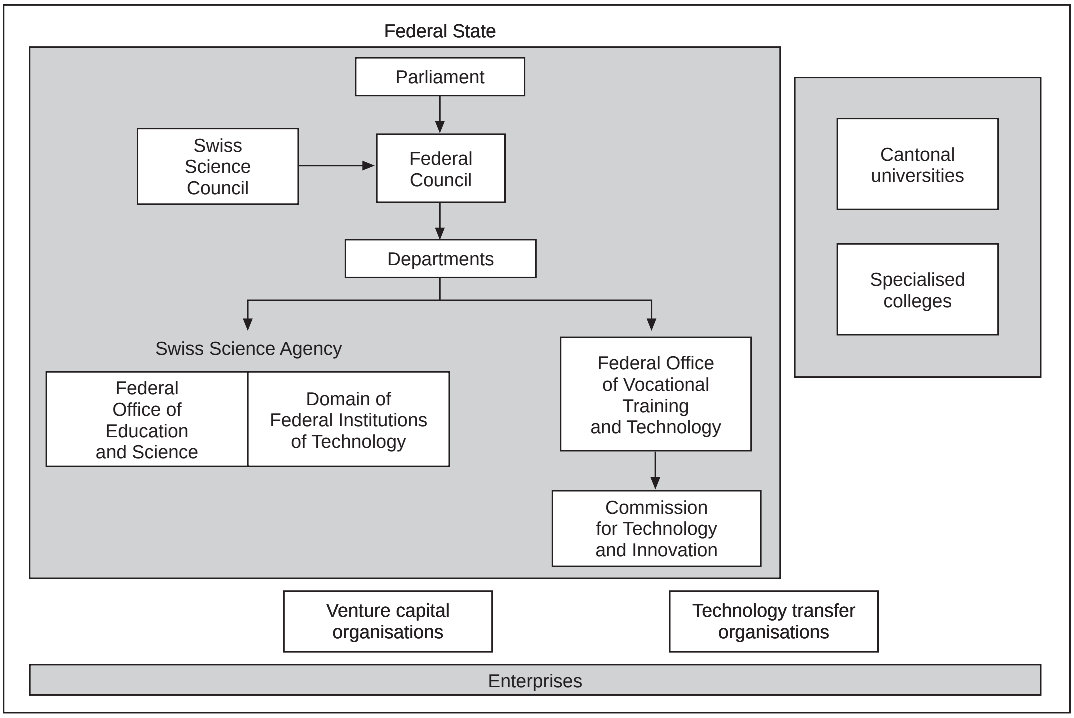
SPAIN — The organisation of technology and innovation policy



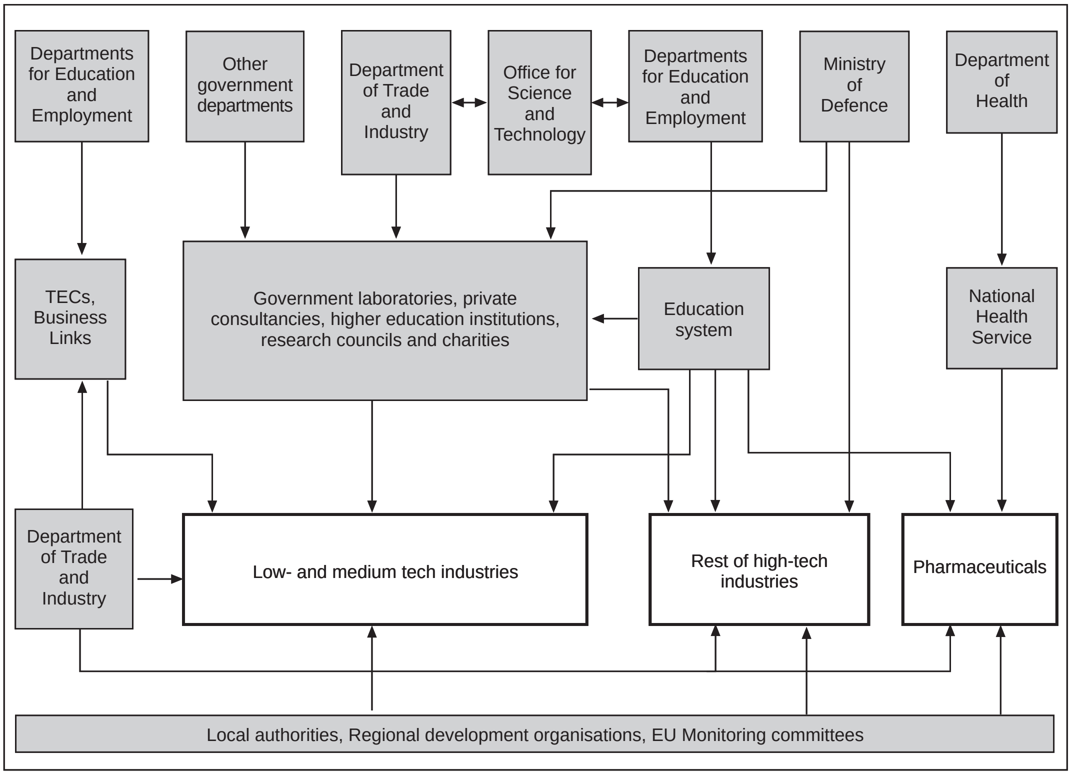
SWEDEN — Institutional profile of the NIS



SWITZERLAND — Institutional profile of the NIS



UNITED KINGDOM — Institutional profile of the NIS



NOTES

1. For more detail about the statistical techniques that are applied to gauge the impact of country-specific and industry-specific factors on productivity growth; see OECD (1998*c*).
2. The Korean economy is a special case among the catching-up economies. Even though it remains substantially below the OECD average in terms of relative income levels, its R&D intensity is quite high and its patenting activity is growing rapidly. This is mainly due to the private sector, however, as the government share of R&D expenditure, and consequently that of the higher education sector, are quite low.
3. Measured here as the intensity of citation of scientific publications in industrial patents.
4. A fuller summary of the work of the Focus Group on Innovative Firm Networks, prepared by Jesper L. Christensen, Anna P. Rogaczewska, and Anker L. Vinding, can be found on the NIS Web site (http://www. oecd.org/dsti/sti).
5. The most important sources of information have been so far the CIS (Community Innovation Surveys) and the PACE surveys (Policies, Appropriability and Competitiveness for European Enterprises). The focus group, while making some use of existing surveys, has concentrated its effort on new data collection and analysis. Results from the other surveys may be obtained from Christensen and Rogaczewska, (1998), where CIS/CIS-like types of data are used to compare inter-firm collaboration in Switzerland, Germany and Spain.
6. A fuller summary of the work of the Focus Group on Cluster Analysis and Cluster-based Policy, prepared by Theo J.A. Roelandt and Pim den Hertog, can be found on the NIS Web site (http://www.oecd.org/dsti/sti).
7. Clusters defined in this way can be interpreted as innovation systems on a reduced scale. This implies that dynamics, system characteristics and interdependencies similar to those described for national innovation systems exist for specific clusters. Consequently, the concept of systemic imperfections can be used as a starting point in the development of cluster-based innovation policies.
8. The same incentives also contribute to the growth in cross-border strategic alliances (Dunning, 1997; Boekholt and Thuriaux, 1998; Porter, 1997).
9. Empirical work supports these central starting points, see Roelandt and Den Hertog (eds.), 1999; DeBresson, 1996; European Commission, 1997*b*; Hagendoorn and Schakenraad, 1990.
10. See in particular the contributions of Drejer *et al.*, 1999; Roelandt *et al.*, 1999; Rouvinen and Ylä-Antilla, 1999; DeBresson and Hu, 1999; as well as DeBresson, 1996; and Porter, 1997.
11. Boekholt and Thuriaux, 1998.
12. See also Held, 1996; Porter, 1997; Roelandt *et al.*, 1999; Rouvinen and Ylä-Antilla, 1999; and Dunning, 1997.
13. A fuller summary of the work of the Focus Group on the Mobility of Human Resources, prepared by Svein Olav Nås and Anders Ekeland (STEP Group, Norway), Christian Svanfeldt (NUTEK, Sweden), and Mikael Åkerblom (Statistics Finland), can be found on the NIS Web site (http://www.oecd.org/dsti/sti) and the STEP Web site (http://www.sol.no/step).
14. Finland, Norway, Sweden.
15. For an assessment of data availability, see Mikael Rosengren, 1998.
16. For example, Heidi Wiig and Vemund Riiser, "Forskermobilitet i instituttsektoren, 1991" (STEP 11/92) [Researcher Mobility in the Norwegian Institute Sector, 1991]; Heidi Wiig and Anders Ekeland, "Forskermobilitet i instituttsektoren i 1992" (STEP 8/94) (this contains comparisons with similar studies in other countries), Heidi Wiig and Anders Ekeland, "Naturviternes kontakt med andre sektorer i samfunnet" (STEP 6/94) [Mobility of Natural Scientists in Norway]; Stenberg *et al.* (1996), Per Vejrup Hansen (1993).
17. Although the Nordic countries have tried to create an inter-Nordic labour market, there are still various formal and practical obstacles. For an overview, see Roos (1994), p. 526.
18. In the main report, the analysis is made at the disaggregated level of 42 sectors.

19. Data for Finland are adjusted to correct for “false” mobility: if a majority of the employees in an establishment in year t has changed employer collectively in year t + 1, the measured mobility is considered as a statistical artefact. This adjustment lowers the mobility rate by 2-3 percentage points.
20. The study found that almost a third of the employees in Norway in 1986 were still in the same establishment eight years later, *i.e.* in 1994. In Sweden, over a seven-year period (from 1986 to 1993), only 20% of all employees stayed in the same establishments. In other words, between 70% and 80% of the employees stay with their employer less than 7-8 years.
21. Well below 1% of industrial establishments were involved in labour mobility from or to NIS institutions in the two countries where this could be calculated (Finland and Norway).
22. A fuller summary of the work of the Focus Group on Organisational Mapping, prepared by M. Dumont, W. Meeusen, L. Sanz-Menendez, J.R. Fernandez-Carro, C.E. Garcia and P. Vock, can be found on the NIS Web site (http://www.oecd.org/dsti/sti).
23. The participating countries were Belgium, Italy, Netherlands, Spain and Switzerland.
24. The software that is used for the graphical analysis, GRADAP 2.0, has a size limit of 6 000 nodes and 60 000 lines.
25. These findings concern only Belgium, Spain and Switzerland. The analysis will be extended to Italy and the Netherlands at a later stage.
26. RSI were calculated using the CORDIS database on overall participation, irrespective of the type of organisation.
27. These profiles have been drawn by national experts as a contribution to the NIS project.

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