The OECD Innovation Strategy

GETTING A HEAD START ON TOMORROW

OECD

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Foreword

In the post-crisis world, and with a still fragile recovery, we are facing significant economic, environmental and social challenges. While no single policy instrument holds all the answers, innovation is the key ingredient of any effort to improve people's quality of life. It is also essential for addressing some of society's most pressing issues, such as climate change, health and poverty.

Innovation today is a pervasive phenomenon and involves a wider range of actors than ever before. Once largely carried out by research and university laboratories in the private and government sectors, it is now also the domain of civil society, philanthropic organisations and, indeed, individuals. Therefore, policies to promote it should be adapted to today's environment and equip a wide variety of actors to undertake innovative actions and benefit from its results. Effective mechanisms for international co-operation in science, technology and innovation will also need to be put in place in order to make innovation an engine for development and growth.

This report presents the OECD Innovation Strategy, the culmination of a three-year, multi-disciplinary and multi-stakeholder effort. It provides analysis and policy guidance on a broad range of issues from education and training to business environment, infrastructure and actions to foster the creation and diffusion of knowledge. These elements can support governments in developing effective innovation strategies to achieve key economic and social objectives. It advocates an approach which takes into account the interplay of different policy domains and brings them together through supportive mechanisms for governance at the local, regional, national and international levels.

The report highlights experience and good practices from countries around the world such as demand-side innovation policies and the establishment of science and technology policy councils. It also points to a number of issues that deserve consideration, such as:

- The need to empower people to innovate. This calls for high-quality and relevant education as well as the development of wide-ranging skills that complement formal education. Curricula and pedagogies need to be adapted to equip students with the capacity to learn and apply new skills throughout their lives.
- The importance of small and medium-sized enterprises, especially new and young firms. These actors translate knowledge and ideas into jobs and wealth, frequently exploiting opportunities that have been neglected by more established companies. Governments must put in place policies to support new and innovative entrepreneurial efforts.
- Fundamental R&D, mostly undertaken and funded by governments, provides the foundation for future innovation.

- Science is vital to innovation, especially to generate "step changes" such as the discovery of the transistor or vaccines. Government support for platforms that enable more actors to engage in innovation networks is an essential underpinning. High-speed broadband connections, for example, allow actors to collaborate, make a wide range of data and information available and provide access to powerful analytical tools that facilitate the creation of new value.

Policies that are vertical in nature and target a particular field, sector, technology or location no longer suffice on their own. They need to be complemented by a horizontal – whole of government – policy approach to innovation. This holds the promise of greater coherence, better performance and a structure more appropriate to the central role of innovation in society today.

Better measurement of innovation and its role in economic growth is also key to fulfilling this promise, as it allows for an effective evaluation of outcomes and constant feedback into policy making. The OECD Innovation Strategy also delivers a new set of indicators, clearly showing that it goes well beyond R&D. This work reflects the diversity of innovation actors and processes and outlines a measurement agenda for furthering progress in this area.

Further work will be required to keep on strengthening the innovation agenda and this strategy in particular. There is a need, for example, to improve the measurement of the many facets of innovation – including those that are "intangible" and currently insufficiently addressed in policy considerations. Governments will also require targeted support as they seek to implement their own national or regional innovation strategies. The OECD, building on its vast evidence-base policy experience, and in co-operation with its many partners, will continue to support innovation policy making in the coming years.

Angel Gurría
OECD Secretary-General

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A full list of OECD committees, expert representatives, workshops and roundtables is available at *www.oecd.org/innovation/strategy*.

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Executive Summary

Innovation drives growth and helps address social challenges

The past two years have seen reduced potential output growth, increased unemployment and soaring public debt. To recover and move towards a more sustainable growth path, new sources of growth are urgently needed.

At the same time, some traditional sources of growth are declining in importance. Many countries have stagnating or declining populations, and this reduces the role of labour input in long-term economic growth. Moreover, investments in physical capital face diminishing returns and may be insufficient to strengthen long-term growth, especially in advanced economies. Innovation, which involves the introduction of a new or significantly improved product, process or method, will increasingly be needed to drive growth and employment and improve living standards. This is true as well for emerging economies that look to innovation as a way to enhance competitiveness, diversify their economy and move towards more high value added activities.

Innovation is already an important driver of growth in some countries. Firms in several OECD countries now invest as much in intangible assets, such as research and development (R&D), software, databases and skills, as in physical capital, such as equipment or structures. Much multifactor productivity (MFP) growth is linked to innovation and improvements in efficiency. Preliminary estimates indicate that in Austria, Finland, Sweden, the United Kingdom and the United States, investment in intangible assets and MFP growth together accounted for between two-thirds and three-quarters of labour productivity growth between 1995 and 2006, thereby making innovation the main driver of growth. Differences in MFP also account for much of the gap between advanced and emerging countries. This suggests that innovation is also a key source of future growth for emerging economies.

This economic challenge coincides with increasing political pressure to meet various social challenges, such as climate change, health, food security, or access to clean water, many of which are global in nature or require global action. These challenges cannot be dealt with by any single country and require better co-ordination of effort by countries and through both supply- and demand-side interventions. Innovation is crucial for solving such problems in an affordable and timely manner. In the absence of innovation, addressing climate change, for example, will be considerably more costly. Moreover, innovation-driven growth makes it easier for governments to make the necessary investments and undertake the policy interventions to address these challenges.

Action on innovation must be a priority for emerging from the crisis

The crisis has only served to underscore the need for innovation as a way to provide new solutions. While expenditure cuts are needed, governments must continue to invest in future sources of growth, such as education, infrastructure and research. Cutting back public investment in support of innovation may provide short-term fiscal relief, but will damage the foundations of long-term growth. Public investment in basic research, in particular, provides the seeds for future innovation, as it did in the past for the Internet and the Human Genome Project. It will also be needed to foster the breakthrough technologies for dealing with climate change and other global challenges.

At the same time, there is considerable scope to improve the efficiency of government spending and innovate in the delivery of public services. Reforms of education and training systems and public research institutions, for example, can help increase returns from public investment in innovation. Moreover, many policy actions that can help strengthen innovation do not require additional or significant public investment. Structural policy reforms of the framework conditions that support innovation, such as the removal of regulatory barriers to innovation and entrepreneurship, including administrative regulations, as well pro-growth tax reforms, can do much to strengthen innovation and growth.

In most countries, markets can also be strengthened to unleash demand for innovative products and services that meet social and global needs. Getting prices right, opening markets for competition and devising innovation-inducing standards and smart regulations are among the approaches that governments can use to unleash innovation in areas such as health and the environment. Better use of public procurement can also be effective, in particular when government is a large consumer. Well-designed demand-side policies are less expensive than direct support measures; they are also not directed at specific firms, but reward innovation and efficiency. Demand is closely linked to supply, however, and supply-side policies are necessary to create the conditions for business to innovate.

Policies need to reflect innovation as it occurs today

If policies to promote innovation are to be effective, they need to reflect the ways in which innovation takes place today. To transform invention successfully into innovation requires a range of complementary activities, including organisational changes, firm-level training, testing, marketing and design. Science continues to be an essential ingredient of innovation, even though innovation now encompasses much more than R&D. Innovation also rarely occurs in isolation; it is a highly interactive and multidisciplinary process and increasingly involves collaboration by a growing and diverse network of stakeholders, institutions and users. Moreover, the emergence of new and important players has added to the complexity of the multifaceted international landscape of innovation.

These and other changes in the innovation process present a challenge to existing national policy frameworks. Policy will need to move beyond supply-side policies focused on R&D and specific technologies to a more systemic approach that takes account of the many factors and actors that influence innovation performance. The objective of policy should not be innovation as such, but the application of innovation to make life better for individuals and society at large. This is no easy task, especially as the scope for policies for innovation broadens. The objective of the OECD's Innovation Strategy is to support this process of policy development, recognising that "one size does not fit all". It is built around five priorities for government action, which together form a coherent and comprehensive approach to policies for innovation that can help underpin an innovation-led recovery and strengthen the role of innovation in the long run.

People should be empowered to innovate

Human capital is the essence of innovation. Empowering people to innovate relies on broad and relevant education as well as on the development of wide-ranging skills that complement formal education. Curricula and pedagogies need to be adapted to equip students with the capacity to learn and apply new skills throughout their lives. At the same time, education and skills development systems require reform to ensure they are efficient and meet the requirements of society today. Improving teacher quality is particularly important for enhancing outcomes; this might include better initial selection of teachers, ongoing evaluation to identify areas for improvement, and recognising and rewarding effective teaching.

Universities, colleges and vocational training centres are essential nodes in the innovation system, both producing and attracting the human capital needed for innovation. These institutions act as essential bridges between players – businesses, governments and countries – in broader and more open systems of innovation. The major policy challenge is to recognise the essential role of universities in the innovation enterprise rather view them, as is all too commonly the case, simply as providers of essential public goods. This requires a greater focus of policy makers on ensuring independence, competition, excellence, entrepreneurial spirit and flexibility in universities.

Entrepreneurs are particularly important actors in innovation, as they help to turn ideas into commercial applications. In the United States in 2007, firms less than five years old accounted for nearly two-thirds of net new jobs. Successful entrepreneurship often comes with practice, hence the importance of experimentation, entry and exit. Yet, only a small part of the population receives entrepreneurial education. Education and training policies should help foster an entrepreneurial culture by instilling the skills and attitudes needed for creative enterprise.

Internationally mobile talent contributes to the creation and diffusion of knowledge, particularly tacit knowledge. To encourage this circulation of knowledge, governments should build absorptive capacity, open labour markets to foreign students, and ensure that the tax regime does not penalise mobile skilled workers. For their part, sending countries can put into place policies that provide opportunities for expatriate researchers to re-enter the domestic labour market. Migration regimes for the highly skilled should be efficient, transparent and simple and enable movement on a short-term or circular basis. Related policies need to be coherent with the wider migration agenda, and with development and aid policies, so as to contribute to the effective management of migration.

People participate in innovation not only by creating, diffusing or adapting technologies in the workplace, but also as consumers. Consumer policy regimes and consumer education should improve the functioning of markets by helping to equip consumers to become active participants in the innovation process and enable them to make informed choices. This has the added benefit of strengthening competition between businesses. It is essential to ensure that the information provided to consumers is easily understandable and takes account of how people process information.

Innovation in firms must be unleashed

Firms are essential for translating good ideas into jobs and wealth. New and young firms are particularly important, as they often exploit technological or commercial opportunities that have been neglected by more established companies. Both market entry and exit are indispensable for the experimentation that leads to the development of new technologies and markets. Simplifying and reducing start-up regulations and administrative burdens can reduce barriers to entry. Bankruptcy laws should be less punitive for entrepreneurs and should offer more favourable conditions for the restructuring of ailing businesses, with due regard to risk management and the need to avoid moral hazard.

Between 20% and 40% of entering firms fail within the first two years. Reallocation of resources to more efficient and innovative firms is crucial to innovation and economic growth. Labour market policies should provide the flexibility needed to reallocate resources from declining to innovative firms, along with support for lifelong learning and re-skilling of workers.

The tax climate for entrepreneurs should be made more neutral; potential entrepreneurs may also be discouraged from leaving their current employment by the financial and health costs associated with losing employer-based health insurance and social security contributions. Where possible, barriers to the transferability of such benefits should be lowered.

The growth of firms is a particular challenge in many countries. Low regulatory barriers can help ensure that high-growth firms do not spend the capital they need to support their growth on overcoming bureaucratic obstacles. Administrative, social and tax requirements that rise with the size of the company should be reviewed as they increase the cost of growth. Policy can also help existing small and medium-sized firms enhance their capacity to innovate*, e.g.* in supporting the formation of relevant skills.

Access to finance is a key constraint for business-led innovation, which is inherently risky and may require a long-term horizon. Restoring the health of the financial system should therefore be a priority. Well-functioning venture capital markets and the securitisation of innovation-related assets (*e.g.* intellectual property) are key sources of finance for many innovative start-ups and need to be developed further. Financial markets should continue to provide sufficient room for healthy risk taking, long-term investment and entrepreneurship, all key drivers of innovation, while ensuring safeguards in case of failure. When public funds are deployed to ease access to finance, they should be channelled through existing market-based systems, and take a clear market approach.

The creation, diffusion and application of knowledge is critical

The creation, diffusion and application of knowledge are essential to the ability of firms and countries to innovate and thrive in an increasingly competitive global economy. Science continues to be at the heart of innovation and public research institutions in many OECD countries require reform in order to maintain excellence and improve collaboration with the business sector.

Today, high-speed communication networks support innovation throughout the economy much as electricity and transport networks spurred innovation in the past. Governments should also foster ICTs, in particular broadband networks, as platforms for innovation by upholding the open, free, decentralised and dynamic nature of the Internet.

In addition to hardware and software, ICT infrastructure includes information that is publicly generated or funded. Provision of this information at no or low cost can stimulate innovation and improve the transparency and efficiency of government. Obstacles that impede the commercial and non-commercial re-use of public-sector information should be addressed including restrictive or unclear rules governing access and conditions of re-use; unclear and inconsistent pricing of information when re-use is chargeable; and complex and lengthy licensing procedures. In general, public information should remain open so as to eliminate exclusive arrangements and allow innovative commercial and non-commercial re-use.

Intellectual property rights (IPRs) provide an important incentive to invest in innovation by enabling firms to recover their investment costs. IPRs should be well protected and appropriately enforced. They contribute to the creation of innovation and are important for diffusing knowledge and creating value. A variety of collaborative mechanisms, such as licensing markets or pools and clearing houses, can facilitate access to and use of knowledge. Patent systems need to be properly tailored to ensure a proper balance between incentives for innovation and the public benefit that flows from dissemination of the knowledge in the marketplace.

In an economy increasingly based on knowledge and innovation, the development of fully functioning knowledge networks and markets could have a significant impact on the efficiency and effectiveness of the innovation effort. Some good practices exist but significant scale-up is required. Governments can first, underpin the development of a knowledge networking infrastructure; second, implement measures, such as the OECD Guidelines on Access to Research Data from Public Funding, to share public-sector knowledge and data; and third, foster the development of collaborative mechanisms and brokerages to encourage the exchange of knowledge and ensure a fair return on investments made.

Innovation can be applied to address global and social challenges

Innovation is a means of dealing with global and social challenges. Global challenges need to be addressed collectively through global solutions and bilateral and multilateral international co-operation. However, current global challenges require more concerted approaches to accelerate technology development and diffusion and bring innovative products to the market. A new model for the governance of multilateral co-operation on international science, technology and innovation should be explored. It could focus on setting priorities, funding and institutional arrangements, procedures to ensure access to knowledge and transfer of technology, capacity building, and the delivery of new innovations into widespread use.

For many of these challenges, market failures – including the simple absence of a market – limit investment and the development and deployment of innovations. Pricing of environmental externalities, such as carbon emissions, will be an important trigger for innovation. Tax policies or other economic instruments can provide the necessary signal and thus foster a market for innovations, as can the removal of environmentally harmful subsidies. Policies should allow the private sector to identify the most promising means of addressing global problems through innovation. Governments will need to take the lead in areas that firms find too risky and uncertain through investment in public research and well-designed support for pre-competitive research in the private sector.

Low-income countries face specific challenges for making innovation the engine of economic development, including poor framework conditions and low human and social capital. In these countries, policies should focus on enhancing educational attainment and strengthening framework conditions. Modernising agriculture through a locally adapted approach in which entrepreneurship, agricultural productivity, and value addition drive poverty reduction and green growth is particularly important.

The governance and measurement of policies for innovation should be improved

Given the increasingly central role of innovation in delivering a wide range of economic and social objectives, a whole-of-government approach to policies for innovation is needed. This requires stable platforms for co-ordinating actions, a focus on policies with a medium- and long-term perspective, and leadership by policy makers at the highest level. Involving stakeholders in policy development can help develop a shared vision and make policies more effective in meeting social goals. This also involves coherence and complementarities between the local, regional, national and international levels.

Evaluation is essential to enhance the effectiveness and efficiency of policies to foster innovation and deliver social welfare. Improved means of evaluation are needed to capture the broadening of innovation, along with better feedback of evaluation into the policy-making process. This also calls for improved measurement of innovation, including its outcomes and impacts.

The way forward – changing the emphasis in policies for innovation

The broad concept of innovation embraced by the OECD Innovation Strategy emphasises the need for a better match between supply-side inputs and the demand side, including the role of markets. Moreover, policy actions need to reflect the changing nature of innovation. This implies an emphasis on the following areas:

- A more strategic focus on the role of policies for innovation in delivering stronger, cleaner and fairer growth.
- Broadening policies to foster innovation beyond science and technology in recognition of the fact that innovation involves a wide range of investments in intangible assets and of actors.
- Education and training policies adapted to the needs of society today to empower people throughout society to be creative, engage in innovation and benefit from its outcomes.
- Greater policy attention to the creation and growth of new firms and their role in creating breakthrough innovations and new jobs.
- Sufficient attention for the fundamental role of scientific research in enabling radical innovation and providing the foundation for future innovation.
- Improved mechanisms to foster the diffusion and application of knowledge through well-functioning networks and markets.
- Attention for the role of government in creating new platforms for innovation, *e.g.* through the development of high-speed broadband networks.
- New approaches and governance mechanisms for international co-operation in science and technology to help address global challenges and share costs and risks.
- Frameworks for measuring the broader, more networked concept of innovation and its impacts to guide policy making.

The OECD stands ready to help governments and international instances to use the Innovation Strategy in designing their approaches to finding national and global solutions. Implementing the Innovation Strategy will be an ongoing and evolving process, which will benefit from monitoring, peer review and the exchange of experience and good policy practices.

Chapter 1

Fostering Innovation: The Policy Challenge

This chapter presents the innovation policy context and discusses why governments need to develop a strategic approach to fostering innovation. It shows that innovation, broadly defined, is a key driver of growth performance and of economic growth. It indicates that it is essential for all governments to develop policies to strengthen innovation performance and outcomes. Because innovation takes various forms, they can adopt different policies and instruments. The mix of appropriate policies to foster innovation depends on many factors; it is important to recognise that "one size does not fit all".

Challenges ahead

Today's world faces unprecedented challenges. The effects of the economic downturn will be felt around the globe for years to come. Even before the economic crisis, lagging productivity growth was a serious threat to prosperity and competitiveness in many countries. The crisis has made it even more imperative for countries to find new and more sustainable sources of growth. In the current difficult budgetary environment, governments are looking for policies and actions that can help accelerate economic growth and ensure future prosperity and progress.

Innovation and the creation and application of knowledge is an important area for government action. Such action is essential if firms and countries are to thrive in an increasingly competitive global economy, and it is here that advanced countries find their greatest comparative advantage. Investing in knowledge creation and enabling its diffusion is the key to creating high-wage employment and enhancing productivity growth. Less advanced economies also look to innovation as a way to enhance their competitiveness and shift to higher value added activities.

Stronger growth performance is not the only major public policy objective that can be served by innovation. Many of society's most pressing challenges know no borders and cannot be met by a single country. The ability to address increasingly urgent issues such as climate change, health, food security and poverty depends on stronger innovation and new forms of international collaboration. Global challenges require collective and innovation-driven responses.

In today's constrained budgetary environment, governments need to find ways to do more with less. Public investment in innovation-related spending – *e.g.* education, research and technology – is a priority in many OECD countries and it has increased in some as part of recent stimulus packages. Clearly, investing in future sources of growth is important and investments in innovation need to be prioritised. However, there is also much scope to do more with existing resources, improve the efficiency of public spending and enhance the functioning of the overall innovation effort.. This suggests that even countries with constrained public finances can take steps to improve their innovation performance.

In elaborating their policies for innovation, governments must ensure that the policy framework for innovation keeps pace with changes in the global economy and changes in the innovation process. In the aftermath of the financial and economic crisis, society – including business – is looking to government to create frameworks that encourage experimentation and growth but also provide some security in case of failure. At the same time, innovation is increasingly looked to as a way to improve the quality of life and address major social and global problems. Policy can provide the framework for channeling innovation towards applications that make life better for individuals, businesses and society at large.

The process of developing, producing, commercialising and diffusing significant innovations – *e.g.* the invention of the transistor, the invention of antibiotics, the introduction of organisational changes in the workplace – has never been simple or risk-free. Nor is it, as it once appeared, a linear progression from scientific research to discovery to technological improvements to finished products to their diffusion across society. Today, it is explicitly recognised that innovation is a broad and complex phenomenon involving many interactive processes. These dynamic processes take place in a range of contexts and landscapes.

Establishing a rationale for government intervention is important. The idea that "market failure" leads to under-investment in research has been the principal rationale for government funding of research and development (R&D) since the early 1960s. In an innovation systems perspective, the presence of bottlenecks or other failures that impede the operation of the innovation system can constitute crucial obstacles to the effectiveness of R&D as well as growth and development. Accordingly, the scope for failure is considerable, an issue that is discussed in further detail in Chapter 7.

The mix of policies for innovation depends on many factors and "one size does not fit all". Firms' innovation performance and characteristics differ both across countries and within industries. The particular strengths and weaknesses of a country, and the opportunities and threats it faces, are also a major factor. Countries also update their policy mix at different speeds, so differences can be observed even if the goal is the same. Differences in political orientations and objectives, as well as policy processes and institutional capacities, play a role. Countries' innovation systems are characterised by a mix of policies which affect firms' behaviour and firms adopt multiple paths to innovation. The economic and industrial history of a country will also shape policy approaches. Finally, the different forms of innovation require a broad range of policy instruments (Box 1.1).

Box 1.1. Customising policies to different forms of innovation

Factors such as a country's economic structure, its firm demography (*e.g.* number of SMEs), its geography and resource endowment, its infrastructure, stage of socioeconomic development, general framework conditions (*e.g.* macroeconomic conditions, regulatory policies and markets) and institutional environment (*e.g.* the education system and science and research base) all play a role in shaping innovation. In addition, innovation differs widely across sectors. Sectors such as pharmaceuticals, chemicals and semiconductors are closely linked with science, while standards have an important impact on innovation in telecommunications and software. Some sectors are dominated by large established firms while others are driven by the entry of smaller specialised firms. The diversity of innovation actors, learning processes, linkages, knowledge bases, institutions and organisation needs to be carefully considered when formulating policy (Malerba, 2005).

Moreover, innovation policy can be characterised in various ways (OECD, 2010). One distinction is between "supply-side" and "demand-side" policy. Another is between "mission-oriented" and "diffusion-oriented" policy. Policy instruments include financial instruments (*e.g.* R&D tax credits) and regulatory instruments such as laws and binding regulations (*e.g.* the use of safety equipment for children in cars). Innovation policy encompasses a wide range and many types of innovations. Distinctions for characterising innovation include: the type of innovation – technological (product and process) or non-technological (organisational and marketing); the mode of innovation – novel innovator (strategic and intermittent), technology modifier, and technology adopters (Arundel and Hollanders, 2005); and the socioeconomic impact – incremental, disruptive or radical.

The impact of an innovation varies markedly. It may lead to radical structural change and strongly affect the entire value chain from suppliers to end users or it may involve incremental modifications to existing products, processes or practices. At the same time, innovation policy is affected by various policy sub-systems whose structural characteristics and governance arrangements influence policy processes and outcomes. This implies that governments need to develop a coherent, interdisciplinary set of policies for innovation, one that is flexible enough to include different policy approaches to different forms of innovation and associated activities.

Because innovations are of different types, occur in many different ways, and have varying effects, they call for different policy responses. For example, research has found that policies that address the tail end of the innovation cycle and encourage demand for innovation are more likely to stimulate incremental innovation than to foster radical innovation (Nemet, 2009). The latter is better induced through technology- (or supply)-push policies (OECD, 2009). For example, some analysts note that addressing climate change and developing alternatives to hydrocarbon technologies require innovation policies that support radical innovation and a technological regime shift (Smith, 2009). Others suggest a number of policy options to combat climate change, such as providing support for many different technologies as well as improving existing ones, introducing supportive price and regulatory policies, using public procurement to catalyse and support demand, and encouraging the broad dissemination of public scientific and technological knowledge (Mowery *et al.*, 2009).

Innovation drives long-run economic growth

Innovation – the introduction of a new or significantly improved product (good or service), process, or method (Box 1.2) – has long been viewed as central to economic performance and social welfare, and empirical evidence has confirmed the links between innovation and growth (Box 1.3). This means that all governments must understand the importance of innovation and develop policies to strengthen its efforts and outcomes.

Box 1.2. Defining and measuring innovation

The latest (3rd) edition of the *Oslo Manual* defines innovation as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations (OECD and Eurostat, 2005). This definition captures the following four types of innovation and is used for measurement purposes:

- Product innovation: the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.
- Process innovation: the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.
- Marketing innovation: the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing.
- Organisational innovation: the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations.

Innovation activities vary greatly in their nature from firm to firm. Some firms engage in well-defined innovation projects, such as the development and introduction of a new product, whereas others primarily make continuous improvements to their products, processes and operations. Both types of firms can be innovative: an innovation can consist of the implementation of a single significant change or of a series of smaller incremental changes that together constitute a significant change. By definition, all innovation must contain a degree of novelty. The *Oslo Manual* distinguishes three types of novelty: an innovation can be new to the firm, new to the market or new to the world. The first covers the diffusion of an existing innovation to a firm – the innovation may have already been implemented by other firms, but it is new to the firm. Innovations are new to the market when the firm is the first to introduce the innovation on its market. An innovation is new to the world when the firm is the first to introduce the innovation for all markets and industries.

Innovation is a continuous process rather than a static activity. This makes it difficult to measure. Firms constantly make changes to products and processes and collect new knowledge. In order to capture this process, the *Oslo Manual* (OECD and Eurostat, 2005) focuses on measurable indicators such as expenditures, linkages and factors that influence innovation activities.

Innovation, thus defined, is clearly a much broader notion than R&D and is influenced by a wide range of factors, some of which can be affected by policy. Innovation can occur in any sector of the economy, including government services such as health or education. The current measurement framework applies to business innovation, however, even though innovation is also important for the public sector. Consideration is being given to extending the methodology to public sector innovation and social innovation, so as to correspond to the reality of innovation today. Fostering innovation requires not only consideration of a wide range of innovation activities but also of the many actors engaged in innovation.

Innovation has long driven rises in living standards. However, until recently, empirical analysis of economic growth provided little hard evidence on the role of innovation in growth performance. Studies primarily considered labour input (often measured as total hours worked) and physical (tangible) capital, such as machinery and equipment, as the factors driving economic growth. Innovation was typically regarded as affecting overall efficiency in the use of capital and labour in the production process – known as multi-factor productivity (MFP) – although the relation between innovation and MFP growth was not well understood and few growth policies explicitly sought to strengthen it. Recent work has expanded the analytical framework in several ways, clarifying several dimensions of the role of innovation (Box 1.3).

Box 1.3. Innovation and growth: a brief overview

The question of what drives economic growth and how to sustain it in the long run is at the core of economics. Neoclassical growth models (*e.g.* Solow, 1957) assert that growth results from the input of physical capital, *i.e.* the stock of machinery, equipment and buildings, labour, and "knowledge" in the production process. However, because of diminishing returns to capital, long-run growth cannot result from the simple accumulation of physical capital, which can only guarantee growth in the short run. Long-run growth can only be achieved by knowledge accumulation and technological progress. Early growth models assumed, however, that technological progress would fall like "manna from heaven" as an exogenously provided public good. This technological progress was considered to be non-excludable, implying that the holder could not withhold the benefits associated with the technology from others. It was also considered non-rival, *i.e.* that use of that good by one agent would not preclude simultaneous use of the same good by another agent. Thus, in the neoclassical growth model knowledge is freely available to all firms and individuals in the economy and exogenous to the system, and its accumulation does not depend on the economic decisions of individuals and firms. Clearly, this was a very simplified and incomplete theory of growth and the role of innovation.

Advances in growth theory have recognised the endogeneity of the accumulation of knowledge capital and human capital: human and knowledge capital derive from investment decisions of individuals and firms in response to economic incentives and therefore to policies and institutions. Current growth models consider knowledge capital to be non-rival but partially excludable. An immediate consequence of the non-rival nature of knowledge is that externalities, in the form of knowledge spillovers between locations and across time, will play an important role in the accumulation of knowledge and growth. Partial excludability, through formal (*e.g.* patent protection) and informal (*e.g.* secrecy) methods of intellectual property protection give innovating firms temporary monopoly power which allows them to recoup the costs they incurred to innovate.

Technical progress has been modelled both as "horizontal"; *i.e.* as a continuous expansion of the varieties of inputs (of unchanging quality) that firms can use (*e.g.* Romer, 1990); and as "vertical", *i.e.* as progressive improvement in the quality of a fixed number of goods (*e.g.* Aghion and Howitt, 1992). An important feature of vertical innovations is creative destruction, since innovations make prior innovations obsolete and allow innovating firms to capture monopoly markets that were previously held by incumbent innovators. Firms' innovation investment decisions will therefore be affected by expectations about the pace of future innovations, since this will affect the profitability of current innovations. Entry and competition therefore play a crucial role in shaping innovation decisions (and therefore long run growth) in these models.

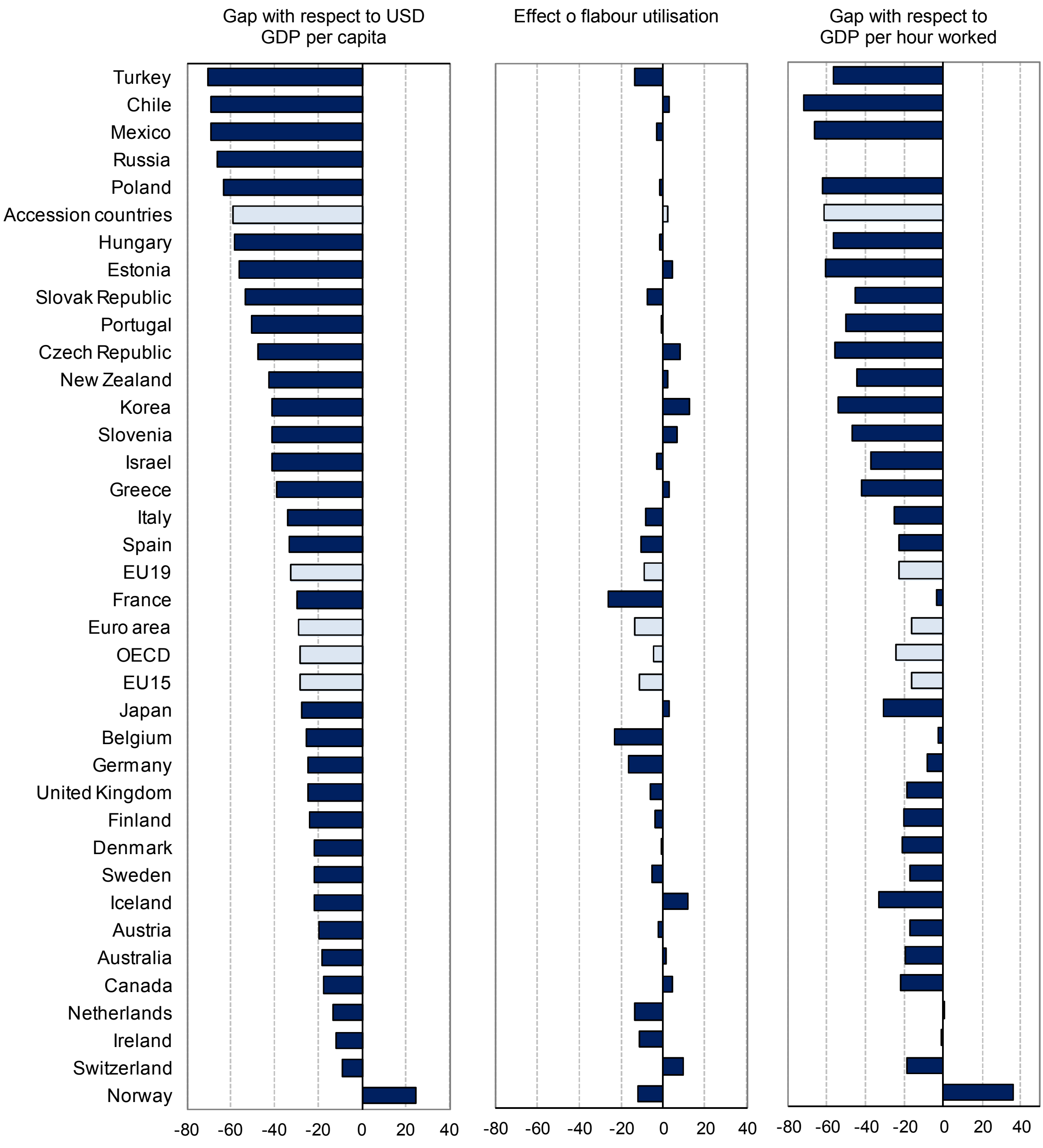
Theoretical and empirical analyses at the macroeconomic and microeconomic level have investigated both the determinants that drive innovation and its contribution to firm performance, measured as productivity growth and/or market value. For many years the focus of both theoretical and empirical contributions has been on technological innovation and on formal R&D. However, attention has widened to broader measures of innovation, to the diffusion of new product and processes, and to investments in innovation other than R&D. Including these broader measures of innovation does create some problems, starting with their measurement

Innovation helps to reduce cross-country income gaps

Innovation not only contributes strongly to growth performance over time, it also plays a major role in explaining differences in income and productivity levels across countries. OECD data show that the income gaps between OECD countries are mainly due to differences in labour productivity (Figure 1.1). While there is considerable scope to improve labour market performance in several countries (particularly since the recent crisis), most of the scope to reduce gaps in income levels is related to improvements in labour productivity. In turn, and as noted above, these are closely associated with innovation.

Figure 1.1. Productivity and income levels, 2008

Percentage point differences with respect to the United States



Notes: Labour productivity and income levels are calculated using GDP at current prices and converted into USD using 2008 purchasing power parities. Labour utilisation is measured as total hours worked per capita. The accession countries aggregate excludes the Russian Federation for which hours worked series were not available at the time of publication. The euro area includes Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. France includes overseas departments. The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Source: OECD, Productivity Database, December 2009.

This is clearly illustrated in Table 1.1, which provides a breakdown of the contributions of total (or multi-) factor productivity, human capital, physical capital intensity and employment to income levels for key OECD countries and regions and for selected non-OECD countries. It shows that income gaps are mostly associated with gaps in total factor productivity (a close proxy for differences in technology and innovation) and with gaps in human capital. This suggests that reducing income gaps between OECD countries and non-OECD countries will heavily rely on improved innovation performance.

Table 1.1. Breakdown of cross-country differences in GDP per capita into their broad determinants, 2005[1,2]

United States = 100

	GDP PPP per capita	TFP	Human capital	Physical capital	Employment
	Y/Pop	*A*	*h*	$(K/Y)^{\alpha/(1-\alpha)}$	*L/Pop*
United States	100.0	100.0	100.0	100.0	100.0
Canada	83.5	72.0	103.3	105.8	106.0
Japan	72.6	52.6	100.4	130.7	105.1
China	9.8	13.6	57.3	105.2	119.5
India	5.2	12.7	47.7	98.3	87.1
Brazil	20.5	29.3	70.1	103.1	96.8
Russian Federation	28.6	31.5	84.9	97.4	99.3
Australia-New Zealand[3]	78.3	64.1	101.5	114.8	104.5
EU27+EFTA[3]	64.7	67.8	91.2	114.1	91.3
Rest of the world[3]	12.3	20.9	59.7	103.6	81.7
Total world[3]	22.8	27.9	64.2	104.2	95.8

1. While equal in principle, Y/Pop and the product of A, h, $(K/Y)^{\alpha/(1-\alpha)}$ and L/Pop can differ in practice for two reasons. First, for countries in which fossil fuel extraction makes a sizeable share of overall output (Russian Federation and a number of countries in the Rest of the World aggregate), TFP levels were estimated for total output excluding the mining and quarrying sector, for reasons explained in the text. Second, geographical area aggregates are computed as arithmetic averages, while geometric means would have to be used for the equality $Y/Pop=Ah\ (K/Y)^{\alpha/(1-\alpha)}\ L/Pop$ to hold.

2. The long-term growth framework is applied at the individual country level. The geographical disaggregation of the world economy presented here matches that of the OECD ENV-Linkages model, as used in Burniaux *et al.* (2008).

3. Population-weighted arithmetic averages.

Source: R. Duval and C. de la Maisonneuve (2009), "Long-Run GDP Growth Framework and Scenarios for the World Economy", *OECD Economics Department Working Papers* No. 663, OECD, Paris.

Innovation and employment

In the current economic climate of increasing budgetary pressure and high unemployment rates, policy makers face two particular challenges: to ensure that policies for innovation represent good value for money and to achieve long-run sustainable growth accompanied by robust job creation. Innovation can affect employment in several ways. Broadly speaking, investment in innovation, or the introduction of new or improved products and processes or new organisational or marketing methods, allows firms to increase their output and tap into new markets. This may be associated with job creation, although firms may also produce more output with their existing labour force. In most cases, innovation will raise labour productivity, allowing for higher wages. As part of the implementation of innovation, some workers may be redeployed within firms to provide new products and services. Others may find their skills no longer required and must seek work elsewhere. This is why effective labour markets and active labour market and training policies are an important part of the policy mix for innovation.

Innovation is also often associated with the setting up of new enterprises to provide the market with new offerings and the creation of new jobs. Evidence for the United States, for example, shows that firms less than five years old accounted for over two-thirds of net new jobs in 2007 (Haltiwanger *et al.*, 2009). Moreover, over time, in addition to the creation of new firms, innovation can lead to the expansion of existing firms because of increased demand for their products or their greater competitiveness. At the same time, innovation can lead to firm closures, if their products or services become obsolete or if they are displaced by more competitive offerings.

In spite of the channels for job creation through innovation highlighted above, it is sometimes feared that the introduction of policies that foster innovation and technological change may lead to fewer jobs overall or threaten the employment of certain groups, such as the low-skilled and those who do routine tasks. One long-standing concern has been that innovation may fuel an increase in demand for skilled workers (as complements to new technologies) and a relative decrease in demand for unskilled or less skilled workers (whose jobs could be replaced by automated processes). More recently, attention has turned to the scope for innovation that involves computerisation and automation to change the nature of tasks within jobs, with a shift in the balance of jobs away from blue-collar and clerical work and changes in the types of things people do at work. Organisational changes may call for new sets of skills and place higher value on different tasks. As a result of information and communication technologies (ICTs), the organisational structures of firms and other entities have changed, bringing increased decentralisation of decision making and new working practices. Evidence suggests that only when they have introduced organisational innovations can firms fully exploit the potential productivity benefits of new technologies.

The empirical evidence on innovation and employment suggests that such concerns should not be overemphasised. In terms of overall employment, the evidence suggests that innovation is associated with employment growth. Studies have shown positive relations between R&D, patents or innovation counts and employment and between ICT and employment (*e.g.* Doms *et al.,* 1995; Van Reenen, 1997; Blanchflower and Burgess, 1998 and Fung, 2006). In terms of changes in demand for workers in different skill categories, there is some empirical support for increased demand for highly skilled workers and decreased demand for low-skilled workers. However, there is also evidence that low-skill occupations are not disappearing. Studies of workers in the United States, the United Kingdom and other European countries suggest that growth in occupations is at the top end of the skill and earnings distribution (*e.g.* scientists, lawyers and managers) and at the bottom end (predominantly service occupations, *e.g.* childcare). Middle skill jobs such as accounting, clerical and routine production jobs are those that are experiencing relative declines (Autor *et al.*, 2006, 2008; Goos and Manning, 2007; and Goos *et al.*, 2009). This is consistent with the view that technological change due to computerisation is changing the task components of occupations. In particular, routine, easily codified tasks may be automated, leaving workers to perform more non-routine tasks, such as those requiring creativity and abstraction or providing interpersonal service.

From a policy perspective, changes in demand for different types of workers and changes in organisational structures highlight the importance of providing workers with a robust set of skills and enabling people to continue to maintain and augment their competences throughout their lives. This calls for strong numeracy and literacy, as well as problem solving, deductive reasoning, and strong communication and collaboration skills (see Chapter 3). Providing these skills requires investment by firms and workers in training and lifelong learning and government's active role in ensuring formal recognition of these investments. Augmenting workers' skills improves their productivity and can have important positive spillovers by facilitating workers' adaptability and mobility and enabling new entrants' smooth integration into the labour market. In addition, labour market and social policies must enhance the adjustment capacity of the economy and make it easier for displaced workers to move into new jobs.

Innovation policies may need to take account of the different effects of different types of innovation on employment in industry sectors. Evidence of the impact of product innovation on employment suggests a positive relationship; recent firm-level data from country innovation surveys in Chile, France, Germany, Italy, Spain and the United Kingdom show that the increase in total sales associated with product innovation contributes to employment growth at the firm level (Benavente and Lauterbach, 2008; Hall *et al.*, 2008; Harrison *et al.*, 2008; Greenan and Guellec, 2001). Industry-level evidence supports this, suggesting that policies that foster experimentation and enable new or existing firms to launch new products are conducive to higher productivity growth and job creation.

Evidence on the impact of process innovation on employment is more mixed; firm-level studies find no significant relationship between this type of innovation and employment, while industry-level studies differ depending on the sectors and countries analysed. To some extent, the impact may be due to natural industry life cycles, with early industry expansion associated with strong product innovation and industry growth, and more mature industries seeking higher productivity more through process innovations (Tether *et al.*, 2005). Recent work by Mastrostefano and Pianta (2009) suggests that for industries in Europe that innovate little innovation tends to have a negative effect overall on employment because of the dominance of process innovations, while industries with a high level of innovation undertake more product innovation and experience a virtuous circle of growing demand, output, jobs and wages. Clearly, both types of innovation contribute to firm survival; however, process innovation may have greater impacts on workers and will thus make greater demands on public policy to facilitate their smooth redeployment.

Finally, in discussing the employment effects of innovation, it is important to recognise other important influences on demand for labour. Of particular note are trade patterns and increasing globalisation; also influential are institutional factors such as minimum wages and labour market regulations, competition policy, and the composition of public spending. Overall, it is important to keep in mind that in this area there are many channels of influence and many interactions with other economic trends.

Key findings and structure of the report

Innovation is a key driver of growth performance, and its contribution to economic growth is likely to increase. Because many OECD countries have stagnating or declining populations, long-term increases in labour input are likely to play a limited role in driving future economic growth. Moreover, investments in physical capital have diminishing returns and cannot strengthen long-run economic growth. An increasing share of economic growth in OECD countries has to come from R&D and innovation. In developing countries, including those with low incomes, innovation is a way of catching up and propelling development.

It is time for a strategic approach to fostering innovation to achieve the core objectives of public policy. It is the aim of the OECD Innovation Strategy to move towards this common goal. It takes a broad, system-wide approach to innovation, bringing together policies and principles in a mutually supportive manner. It recognises the fundamental role of people in both the public and private spheres, of firms, operating in an interconnected world where markets are more sophisticated and demanding than ever before, and of knowledge creation and diffusion. Its aim is not a one-size-fit-all, linear approach. Rather, its message is that a mobilising vision – and the ambition to achieve it through policy coherence and effective co-ordination – can help governments improve economic performance, address societal challenges and enhance welfare, through innovation. This calls for horizontal as well as vertical co-ordination of policies. With appropriate policies, innovation will result in win-win outcomes and greater well-being at both national and global levels. To this end, this report studies key elements of the innovation landscape and of the policies that affect and drive innovation.

This report draws on the analytical literature, presents the most recent available data and brings together a wide range of OECD studies. More than 15 policy committees from the OECD participated in and contributed to the project. It also benefited from substantial specialist input via an expert advisory group, numerous workshops, a series of country roundtables with policymakers, and extensive stakeholder consultation. A web-based "innovation portal" was developed to encourage an open, informal exchange of ideas among the broader innovation community. Annex A provides further details on these initiatives. In what follows, Chapter 2 presents a snapshot of the innovation landscape with a selection of data that show how innovation is occurring today. Chapters 3 to 7 are built around five priorities for government action that emerged during the project:

- empowering people to innovate (Chapter 3);
- unleashing innovation (Chapter 4);
- creating and applying knowledge (Chapter 5);
- addressing global and social challenges through innovation (Chapter 6); and
- improving the governance and measurement of innovation (Chapter 7).

Finally, Chapter 8 draws the work together and offers suggestions on the way forward and actions needed to implement the OECD Innovation Strategy.

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Chapter 2

Innovation Trends

This chapter presents a brief picture of the innovation landscape. It discusses how innovation is defined and measured and how the concept has broadened to include non-technological activities such as organisational change and marketing. It presents a selection of data and indicators which show that not only R&D but various other inputs are needed for effective innovation. It looks at how the innovation process has opened up and why collaboration has become a key to innovation. It also examines the shifting geography of innovation, the emergence of new global players and the global competition for talent.

New approaches to measuring and analysing innovation

Research on innovation has been under way for decades both in academic circles (Fagerberg, 2005) and at the OECD (*e.g.* OECD, 1991, OECD, 1992). However, the notion of what innovation involves and what role policies to encourage innovation can play has changed considerably over the past decade. It is increasingly recognised that, in addition to R&D, innovation encompasses a wide range of activities, including organisational change, training, testing, marketing and design (Box 1.2). These activities can strengthen capabilities for developing innovations or the ability to adopt innovations developed by other firms or institutions successfully.

Moreover, a better understanding of the main components of GDP and productivity growth is a necessary first step in analysing growth. However, to answer more fundamental questions about what determines the growth of these components, and their economic and social consequences, it is necessary to analyse the role of public policies, economic incentives, organisations, market structure, foreign trade and investment, and other institutional factors, along with their complementarities and synergies. Better insight into the factors that determine multi-factor productivity growth is particularly helpful, as this is the aspect of economic growth that remains to be explained once standard factors are taken into account (Box 2.1).

Box 2.1. Improving the measurement of innovation

Appropriate measurement of innovation is critical for policy making. Sound measurement and evidence help policy makers evaluate the efficiency of their policies and spending, assess the contribution of innovation to achieving social and economic objectives, and legitimise public intervention by enhancing public accountability. Despite advances such as innovation surveys in the business sector, current measures of innovation do not adequately take account of the key role innovation plays in today's economy. It is necessary to go beyond aggregate numbers or indices since they are unable to reflect the diversity and linkages of the actors and activities that constitute the innovation process today.

Moreover, many innovation indicators only capture part of the innovation process. R&D data provide information about some of the inputs to innovation but have little information on the outputs. They tend to be more useful for measuring technology-based activities, which are influenced by industrial structure, and only cover one element of the broader concept of innovation. For their part, patents are an indicator of invention rather than innovation since not all patents are commercialised, and some types of technology are not patentable. The number and citation impact of scientific publications, or bibliometrics, is another output indicator which also has well-known limitations.

The OECD and the research community are working to develop a new set of indicators to cover the broader notion of innovation and its link to economic performance and growth (OECD, 2010a). This will require linking existing data sources and making better use of internationally comparable data at the firm, individual and organisation level. It will require the collection of additional material, as well as better understanding of currently unmeasured factors in the innovation process.

Sound evidence on the sources of multi-factor productivity growth, *i.e.* the sources of technological and non-technological innovation, is found through firm-level analysis, which provides more detailed insight than country-level analysis. It is after all mainly firms that innovate, from small start-ups to large multi-establishment and multinational firms. Moreover, aggregate analysis conceals their significant heterogeneity. Firms' performance and characteristics differ across countries and within industries, and they may take many paths to innovation. The advantage of micro-level analysis lies in its effort to model the channels through which specific firms' knowledge assets or channels of knowledge access affect their productivity.

Advances in the last decades in data collection and availability, in analytical methods and in computing power have revealed important relations in firm-level data between R&D and patents and between productivity growth and firm value. They have added to knowledge of the private and social returns to R&D (Hall *et al.,* 2009) and of knowledge production functions (*e.g.* Griliches and Pakes, 1980; Crepon *et al.,* 1998). Recent evidence also indicates the importance of complementarities in investments in ICT and organisational and managerial capabilities (Bresnahan *et al.,* 2002; Crespi *et al.,* 2006; Bloom *et al.,* 2007). As yet, however, existing firm-level evidence has only captured part of the innovation process.

Firm-level analysis has also linked investment in innovation with improved outcomes, showing that the proportion of a country's firms engaging in innovation spending is closely correlated with the proportion of its successful innovators. A recent study using firm-level, "microdata"[1] for 21 countries showed that firms investing more in innovation per employee are also those with higher innovation sales and higher productivity levels (Box 2.2) (OECD 2009a, 2010b).

Box 2.2. Product innovation and productivity at the firm level

Research teams from 21 OECD and non-OECD countries used a variant of the standard Crepon, Duguet and Mairesse (CDM) econometric framework to estimate the link between innovation and productivity. This framework structurally models firms' innovation investment decision, the innovation process and the role of innovation in the production of output.

The main results show that:

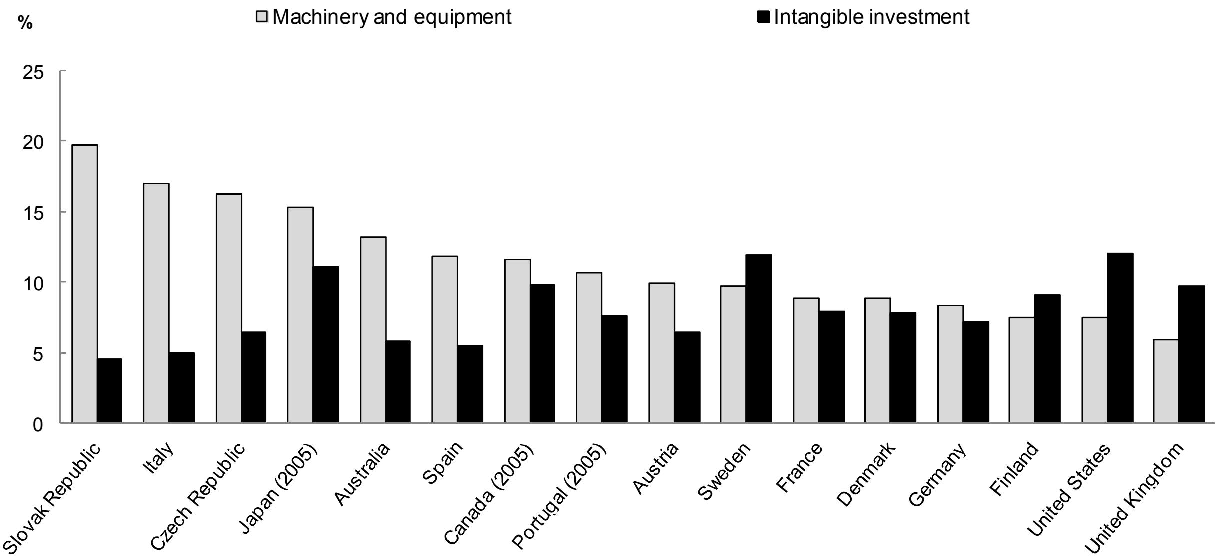
- Firms operating in international markets, receiving public financial support and involved in collaboration are investing more in innovation than other firms.
  - Firms active in international markets are 40% to 70% more likely to innovate than other firms. After correcting for the fact that not all firms are innovative, firms involved in collaboration spend 20% to 50% more on innovation than non-collaborating firms. Similarly, firms receiving public funding invest 40% to 70% more than those not receiving public funds. These results hold for most of the 21 countries participating in the project.
- Firms introducing both product and process innovations and those spending more on innovation earn greater returns from innovation than other firms.
  - Firms introducing both product and process innovations derive on average 30% more innovation sales per employee than those introducing only product innovations. Similarly, firms with higher innovation expenditure per employee have more innovation sales per employee than other firms. The elasticity range is between 0.1% and 0.3% for most participating countries.
- Firms with higher innovation sales intensity are also those with higher productivity levels.
  - Firms with a higher intensity of innovation sales are also those with higher productivity levels. This relation holds for the majority of countries with elasticities ranging between 0.3% and 0.6%.
- Firms' distance from the global technology frontier matters for innovative firms.
  - A firm's productive capability is proxied by how far its productivity level (measured either by turnover per employee or value added per employee) is from the top productive firms worldwide. Firms with a large productivity gap at the beginning of the period are considered far from the technology frontier, while those on a par with or with a small productivity gap compared to the top productive firms are close to the technology frontier.
  - The microdata analysis shows that firms further away from the technology frontier invest less in innovation per employee and have lower returns from innovation (lower innovation sales per employee) than those closer to the frontier. However, firms with a low productivity level at the beginning of the period are as likely to innovate as those with a higher productivity level. These findings hold for firms in almost all participating countries.
- Public support makes a difference, especially for firms that are further away from the technology frontier.
  - While both firms close to and far away from the technology frontier benefit from public funding for innovation, those that are further away from technology frontier that receive public funding spend 60% to 100% more on innovation than those that do not receive public funding. For firms closer to the technology frontier, those that receive public funding spend 30% to 50% more on innovation than those that do not receive public funding.

Source: OECD (2009), *Innovation in Firms: A Microeconomic Perspective*, OECD, Paris; OECD (2010), *Innovation and Firms' Performance: Exploiting the Potential of Microdata* (working title), OECD, Paris, forthcoming.

Intangibles contribute to growth

Innovation entails the production of new knowledge from complementary assets – R&D, but also software, human capital and organisational structures – many of which are essential for fully realising productivity gains and efficiencies from new technologies. As such intangible assets become strategic factors in firms' value creation, their role in the economy has become as important as that of tangible assets, accounting for up to 12% of GDP (Figure 2.1). In Finland, Sweden, the United Kingdom and the United States, investment in intangibles is now equal to or even superior to investment in tangibles such as machinery and equipment and structures. Over the past decade, investment in intangibles has grown as a share of GDP in many OECD countries while investment in tangibles has stayed the same or declined. The relative importance of intangibles in the investment strategies of the business sector has therefore increased. Investment in intangibles leads to creating and applying knowledge, and it is here that firms in OECD countries find their greatest comparative advantage.

Figure 2.1. Investment in fixed and intangible assets as a share of GDP, 2006



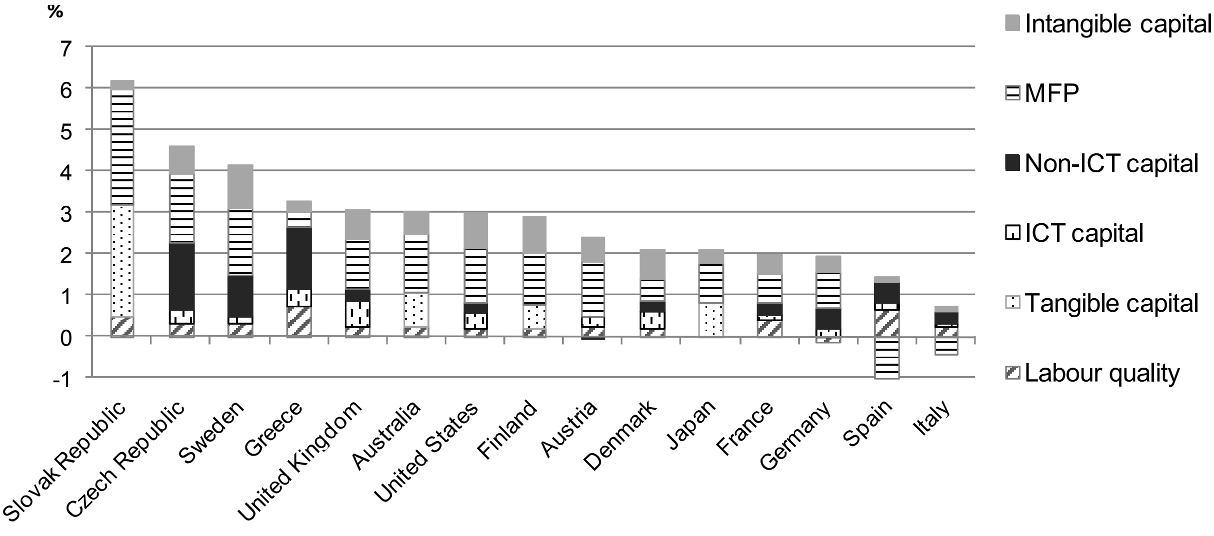
Notes: These estimates are based on national studies. They do not yet reflect standardised methods and definitions. Estimates refer to the total economy for Canada, Japan and Sweden; the market sector for Australia, France, Germany, Italy, Spain and the United Kingdom; the non-financial business sector for Finland; and the non-farm business sector for the United States.

Source: Data on intangible assets for the United States provided by C. Corrado; data for Japan provided by T. Miyagawa; data for Sweden provided by H. Edquist; data for Germany, Italy, Spain and the United Kingdom provided by J. Haskel, A. Pesole and members of the COINVEST project; data for Austria, Denmark and the Czech Republic provided by J. Hao and B. van Ark; data on intangible and tangible investment for Australia provided by P. Barnes; for Canada by N. Belhocine. Data on tangible investment for France is based on INSEE data. For other countries figures for tangible investment are OECD calculations based on EU KLEMS Database and OECD, Annual National Accounts Database.

To understand the role of innovation in the economy and its contribution to economic growth, it is important to properly account for this "intangible" capital. Traditionally, both national and firm accounting practices treated investment in non-market intangibles, such as internal R&D, as current expenditure rather than as investment. National accounts have now started to capitalise, even if only partially, investments in intangibles such as software and R&D. However, most intangible investment is still excluded from the national accounts.

Estimates of intangible assets by Corrado *et al.* (2009) for the United States indicate that the conventionally measured capital stock is underestimated by some USD 1 trillion and the business capital stock by up to USD 3.6 trillion.[2] Adding this capital to the standard growth accounting framework changes the observed patterns and sources of US economic growth significantly. In particular, the rate of change of output per worker increases more rapidly in the presence of intangible capital, and capital deepening – tangible and intangible – becomes the dominant source of labour productivity growth. Corrado *et al.* also find that from 1995 to 2003 the contribution of intangible assets to labour productivity growth was equal to that of investment in tangible assets. Finally, the inclusion of intangible capital in the US growth accounts explains a larger share of labour productivity growth, leaving a smaller contribution of MFP to labour productivity growth.

Figure 2.2. Contribution of intangible investment and multi-factor productivity growth to labour productivity growth, 1995-2006[1]



Note: These estimates are based on national studies. They do not yet reflect standardised methods and definitions.

1. Or nearest available period.

2. Japanese estimates do not account for the contribution of labour quality.

Source: C. Corrado, C. Hulten and D. Sichel (2009), "Intangible Capital and US Economic Growth", *Review of Income and Wealth*, 55(3), September, pp. 661-685, for the United States; H. Edquist (2009), "How Much Does Sweden Invest in Intangible Assets", *IFN Working Paper* No. 785, Research Institute of Industrial Economics, for Sweden; K. Fukao, T. Miyagawa, K. Mukai, Y. Shinoda and K. Tonogi (2009), "Intangible Investment in Japan: Measurement and Contribution to Economic Growth", *Review of Income and Wealth*, Vol. 55(3), pp. 717-736, for Japan; P. Barnes and A. McClure (2009), "Investments in Intangible Assets and Australia's Productivity Growth", Productivity Commission Staff Working Paper, Canberra, for Australia; G.M. Marrano, J.E. Haskel and G. Wallis (2009), "What Happened to the Knowledge Economy? ICT, Intangible Investment and Britain's Productivity Record Revisited", *Review of Income and Wealth*, Vol. 55(3), pp. 686-716, for the United Kingdom; and B. Van Ark, J.X. Hao, C. Corrado and C. Hulten (2009), "Measuring Intangible Capital and Its Contribution to Economic Growth in Europe", *EIB Papers* 14(1), for Austria, the Czech Republic, Denmark, France, Germany, Greece, Italy, the Slovak Republic and Spain.

Estimates show that intangible investment accounts for up to one percentage point of labour productivity growth in Sweden, and just below that in Denmark, Finland, the United Kingdom and the United States. In these countries, intangible investment accounts for up to 25% of total labour productivity growth (Figure 2.2). Investment in intangibles is not the only part of labour productivity growth that is associated with innovation, however. Much multi-factor productivity growth, *e.g.* improvements in the joint productivity of capital and labour, is due to spillovers from investments in innovation and from a range of efficiency improvements made by firms.

Between 1995 and 2006, the combination of investment in intangibles, investment in ICT and multi-factor productivity growth accounted for between two-thirds and three-quarters of labour productivity growth in several OECD countries. This demonstrates that innovation is the main driver of growth in advanced economies.

The scope of innovation has broadened

Innovation is a continuous, pervasive activity that takes place throughout the economy. Firms constantly change products and processes, collect new knowledge, and develop new ways of working. Basic aggregate indicators from innovation surveys show that the share of firms developing a product or process innovation ranges from over half of all firms in Austria, Germany, Luxembourg and Switzerland to less than a third in France, Japan and Norway. Firm size is an important factor for innovation, and differences among countries are less pronounced among large firms with 250 employees or more. Innovation reaches 70% or more in such firms in nine out of 16 countries for which data are available (OECD, 2009a). [3]

The different types of innovation are not necessarily confined to particular sectors of the economy. Industries that may be regarded as less innovative, primarily because of their low R&D intensity, such as printing and paper products or textiles and clothing, frequently have as much propensity to innovate as those in communication or financial services, which are often regarded as the leading innovation industries (ABS, 2006a; Statistics New Zealand, 2007; OECD, 2010a).

At the same time, innovation is highly skewed, as a small proportion of firms account for the majority of inputs and outputs. Sub-national innovation data from Australia have shown, for example, that less than 10% of firms account for 80% of innovation expenditure and innovation sales (Smith and O’Brien, 2008). Patterns are similar at the national level (ABS, 2006b). In 2008, the top ten R&D firms worldwide spent more than EUR 58 billion on R&D. This represented about a quarter of the R&D performed by the world’s top 100 firms (European Commission, 2009) and more than total German industrial R&D (EUR 46 billion), yet Germany ranks third in terms of industrial R&D, behind the United States and Japan. The concentration of R&D performers is also apparent at the country level. Canadian data show that the 25 largest Canadian R&D firms performed 33% of all domestic industrial R&D in 2009 (Statistics Canada, 2010). Likewise, in 2008 the top ten patenting firms filed about 8% of international patents (Patent Cooperation Treaty, PCT) and the top 20 filed 12%. Patenting is similarly concentrated in major areas such as the People’s Republic of China, Europe, Japan and the United States (WIPO, 2008).

For their part, services play a key role in developed economies. They account for nearly 70% of total value added (OECD, 2009b) and are the main source of skilled job creation in the OECD area (OECD, 2009c). Innovation surveys have confirmed that service-sector firms are also innovative. However, their innovation differs from innovation in the manufacturing sector. For example, manufacturing firms tend to undertake more in-house innovation and are more likely to introduce new-to-market innovations. On average service firms tend to undertake less innovation than manufacturing firms, but there are wide variations in service industries and countries. For example, knowledge-intensive business services (KIBS), which include telecommunication services, finance, computer and R&D services, have in-house R&D and innovation rates similar to those in high-technology manufacturing (OECD, 2010a).

Non-technological innovation is of growing importance

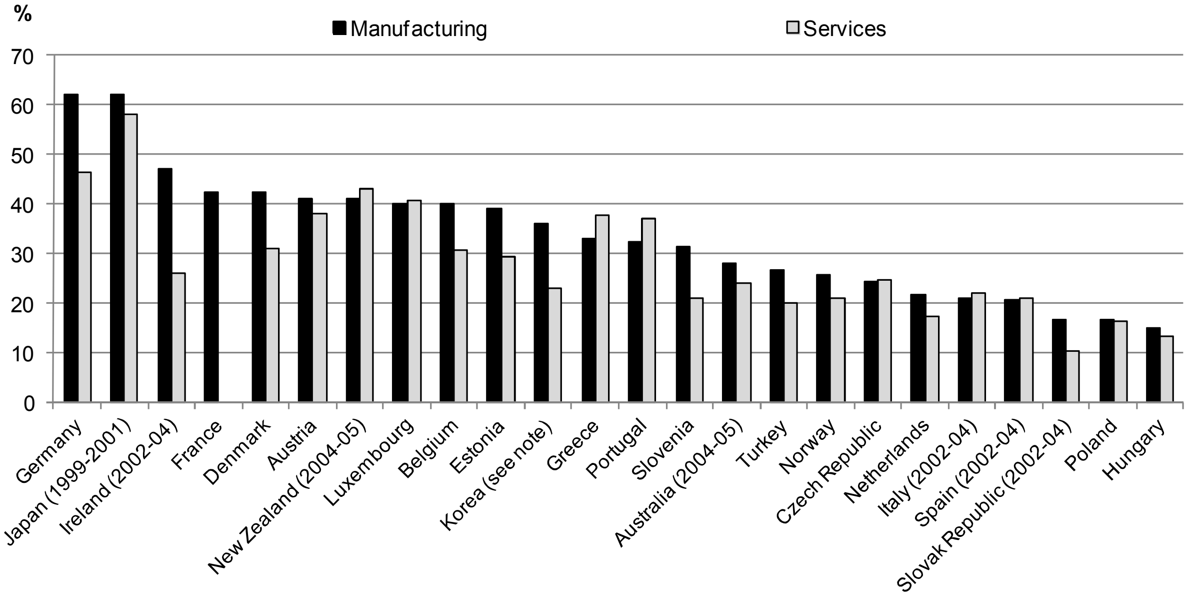
Recent years have seen increased interest in non-technological forms of innovation and their contribution to productivity performance, especially in countries whose industrial specialisation and structure limit the scope for technology-based R&D activities. Examples of marketing and organisational innovations include first-time use of product placement in movies or television programmes, implementation of a significant change in the design of a furniture line to give it a new look and widen its appeal, first-time introduction of training programmes to create efficient and functional teams which bring together staff from different backgrounds or areas of responsibility, and first-time implementation of an anonymous incident reporting system to encourage the reporting of errors or hazards in order to identify their causes and reduce their frequency (OECD and Eurostat, 2005).

There is as well a growing understanding of the complementary nature of technological and non-technological innovation. Investment in innovation, as measured through a range of "intangibles" such as R&D, computerised information, branding, firm-specific training and organisational investments, is growing.

The commercialisation of new products often requires the development of new marketing methods, and a new production technique often needs to be supported by organisational change. In most countries, sectoral differences between non-technological and technological innovations are not marked (Figure 2.3). Both manufacturing and services engage in product, process and non-technological innovation and differences appear mainly related to the characteristics of specific industries and firms. Large firms, for example, engage far more than SMEs in non-technological innovation (OECD, 2009c).

The concepts of technological (product, process) and non-technological (marketing, organisational) innovation are useful from a practical perspective, since the relevant data are available. However, they do not fully take account of the fact that today's firms adopt mixed modes of innovation: certain types of innovation tend to go hand in hand, while others tend to be independent or to substitute for each other; certain innovative activities (*e.g.* co-operation or patenting) are more closely related to certain types of innovation than to others (OECD, 2009a).

Figure 2.3. Non-technological innovators by sector, as a percentage of all firms, 2004-06 (or nearest available years)



Notes: For Korea, data are for 2002-04 for manufacturing and 2000-02 for services. For France, data cover manufacturing only.

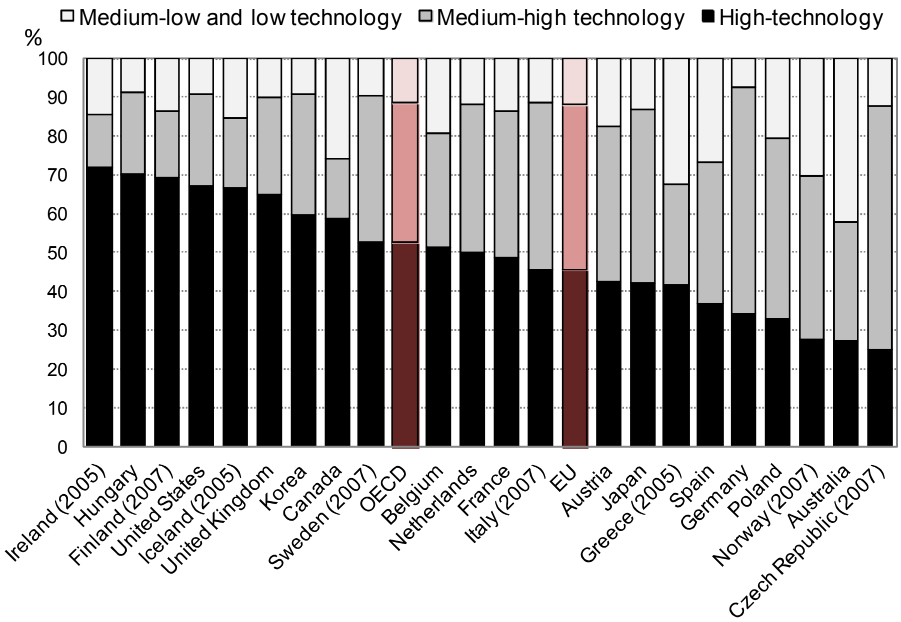
Source: OECD based on Eurostat, CIS-2006 (April 2009) and national data sources, complemented by microdata indicators (December 2009).

An OECD study based on firm-level data for 21 countries shows that five innovation patterns are common to most countries analysed. One involves some form of new-to-market innovation linked to own generation of technology (in-house R&D and patenting). A second includes product innovation with marketing expenditures or marketing strategy changes. A third involves the upgrading of processes with spending on equipment, often with external or partnership-based development. A fourth is broader innovation involving organisational and marketing-related innovation strategies. A fifth is networked innovating, in which firms seek external sourcing of knowledge, often from the public knowledge base and through formal collaboration. The first mode (in-house R&D and patenting) can be seen as the traditional technological innovation strategy, while the other four extend the notion of innovation (OECD, 2009a, 2010a).

Low-technology sectors innovate

A significant amount of R&D is performed in low-technology industries, particularly in resource-based economies. In 2006, R&D in medium-low- and low-technology industries represented more than one-quarter of manufacturing BERD in Canada and Spain, and more than 30% in Australia, Greece and Norway (Figure 2.4). The oil and aquaculture sectors provide examples of innovation in resource-based industries which rely on the science base and combine R&D with engineering and other types of innovation in ways that are not always easily captured by conventional indicators and statistics (Box 2.3).

Figure 2.4. Share of business R&D in the manufacturing sector by technological intensity, 2006



Source: OECD (2009), *Science, Technology and Industry Scoreboard 2009*, OECD, Paris.

Box 2.3. Innovation in the Norwegian oil and aquaculture clusters

The development of the Ormen Lange field in the Norwegian Sea is one of the largest and most demanding industrial projects ever carried out in Norway. Hydro, a Norwegian petroleum company, is the operator. The field is situated in an area of the Norwegian Sea where climatic and oceanographic conditions make this one of the world's most challenging development projects. Norwegian research and industrial centres of expertise have been engaged to find solutions to a set of challenges that had not previously arisen for oil and gas development on the Norwegian continental shelf. Together with several partners in the Ormen Lange field, Hydro is implementing a major pilot programme to test the viability of a sub-sea compressor off the Norwegian coast. This highly innovative project would eliminate the need for a conventional platform, saving billions of Norwegian kroner and halving operating costs.

The Norwegian aquaculture industry is a modern, internationally competitive industry that produces high-quality food efficiently. In terms of value, aquaculture products account for almost half of Norway's total fish exports. Salmon and trout are the main species; however, efforts are under way to farm new species, such as cod, halibut, wolf-fish and shellfish. Industry-related research in the fishing and aquaculture sector is conducted at a high international level. More and more knowledge and expertise are required in the marine sector to improve competitive abilities and create new employment in existing and new related industries. Many opportunities linked to the better use of by-products, biotechnology and marine resources have not yet been seized. Several companies are engaged in aquaculture across the world. For example, Marine Harvest is one of the world's leading seafood companies and produces about one-third of the world's farmed salmon and trout. It is present in 20 countries and has 9 000 employees worldwide. Other major companies are Domstein, Aker Seafood and Salmar.

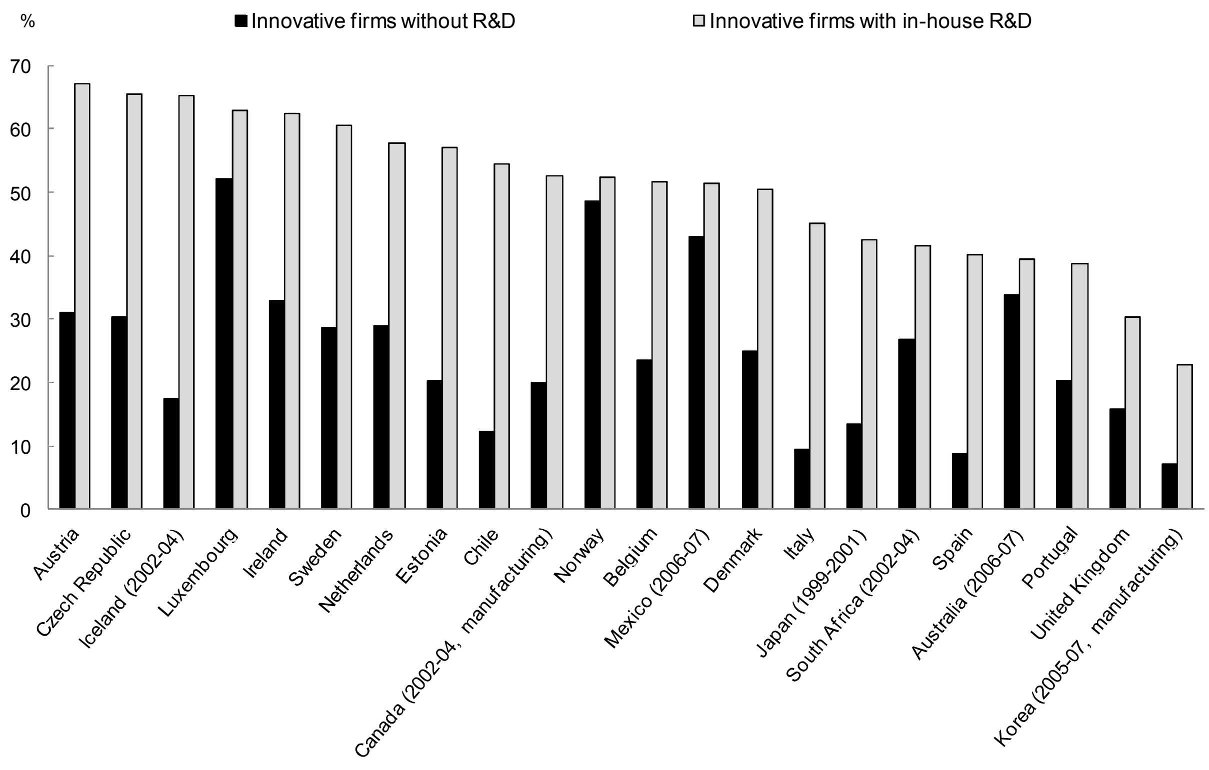
Source: OECD (2008), *OECD Reviews of Innovation Policy: Norway*, OECD, Paris.

Between one-quarter and one-half of all low-technology firms innovated in 2004-06, and around one-half of these did not have any R&D activities (OECD, 2010a).The share of highly skilled workers in low-technology industries has been increasing over the last ten years but is still slightly below the overall share of highly skilled workers in the manufacturing sector as a whole.[4]

Non-R&D expenditures are sometimes more important for innovation than R&D, and many of the countries with the highest proportion of successful innovators also have the highest propensity to engage in non-R&D innovation spending. This indicates the importance of a broad view of innovation inputs (Jaumotte and Pain, 2005). New results from innovation surveys show that in most countries, more than a quarter of innovating firms introduced new products or processes without performing R&D. Moreover, a significant share of these non-R&D performing firms introduced product innovations that were first on their markets (Figure 2.5). Thus, non-R&D performing firms are able to develop new products or processes with an important element of novelty (OECD, 2010b).

Figure 2.5. New-to-market product innovators with and without R&D, 2006

As a percentage of innovative firms by R&D status



Note: For Spain, R&D activity refers to the year 2006 only.

Source: OECD (2010), *Measuring Innovation: A New Perspective,* OECD, Paris, based on OECD Innovation Microdata Project.

The innovation process is more open

The complexity and costs of engaging in innovation – in particular at the frontier – continue to increase. Some innovations are realised through the convergence of different fields and technologies (*e.g.* social sciences, microelectronics, engineering and life science technologies) (Chapter 5). Such innovations promise new added value but are inherently risky, since business models are uncertain, costs are high and new potential competitors emerge in a very fluid business environment. After decades of trade liberalisation, markets have become more globalised, opening new opportunities as well as intensifying the level of competition. Some product life cycles have shortened or are under pressure as a result of more intense and global competition and continued technological progress, and companies are forced to innovate more quickly and develop products and services more efficiently.

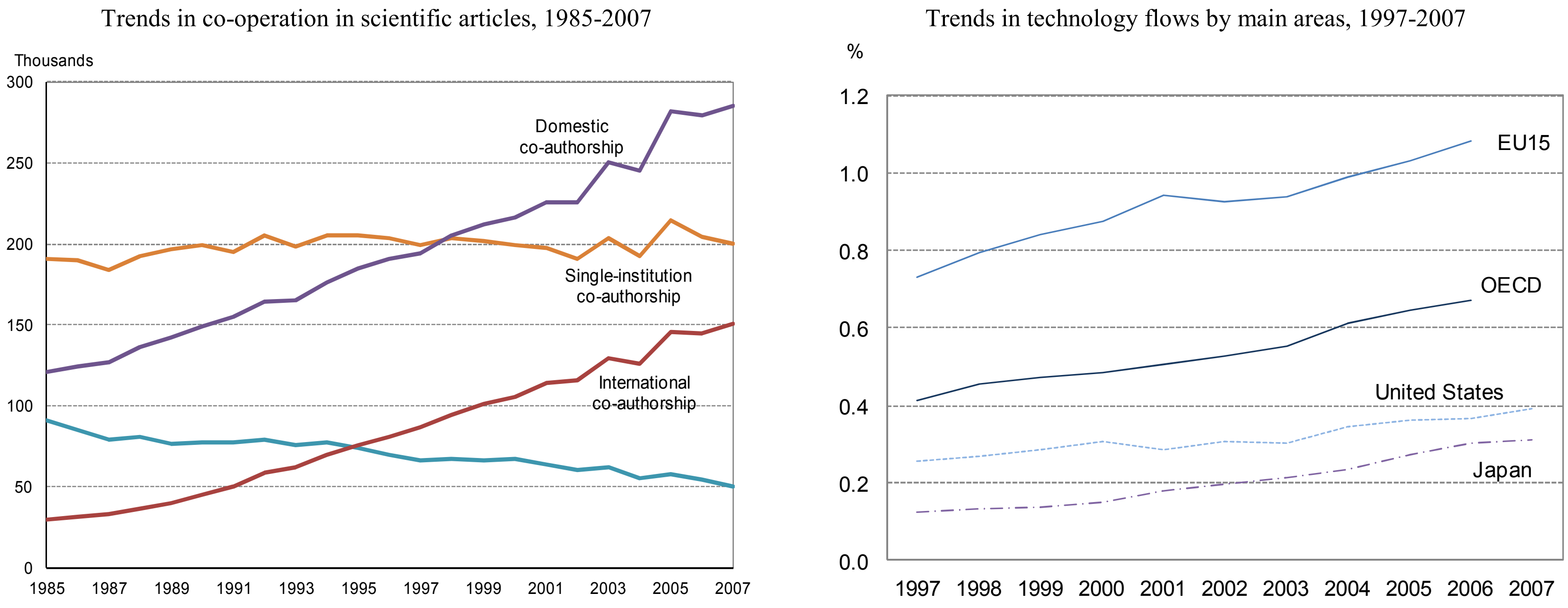
As a result of these trends, firms feel the need to partner to share costs, find complementary expertise, gain access to different technologies and knowledge and collaborate as part of an innovative network. These networks are increasingly global and call for individuals and institutions to take a more "open" perspective on the innovation process, in which collaboration and competition coexist. Users, including suppliers and end users, also affect the innovation process by shaping and stimulating market demand for innovation. Studies show that from 10% to 40% of users engage in developing and/or modifying goods and services (von Hippel, 2005). These innovating users are typically "lead users", *i.e.* they are at the leading edge of the market. Innovation by users is often widely distributed rather than concentrated, with the result that innovations are combined and leveraged in so-called innovation communities. In these very direct, informal user-to-user co-operation networks, users help each other to solve problems and innovate (Box 2.4).

Box 2.4. User-generated innovation: open source software

Free and open source software (OSS) projects are examples of relatively well-developed and very successful forms of Internet-based innovation communities, in which innovations are freely disclosed. They involve a copyright-based licence to keep private intellectual property claims out of the way of both software innovators and software adopters, while preserving a commons of software code that everyone can access (O'Mahony, 2003). Open source can be defined as a set of principles and practices on how to write software, the most important of which is that the source code is openly available. It is not only the source code that is important but also the right to use it.

Open source software started without any enterprise involvement (often university-based research) with enhancements to the code available to everyone on an equal basis. It is a collaborative, community model based on a process that does not allow any contributor to claim ownership to intellectual property on any portion of the code developed within the open source framework. More recently, professional companies have also become active in open source software since they can create value from their IP over and above what they give away. The trend is for firms to adopt a hybrid approach that involves both proprietary and open source models, as they craft approaches to development and commercialisation that reflect their ever evolving business models (OECD, 2009d). Companies use strategies that combine the benefits of open source software with the control of (some) proprietary knowledge by sharing rights for using technology and collaboratively developing new technology (West, 2003). Companies may profit from open source software by selling installation, service and support with the software, by versioning the software, by integrating the software with other parts of the IT infrastructure and by providing proprietary complements (Chesbrough, 2003). Different business models can be developed: for example, making portions of intellectual property freely accessible in order to stimulate innovative activity around input and/or complementary technologies.

Figure 2.6. Collaboration has increased



Notes: Technology flows refer to the average of technological payments and receipts. Changes in technology flows include intra-area flows for EU15 and OECD total. Denmark, Greece, Iceland and Turkey are excluded. Data partially estimated.

Source: OECD (2009), *Science, Technology and Industry Scoreboard 2009*, OECD, Paris.

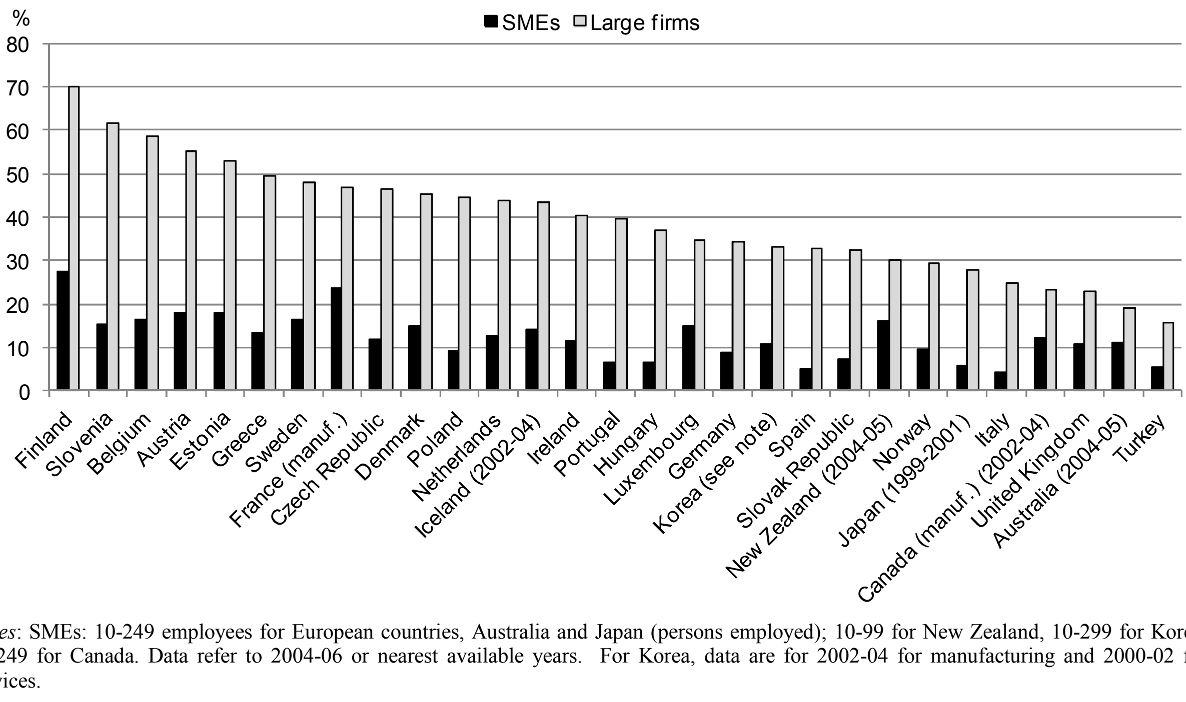
Collaboration has become a key to innovation

Confronted with increasing global competition, rising costs, the growing integration of different technologies many companies collaborate with external partners, whether suppliers, customers or universities, to stay abreast of developments, expand their market reach, tap into a larger base of ideas and technology, access specific skills and competences and get new products or services to market before their competitors. An OECD cross-country study of innovation at the firm level showed that collaboration is an important part of the innovation process: in 16 out of 18 countries, firms that collaborated on innovation spent more on innovation than others. This suggests that collaboration is unlikely to be undertaken mainly as a cost-saving measure, but instead to extend the scope of a project or to complement firms' competences (OECD, 2009a). Moreover, available evidence suggests that international collaboration has increased over time, in terms of scientific collaboration as well as of international knowledge flows (Figure 2.6).

Large firms appear significantly more likely to collaborate on innovation than small and medium-sized enterprises (SMEs) (Figure 2.7). This may reflect the higher rate of new product development in large firms as well as easier access to partners and more resources to engage in such relations. In the same way, SMEs which are part of a group tend to collaborate more frequently on innovation than independent ones, although still less than large firms (OECD, 2010a).

Figure 2.7. Companies collaborating in innovation activities, by size, 2004-06

As a percentage of all firms



Notes: SMEs: 10-249 employees for European countries, Australia and Japan (persons employed); 10-99 for New Zealand, 10-299 for Korea, 20-249 for Canada. Data refer to 2004-06 or nearest available years. For Korea, data are for 2002-04 for manufacturing and 2000-02 for services.

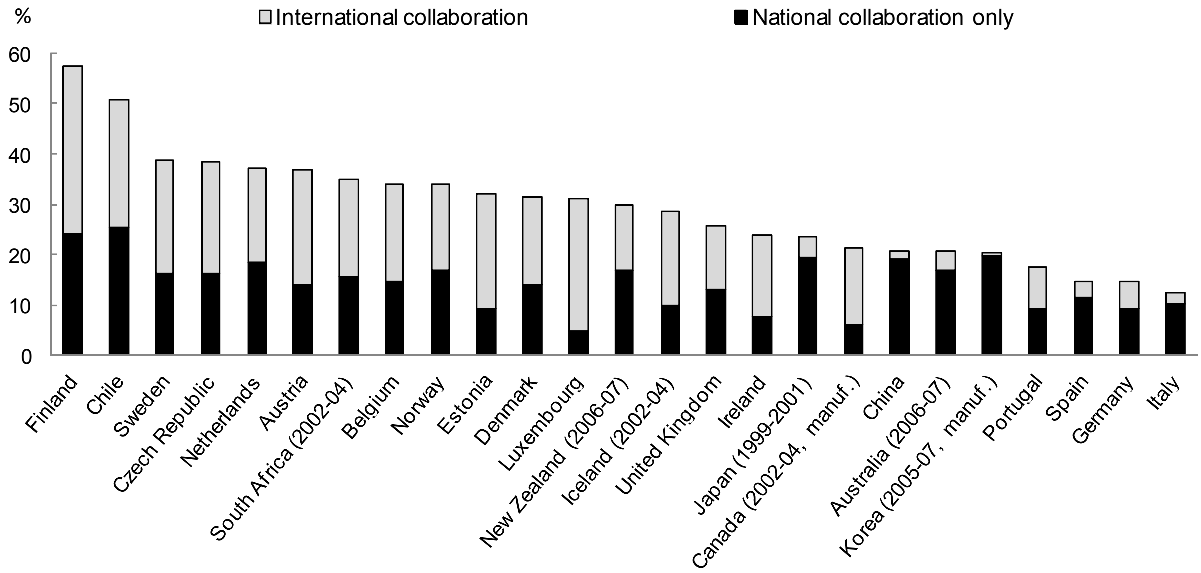
Source: OECD based on Eurostat, CIS-2006 (April 2009) and national data sources.

Results from the European Community Innovation Survey (CIS-2006) and other national innovation surveys show that in most countries suppliers of equipment, materials and components or software are the most sought-after innovation partners, followed by clients or customers. While universities and government research institutes are considered a valuable source of knowledge for companies' innovation activities, especially in more upstream research and exploration activities, they represent only a small share of collaborations on innovation. Firms in Finland report the largest share of collaboration with higher education or government institutions (15%) compared to only 2.4% in Japan (OECD, 2009a, p. 57). However, these results only indicate the existence of some sort of collaboration, not its frequency or intensity. Nevertheless, they are noteworthy because most innovation is incremental and involves small-scale change which would not necessarily require collaboration with universities and government research institutions. There is also considerable diversity; in all countries with available data, large firms report more co-operation with higher education or government institutions than SMEs.

Differences between industries are also marked. Collaboration on innovation, with any type of partner, is important in manufacturing as well as in services, notwithstanding some differences among countries. Industries such as chemicals, pharmaceuticals and information and communication technology (ICT) typically have higher levels of co-operation. In all countries except the United Kingdom, manufacturing firms co-operate more on innovation than service firms (OECD, 2009a, p. 57). In the majority of countries, collaboration with foreign partners is at least as important as domestic co-operation (Figure 2.8). Firms in smaller open economies are more likely to seek partnerships abroad in order to find the competences needed for their innovative projects.

Figure 2.8. Companies with foreign and national collaboration on innovation activities, 2004-06

As a percentage of innovative firms

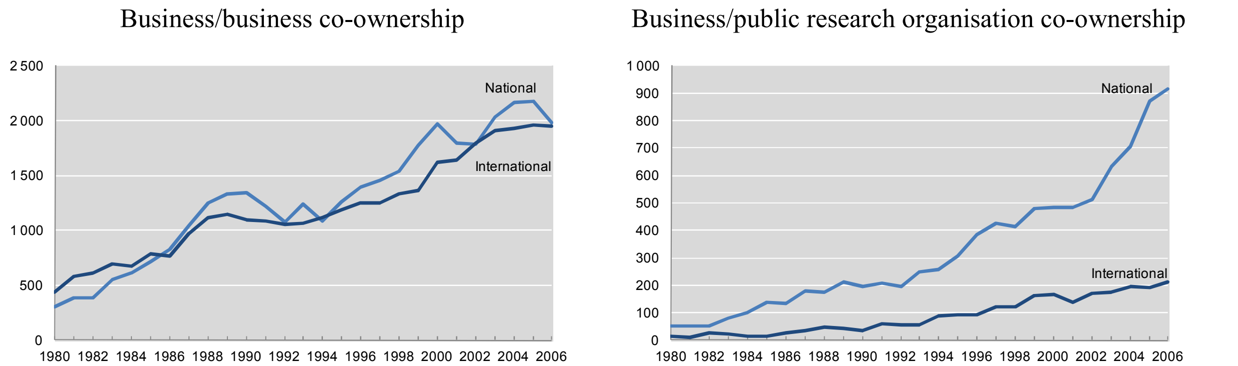


Note: Data refer to 2004-06 or nearest available years.

Source: OECD (2010), *Measuring Innovation: A New Perspective*, OECD, Paris, based on OECD Innovation Microdata Project.

The number of national and international joint filings from the business sector at the European Patent Office (EPO) has grown more or less at the same pace since 1980 to reach similar levels (Figure 2.9). As with the results based on Community Innovation Survey (CIS) data, technology collaboration measured by co-assignments between companies and public research institutions (universities and public research organisations) are less frequent but are growing. EPO co-applications between business and public research mainly involve institutions from the same country (national joint filings) although both national and international joint filings have grown significantly in recent years.

Figure 2.9. EPO applications with multiple applicants and at least one of them from the business sector, priority years 1980-2006



Notes: Data relate to patent applications filed to the European Patent Office (EPO), by priority date and applicant's country of residence. Institutional sectors are identified using an algorithm developed by Eurostat and Katholieke Universiteit Leuven. Public research organisations cover the government sector, the higher education sector and hospitals.

Source: OECD Patent Database 2010.

Open innovation expands access to knowledge

The degree of openness in innovation differs across firms and industries, depending on factors such as the importance of the technology for the firm, the strategy of the firm, or the characteristics of the industry (OECD, 2008b). While companies traditionally seek to retain their core capabilities (in technology and markets) and develop them internally to the greatest extent possible, open innovation may be a faster, less risky alternative to in-house development, particularly when the objective is to diversify in terms of technology and/or markets.

Companies source external knowledge in various ways: partnerships with external parties (alliances, consortia, joint ventures, joint development, etc.); or acquisition or sale of knowledge (contract R&D, purchasing, licensing). Companies also increasingly use venturing to find external partners for commercialising innovations that are not used internally (divestment, spin-out, spin-off). This more open approach to innovation, however, is not without transaction costs (*e.g.* sourcing and processing of new knowledge) and even financial costs (*e.g.* purchasing of knowledge).

Box 2.5. Global Open Innovation in Quilts of Denmark

Part of the open innovation strategy of Quilts of Denmark (one of the 59 company case studies included in the OECD *Open Innovation* project) is built on tapping into global knowledge. Quilts of Denmark collaborated with NASA in order to optimise in-house innovation. The quilts made by Quilts of Denmark are based on knowledge provided by sleep researchers who tell Quilts of Denmark about the real needs for quilts, *e.g.* temperature regulation in relation to insomnia. Quilts of Denmark worked on a technology for regulating the temperature in quilts but it was not completely successful. Quilts of Denmark then learned in a scientific journal that NASA had solved this problem and invented a technology called TempraKON®. When Quilts of Denmark contacted NASA, NASA was surprised that a small company from Denmark was interested in their technology and was ready to share its knowledge. However, it had taken Quilts of Denmark two weeks to contact the right person at NASA, so persistence was important.

NASA sells rights to some technologies that can be used for peaceful purposes. NASA receives public funding for research, but in return the technologies must be used to improve the quality of life on earth. The company Outlast had bought the rights to this technology for use in materials for house insulation. Quilts of Denmark contacted Outlast and they agreed on a joint development. Basically Outlast kept the rights for insulation materials and Quilts of Denmark received the rights for down quilts and pillows. However, NASA's technology could not be transferred directly to the company's quilts, since quilts are soft and the technology invented by NASA was very stiff. The technology was modified in a lengthy development project with Outlast. A producer of winter jackets now has a licence to use the technology owned by Quilts of Denmark.

Source: OECD (2008), *Open Innovation in Global Networks*, OECD, Paris.

One of the most obvious benefits of open innovation is the much larger base of ideas and technologies on which to draw (Box 2.5). It offers firms a way to explore new growth opportunities at lower risk and greater flexibility and responsiveness potentially at lower costs. Open innovation not only increases the speed of exploitation and captures economic value from ideas through inward licensing or spinning out unused ideas, it also creates a sense of urgency among internal innovators to use or lose internally available knowledge and technologies.

When companies look for external sources of innovation by tapping into knowledge from research institutes, companies and adjacent markets, they tend to search for specific technologies or products rather to collaborate with specific companies. Other motivations for using external sources of innovation are to increase the number of ideas for new projects, to attract and retain talent, and to increase external funding of ideas and technology development (OECD, 2008b).

Results from innovation surveys for 2004-06 show that 10% to 20% of innovators had their new product or processes mainly developed by others. Some of these firms performed in-house R&D, which indicates that they contract out new products or processes not because they lack in-house capability, but in order to find complementary capabilities (OECD, 2010a).

Open innovation also has drawbacks, such as the extra costs of managing co-operation with external partners, lack of control, adverse impact on the company's flexibility, dependence on external parties, and the potentially opportunistic behaviour of partners. Human resource management and the management of different partners are an important aspect of open innovation, since success often depends on involving external partners in the company's innovation activities. Open innovation can make the management of innovation more complicated and may result in the loss of some competences and greater dependence on external actors. The effective management of intellectual property

(IP) is crucial, not only to identify useful external knowledge but especially to leverage a firm's own IP to create value. The development of knowledge networks and markets, as well as collaborative mechanisms for the management of IP offers promise in stimulating open innovation. These issues are discussed in more detail in Chapter 5.

The geography of innovation is expanding

New global players have emerged

Global patterns of R&D, science performance and innovation are changing and new players have emerged. Rapid growth in China has been accompanied by a dramatic increase in R&D expenditure and R&D employment, and future targets for Chinese R&D intensity suggest that growth will continue. More generally, the increased presence of the BRICS (Brazil, the Russian Federation, India, China and South Africa) economies in science, technology and innovation points to shifts in the geographical composition of global science and technology activity (Figure 2.10). It is noteworthy that Brazil, China and South Africa have reduced the share of their patents involving international co-invention over the past decade, which may be further indication that they are strengthening their domestic technological capabilities.

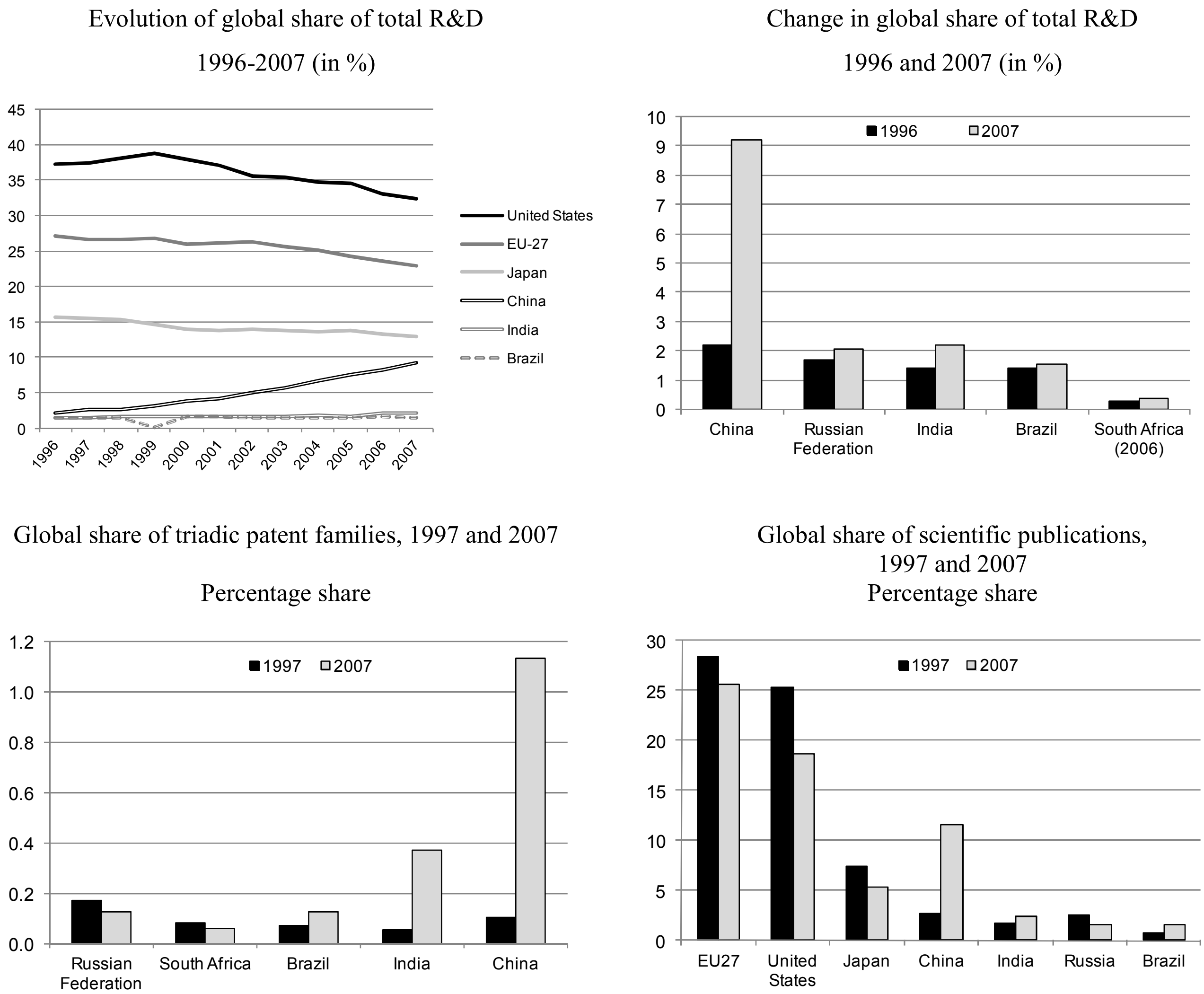
Scientific capacity is also growing strongly in some emerging economies. Over 1996-2007, scientific articles from the BRIICS (Brazil, the Russian Federation, India, Indonesia, China and South Africa) more than tripled, while those from Latin America doubled. Growth has also been strong in Korea and Turkey with output more than tripling. While the publication of scientific articles remains concentrated in a few countries, the global share of scientific publications has fallen in Japan, the EU27 and the United States. [5]

R&D is globalising through many channels

Alongside these trends is the continued internationalisation of R&D, which is occurring at a much faster pace and spreading more widely. Until recently, the R&D capabilities of firms have been less globalised than activities such as marketing and production. Firms now increasingly offshore R&D to other countries both to link R&D to markets but also to source technological capabilities, tap into centres of increasingly multidisciplinary knowledge, lower R&D costs and access highly skilled human capital (OECD, 2008c).

While R&D investments are still concentrated in the United States, the European Union and Japan, non-OECD economies account for a growing share. In 2007, the share of the three main OECD regions in total R&D expenditure remained stable at around 42% for the United States, 30% for the EU and 17% for Japan.[6] The non-OECD countries for which data are available accounted for around 20% of overall R&D expenditure (expressed in current USD PPP), up from 15% in 2003. China accounted for around half of the non-OECD share and ranked third worldwide, behind the United States and Japan, but ahead of individual EU member states.

Figure 2.10. Global R&D trends in major OECD regions and selected non-member economies



Notes: Patent counts are based on the earliest priority date, the inventor's country of residence and fractional counts. The data mainly derive from the EPO Worldwide Statistical Patent Database (September 2009).

Source: R&D figures based on data for 79 non-OECD countries (UNESCO Institute for Statistics) and 30 OECD countries (OECD Main Science and Technology Indicators Database 2009/2); OECD Patent Database, 2010; and Scopus Database 2009.

Most OECD governments recognise that the best way to benefit from global innovation networks is to strengthen domestic innovation capabilities and develop local talent in order to foster home-grown innovation but also to attract foreign talent and foreign direct investment related to R&D. OECD countries are still adapting national policy frameworks to a more global innovation system, for example by fostering cross-border financing of research and internationalising the higher education sector (OECD, 2008d).

Multinational enterprises play a major role in R&D investment and patent performance in some emerging economies (OECD, 2008c). The changing landscape of global R&D is also apparent in the growth of R&D sourced from abroad (from private business, public institutions or international organisations), which represented, for example, around 10% of total business enterprise R&D in the EU27 in 2006. The weight of foreign multinationals in the economy and the domestic production of technology seem to matter in this respect. In most countries, the financing of business enterprise R&D from abroad comes mainly from other business enterprises.

In most OECD countries, the share of foreign affiliates in industry R&D is growing as foreign firms acquire local R&D-performing firms (*e.g.* through mergers and acquisitions) or establish new subsidiaries. For countries for which data are available, around two-thirds of funding from business sources abroad is intra-company funding (OECD, 2009c).

The expansion of markets worldwide has also been a driver of the promotion of innovation and productivity gains (OECD, 2008e). Progress in reducing tariffs, dismantling non-tariff barriers and liberalising capital markets has expanded opportunities for trade and international investment. This enhances competitive pressures and increases the size of markets available to innovators, while facilitating the spread of knowledge, technologies and new business practices. Technological advances in ICT have helped make it possible to slice up the value chain and to fragment the production of goods and services across countries (Box 2.6) (OECD, 2008f). This benefits low-income countries as well as the BRICS.

Box 2.6. The ICT sector, Asia and globalisation

Changes in the geography of the technology industry have made Asia an essential element in the global ICT value chain. Most multinational firms use Asia as a production and assembly hub, and China has overtaken the United States in ICT exports. Asia is also catching up as a location for firms' higher value-added activities such as R&D, both for foreign firms and, increasingly, domestic ones. Asian firms such as Huawei (China) or Tata Consultancy (India) are among the top ICT firms in terms of revenue. The sums spent domestically on R&D and the international patenting efforts in Asia are impressive. In 2008 Samsung spent more on R&D than Intel. Asia is also becoming a target for new collaborations to drive innovation, both within Asia (*e.g.* co development of optical storage media by Samsung and Toshiba) and between OECD ICT firms and Asian partners. Chinese and Indian firms and universities have become strategic research partners for OECD ICT firms (*e.g.* Ericsson and China Datang Telecom on alternative 3G network protocols; Microsoft and India's Infosys on enterprise resource planning software; Yahoo and India's Tata on cloud computing). A few alliances are also forming between Indian and Chinese ICT firms (mainly in the area of software and ICT services) and between Russian and Chinese ICT firms.

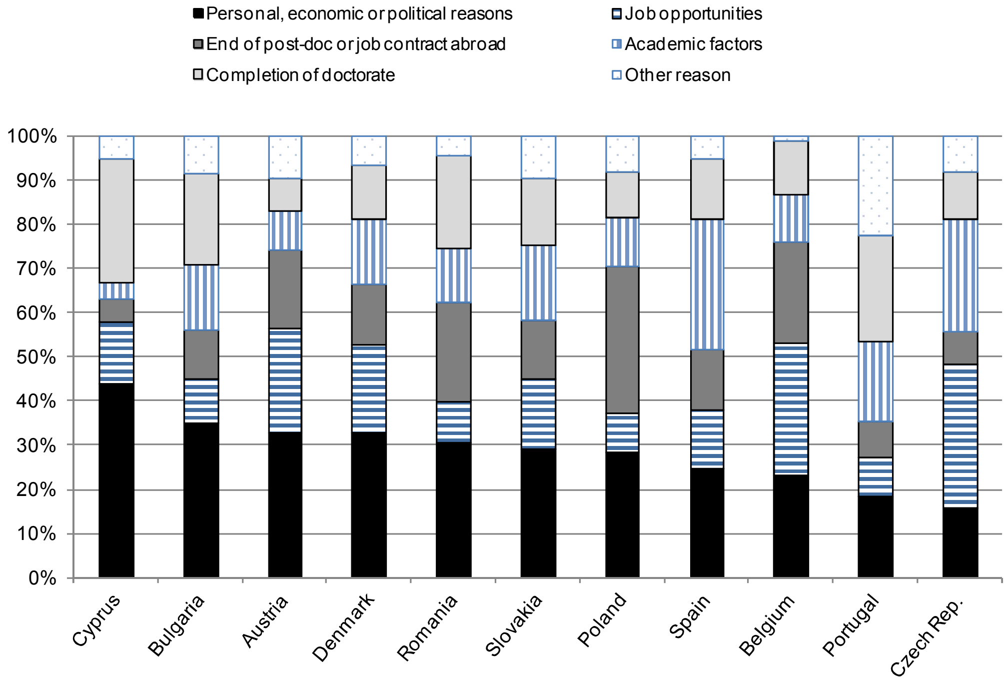
Source: OECD (2008), OECD *Information Technology Outlook 2008*, OECD, Paris.

Global competition for talent is increasing

Another driver behind the globalisation of innovation is the international mobility of the highly skilled and the growing global competition for talent (OECD, 2008g). While mobility contributes to innovation through the creation and diffusion of both codified and tacit knowledge, migration plays an important role in shaping skilled labour forces throughout the OECD as more economies participate in R&D and innovation activity. Both private industry and academia seek out foreign staff for their specific knowledge or abilities, their language skills, and their understanding of foreign markets.

Various factors contribute to flows of the highly skilled. In addition to economic incentives, such as opportunities for better pay and career advancement and access to better research funding, mobile talent also seek higher quality research infrastructure, the opportunity to work with "star" scientists and freedom to debate. Less amenable to potential government policy, but still important, are family or personal ties that draw talent to certain locations (Figure 2.11).

Figure 2.11. Reasons given by national citizens with a doctorate for returning to their home country, 2006



Notes: 1990-2006 doctoral graduates (1987-2005 graduates for Denmark; 2005 data for Belgium and Denmark).

Note by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

Note by all the European Union Member States of the OECD and the European Commission: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

Source: L. Auriol (2010), "Careers of Doctorate Holders: Employment and Mobility Patterns", *STI Working Paper 2010/4*, Directorate for Science, Technology and Industry, OECD, Paris.

While evidence on the direct impact of international mobility on innovation is limited, some data suggest that immigrants contribute strongly to patent applications and creation of technology firms. Mobile workers often provide the "spark" for new innovations; for example, over half of Silicon Valley start-ups have had one or more immigrants as key founders. Studies from several countries highlight a trend towards more international co-authorship of academic articles, while other work suggests that the impact of collaborative work, as measured by citations, is greater than the average impact of national work. Some emerging economies have also benefited from large and well-educated diasporas that have helped enhance their innovation and growth via return migration or venture capital flows to the home country (OECD, 2008g).

Mobility is leading to greater labour-market internationalisation and integration, and competition for talent is now influencing innovation policy initiatives across the globe. The growing sums spent on R&D in non-OECD countries and their human capital resources, coupled with the increasingly internationalised activities of technology firms, all suggest that the opportunities for mobile talent will continue to grow (see Chapter 3).

Benefiting from global innovation at the local level

As the innovation process broadens and becomes more open and collaborative, innovation systems have become global and global innovation networks have emerged. The challenge for governments is to tap into and exploit these global networks to access new knowledge and markets while generating value locally. Given the fluidity with which people and firms can move, this is increasingly difficult. People and firms are attracted or deterred mainly by local factors. For innovative firms the most important factor is gaining access to markets and human capital. For people it is the availability of opportunities: jobs, education and high quality of life.

Policy makers are seeking ways to help anchor local investment. Among possible starting points are local services, which are a growing and critical component of the bundle of activities that constitutes the innovation system. Services such as maintenance of jet engines or the installation and tailoring of a computer network capture value locally. Services close to users are increasingly essential for maintaining an innovative edge and allowing "mature" industries such as footwear or steel to stay competitive. The issue for policy is the fact that innovation in services is poorly understood and frequently hidden or non-technological in nature and thus poorly supported by existing policies.

Institutions of higher learning can play an important role by both producing and attracting the human capital needed for innovation. They can act as essential bridging institutions between players – businesses, governments and countries – in more open and broad systems of innovation. They also provide an important dimension of quality of life that can attract the highly skilled from around the globe. They can be the anchor for clusters of innovative activity that participate in global networks, while rooting value locally. The policy challenge is to encourage a view of universities as essential cogs in the innovation machine and possessed of independence, a competitive and entrepreneurial spirit, and flexibility.

Location matters for innovation and some regions are becoming centres of innovation

The link between innovation and growth has long been recognised, but the way in which it affects regional performance has recently become clearer. Analysis of regional data shows that innovation positively influences regional growth rates (OECD, 2009e). Interest in regional innovation has been spurred by the fact that some places appear to use innovation-related assets and investments more effectively than others. Many leading firms in knowledge-intensive industries such as ICT and life sciences have emerged in a limited number of regions which appear to provide a particularly conducive environment for business innovation. This suggests that geography is still important, and that drivers of economic change, particularly globalisation and technological advances, are not necessarily "flattening" the world economy. In addition, some innovators have narrowed their focus to the areas in which they believe they have a competitive advantage. Instead of "flat", the landscape of innovation is increasingly "spiky", with specific actors specialising in particular aspects of the innovation process. This is leading to a growing role for regions. When firms can access production factors from anywhere across the globe, localised knowledge is still relevant. For this reason, policy makers in other regions seek to replicate or to nurture the positive environmental conditions that such regions offer.

Although R&D and patents are imperfect proxies of innovation, they point to large regional disparities and spatial concentration in inventive outcomes. While innovative city-regions such as San Diego, Boston, Stockholm or Eindhoven generate more than 400 patents per million inhabitants annually, other large cities produce less than half that number. More than one-third of OECD regions generate less than ten patents per million inhabitants a year. Table 2.1 shows that such regions tend to invest less in R&D as a percentage of regional GDP, their firms engage less in R&D, and they have smaller shares of total employment in high-technology sectors. This presents a public policy challenge: how to design and target innovation policy to make it relevant and effective in different places, particularly when R&D and patented innovations represent a negligible part of the innovation activity of firms located there. One possibility is to increase the absorptive capacity of firms, for example, through technical training of key staff by regional education institutions.

Table 2.1. Correlations between patenting and other indicators of innovation, 2006 or latest available year

Patents per million, class	Number of regions in class	As % of all regions	Of which % of the regions that are rural	Average expenditure on R&D as % of GDP	Average employment in high-technology sectors
0-10	112	33.43	46.43	0.57	23.26
10-50	52	15.52	44.23	1.57	28.52
50-250	85	25.37	41.18	1.63	37.50
250 +	86	25.67	18.60	2.41	43.24

Source: OECD Regional Database 2006.

Patterns of innovation performance change slowly, but some regions have emerged in recent years. In some regions, traditional industries provide the basis for innovations that lead to new activities. The traditional engineering strengths of Turin, Italy, and Gothenburg, Sweden, built up over decades of specialisation in the automobile industry, have provided the technical foundation for advanced materials and road-sensing technology industries, respectively. Certain regions have progressed from moderate to high performance on indicators of research-driven innovation (*e.g.* Catalonia, Spain; the Basque Country, Spain; and Florida, United States). Other regions that were weakly involved in such activities have become more integrated into knowledge- and research-intensive activities (*e.g.* Andalusia and Galicia in Spain, several regions of eastern Europe). In contrast, some leading regions, particularly in the United States and Scandinavia, have seen their position decline in relative terms. Even with the most recent relative shift of innovation-related investment to specific regions in Asia (*e.g.* in India and China), some OECD regions have made strong efforts to improve the level of investment and/or see improved outcomes from their innovation effort (OECD, 2008h).

Key findings

This chapter has highlighted some of the key aspects of innovation today. First, it emphasised a broad view of innovation, which encompasses R&D but also non-technological activities such as organisational change and marketing. It recognised that innovation takes place in a range of settings, not only high-technology but also low-technology sectors, resource-based economies and service industries. In this view, innovation pervades society, from individuals and communities of users to the firm and government providers of public services such as education and health. It is not just the generation of new knowledge or technology through R&D but also its application, broadly understood. The chapter also highlighted the open nature of innovation, the role of collaboration and the emerging notion of co-innovation.

The chapter also recalled that while new global players such as the BRIC countries have emerged, innovation capabilities still concentrate in particular localities and clusters. As a result, local and regional policies matter for linking these nodes of innovation to global networks and value chains and ensuring that national benefits accrue from innovation. Finally, innovation, as it is understood today, widens the domain of innovation policies and requires co-ordination and new institutional arrangements that extend beyond S&T ministries to a "whole-of-government" approach. The capacity of policy makers to develop and implement policies to support innovation in this new context will also depend on expanding the evidence base, including through the creative use of existing innovation indicators and the development of additional indicators to design and evaluate policy interventions.

Notes

1. Firm-based microdata indicators reflect the behaviour of individual firms. Firms differ in their innovation activities (*e.g.* performing R&D, collaborating, etc) and the type of innovation they perform (product, process, organisational, marketing). Microdata allows for combining responses to multiple questions and identifying firms' innovative profiles, which can then be aggregated at the country level.
2. An amount equivalent to around 29% of US GDP in 2005, or around 12% of US business capital stock.
3. Not all countries run an innovation survey or participated in the OECD innovation microdata project. For instance, the United States does not have an innovation survey, hence it does not appear in the figures which make use of innovation survey data.
4. Calculations from OECD ANSKILL Database 2008.
5. OECD calculations, based on SCOPUS Database.
6. OECD Main Science and Technology Indicators 2009/1.

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Chapter 3

Empowering People to Innovate

People are at the heart of the innovation process, and this chapter explores the roles they play. Innovation relies on a skilled labour force, not only for high-technology and research sectors but throughout the economy and society. More networked innovation processes enable broad participation in the innovation process, beyond corporate R&D laboratories to users, suppliers, workers and consumers in the public, business, academic and non-profit sectors. Enabling people throughout the economy and society to participate in innovation will provide new ideas, knowledge and capabilities, and enhance the influence of market demand on innovation. Policies need to reflect and encourage their broader engagement.

Introduction

People are at the heart of the innovation process. They generate the ideas and knowledge that power innovation, and then apply this knowledge and the resulting technologies, products and services in the workplace and throughout society. Empowering people to innovate relies not only on broad and relevant formal education, but also on the development of wide-ranging skills, and on providing people with opportunities to use and leverage these skills throughout the economy and society. This chapter explores some of the key dimensions of the role of people in the innovation process, and it provides insights on policies that are particularly important for empowering people to innovate. More specifically, it focuses on the challenges facing education systems, the use of the female workforce, international mobility of the highly skilled, the role of workplaces in fostering innovation, means of engaging consumers in innovation, and the development of entrepreneurial attitudes. It begins by examining the importance of human capital and the skills required for innovation.

Human capital is fundamental to growth and innovation

Human capital is a measure of the quality of labour and reflects people's skills and competences. It has been defined as "the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being" (OECD, 2001, p. 18). Countries have long made human capital a priority because of its significance for economic and social development. In fact, a significant part of cross-country differences in per capita income shown in Table 1.1 in Chapter 1 are due to human capital. At the macroeconomic level, the link is well established between human capital, measured as the level of formal educational attainment, and economic growth.

According to recent OECD calculations, “if the average time spent in education by a population rises by one year, then economic output per head of population should grow by between 4% and 6% in the long run” (OECD, 2007a, p. 34). Higher levels of human capital also tend to be associated with better health and happiness and social benefits such as lower crime and higher levels of social engagement (OECD, 2001). Improving the quality of human capital and using it efficiently are thus among the primary avenues for raising productivity, boosting GDP per capita, and contributing to a healthy and safe society.

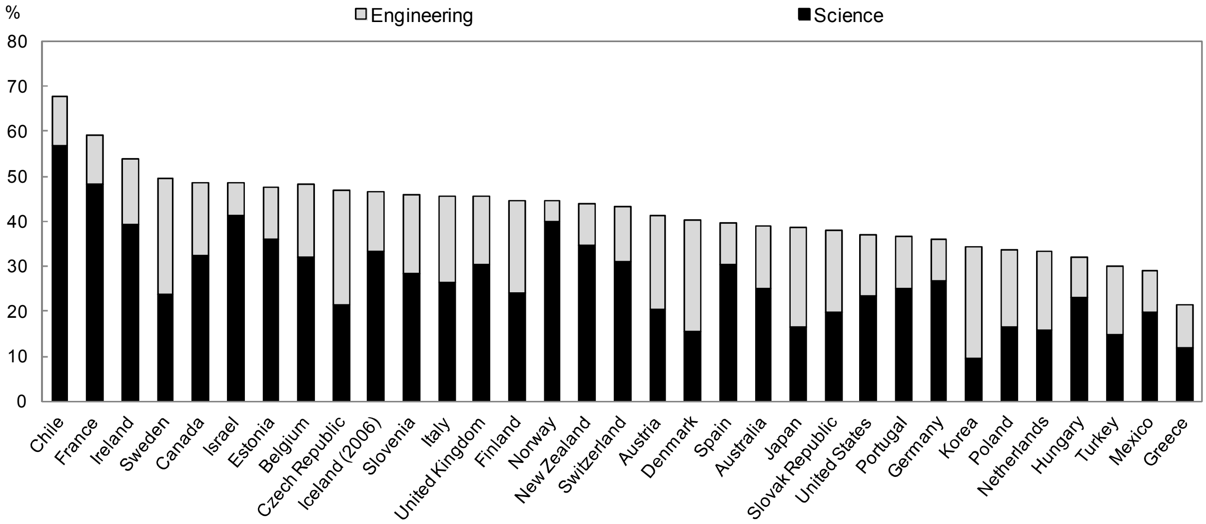
Human capital has particular significance for innovation because skilled people create and use knowledge. It spurs innovation through channels such as the generation of new knowledge, the adoption and adaption of existing technologies and ideas, and the ability to adapt to change and to learn new things. A body of highly skilled people may also encourage investment in factors, such as capital equipment, that contribute to the innovation process. It can also generate “spillovers”, such as raising the human capital accumulation of others.

Skills require education and education levels of the adult population have improved dramatically over time. Among younger cohorts, upper secondary education has become the norm in almost all OECD countries and tertiary education attainment has also risen strongly (OECD, 2009a). In 2007, around one-third of 25 to 34 year-olds had attained tertiary education, compared with 20% for the oldest cohort (55-64 year-olds). The OECD average for the total population of 25-to-64 year-olds was 28%. Higher education at the doctoral level has also expanded in recent decades, owing particularly to the increased participation of women (Auriol, 2010). In the OECD area, doctoral degrees awarded rose from 146 000 in 1999 to around 212 000 in 2007 and represented 1.5% of the population at the typical age of graduation.

However, behind these aggregate increases, differences in fields of study are apparent. Most students graduate in social sciences, business and law. In absolute terms, the number of students graduating in science and engineering increased from 1998 to 2007 in most OECD countries, but in relative terms their share in total graduates decreased by more than half. Similarly, while the absolute number of S&E doctorates increased by a third in OECD countries, the relative share of S&E doctorates has fallen since 1998 in more than half of the countries for which data are available. Nonetheless, science and engineering remain popular in many economies (Figure 3.1). In Canada, Chile, France, Ireland, and Israel, for example, close to or over 50% of all doctoral degrees are in science and engineering.

Many countries are concerned that the supply of skilled people does not, or soon will not, keep pace with the demands of knowledge-based, innovative economic activity. The increasing supply of tertiary graduates associated with the expansion of tertiary education has not led to a decrease in average returns to tertiary education. This suggests that there is no over-supply of tertiary graduates (OECD, 2008a, p. 194). Many studies have examined the increasing demand for science and engineering skills, the rising importance of non-routine analytic and interactive tasks, and the perceived skills gaps in the working population (HLG, 2004; Wilson, 2009; INSEAD, 2009; and Casner-Lotto and Barrington, 2006). Some countries seem to have experienced a “hollowing out” of moderately skilled jobs (as defined by wages). This has been attributed to computerisation or offshoring of routine and repetitive tasks and strong growth in employment in professions that require more abstract cognitive skills and the performance of non-routine tasks (see, for example, Brook, 2008, on the United Kingdom).

Figure 3.1. Share of science and engineering doctorates in total doctorates, 2007



Note: The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Source: OECD (2010), *Measuring Innovation: A New Perspective,* OECD, Paris, based on OECD Education Database, February 2010.

At the same time, however, data show that the overall skill composition of employment in OECD countries has been relatively stable over the last decade, with the share of workers with low, medium and high skill levels (as classified by their occupation) essentially static at around 16%, 48% and 36%, respectively. There is conflicting evidence from firms on the real extent of "shortages" of skilled labour, and some data show "overqualified" graduates working in jobs that do not appear to require a high level of expertise. For example, in more than half of the 20 countries for which data are available, more than 10% of doctorate holders are employed in jobs unrelated to their degree or below their qualification (Auriol, 2010). Some commentators suggest that the efficient use of human capital is more of an issue than absolute levels of supply (Accenture and the Lisbon Council, 2007).

More generally, the demand for skills across economies is quite diverse. The type of skills required for innovation vary widely across industries, firm size and ownership structure (Toner, 2009). Moreover, even within industries there are differences in the propensity to innovate, and some industry-level studies find only weak links between various measures of skills and innovation intensity. Each industry and firm innovates in its own way. Given countries' specific characteristics, no single skills profile or policy approach can optimise innovation potential across all firms, industries or countries. In formulating policy for human capital for innovation, each country must consider its particular characteristics and context, in order to plot the best way forward. Recent country innovation strategy documents have been highlighting the importance of human capital for innovation (Box 3.1).

Current indicators of human capital generally focus on levels of formal education or classifications of occupations. However, these are only proxies and better measurement of human capital remains a challenge. The OECD is currently working to gather better and more detailed information on people's skills through the OECD Programme on the International Assessment of Adult Competencies (PIAAC).

Box 3.1. Countries' innovation strategies: the role of human capital

A number of countries have prepared national innovation strategies in the past two to three years. Without exception, these strategies have highlighted the importance of human capital in meeting goals for innovation, economic growth and living standards and all express an intention to increase supplies of skilled people. For example:

- Improving skills and expanding research capacity is a key facet of Australia's innovation policy agenda to 2020 (Commonwealth of Australia, 2009).
- Canada lists "people advantage" (being a magnet for skilled people) as one of three pillars of its innovation strategy (Industry Canada, 2007).
- Innovative individuals and communities are one of four key areas around which Finland's innovation strategy and policy measures are structured (Ministry of Employment and the Economy, 2008).
- Norway regards "creative human beings" as one of three key focal points of innovation policy (Ministry of Trade and Industry, 2008).
- The United Kingdom aims to maximise the innovative capacity of its population as part of its strategy to promote innovation across society and the economy and to make the United Kingdom a leading location for an innovative business, public service or tertiary-sector organisation (Department for Innovation, Universities and Skills, 2008).

In the United States, educating the next generation with 21st century knowledge and skills and creating a world-class workforce is one of the four building blocks of American innovation (Executive Office of the President, 2009).

Innovation requires wide-ranging skills

Innovation covers a wide range of activities, including invention and implementation, as well as breakthroughs and minor improvements. It therefore necessitates a wide variety of skills. Among those commonly mentioned in the literature are (Ananiadou and Claro, 2009; Kergroach, 2008; OECD, 2001; Stasz, 2001):

- *Basic skills and digital age literacy.* These include reading, writing and numeracy and the skills to use digital technology and access and interpret information in a knowledge-based society.
- *Academic skills.* These are associated with disciplines found in educational institutions such as languages, mathematics, history, law and science. These skills are generally obtained through the education system and are transferable across situations.
- *Technical skills.* These are specific skills needed in an occupation and may include both academic and vocational skills and knowledge of certain tools or processes.
- *Generic skills.* Commonly mentioned skills in this category include problem solving, critical and creative thinking, ability to learn, and ability to manage complexity. The transferability of so-called generic skills is debated, with some authors arguing that they have an important firm-specific element. Problem solving, for example, takes place within a certain work environment and culture and is influenced by routines and procedures (Payne, 2004). In addition, to solve anything but the simplest problem, expertise and specialist bodies of knowledge are likely to be required.

- *"Soft" skills.* This category is sometimes grouped with (or classified as) generic skills. It includes working and interacting in teams and heterogeneous groups; communication; motivation; volition and initiative; the ability to read and manage one's own and others' emotions and behaviours during social interactions; multicultural openness for understanding and communicating across cultures; and receptiveness to innovation.
- *Leadership.* Similar in nature to "soft" skills, this includes team-building and steering, coaching and mentoring, lobbying and negotiating, co-ordination, ethics and charisma.

Managerial and entrepreneurial skills are also mentioned in the literature in terms of putting innovative ideas into practice and enabling organisations to adapt and respond in competitive environments (Box 3.2). These skills may be seen as a mix of competences related to leadership, communication and self-confidence, as well as relevant technical skills, and are readily transferable. In this respect, some studies specifically highlight commercial aptitude and creativity. The latter concept relates broadly to the generation of new ideas and is closely linked to design and the transformation of ideas into new products and processes (Hollanders and van Cruysen, 2009).

Box 3.2. Managerial and entrepreneurial talent

Managers and entrepreneurs play a crucial role in building innovation capacity and performance. They put innovative ideas into practice, either by starting a new business or by managing innovative capacity within existing firms. There is now significant empirical evidence in support of the view that effective use of knowledge and technologies depends on the quality of management: well-managed firms excel in productivity, profitability and sales (Bloom and Van Reenen, 2007). Studies also show that firms that adopt continuous innovation strategies are managed by more highly educated and better informed managers (Lal and Dunnewijk, 2008). Such entrepreneurial talent is increasingly needed not only for new ventures and start-ups, but also for large corporations and mature industries.

There is no standard view of what constitutes managerial and entrepreneurial talent, competencies, capabilities and skills. They are usually taken to be general skills – the ability to build teams, communicate, motivate, mentor and develop, as well as engage in entrepreneurial activities. Some studies distinguish between the wealth creation and business entry role of entrepreneurs and the growth-sustaining and co-ordinating role of managers. Others argue that these skills lie on a continuum and that good management skills are essential for successful entrepreneurial activities (Green *et al.*, 2009).

Some managerial and entrepreneurial skills can be cultivated through learning, observation and experimentation, and experience; however, the degree to which entrepreneurial talent is genetic rather than learned is debated. There is not yet any strong evidence-based research that shows a significant and meaningful correlation between particular programmes for educating entrepreneurs and their performance (Green *et al.*, 2009). Nevertheless, it is commonly accepted that managerial and entrepreneurial skills should be part of the curriculum, and that exposure to such skills is essential in the early stages of education (Green *et al.*, 2009). Entrepreneurship education is discussed in further detail later in this chapter.

While the range of skills potentially valuable for innovation is very wide, it is not the case that all workers should have all the skills or that all countries should seek to achieve the same skill mix. For example:

- Business strategies and product strategies differ. Some firms may follow a high-technology strategy which requires high levels of workforce skill; others may choose a low-cost high-volume strategy that requires fewer skills. The Council of Canadian Academies (2009) find that the choice of innovation as a business strategy is influenced by sector characteristics, competition levels, the climate for new ventures, public policies that encourage or inhibit innovation, and business ambition, with the relative importance of these factors varying from sector to sector and over the lifecycle of firms.

- Overall industry structure will strongly influence the combination of skills needed. for instance, specialist supplier firms (such as instrument or software suppliers) may require high-level vocational and practical skills as well as good communication skills to work with clients, while science-based firms (such as pharmaceuticals) may be most dependent on R&D professionals and academic scientists (Tether *et al.*, 2005).
- In addition, the way in which countries go about their innovative activities differs. Some host industries in which workers are actively involved in driving new innovations; others are home to industries whose primary activity is adaption and adoption of existing innovations. Noting this, Toner (2007) argued that the skills of technicians and tradespersons are particularly crucial for incremental innovation, as their technical competence and practical skills enable them to "learn by doing" and "learn by using".

Given the changes in the structural make-up of economies, some studies point to an increased need for "soft skills" (OECD, 2001, p. 27). Employers also demand workers who are adaptable and "trainable", and greater demand for "shared knowledge" in the workplace implies more effective management practices, team working and flexibility. With the expansion of ICT and the Internet, some argue that ICT literacy has become almost as important as general literacy and numeracy for most jobs (OECD, 2008a, p. 200).

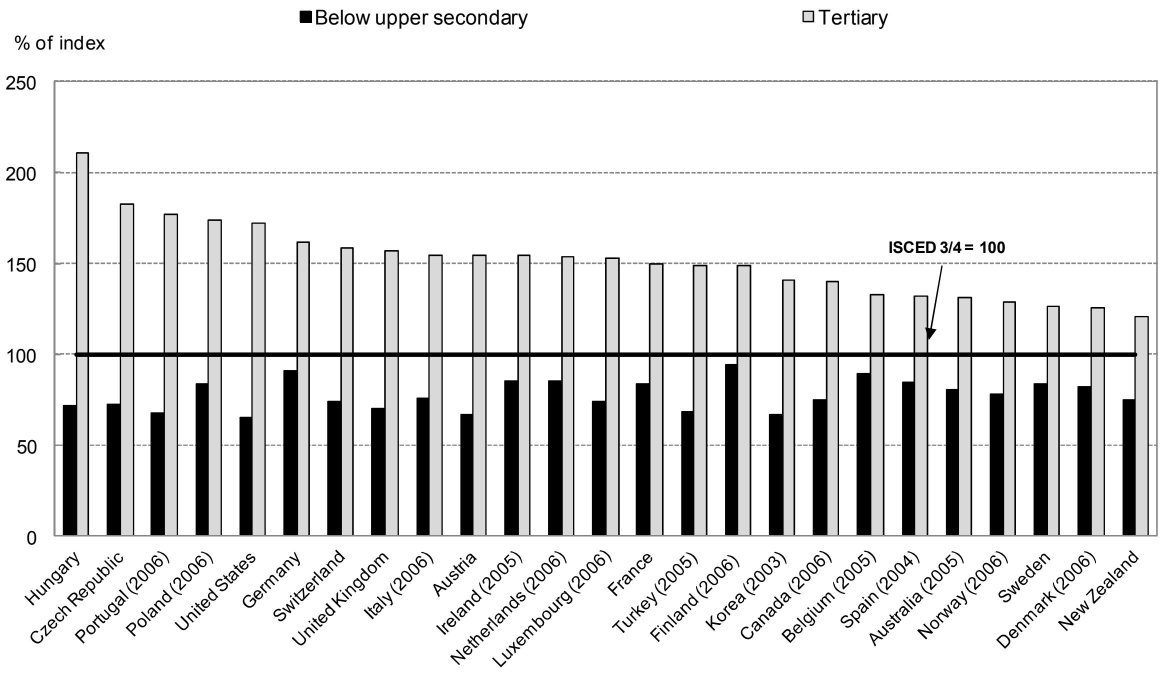
Globalisation also affects the skill requirements on the labour market. Tether *et al.* (2005, p. 52) suggest that as production becomes increasingly globalised, societies cannot sustain a model in which innovation is driven by a small trained elite and supported by a large body of relatively low skilled production workers. Instead, all workers must have the skills to adapt, to engage with innovation, modify their tasks or change jobs. Such skills may be best achieved through a generalist education and on-the-job training (OECD, 2008a). Because globalisation leads to greater collaboration, firms also need good skills for forming trust-based relationships (Tether *et al.*, 2005, p. 95).

FORA (2009) recently argued that greater emphasis on user needs as a driver of innovation and increasing collaboration between the public and private sectors to meet global and public-sector challenges has created the need for new multidisciplinary skills and competences. People with a background in the social sciences (*e.g.* anthropologists, sociologists and ethnologists) who understand user behaviour are increasingly valuable to firms, as are those with the skills to work in multidisciplinary innovation teams. FORA also suggests that those in the arts, such as architects and designers, will be crucial to innovation in the future, especially if they also have business skills.

While empirical evidence on the importance of various skills in the labour market can be gleaned from aggregate, industry, firm and occupational data, it does not usually specifically address innovative activity and it is often presented at a high level of aggregation. For instance, a study of wage premiums in 21 OECD countries indicated that the hourly wage of people who completed tertiary education was, on average, 11% higher for each year of tertiary study they undertook than that of people with an upper-secondary qualification (Strauss and de la Maisonneuve, 2007; Figure 3.2).

Figure 3.2. Relative earnings by level of education, 2007

Upper secondary and post-secondary non-tertiary education = 100



Source: OECD (2009), *Education at a Glance 2009*, OECD, Paris.

De Coulon *et al.* (2007) used data from the 2004 British Cohort Survey to estimate the wage effects in the United Kingdom's labour market of literacy and numeracy (so-called "basic skills") measured at age 34. Taking into account a person's family background and general ability, an increase in literacy (numeracy) skills by one standard deviation[1] was associated with an increase in hourly wages of 14% (11%). The results were similar when estimated for men and women separately. Using a different model that attempted to correct for possible measurement error and endogeneity produced an even stronger positive relationship between basic skills and earnings.

A broad indication of the levels of skills used in different industries can be inferred from surveys of literacy, numeracy and general "life skills". The international Adult Literacy and Life Skills Survey (ALL) found that industries including knowledge-intensive market services, high and medium-high technology manufacturing and public administration, defence, education and health, feature comparatively high proportions of adults at skill levels 3 and 4/5 (OECD and Statistics Canada, 2005). The skills measured in the survey were prose literacy, document literacy, numeracy and problem solving. Overall, skill level 3 was considered a minimum level for coping in a modern economy, while level 5 implied proficiency in, for example, searching for information in dense texts or using specialised background knowledge, or understanding abstract and formal mathematical and statistical ideas. There were some significant variations by country; for instance, Norway also had very high proportions of adults at skill levels 3 and 4/5 in the primary industries. For all countries, high and medium-high technology industries had comparatively higher proportions of skilled workers compared to low and medium-low technology manufacturing industries.

In the future, firm-level studies, in particular those using linked or matched employer-employee data, hold great promise for giving new insight into the issue of skills for innovation. The OECD's Programme for the International Assessment of Adult Competencies (PIAAC) may also help better understand the skills needed for innovation. The results of the full PIAAC survey, due in 2013, will provide valuable information about the skills actually used in workplaces and will represent an important source of evidence for policy making.

Building the skills required for innovation presents new challenges for education systems

Conveying knowledge to individuals and developing their competences are vital for building a skilled talent pool for innovation. Formal education is of course a key factor in forming human capital. OECD countries invest around 6% of GDP in education and investment has grown in real terms to support rapidly expanding systems. The main challenges are to improve the quality of all levels of education to equip individuals with good academic knowledge and social and behavioural skills and to increase access to and equity in education. This will require a careful balancing of economic and social goals. Innovation in education (Box 3.3), and enhancing the efficiency of public spending is also crucial, as available indicators reveal significant differences in the effectiveness of public spending across countries.

Early childhood education

Early childhood education is a growing priority in many countries in recognition of its contribution to a wide range of social, economic and educational goals. It provides very young children with a good start in life (OECD, 2006a) and can enhance children's school-related achievement and behaviour through their high school years. Research suggests that investment in young children brings significant benefits not only for children and families but for society at large, and support for the view that early childhood education and care should be seen as a public good is growing. However, most OECD countries tend to spend more on children later in their lifecycle. n this respect, more public spending on early childhood education and care is desirable in many OECD countries (OECD, 2009d).

The benefits from investment in early childhood education and care are directly associated with the quality of the programmes provided. As a significant share of the early childhood workforce have either little or no qualification in a number of countries, improving the quality of provision will require addressing major challenges: shortages, high turnover, staff qualifications and heavy workloads. This workforce also faces a lack of career paths, thus making the sector less attractive to potential employees.

Primary and secondary education

Primary and secondary schooling lays the foundations for individuals' social, economic and educational outcomes and their ability to work in an innovation-driven society and contribute to innovation. Students are introduced to various fields of knowledge, and their career choices and motivation for further learning are influenced by their overall school experience. Education systems face three key innovation-related challenges: increasing upper secondary school completion rates; raising the quality of learning outcomes; and improving the acquisition of generic, social and behavioural skills that may be conducive to innovation-friendly and entrepreneurial attitudes.

Box 3.3. Innovation in education

Innovation in education has attracted increasing attention. The US stimulus package has for example allocated USD 650 million of its USD 5 billion investment in school reform to a new Investing in Innovation Fund (i3). The fund supports local efforts to start or expand research-based innovative programmes to help close the achievement gap and improve outcomes for students. In 2009, the Netherlands also published an explicit Social Innovation Agenda for Education, and Hungary is reviewing its educational innovation system. However, most countries still need to turn their implicit educational innovation strategies into explicit ones.

In recent years, greater emphasis has been placed on the development and use of evidence in teaching. Educational research based on methodologies for measuring causal impacts has grown and increased the body of available knowledge. New links with neuroscience are also promising as they allow better understanding and diagnosis of certain learning difficulties. The enhancement of educational research will remain a serious challenge in the years to come, and developing the necessary evidence will require further work.

New educational products, resources and teaching methods are another source of innovation in education. ICT has led to the development of resources such as learning management systems and other information systems and diagnostic tools. While the impact of these resources on the quality or cost-efficiency of education is still to be assessed, the increasing involvement of businesses in the production of new educational resources or models opens new avenues. In many cases, however, this market is limited by insufficient demand from schools (OECD, 2009b).

Some education systems are establishing a new generation of sophisticated information infrastructures, such as longitudinal information systems which give rapid feedback to teachers, parents and other stakeholders. In addition to potentially changing the culture of the teaching profession, these systems may remove a key barrier to educational innovation: the difficulty of demonstrating the positive value of educational innovations. As long as innovation cannot be clearly linked to better achievement of educational objectives (learning outcomes, equity, access, cost-efficiency), the innovation process will be slowed by a lack of demand or avoidance of what may simply appear to be another educational fad.

To develop new models of educational delivery, most governments encourage experimentation by the public school systems or fund access to private schools offering alternative schooling models. Innovation and experimentation funds as well as innovation prizes and rewards give stakeholders incentives to develop innovative methods. Some countries have used market mechanisms within their public education systems in order to facilitate innovation (*e.g.* charter schools). These mechanisms have generated organisational and marketing innovation. While it is less clear that they have led to innovation in the core business of education, they have contributed to the dissemination of alternative learning environments (collaborative learning, bilingual schools, computer schools, etc.). New models of higher education institutions are also appearing in OECD countries, based on storytelling curricula, engineering projects or purely online learning.

User-driven innovation has also become more prominent in the past decade in education owing to the Internet. A number of higher education institutions now offer open educational resources. In addition, wikis and repositories of different types of educational resources are available to students and teachers worldwide.

Insufficient evidence that an educational innovation represents a significant improvement over traditional or mainstream practices hinders the demand for innovation: students, parents or teachers tend to prefer well-known methods rather than experiment with new ones. Potential innovators also lack incentives to innovate in view of the lack of a clear market for their new products or models. As a result, the use and development of innovations remains fragmented (OECD, 2009c). This is why measurement and evaluation of educational change and innovation will be essential to unleash innovation in education.

Today, only a small minority of students do not complete compulsory education (*i.e.* primary and lower secondary) but a considerable share do not complete upper secondary school or leave school with poor literacy and numeracy skills. The lack of an upper secondary credential negatively affects subsequent participation in the labour market, productivity and the likelihood of participating in adult education and continuous training. It also raises the risk of becoming and staying unemployed because of obsolete skills or structural change in the economy. Early prevention of dropouts is the best approach and those at risk should be monitored closely. Good quality vocational tracks in upper secondary education are also essential (OECD, 2009e).

Research indicates that teaching quality is an extremely important factor in student outcomes. The OECD has developed a number of general policy recommendations for employment and deployment of teachers: emphasising criteria for selection into initial teacher education, ongoing evaluation throughout the teaching career to identify areas for improvement, and recognising and rewarding effective teaching (OECD, 2009e). Research also shows that efficiency in the provision of primary and secondary education can be improved (OECD, 2008b; Schleicher, 2006). This is particularly important in a period of scarce public finances. Policies to bring poorer-performing schools closer to the national average can help improve students' education and skills overall. Among measures to be considered in this respect are sufficient autonomy for schools in the use of their resources and increasing the size of schools, where possible (OECD, 2008b).

Traditional approaches to teaching and learning are sometimes associated with cultures of grading and assessment that are not conducive to high levels of self-confidence or the development of the generic, social and behavioural skills required for innovation. Modern pedagogies based on collaboration, projects and games are often claimed to better equip individuals with the social and behavioural skills needed in an innovation-driven society (OECD, 2008c). They can be adopted at all levels of education and training, generally as a supplement to more traditional ways of teaching.

Another area for attention in terms of student outcomes is good curriculum design in order to provide students with attractive and relevant content. The OECD Global Science Forum recommended redesigning the science curriculum, for example, particularly in secondary education (OECD, 2008d). To encourage students to pursue science, engineering or technology careers, study programmes should take account of the capacities and interests of the majority of students. They should concentrate more on scientific concepts and methods than on retaining information and move away from a disciplinary approach that hinders access to interdisciplinary areas where much new and groundbreaking R&D is undertaken.

Tertiary education

Teaching and producing well-trained graduates is an essential part of the mission of the tertiary sector; research and training the next generation of academics and researchers is another. Today, tertiary institutions are being asked to enhance the quality of their teaching, have greater relevance to learner and labour market needs, feed R&D into business and community development and contribute to internationalisation and international competitiveness (OECD, 2008e). It has been noted that countries with high-quality tertiary education tend to derive more benefits from domestic R&D and from R&D spillovers from abroad.

For research and innovation, the main challenges for tertiary education are to train quality graduates who can contribute directly or indirectly to innovation in their workplace, to foster research excellence, to build links between tertiary institutions and other research organisations and industry, and to improve the ability of tertiary education to disseminate the knowledge it creates. Policy makers are challenged to ensure that the system provides value for money.

The OECD has made a number of suggestions for enhancing the role of tertiary education in this respect (OECD, 2008a). They include ensuring an adequate research infrastructure, better processes for selecting research priorities and assessing and funding research. While reserving the steering role for government, the public authorities should enable tertiary education institutions to become catalysts for innovation, notably at the local and regional level, and to have considerable room for manoeuvre, for example to shift instructional capacity to fields of high labour demand. Plans for empowering institutions may include legislation permitting institutions to become self-governing legal entities, in the form of foundations or not-for-profit corporations (OECD, 2008e). Reforms in the direction of greater autonomy of higher education institutions would also require greater accountability, as well as greater reliance on independent and public evaluation of their performance (OECD, 2008b).

Governments can also take steps to improve ties between tertiary education and the labour market and ensure that the demands of the economy are met. They can improve the co-ordination of labour market and education policies (perhaps by developing arrangements that integrate education, training and employment issues), improve data on and analysis of graduates' labour market outcomes, and strengthen career guidance services (OECD, 2008a). Linkages can also be broadened from the traditional research focus on co-operative projects to include industry representation on education management boards or the development of co-operative education programmes (OECD, 2008c).

Substantial reforms currently taking place in tertiary education systems aim at encouraging institutions to be more responsive to the needs of society and the economy, to improve quality and broaden access. Most countries have now established quality assurance agencies, with the double objective of improvement and accountability. While international rankings of higher education institutions based on research have become a powerful driver of change, too little attention has been given to quality teaching. Greater efforts to measure learning outcomes of tertiary education graduates are needed to strike a better balance and help institutions improve their quality. Attention to funding policies in tertiary education is also essential to increase access and quality; many countries need to expand and diversify their student support system to alleviate excessive reliance on paid work or family support. Moreover, where limited public funds ration student numbers, jeopardise levels of spending per student, or restrict financial support for disadvantaged groups, charging or increasing tuition fees may be a solution (OECD, 2008e).

More broadly, despite differences across countries, a common policy priority is a comprehensive and coherent vision for the future of tertiary education (OECD, 2008e). Ideally this would result from a systematic national review of tertiary education and lead to a clear statement of its strategic aims.

Vocational education and training

Vocational education and training (VET) is vital for the innovation process, as the skills it provides are central, but not exclusive, to incremental innovation activities. Many firms do not develop new-to-the-world, radical products and processes. Rather, they reproduce products already on the market, using off-the-shelf technology or make incremental improvements to existing products or processes to better meet the needs of users. This requires activities such as tooling up, design work, developing prototypes and testing, which are key aspects of vocational training. Studies have also shown that firms in countries with a relatively large proportion of their production workforce with post-secondary VET qualifications have lower defect rates, less need for quality checkers, fewer plant breakdowns, and more rapid introduction of new products (Toner, 2009).

With respect to innovation, a key challenge for VET is to connect effectively to the world of work to ensure that employers can find the skills they need to advance their innovation activities. Recent OECD work has highlighted a number of policy recommendations to help countries increase the responsiveness of VET systems to labour market requirements (OECD, 2009f). Since student preferences, on their own, do not always adequately reflect labour market needs, and forecasting is difficult if not hazardous, VET programmes should include an element of workplace training, as the willingness of employers to provide such training indicates labour market demand.

Employers and unions need to be involved in curriculum development, and programmes should provide both generic transferable skills and occupation-specific skills that provide graduates with a basis for lifelong learning, mobility and changes in their working careers. Encouraging exchange between VET institutions and industry, so that VET teachers and trainers spend time in industry to update their knowledge and trainers in firms spend time in institutions to update their pedagogical skills, improves the quality of training and helps further strengthen bridges between education and the world of work. Other policies to be considered include sharing the costs of VET among government, employers and students, in line with their respective benefits, adopting national assessment to ensure quality and consistency, and strengthening the knowledge base on VET education to allow for continuous improvement in the sector.

Lifelong learning

Learning that takes place on the job is a crucial component of skilled workers' competences and helps shape innovation outcomes. Recent work using firm-level data found for example that firm expenditures on training were strongly associated with "process modernising" modes of innovation in a number of countries (OECD, 2009g). Such innovation related to new methods of manufacturing, delivery or distribution tended to involve expenditures on machinery. In other countries, training was associated with additional modes of innovation; in Brazil, for example, training was linked to undertaking new-to-market innovation using in-house R&D and patents as well as design and other IPR inputs, as well as to undertaking marketing-based modes of innovation. For more informal learning at work, some skill domains, especially those involving cognitive skills, may require significant investments in education and training; however, for communication skills, work context and work experience might play a more important role.

The importance of work-based learning highlights the fact that skills acquisition is a lifelong process. Learning a set of skills at school, technical college or university or through on-the-job training may no longer enough to carry people throughout their working life. The pace of innovation and changes in countries' industrial structures mean that many people need to upgrade their skills throughout their adult lives (OECD, 2007b). Moreover, there are limits to the ever-lengthening duration of initial education (OECD, 2009e).

Several tools can encourage ongoing skills acquisition. To form a base for lifelong learning, schools need to motivate individuals to continue to learn and to adopt practices that increase students' capacity for independent learning. All forms of learning need to be recognised and made visible on the basis of their content, quality and outcomes (Box 3.4). Qualifications systems also need to promote and be responsive to lifelong education and training systems. With the number of stakeholders involved in lifelong learning extending beyond those covered by education authorities, co-ordination in policy development and implementation will be essential.

Work on adult education shows the importance of improving the visibility of rewards to learning as a way to motivate people to learn (OECD, 2005). Fewer than one adult of working age in five is likely to participate in job-related informal education and training in the course of a year (OECD, 2009e). Barriers such as lack of time due to work or family obligations, as well as lack of resources to pay for training, play a role in lowering participation. Research shows that at least some secondary education raises the likelihood of participation in further learning and training, further indication of the imperative of solid basic skills for all. To the extent that adult learning generates considerable private returns, in principle much of it should be co-financed. However, where financial constraints are particularly challenging there is a case for governments to offer assistance and incentives for low-skilled and disadvantaged groups, as well as for certain types of firms (OECD, 2005).

Box 3.4. Recognition of informal and non-formal learning

The lack of a formal qualification can sometimes lead to underuse of a person's skills and knowledge, even if their abilities are equivalent in practice to those of a formally qualified person. Recognition of the competences gained from non-formal and informal learning (through, for example, granting credits towards a formal qualification) has the potential to improve the use of existing human capital and could encourage people to engage and invest in learning. Recent OECD work, summarising existing practice in 22 countries, suggests that qualification recognition systems need to become more transparent and provide greater clarity about when recognition is a credible alternative to training. Evaluation of recognition systems will also be important to prove that the process is well-founded and provides an efficient and effective mechanism for valuing experience.

Source: OECD (2010), *Recognising Non-Formal and Informal Learning: Outcomes, Policies and Practices,* OECD, Paris.

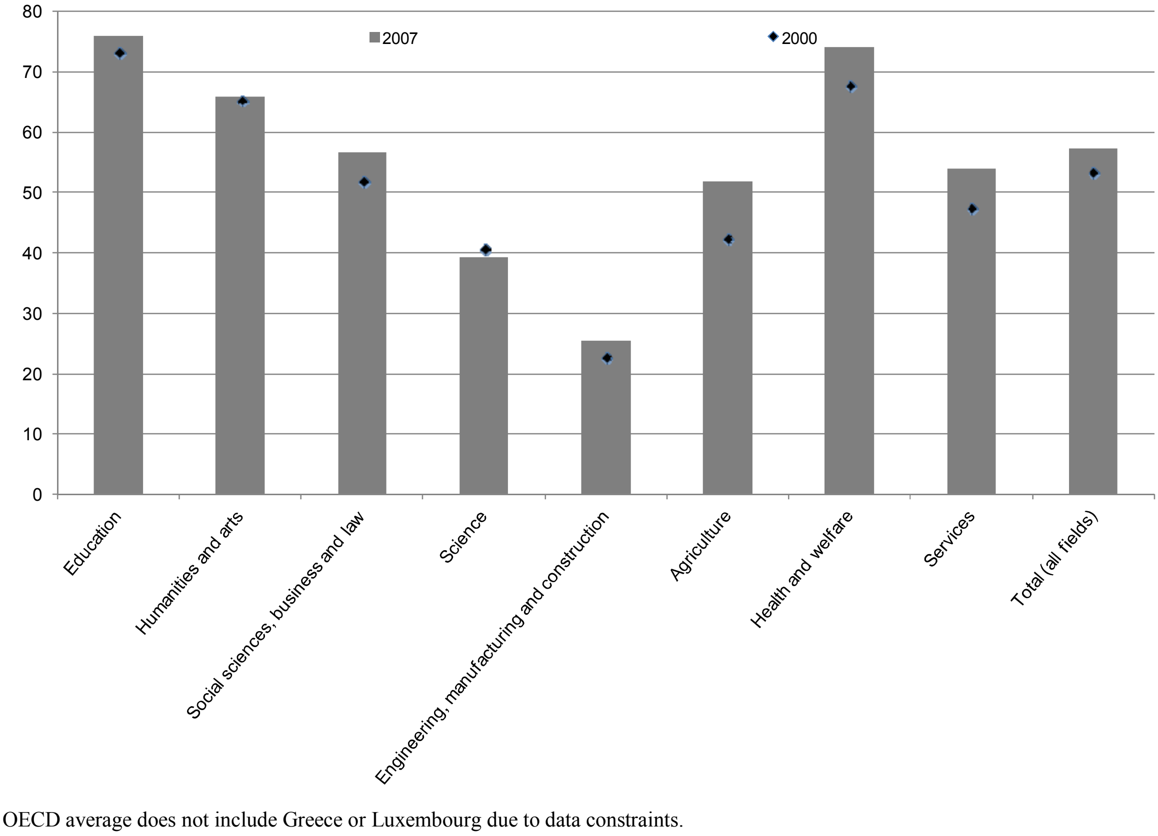
The tax treatment of expenditures on education and training, as well as the tax treatment of the corresponding increase in income, will also influence the incentives of individuals and firms to fund additional learning. For individuals, the progressivity of personal income tax systems can be a disincentive to study and train, although this may be somewhat offset by systems of tax credits or allowances. For firms, policies on social security contributions, allowances and tax credits will affect their willingness to invest in the skills of their workforce. However, a recent study (CEDEFOP, 2009, p. 107) suggested that the use of tax incentives to promote training and education should be considered “as a supplementary measure rather than the main instrument in the policy makers’ arsenal”. It recommended targeted incentives for certain groups, as suggested above, as well as attempting to remove some of the obstacles to participation in training.

Using human capital for innovation requires better utilising the female workforce

Better use of female talent and skills will be an important goal for innovation policies. Women are now awarded over 50% of all first tertiary degrees in OECD countries (OECD, 2009a, Table A3.6) and also represent more than 50% of professionals and technicians in many OECD countries (OECD, 2009h). Nevertheless, a low level of participation of women in the labour force is a problem in many OECD countries. In addition, some sectors and fields (*e.g.* science and engineering) are very predominantly male, with female participation rising only very slowly (Figure 3.3). The OECD’s work on family-friendly policies shows that certain social and labour market policies are the key to encouraging women to participate in the labour force, notably tax and benefit systems, workplace practices and policies related to childcare. Overcoming additional factors, such as gender stereotypes, may also be important for raising female participation in the science and technology area and increasing their potential to contribute to innovative activity.

Figure 3.3. Percentage of degrees awarded to women, by subject, 2000 and 2007

OECD average[1]



1. OECD average does not include Greece or Luxembourg due to data constraints.

Source: OECD Education Database, 2009.

In higher education and research, two observations have stood out for some time. First, women are concentrated in certain fields, particularly biology, health and pharmaceuticals, and participate much less in fields such as engineering and computing (OECD, 2006b). For example, 27% of graduates in mathematics and computer science are female, compared with 73% in health and welfare (OECD 2009a, Table A3.6). Second, there is a "scissor" effect, *i.e.* female participation levels steadily drop at higher seniority levels. For example, in medical sciences, half of the researchers in the higher education sector in Europe are females but they represent less than 20% of professors (EC, 2009a). In addition, women make up a small proportion of scientists in highly visible top positions (*e.g.* university rectors), on boards, and in R&D-intensive sectors (EC, 2008a). Women also tend to apply for funding less often, for lesser amounts and to less prestigious bodies (EC, 2009b).

The relatively low participation of women in science has been viewed with unease in many policy circles, particularly given the challenges of ageing populations, a growing interest in tapping innovation to address global challenges, and the associated demand for skilled workers. There are concerns that the skills of some highly trained women are underutilised and that social and individual investments in education risk being lost (OECD, 2006b). Furthermore, from the perspective of equality between the sexes, many countries seek more balanced representation of men and women across a range of workplaces and activities. Such a goal does not threaten scientific excellence; more diverse research teams are more open to new ideas, procedures and experiments, and are thus more innovative (EC, 2008a).

To some extent, study fields and participation in the scientific workforce are a result of personal choice. There is also some evidence that female participation is increasing. For example, the proportion of female professor/A-grade staff is higher among younger age groups than older age groups in a number of European countries, indicating a generation effect. Moreover, researcher numbers and PhD graduates in science are growing faster among women than men, such that "catch-up" is occurring (EC, 2009a). Data from the United States also show that women with recent doctorates represent a larger percentage of full-time tenured or tenure-track faculty and full-time full professors than women in general (NSF, 2009, p. 15).

Nevertheless, there is compelling evidence of barriers to female participation (EC, 2008a, 2008b). For example, persistent gender stereotypes related to certain scientific fields, science as a profession, and the role of women and men in general can influence career choices. In some cases, overtly sexist behaviour and criticism of efforts towards equality may serve to devalue female participation in science careers and reinforce imbalances. Reaching higher-level positions can be made difficult by non-transparent nomination and appointment procedures; informal processes and use of "old boy networks" are particularly challenging. As in other occupations, some sought-for characteristics, such as a willingness to work after hours and rapid advancement through career stages, tend to count against people with family responsibilities (which still mainly fall to females) and those who take career breaks (including maternity leave). As science funding is highly dependent on external sources and as grants are normally allocated to full-time positions, part-time work can be difficult, and the speed with which the science and technology knowledge frontier changes can make it difficult for researchers to re-enter after a break.

Countries have adopted a variety of policies and approaches to address gender issues in science. They have introduced equal opportunity legislation, gender mainstreaming,[2] units for women in science ministries, targets and quotas, networks and mentoring programmes, and policies on maternity and paternity leave (EC, 2008b; OECD, 2006b). However, such policies frequently only affect universities and public research institutions, not private-sector bodies, and most have not been evaluated (or been able to be evaluated, due to lack of data) to assess their effectiveness and efficiency in boosting female participation. Moreover, gender mainstreaming should address both men and women concurrently to be effective, but this has not always been the case.

Recent policy recommendations include funding networks and supporting programmes to increase public awareness of the gender issue, improving the representation of women on funding decision-making bodies (perhaps with mandatory targets on gender balance), and asking the scientific community to commit to standardised, transparent procedures with clear quality criteria for appointments (EC, 2008a). Improving accountability and transparency in research funding, publishing procedures and criteria, using international evaluators and instituting grievance procedures have also been suggested, as a way to help address the gender imbalance in funding applications (EC, 2009b). Measures to enhance the work-life balance of researchers are frequently recommended, with suggestions such as increased funding for mobility of researchers with family.[3]

International mobility can play a role in innovation in both sending and receiving countries

International mobility of skilled human resources plays an important role in innovation (OECD, 2008f). Tapping into this pool of talented people provides countries with an additional source of skilled labour and can help fill shortages. More importantly, mobile talent contributes to the creation and diffusion of knowledge, particularly tacit knowledge, which is more effectively shared within a common social and geographical context. It is this type of knowledge that often provides the "spark" that leads to advances in science and technology by providing the combination of codified information and contextual understanding needed to create something new.

Most OECD countries are net beneficiaries of international flows of people with tertiary education. Australia, Canada, France and the United States, in particular, have had strongly positive net inflows of such migrants. For some countries, intra-OECD flows add substantially to the stock of highly educated individuals, while for others, non-OECD migrants (especially from the People's Republic of China, India and the Philippines) play a more important role. Factors such as relative wage premiums, career advancement, research opportunities, higher-quality research facilities, the opportunity to work with significant peers and in prestigious institutions, increased autonomy and freedom to debate are strong drivers of skilled mobility. Migration policy settings also clearly play a role in enabling or hindering migratory flows, while family and personal factors are strongly associated with return flows of migrants.

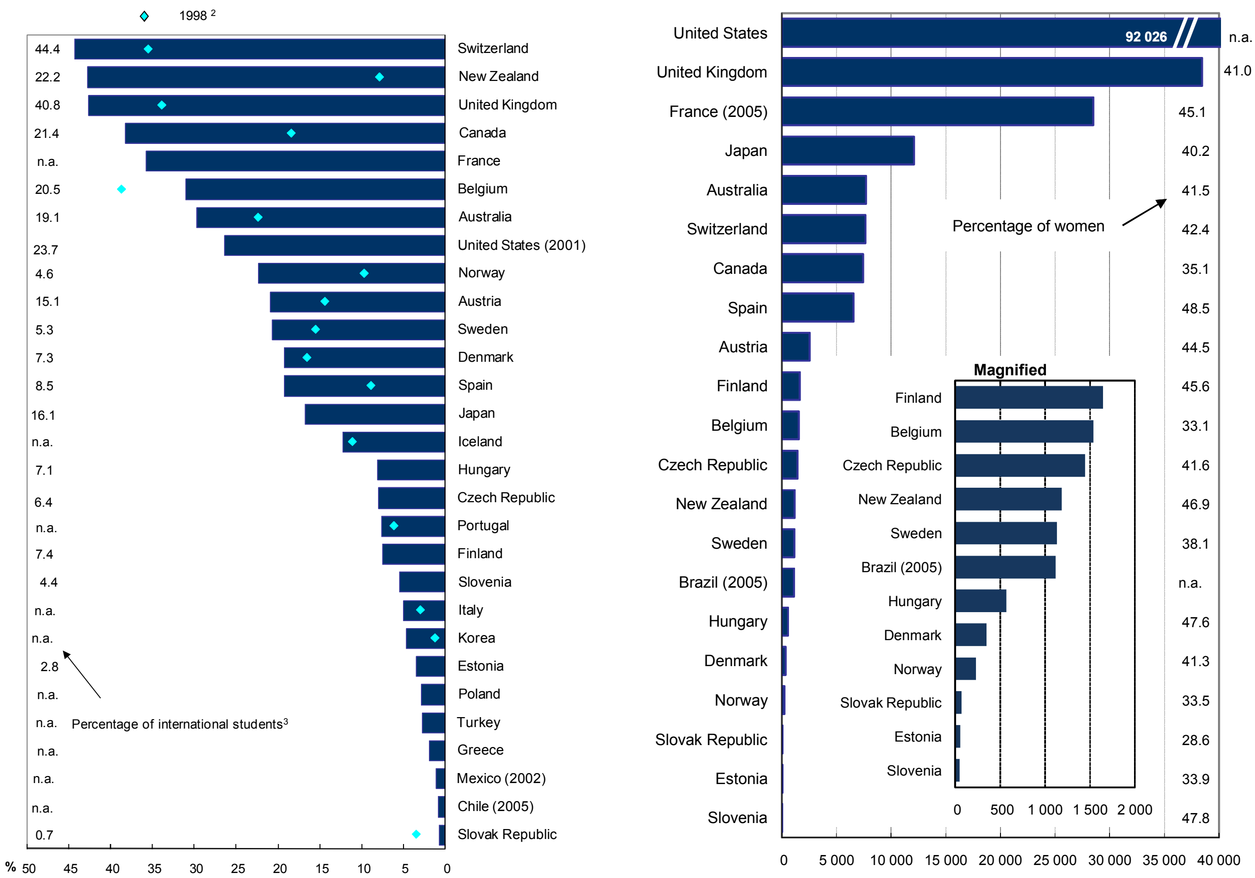
Figure 3.4. Foreign and international doctoral students

Share of foreign doctoral students, 2006

As a percentage of total doctoral enrolment in host country

Number of international doctoral students, 2006

By host country



Source: OECD (2009), *OECD Science, Technology and Industry Scoreboard 2009*, OECD, Paris.

International flows of tertiary-level students make a significant contribution to highly skilled mobility (Figure 3.4). The number of students enrolled outside their country of citizenship has more than tripled since 1975, and in 2007 more than 2.5 million foreign students were enrolled in OECD countries (OECD, 2009a, p. 334). In some countries, foreign and international students make up a significant proportion of the student body. With globally oriented firms seeking internationally competent workers with foreign language and cultural skills, and increased collaboration across countries in R&D and academic activities, students can leverage their labour market prospects by studying in tertiary educational institutions in countries other than their own.

Academic staff also cross borders for teaching and research, although data are scarce compared to those on student mobility (OECD, 2008a). However, flows of academics abroad have clearly been increasing. In most countries, this involves short-term leaves, exchange visits and research collaborations, and the proportion of teachers involved in short stays abroad is considerably larger than for longer stays.

However, as noted in Chapter 2, quantitative evidence on the effect of international mobility of skilled people on innovation is not readily available. Many variables and factors influence science and technology outputs and outcomes and are difficult to disentangle. Nevertheless, a picture is starting to emerge of increasing internationalisation of the labour market for the highly skilled, strong immigrant contributions to patent applications and the creation of technology firms, growing international co-authorship of academic articles and increasing collaborative work (OECD, 2008f).

Most countries have a range of policies focused on assisting and encouraging mobility. These are also important for attracting and retaining talent. Policies range from economic incentives to encourage inflows, immigration-oriented assistance, procedures for recognising foreign qualifications, social and cultural support, and support for research abroad (OECD, 2008f). Some countries focus on a few policy mechanisms, while others offer "something for everyone". However, few countries' policy approaches are part of an explicit mobility strategy. There is generally more support for inflows of researchers and other highly skilled than for outflows, perhaps because countries judge outward mobility to be adequate or because they are reluctant to encourage it. Since many countries offer support for mobility, as opposed to permanent migration, researchers may use these policies to work in a number of countries.

"Brain circulation" can stimulate knowledge transfer to sending countries. Returning professionals make the knowledge they have acquired available to their home country and maintain networks abroad which facilitate continuing knowledge exchange. To make the most of brain circulation, the home country needs to have sufficient absorptive capacity and returning migrants need to be able to re-enter local labour markets at a level that is appropriate for their skills and knowledge. The existence of a skilled diaspora enhances the transfer of knowledge by acting as a conduit for flows of knowledge and information back to the home country. In some emerging economies, diaspora networks play a vital role in developing science and technology capacity. Taken together, these effects suggest that knowledge flows associated with the emigration of researchers and scientists can provide benefits to sending countries. The mobility of researchers therefore is not necessarily a zero-sum game in which receiving countries gain and sending countries lose.

Policy on mobility should aim to support knowledge flows and the creation of enduring linkages and networks across countries. It should be coherent with the broader environment for innovation and scientific endeavour as skilled migrants need to operate in a system that enables them to use, create and disseminate knowledge. Migration regimes for the highly skilled should be efficient, transparent and simple, and enable movement on a short-term or circular basis. Policy should also support ongoing connections to nationals abroad. These policies also need to be coherent with the wider migration agenda and with countries' efforts in the development and aid arena, so as to contribute to the effective management of migration overall. At the same time, mobility policy must have realistic goals. Family connections, and cultural and language differences, will continue to place upper bounds on mobility. The impact of mobility policy will also be tempered if the overall economic policy environment is not conducive to the creation, diffusion and use of knowledge.

Finally, it is important to remember that many OECD countries and a growing range of non-member economies aim to attract the same pool of highly skilled researchers and scientists. Relying extensively on international flows and mobility policies to fill existing or future gaps in supply may therefore entail risks. Policy also needs to focus on addressing shortcomings in national policies that may limit the supply of human resources.

Workplaces play a crucial role in fostering innovation

In every economy, more efficient use of resources is an important source of continuing productivity growth. Introducing new processes, adopting best practices, or simply reorganising workers' responsibilities, can lower costs, raise productivity and ensure that the talents of individuals are being used.

Similarly, in individual workplaces, the use of material and human resources and the scope for further developing workers' skills and knowledge in the work environment contribute significantly to a firm's innovation and productivity performance. In particular, interaction and learning within firms enable employees to share information, challenge existing patterns, and experiment and collaborate to improve products and processes. Effectively harnessing the workforce can allow people from different disciplines to work together to solve problems, leading to greater openness and creativity. The animation studio Pixar, for example, actively works to construct an environment that creates constant opportunities for giving and receiving feedback in a positive way (Catmull, 2008).

Forms of work organisation that act to empower workers and engender commitment to innovation at all levels of the workforce have been associated with innovation. There is a range of nomenclature for such organisational forms, one of which is the "high performance work system" (HPWS), but the broad concepts are similar.[4] Common features of this type of system are broad job classifications (allowing functional flexibility), job rotation, work teams and delegation of authority, incentives to actively participate in innovation, and measures to monitor, evaluate, capture and diffuse improvements that are devised in one work team to others (Toner, 2009). Firms implementing HPWS-type arrangements also engage in a high rate of training across all occupational groups. Communication, teamwork and social skills are crucial for the successful implementation of this type of system, in addition to key technical skills related to the particular job and industry.

Another concept that has emerged from the focus on the work environment is that of the "learning organisation". Here, the idea is that the translation of information into business success can be supported (or inhibited) by the impact of individual behaviours, team organisation, organisational practices and structures, and the underlying organisational culture on learning, be it at the individual, team or firm level. People working in organisations that could be classed as "learning" more frequently consider that they apply their own ideas in their work, find their job intellectually challenging and have opportunities to learn and grow (Greenan and Lorenz, 2009). The human management practices of firms are clearly central to learning; some human resource management practices associated with learning organisations include employee involvement, opportunities for further vocational training or informal learning, rewards for risk taking and supportive management.

European evidence supports the connection between learning organisations and innovation. In European countries where work is organised to support high levels of employee discretion in solving complex problems, firms tend to be more active in developing innovations in house (Greenan and Lorenz, 2009). In countries where learning and problem solving on the job are constrained and employees have little discretion, firms tend to engage in a supplier-dominated innovation strategy. The bottleneck to improving innovative capabilities might not be low levels of R&D expenditure, which are strongly influenced by industry structure and consequently difficult to change, but the presence of working environments that do not provide a fertile environment for innovation. While many European workers are in settings that draw on their capacities for learning and problem solving, there are important variations in the spread of learning forms of work organisation.

At the same time, certain forms of work organisation demand particular skills of employees. Pilot results from the OECD's PIAAC study found, for example, that workers who participated in quality-improvement circles had higher reading and numeracy skills and greater communication skills, while team-working was associated with greater internal communication skills. Greenan and Lorenz's work found that measures of firms' investments in continuing vocational training were strongly associated with learning forms of work organisation, suggesting that firm-specific training has an important role in developing capacity for knowledge exploration and innovation.

While many decisions about how human resources are used and developed are the subject of firms' individual human resource management policies, governments may be able to shape national institutions to support higher levels of employee learning and discretion in the workplace. Greenan and Lorenz (2009) found that national systems that combine high levels of labour market mobility with relatively high levels of employment security and expenditure on active labour market policies are associated with adoption of forms of work organisation and knowledge exploration that promote innovation at the firm level. At the same time, as discussed in Chapter 4, it is important to ensure that employment regulations foster efficient organisational change. Training and skills development for innovation is a greater challenge for small and medium-sized enterprises (SMEs), which have up to 50% less participation in formal training programmes than large firms. Policy needs to foster greater awareness in SMEs of the link between training and innovation.

Perceptions of potential career paths are influential

The careers open to highly trained people range widely across the public and private sectors and across a vast number of fields and specialisations. Research shows that views of different careers are formed from a very young age as children pick up ideas from adults and from the media (Foskett *et al.*, 1999). Perceptions of reality, rather than objective reality, are also of great importance. Young people develop images not only of themselves and their capabilities and desires, but also of the value of various education pathways, the nature of jobs, and their own role in society and the economy.

Concerns have been expressed about the attractiveness of certain careers and the impact on young people in terms of pursuing science, technology and innovation in their studies and beyond. A particular area of concern has been academic research careers. A European study of human resources for science and technology highlighted a range of potentially discouraging factors relating to academic research careers: low starting pay, limited material rewards at senior levels compared with other professions and little wage differentiation between cohorts; strong specialisation by field of research and a resistance to training in broader teaching or managerial skills; and difficulties in moving institutionally and internationally, because of tenure, pension rights and "customs" about movement and job change (HLG, 2004). An OECD workshop on "Research Careers for the 21st Century" also highlighted challenges relating to working conditions, employment structures (more temporary contracts and slower access to tenure) and a decline in the "linear career track" for academics (OECD, 2007c). Rigidities relating to tenure were clearly apparent, with respect to both the "mindset" of what a research career should be and the opportunities available to researchers in an often restrictive system.

Better employment arrangements in academia are needed to improve transparency and career prospects, and researchers should prepare for more complex and diverse career paths (OECD, 2007c). Without reforms to adapt employment arrangements to new research models and working methods, combined with efforts to offer transparent recruitment processes and clearer career prospects, research careers may continue to suffer from negative perceptions and difficulties for attracting candidates. Policy approaches that may help improve the attractiveness of academic careers in general include: greater flexibility of roles and workloads of academics, career structures and types of employment; better entrance conditions for young academics (*e.g.* well-structured induction schemes, mentoring, etc.); professional development throughout academic careers; and facilitation and recognition of collaboration and mobility experiences (OECD, 2008a).

Consumers contribute increasingly to innovation

Consumers today have increasing opportunities to influence the design, introduction and trajectory of new products and services in both the private and the public sector. They also have the ability to directly influence innovation and encourage the development of new technologies. In recent years, there has been a growing government emphasis on the importance of collaboration with citizens and service users to improve service delivery and as a driver for innovation (OECD, 2009i). In the public sector, harnessing people's interests, energies, expertise and ambitions can challenge traditional approaches to public service and spur new forms of activity and delivery in areas as diverse as personal services (such as health), transactional services (for example, payments), democratic functions and services (such as interaction with government), regulatory services (for instance, related to the environmental sector) and collective services (such as community safety). Increased user involvement puts pressure on government entities to ensure that their staff have skills to manage dialogue and collaborative approaches and may spur changes in the public workforce

A specialised group of consumers – lead users – plays a particular role in steering innovation, notably in the private sector. These individuals innovate to improve products they use or solve problems that arise as part of their work or daily activities. They develop their ideas without involving companies, but firms or organisations may pick up their ideas and put them to use in their products or activities. FORA (2009, p. 27) give the example of an intelligent drug infusion pump for anaesthesia, which was developed by a physician at Massachusetts General Hospital and later commercialised for wider use.

To the extent that consumers in general increasingly deal with technological change and innovation, they need to have the appropriate skills. They need to be able to read and understand detailed information, as in many sectors the principle of disclosure is the mainstay of consumer protection. However, a sizeable proportion of consumers have levels of literacy that suggest they are ill-equipped to cope with such challenges. More generally, consumers need to be able to research, assimilate and critically analyse information; this not only benefits consumers it also contributes to effective competition and well-functioning markets. They need to be able to manage resources effectively, to assess risk and exercise balanced judgement in making responsible decisions, to communicate effectively and to know when to seek professional advice (UKOFT 2004).

The policy challenge relates to consumer education to develop and enhance the skills and knowledge to make informed choices, think critically and be pro-active. It is ideally a continuous process that builds and renews consumers' skills over their lifetime and is a means of encouraging their contribution to various forms of innovation (OECD, 2009j). The OECD has developed a 'consumer policy toolkit' to assist governments in this area (OECD, 2010b).

Entrepreneurial attitudes lead to innovation

Entrepreneurial skills are of particular interest for innovation because entrepreneurs play a key role in driving innovation. The public sector, the private sector, academia and the non-profit sector all have roles to play in facilitating the creation of an entrepreneurial culture and developing the attitudes and skills necessary to encourage and support the creation of innovative ventures. Factors of particular relevance in this context are discussed below.

Culture and attitudes towards entrepreneurship

Although many countries have made progress towards encouraging a more favourable culture and environment for entrepreneurship, much remains to be done. The perceived image of entrepreneurship is affected by many factors, among them the media and the school system. In many countries, entrepreneurship does not have a positive image. Government policies can promote an entrepreneurial culture, for example by encouraging events that highlight entrepreneurial role models and by supporting the intergration of entrepreneurship into the education system. However these policies need to take a long-term perspective, since culture typically changes slowly over time. Research shows perceptions of entrepreneurial opportunities to be quite high across countries, although they have dropped slightly as a consequence of the economic crisis. However, the fear of failure may make people hesitate to start a business (OECD, 2009k).

Innovation requires people with the skills and attitudes to be entrepreneurial in their professional lives, whether by creating their own companies or innovating in existing (small and large) organisations. It is therefore important to develop entrepreneurial skills and attitudes at all levels of formal education and throughout lifelong learning. This includes building self-confidence, self-efficacy and leadership skills. Entrepreneurship education may help change the mindsets of young people about entrepreneurship and encourage them to consider it as a possible path for the future. To this end methods and tools to encourage creative and innovative thinking are likely to be important (EC, 2007).

Entrepreneurship education policy

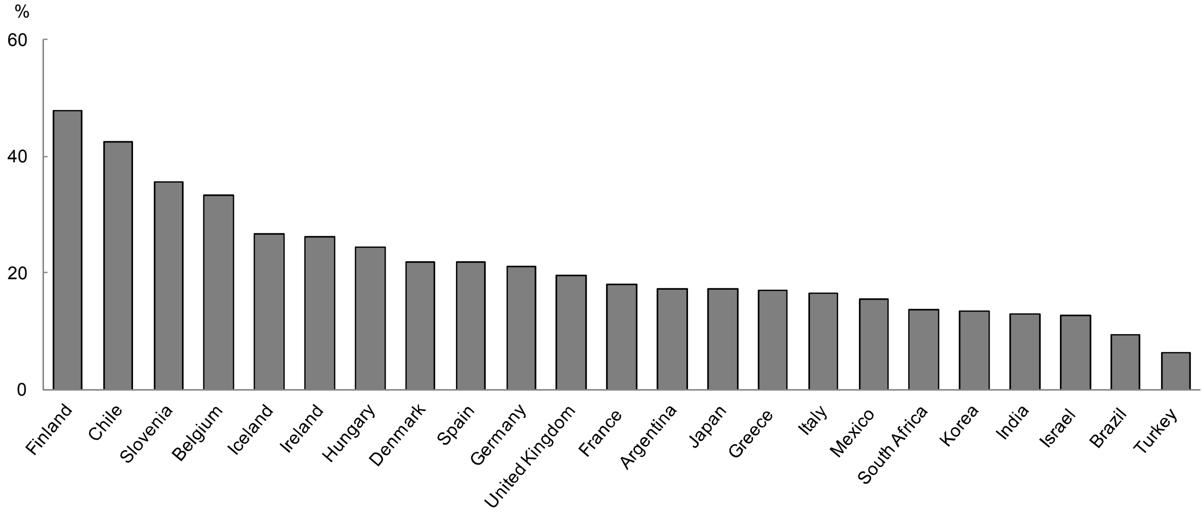
There is no "one size fits all" solution for entrepreneurship education and, indeed, the concept is still working to achieve full academic credibility. The challenges and opportunities for entrepreneurship vary dramatically in different parts of the world and in different segments of education and the local context must be taken into account when devising and tailoring a set of programmes and initiatives. As noted in Box 3.2, there is not yet strong evidence linking academic programmes to entrepreneurship outcomes, and gaining the support of heads of academic institutions as well as governments will be important to further incorporate entrepreneurship as an area of study in education systems. In this respect, more effective measurement and evaluation of the impact of entrepreneurship education programmes is needed, although the methodological challenges in linking policies to outcomes is acknowledged. Evaluations should be based on a broadly defined set of outcomes, rather than narrow measures such as the number of start-ups which focus on short-term results without measuring the longer-term impact.

In general, entrepreneurship education requires experiential learning and a focus on critical thinking and problem solving (EC, 2008d). According to the World Economic Forum (2009), it should be interactive, encouraging students to experiment and experience entrepreneurship by working on case studies, games, projects, simulations, real-life actions, internships with start-ups and other hands-on activities that involve interaction with entrepreneurs. The curriculum should be based on local materials, role models and examples that include appropriate representation of gender, youth, indigenous people and people with a disability, as well as informal enterprises and those based in rural areas. Entrepreneurship education should be very closely linked with practice, and educators should be encouraged to reach out to the business community and integrate it into the learning process. Mentoring potential entrepreneurs and exposing them to business through links with experienced entrepreneurs and managers as well as with large mature firms is critical.

There is a need to expand the number of entrepreneurship educators and provide appropriate training, particularly in interactive teaching methods, as well as incentives and recognition. Entrepreneurs and others with entrepreneurial experience should also be encouraged and trained to teach. They provide value in the classroom and may improve attitudes on entrepreneurship within the institution as well as create closer links with the local community. Developing cross-disciplinary approaches and interactive teaching methods require new models, frameworks and paradigms (World Economic Forum, 2009). It is also necessary to provide entrepreneurship training and apprentice programmes beyond formal education systems, in rural and community programmes, especially in developing countries.

While entrepreneurship education is important at all educational levels, universities can play a key role by helping students to learn not only how to start but also how to expand enterprises, including across borders. Entrepreneurship in higher education has received greater attention in the past ten years, although there are large differences among countries (Figure 3.5). Recent work on entrepreneurship recommends scaling up university provision of entrepreneurship programmes through the use of interactive and experiential teaching methods (OECD, 2010c). However, entrepreneurship is not only about business and/or for business students (EC, 2008c). It is important in all disciplines and sectors. This suggests that more needs to be done, particularly in the areas of curriculum development, the training and development of entrepreneurship teachers, cross-border faculty and research collaborations, and facilitation of spin-outs from technical and scientific institutions.

Figure 3.5. Percentage of the population aged 18-64 years old who received any type of training in starting a business, during or after school, 2008



Note: The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Source: OECD (2010), *Measuring Innovation: A New Perspective*, OECD, Paris, based on N. Bosma, Z.J. Acs, E. Autio, A. Coduras and J. Levie (2009), *Global Entrepreneurship Monitor: 2008 Executive Report*, *www.gemconsortium.org*.

In most countries, the bulk of entrepreneurial funding for schools and universities still comes from governments, although companies, foundations and alumni have begun to contribute. While there are more entrepreneurship education programmes today than a decade ago, scalability and penetration remain key challenges. Technology and the media provide means of reaching greater economies of scale and providing greater access and sharing of practices. Technology and the media can facilitate the development of innovative, interactive programmes and materials and help reach larger audiences, including those in developing countries or regions which might not otherwise have access to entrepreneurship education.

Key findings

Human capital is the source of innovation. People generate the necessary ideas and knowledge, and they apply this knowledge, and the technologies, products and services that it may generate, in the workplace and as consumers. Empowering people to innovate requires not only broad and relevant education but also the wide-ranging skills that complement formal education. Opportunities to use and leverage these skills throughout the economy and society are vital.

Education, from early childhood through primary and secondary school, lays the foundation for individuals' ability to work in an innovation-driven society. Universities and colleges are also essential nodes in the innovation system, as they both produce and attract the human capital needed for innovation. They contribute to the local quality of life and can help to attract the highly skilled from around the globe. Vocational education and training play an important role in innovation, by helping firms make incremental changes to production processes and adopt technologies, and by lifting the overall capacity to innovate. Moreover, the acquisition of skills is a lifelong process; it does not end with formal education. The ongoing acquisition of further skills needs to be encouraged.

Women should play a larger role in the innovation process. The low participation of women – and other underrepresented groups – in certain parts of the innovation process limits the diversity that is essential for innovation to flourish. International mobility of skilled human resources is also important for innovation and provides countries with an additional source of skilled labour. In the workplace, there is scope for further developing workers' skills and knowledge.

Consumers also support and encourage innovation and the competitive process. They have opportunities to influence directly the design, methods of supply, introduction and uptake of new products and services. Entrepreneurs play a particularly important role in driving innovation, yet only a small part of the population receives entrepreneurial education.

The policy principles that emerge are:

1. Education and training systems should equip people with the foundations to learn and develop the broad range of skills needed for innovation in all of its forms, and with the flexibility to upgrade skills and adapt to changing market conditions. To foster an innovative workplace, ensure that employment policies facilitate efficient organisational change.

a) *Equip people with skills for innovation.* Policy makers should ensure that education and training systems are adaptable and can evolve to accommodate the changing nature of innovation and the demands of the future. This will require curricula and pedagogies that enable students to develop the capacity to learn new skills throughout their lives. Policy should also strengthen human resource development so as to take full advantage of information and communications technologies.

b) *Improve educational outcomes.* Despite unprecedented growth in educational attainment in OECD countries a considerable share of children still do not complete upper secondary education or leave schools with poor literacy and numeracy skills. This core phase of education is fundamental for laying the foundations for other social, economic and educational outcomes, including the ability to work and contribute to innovation as an adult. At least some secondary education helps to participate in further learning and training. While virtually all young people in OECD countries have access to at least 12 years of formal education, mechanisms are needed to ensure that solid educational foundations are universal.

c) *Continue to reform tertiary education systems.* Tertiary education systems need to enhance access, improve quality and operate efficiently. Public authorities should enable tertiary education institutions to become catalysts for innovation, notably in their local and regional settings. While the steering role should be reserved for government, institutions should have considerable room for manoeuvre. Plans for empowering institutions may include legislation that allows institutions to become self-governing legal entities, in the form of foundations or not-for-profit corporations. The tertiary sector also needs to retain sufficient diversity to respond to future needs in the innovation system. A priority for countries should be to develop a comprehensive and coherent vision for the future of tertiary education.

d) *Connect vocational education and training to the world of work.* This requires a good balance between occupationally specific skills that meet employers' needs and generic transferable skills that provide graduates with a basis for lifelong learning, mobility and changes during their working career. Available policy options include engaging employers and unions in curriculum development, sharing the costs beyond secondary level among government, employers and students, improving vocational teaching and training, adopting national assessments to verify quality and consistency and ensure workplace training is of good quality.

e) *Enable women to play a larger role in the innovation process.* Although more women than men now gain tertiary degrees, women's participation in the labour force is low in many OECD countries. Science and engineering are still predominately male-dominated. Certain social and labour market policies, such as tax and benefit systems, workplace practices and childcare, are key to providing incentives to women to become engaged in the labour force and innovation.

f) *Support international mobility.* Policies on mobility should aim to support knowledge flows and the creation of enduring linkages and networks across countries. Migration regimes for the highly skilled should be efficient, transparent and simple, and enable movement on a short-term or circular basis. Policy should also seek to support ongoing connections to nationals abroad. These policies need to be coherent with the wider migration agenda and with countries' efforts in the development and aid arena so as to contribute to the effective management of migration overall.

g) *Foster innovative workplaces.* Employee involvement and effective labour-management relationships and practices help foster creativity and innovation and raise productivity. It is important to ensure that employment policies encourage efficient organisational change. Learning and interaction within firms is important for their innovation performance, and they rely to a great degree on managers and entrepreneurs. While many decisions about how human resources are used and developed are the subject of firms' individual human resource management policies, governments may be able to shape national institutions to support higher levels of employee learning and training in the workplace.

2. Enable consumers to be active participants in the innovation process.

a) *Encourage consumers to be active participants in the innovation process.* Consumer policy regimes and consumer education are needed to ensure that consumers can make informed choices.

3. Foster an entrepreneurial culture by instilling the skills and attitudes needed for creative enterprise.

a) *Equip people with entrepreneurial and management skills.* Entrepreneurial learning should be part of the education curriculum at all levels. This requires commitment from government (often the primary funders of the education), educational institutions themselves and other key stakeholders.

Notes

1. Under the specifications of the model, this was equivalent to a person moving from the median of the literacy/numeracy distribution to the 84th percentile.

2. Gender mainstreaming has been defined by the United Nations Economic and Social Council as "the process of assessing the implications for women and men of any planned action, including legislation, policies or programmes, in any area and at all levels. It is a strategy for making the concerns and experiences of women as well as men an integral part of the design, implementation, monitoring and evaluation of policies and programmes in all political, economic and societal spheres, so that women and men benefit equally, and inequality is not perpetuated. The ultimate goal of mainstreaming is to achieve gender equality." [European Commission (2008) (*Benchmarking Policy Measures for Gender Equality in Science*, EUR 23314, Luxembourg, p. 30].

3. Work-life balance issues are not unique to the science, technology and innovation workplace. A discussion of national policies for reconciling work and family life can be found in OECD (2007). *Babies and Bosses*, OECD, Paris.

4. For example, the United Kingdom Commission for Employment and Skills (UKCES) uses the term "high performance working" (HPW). [UKCES (2009), *High Performance Working: A Synthesis of Key Literature, Evidence Report 4*, August; UKCES (2010), *Skills for Jobs: Today and Tomorrow, The National Strategic Skills Audit for England 2010, Volume 1: Key Findings*.]

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Chapter 4

Unleashing Innovations

This chapter discusses innovation in the business sector and policies for strengthening innovation in firms. It draws attention to the importance of good framework conditions and regulations that do not impede innovation and create a sound business environment. This includes well-functioning product, labour and financial markets and openness to domestic and international competition. Specific policy areas for particular attention are the public and private financing of innovative efforts and the fostering of the start-up and growth of new firms.

Introduction

Enterprises make a vital contribution to innovation, and a dynamic business sector is a main source of and channel for both technological and non-technological innovation. Yet in many OECD countries, firms do not have sufficient incentives to invest in innovation and primarily compete on low costs or other favourable factor conditions. Improving incentives for firms to invest in innovation through better framework conditions can strengthen innovation in the business sector. Yet, although the realised and potential benefits from innovation are clear, incentives to invest in innovation may still be inadequate to move countries up the value chain or to address important social challenges. It is commonly recognised that important market and systemic failures can reduce the incentives to invest in innovation:

1. When competitors and other innovators are able to use and benefit from new knowledge created by a firm, the benefits to society from investments in innovation can exceed the private returns. At the same time, because innovators cannot appropriate all the benefits of their investment, the overall level of investment will be less than socially optimal.
2. The outcomes of innovation efforts are highly uncertain, especially in their early stages. This may make it difficult for firms to raise external funding for R&D.
3. In an innovation systems perspective, the presence of bottlenecks or other failures that impede the operation of the innovation system can constitute crucial obstacles to the effectiveness of R&D, *e.g.* rigidities in product or labour markets, in the public institutions supporting research and innovation, or in the alignment of incentives guiding public and private actors in innovation.

These factors have served as the rationale for government intervention in science, technology and innovation. To address market failures, all OECD governments have put in place specific measures to encourage innovation (OECD, 2006a).

In essence, innovation requires sound framework conditions and policies that facilitate innovation in general and the start-up and growth of new firms. New and young firms play an important role, as they often exploit technological or commercial opportunities that have been neglected by more established companies. This chapter therefore discusses general framework conditions and regulations, the financing of innovation, and the role of demand-side policies. It also discusses entrepreneurship and policies that can foster it.

Strengthening the framework for innovation

This section presents the broader economic environment for innovation efforts and performance. A country's policies in terms of its macroeconomic settings and regulatory environment, its financial system, trade and openness, markets and competition, labour relations and taxation are of vital importance to its innovative capacity.

Macroeconomic policies

Stable macroeconomic policies are essential for economic activity and can lead to higher growth of GDP per capita and productivity (OECD, 2001,; 2006a). Fiscal discipline, low inflation rates and little variability in inflation help to reduce uncertainty and enhance the efficiency of resource allocation. This results in a better environment for decision making and frees resources for private investment. Moreover, strong and stable rates of output growth provide favourable conditions for firms seeking to introduce new products or to undertake significant organisational changes.

For example, regression analysis of 21 OECD countries for the period 1971-98 found the variability of inflation to be an important negative influence on output per capita. This supports the hypothesis that uncertainty about price developments affects growth via its impact on economic efficiency (OECD, 2003a, p. 82). In another study, Jaumotte and Pain (2005a) found that stable macroeconomic conditions and low real interest rates help to encourage the growth of innovation activity. Factors that help to lower the level of real interest rates can stimulate innovation because of the impact on the user cost of R&D capital.

The regulatory environment

Regulatory regimes influence the size, dynamism and functioning of firms, including innovative firms. Their effects can be positive or negative. Regulations are generally justified by the need to correct market failures in order to improve welfare, including from a health, safety and environment perspective, while minimising distortions in order to preserve the functioning of markets. However, they may also impede trade and competition or positive risk-taking behaviour. The effects of specific regulations in labour markets and human resources, finance and access to capital are discussed in the sections further below, as are the implications of the regulatory frameworks for entrepreneurship and new firms.[1]

Regulation is inherently linked to managing risk in order to reduce the incidence of hazardous events (OECD, 2010a), while innovation implies taking risks in order to be able to enjoy the rewards that can be achieved Regulation should therefore ensure that the benefits of regulation fully justify the costs and that innovation is not unduly restricted. For this reason, regulation should be subject to quality requirements. These are generally applied to new regulations, as part of regulatory impact assessment (RIA). The 1995 OECD Recommendation on *Improving the Quality of Government Regulation*, calls on countries to "promote innovation through market incentives and goal-based approaches" when developing good regulation. The 2005 OECD *Guiding Principles for Regulatory Quality and Performance* make explicit reference to the issue of risk assessment, as they invite countries to "assess risk to the public and to public policy in a changing environment as fully and transparently as possible, thereby contributing to a better understanding of the responsibilities of all stakeholders".

Existing regulations can prevent the emergence of new technologies, as occurred in the electricity generation sector, by reducing incentives to innovate (Veugelers and Serre, 2009). Regulations should be screened and reassessed to ensure that they do not unnecessarily impede innovative behaviour and the entry of technological and non-technological innovations.

Risk assessment and risk management tools can play an important role in guiding when and how to regulate. The goal of risk management in regulatory frameworks is to find a balance between the opportunities for greater flexibility and innovation and limiting the adverse consequences of mistakes. The case for a risk-based approach to regulation can easily be made on efficiency and effectiveness grounds. Regulation should be proportionate to the problem that it seeks to address. This calls for a risk-based approach that provides guidance on the magnitude of the regulatory problem and on when and how to regulate and should be underpinned by scientific evidence and a robust means of assessing the impact of regulation. (Hood and Rothstein, 2002).

Many countries have undertaken reforms to improve the quality of regulation. For example, many have attempted to address concerns about paperwork and administrative burdens for small and medium-sized enterprises (SMEs) through the introduction of one-stop shops and better electronic networks for the provision of information (OECD, 1999a).

The role of financial markets and venture capital

A growing number of empirical studies have shown that the scale of financial market development and well-functioning financial systems can have an important impact on long-run economic growth. In particular, they can help to ease the external financial constraints faced by firms that want to make long-term investments. Similar issues arise for investment in R&D and thus in innovation, since some projects are inherently more risky than others, given potentially long and uncertain payback periods, and the likelihood of asymmetric information between prospective borrowers and lenders is high.

Econometric analysis by the OECD (Jaumotte and Pain, 2005b) suggests that the scale of financial development, stock market capitalisation and the share of corporate profits in GDP all have significant positive effects on R&D expenditures. However the impact of financial market development on R&D is found to lessen when the share of corporate profit is high, indicating that more readily available internal finance is likely to reduce the need for external finance. Stock market capitalisation is also found to have a significant positive effect on patenting in addition to its effects through R&D, suggesting that equity-based financial systems may provide more favourable conditions for firms seeking to raise external finance for innovation.

An effective integrated market for financial services is necessary to provide more and cheaper capital for investment, including equity sources such as venture capital, which is increasingly a cross-border activity (EVCA, 2005a). Key to this process is the need to promote institutional investor choice, reduce trading costs and expand the investment funds available. Efficient legal investment structures and stock markets are necessary to recycle and redeploy financial wealth. Secondary stock markets, geared towards smaller firms, play an important role in entrepreneurship and innovation. In the United States, the NASDAQ exchange, created in 1971, led to improved initial public offering (IPO) opportunities for entrepreneurial firms and helped catalyse the emerging venture capital industry.

Continuing improvements in financial reporting are useful to enterprises engaged in innovative activity (OECD, 2008a). In particular, ensuring that information on intellectual assets is consistent and comparable over time and across companies help investors to better assess future earnings and the risks associated with different investment opportunities. This should contribute to making financial markets more efficient and improve the ability of firms to secure funding at a lower cost of capital. Governments can assist in efforts to promote identification and dissemination of best practices in reporting.

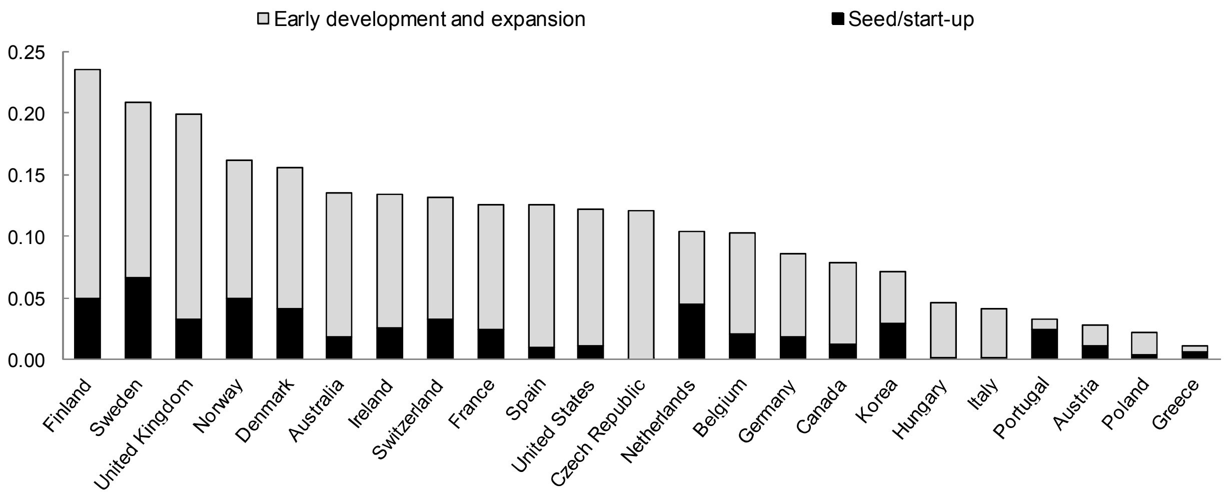
Venture capital is an important source of funding at the seed, start-up and growth phases for entrepreneurial firms, especially young, technology-based firms with high growth potential (Figure 4.1). Venture capital firms focus on investing in high-potential companies, either in sectors in new and rapidly developing technology fields or in those where market or operational inefficiencies can be improved to enhance the competitive situation of existing businesses. Venture capital firms not only fund but also support the development of high-potential companies in the early stages of their development and growth in new and innovative areas for which other sources of finance are hard to access.

In designing government support for venture capital, it should be noted that venture capital seems only to reach a small percentage of start-ups (1-2% by most industry estimates), usually technology or science based high-growth companies. Professionalisation in the venture capital market goes often together with higher rates on return on investments, often resulting in the moving up of venture capital providers, including public actors, to providing support to larger firms. Hence, (too) small, young and risky companies risk again to be left without venture capital; early stage companies *e.g.* are often forced to look then for capital with relatives and or friends, but often lack the expertise investors may provide.

Venture capital differs significantly among countries and is very sensitive to market cycles not only in terms of the amounts invested but also in terms of the stages of investment. Depending on market conditions, venture capital funds might invest more in the later stages, leaving gaps at the pre-seed and seed stages where profit expectations are less clear and investment risk is much higher.

Figure 4.1.Venture capital investments, 2008

As a percentage of GDP



Notes: The OECD defines here venture capital as the sum of "seed/start-up stages" and "early development and expansion stages". The latter includes the following. For Australia: early expansion, late expansion, turnaround. For Canada: other early stage, expansion, turnaround. For Korea: initial-early stage, middle stage-early (firms three to five years), middle stage-late (firms five to seven years). For Japan: early stage, expansion. For the United Kingdom: other early stage, expansion. For the United States: early stage, expansion. For European countries (except the United Kingdom): growth, rescue/turnaround.

Source: OECD, based on data from Thomson Financial, PwC, EVCA, National Venture Capital Associations, Australian Bureau of Statistics and Venture Enterprise Center.

Results from the venture capital industry seem to suggest that venture-backed firms outperform non-venture-backed firms in terms of job creation and revenue growth. For example, according to the National Venture Capital Association (NVCA) in the United States, employment growth in venture-backed companies increased by 1.6% from 2006 to 2008 while total US private-sector growth was only 0.2%. Revenue growth was 5.3% for venture-capital backed firms compared to 3.5% total revenue growth over the period (NVCA, 2009). Similarly, the European Venture Capital Association (EVCA) reports that private equity and venture capital-financed companies created over 1 million new jobs in Europe from 2000 to 2004, with employment growing at an average rate of 5.4% annually, compared to a 0.7% growth rate in total employment in the EU25 (EVCA, 2005b).

Business angels, who are often experienced successful entrepreneurs or business people, have become an increasingly important source of equity capital. This is a segment which currently falls between informal founders, friends and family financing and formal venture capital investors. It is growing but becoming more formalised and organised. Recent evidence has shown that business angels play a significant role especially in the early-stage financing of entrepreneurial firms. In terms of the number of business angels and investments, the United States clearly leads. However, Europe (and Asia) have been catching up. Within Europe, larger countries have larger numbers of business angel networks, but Sweden, a small country, has significant business angel activity (OECD, 2009a).

Openness to trade and investment

The expansion of markets worldwide has been one of the main drivers behind technological innovation and productivity gains (OECD, 2001). Progress in reducing tariff barriers, dismantling non-tariff barriers and liberalising capital markets has opened up opportunities in trade and international investment. This increases the size of markets available to innovators and consumers, while facilitating the spread of knowledge, technologies and new business practices. Analysis suggests that an increase of 10 percentage points in exposure to trade (a weighted average of export intensity and import penetration), for example, could increase steady-state output per capita by as much as 4% (OECD, 2003a, p. 89).

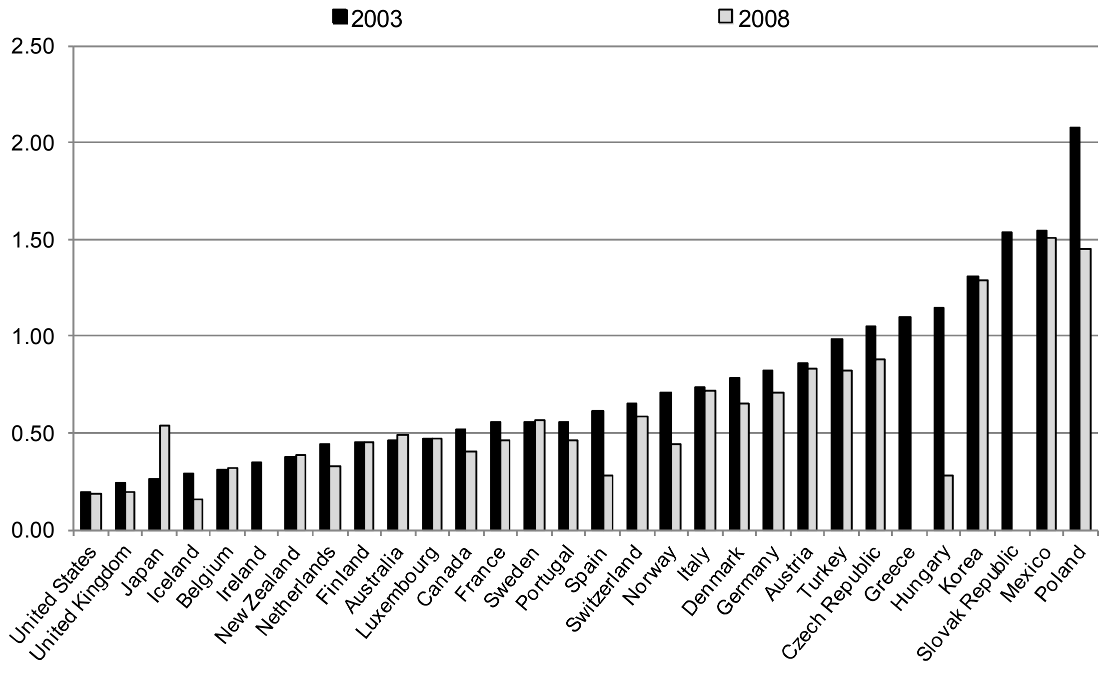
Equally important are culture and readiness for change: this means recognising that knowledge and ideas are important for economic growth and being willing to transfer and share these among economic agents (OECD, 2008b). Innovation performance is in fact closely related to the degree of an economy's openness to knowledge and ideas generated abroad. Apart from effects due to stronger competitive pressures, greater openness can lead to increased knowledge absorption via various channels, including imports of goods and services, investment flows, mobility of workers, and collaborative research and innovation (OECD, 2006a). Studies suggest that the benefits of foreign knowledge diffuse more rapidly through the direct transmission of ideas than through trade in goods and services that embody them. As a result, international mobility of skilled researchers (see Chapter 3) and multinational firms as well as open innovation may be especially important channels for knowledge transfer.

In many OECD economies the share of business-sector R&D funded and performed by foreign-owned firms is rising steadily over time (OECD, 2009b). This suggests that national innovation performance may be affected, in at least some countries, by policies that influence the location of internationally mobile research activities and the opportunities for national firms to benefit from the knowledge they bring. Weak restrictions on foreign direct investment (FDI) can help improve cross-border knowledge transfers (Jaumotte and Pain, 2005b). While restrictions on trade and investment have fallen substantially over the past decade, several OECD countries still face substantial barriers, and this is likely to affect innovation in their economy (Figure 4.2).

The importance of international spillovers for innovation does not imply that countries would be better off if they simply used the research of others rather than attempt to maximise their own innovation efforts. If all countries adopted such a view, global welfare would clearly be adversely affected. Even for individual countries there would be a cost. Jaumotte and Pain (2005a) show that absorptive capacity matters for maximising benefits from the use of the stock of international knowledge. In the absence of trained scientists and engineers, whether in the private sector or public research organisations, international spillovers would be greatly reduced. This points to potential complementarities between science and innovation policies and the stimulus to innovation provided by favourable framework conditions.

Figure 4.2. Barriers to trade and investment

Scale of 0-6 from least to most restrictive



Notes: The indicator values for Greece, Ireland and Slovak Republic are preliminary. 2008 data refer to beginning of 2008.

Source: A. Wölfl, P. Holler, M. Morgan and A. Worgotter (2009), "Ten Years of Product Market Reform in OECD Countries – Insights from a Revised PMR Indicator", *OECD Economics Department Working Papers*, No. 695, OECD, Paris.

Competition

Policies that affect the intensity of competition affect innovation efforts. However, neither economic theory nor empirical studies have been able to determine the level of competition that leads to the most innovation (OECD, 2010b). On the one hand, strong competition encourages companies to innovate to catch up with, get ahead of, or stay ahead of competitors. On the other hand, a degree of market power may stimulate innovation activity by facilitating the recovery of related expenses. In the middle ground, some research has found that many industries exhibit an inverted U-shape correlation between market concentration and business R&D, suggesting (to the extent that concentration and R&D are good proxies for competition and innovation, respectively) that moderate levels of competition are most highly correlated with more innovation. However, the extent of the relation is influenced by the industrial sector and the stage of technological development. Empirical support for the inverted U theory appears to be mounting; it suggests that sound, pro-active competition law enforcement is an important driver of innovation because almost all enforcement occurs in concentrated markets with relatively little competition. The inverted U theory also serves as a reminder that a balance must be struck: the right policy environment for innovative activity is one that gives adequate rewards to innovation while ensuring competitive pressures that encourage firms to create, implement and diffuse innovations (OECD, 2006a). It has also been argued that, for any given level of protection of intellectual property rights (IPRs), greater competition is likely to lead to stronger productivity performance (OECD, 2003a, p. 99).

An appropriate level of competition also plays a role in policy decisions on mergers. A proposed merger's expected effect on innovation is a factor which competition authorities typically take into account. Given the uncertainty about the relation between competition and innovation, and difficulties for assessing levels of competition in the market (considerations include not just concentration but also geographic factors), case-specific inquiries are often necessary to determine whether a merger will promote or prevent innovation. A merger may lead to efficiencies in R&D, but reduced rivalry and greater market power may slow the post-merger rate of technological change. In some cases, firms seeking to merge claim dynamic efficiencies that can facilitate or encourage innovation; however, these are extremely hard to measure, and quantitative assessments do not yet appear to be feasible. Overall, the traditional framework for reviewing mergers is applicable to innovation-intensive markets, although some customisation is needed for defining markets and assigning market shares, assessing the significance of changes in market structure, giving proper weight to benefits reaped by consumers from innovation, assessing the ability of merging parties to exclude or restrict competitors, and designing appropriate remedies (OECD, 2003b).

Competition law is also concerned with the intersection of anti-trust and IPRs. Most agree that competition law should not be used to "bludgeon" IPRs, since this could stifle innovation. Compulsory licensing as an anti-trust remedy should be considered with caution and required only after a careful review and in the face of clear anti-competitive behaviour. In new areas such as biotechnology, the rapid growth and complexity of the industry call for caution by competition authorities, whose actions might have the unintended effect of discouraging innovation. For example, while collaboration between patent holders may present anti-competitive characteristics, it may also encourage pro-competitive behaviour, such as increasing access to goods, technologies, information and services. Indeed, a number of competition authorities are becoming more open to the use of collaborative mechanisms (OECD, 2005).[2]

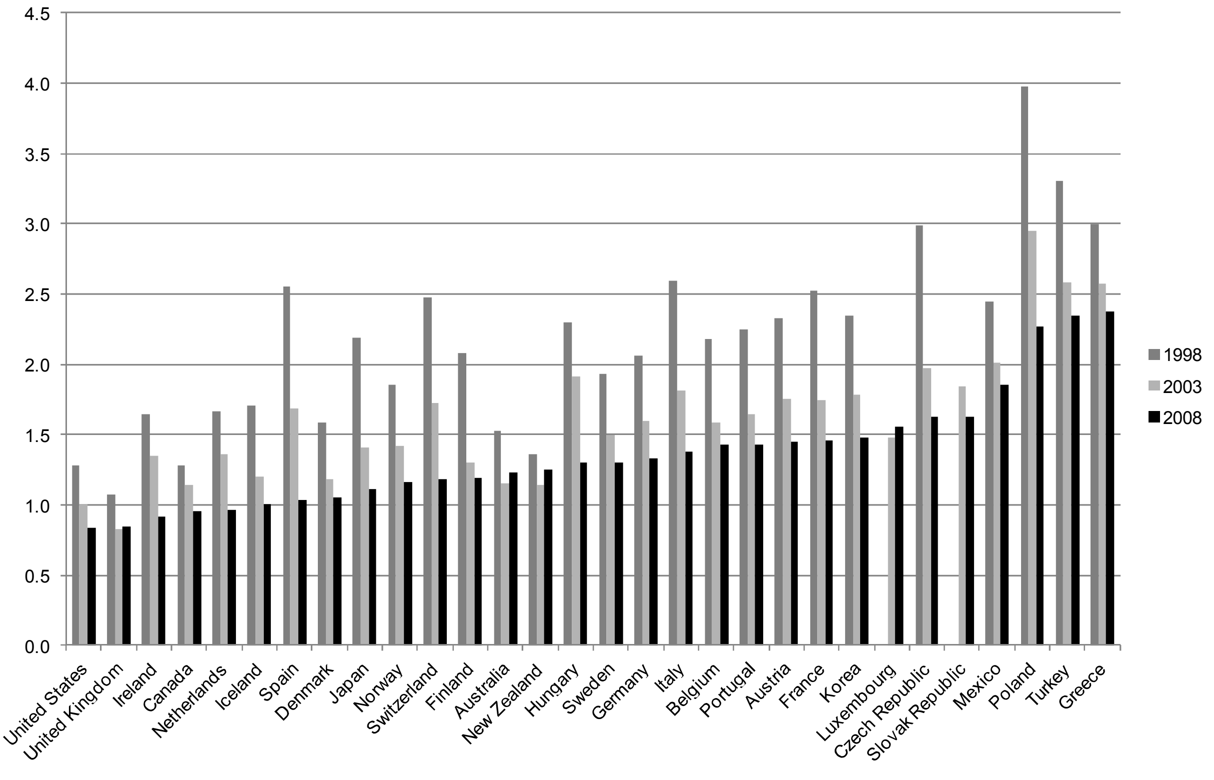
Empirical studies show that competitive product markets force companies to be more efficient and to increase labour or multi-factor productivity (MFP), for instance by adopting new technologies and being innovative (Wölfl *et al.*, 2009). Nicoletti and Scarpetta (2003) show that countries in which public ownership in the business sector is limited and barriers to entry are low are more successful at improving growth of MFP than countries with stringent anti-competitive regulation. More generally, regulation that limits competitive pressures tends to lower long-run productivity, and at the aggregate level the burden of regulation appears to be greater the further a country is from the technology frontier. The OECD's new "Competition Assessment Toolkit" can assist governments in reducing unnecessary restrictions on competition. The kit provides a general methodology for identifying unnecessary restraints and developing alternative, less restrictive policies that still achieve government objectives.

Of the many policy levers studied by Jaumotte and Pain (2005a), appropriate anti-competitive regulation was found to be the second most powerful incentive for raising business R&D spending. Conway *et al*. (2006) look at the knock-on effects of product market regulation in some sectors on other sectors in terms of the regulatory burden that firms face indirectly via the use of intermediate inputs from highly regulated sectors. They highlight the detrimental effect of regulation on labour productivity in non-manufacturing sectors and also in sectors using ICT. Finally, as a complement to industry-level analyses, Arnold *et al*. (2008) analyse the regulation-productivity link at the firm level. Their results suggest that burdensome regulations have been particularly harmful for an economy's ability to allocate resources to the most efficient firms and for productivity growth in firms operating close to the technological frontier. Other work covering 18 countries and 18 manufacturing industries, also found an unambiguous negative association between R&D intensity and indicators of non-tariff barriers and inward-oriented economic regulation (Bassanini and Ernst, 2002).

While overall levels of product market regulation in OECD countries have come down substantially over the past decade (Figure 4.3), several areas call for further reform (Wölfl *et al.,* 2009; OECD, 2010c). First, state control of businesses remains relatively strong in several countries, even excluding the recent increase in state ownership following the economic crisis. Second, while the reform process has advanced significantly in certain sectors, others still show scope for reform. For instance, restrictive regulations in the postal sector reflect a large share of public ownership of the incumbent and relatively little liberalisation of competitive activities. In professional services and retail trade relatively restrictive regulation reflects stringent access requirements and constraints on business conduct in professional services and persistently restrictive licensing for setting up retail outlets. *Going for Growth* (OECD, 2010c) provides recommendations for several OECD countries on areas in which further regulatory reform is warranted.

Figure 4.3. Evolution of aggregate product market regulation since 1998

Scale of 0-6 from least to most restrictive



Note: 2008 data refer to the beginning of 2008.

Source: OECD, Product Market Regulation Database; and A. Wölfl, P. Holler, M. Morgan and A. Worgotter (2009), "Ten Years of Product Market Reform in OECD Countries – Insights from a Revised PMR Indicator", *OECD Economics Department Working Papers*, No. 695, OECD, Paris.

Labour market regulations and industrial relations

The influence of labour market policies on incentives to innovate varies according to the type of industry and the wage bargaining systems in place (Bassanini and Ernst, 2002; OECD, 2006a). For most industries, not least in services, full exploitation of cost-reducing innovations will often require staff reduction or changes in the skill mix of the workplace. Stringent job protection raises the cost of such changes and reduce the profitability of innovations. Nevertheless, in periods of technological change, well-functioning labour markets are crucial. Affected workers should be given the support and the incentives they need to find new jobs or to retrain.

As noted in Chapter 3, in strengthening the impact of innovation, "high performance work practices and/or systems", based on innovation, high skills, organisational flexibility and trust, are generally linked to better outcomes – higher labour productivity, higher sales, positive employment performance and lower staff turnover, as well as stronger and more productive linkages with customers and suppliers. The key features of high performance workplaces are the organisation of work to exploit technology effectively and the premium placed on building and using intangible assets, most importantly technology and human resources, to use assets more effectively. Countries therefore need to ensure that firms are able to experiment with and adopt new forms of organisation that better meet their needs. Reform of regulatory structures to promote competition and innovation and to reduce barriers and administrative rules for new entrants and start-ups can yield considerable benefits.

Taxation and innovation

There are various links between the structure and levels of taxation in an economy and innovation. Tax systems finance public expenditures and are used to address social and economic objectives, such as equity. Taxes also affect the decisions of firms and households to save or invest in human capital, for example, and can have a bearing on innovative activity.

For firms, corporate taxes can distort factor prices, resulting in substitution between capital and labour and an inefficient combination of inputs that lowers total factor productivity (TFP). Reducing corporate tax rates and removing special tax relief can enhance investment by improving its quality (by reducing tax-induced distortions in the choice of assets) and increasing the return on innovative activities. Empirical evidence shows that firms that are in the process of catching up with the technological frontier are particularly affected by corporate taxes. This suggests that corporate taxes may have a particularly negative effect on innovation incentives for catch-up firms by disproportionately reducing their after-tax return to innovation. Greater certainty and predictability in the application of corporate income tax and reduced complexity and administrative costs may also lead to higher investment. To the extent that corporate tax reduces FDI and the presence of foreign multinational enterprises (MNEs), it can hinder technology transfers and knowledge spillovers to domestic firms (OECD, 2008c).

Tax policies targeted to small businesses, especially those engaged in innovative activities, include favourable depreciation rules for capital expenditures and reduced capital gains taxes after the initial public offerings of qualified small business stock. These targeted tax preferences may offset the high tax compliance costs relative to their size that small businesses face (Slemrod, 2004) and are considered a more market-oriented approach (than direct support measures) for dealing with market failures and information asymmetries that might be particularly burdensome for young and often small innovative companies. In many countries R&D tax credits are more generous for smaller firms (*e.g.* Belgium, Canada, the Netherlands, Norway and the United Kingdom), since the problems of asymmetric information that affect financing of R&D activities by banks or outside investors are likely to be particularly great for young innovative companies.

Some countries offer preferential tax treatment to young innovative companies (Box 4.1). These additional tax measures include immediate cash payment rather than use of carry-forward and carry-backwards provisions (Canada, France, Norway and the United Kingdom); exemption from social costs for all researchers and technicians (Belgium and France). Within the European Union, governments can give extra incentives to firms less than six years old which spend more than 15% of their total revenues on R&D across all regions and sectors without breaking EU state aid rules.

Box 4.1. Young innovative companies in France

France's *Jeunes Enterprises Innovantes* (JEI), programme, introduced in 2004, targets young companies that are less than eight years old, have fewer than 250 employees and less than EUR 50 million in turnover, devote at least 15% of their expenditures to R&D and are independent and not listed on a stock exchange. The measures included in the JEI programme are *i)* exemption from social costs for all R&D-related employees in the broad sense, *i.e.* researchers, technicians, patent attorneys, but also managers and those involved with testing; *ii)* exemption from corporate income tax for the first three years and a 50% discount for an additional two years up to a ceiling of EUR 200 000 over 36 months; and *iii)* possible relief from local taxes on properties and buildings for seven years. The JEI and the research tax credit (CIR) are not mutually exclusive.

Source: www.industrie.gouv.fr/enjeux/innovation/jei.html.

Taxes for a greener and innovative economy

It is widely accepted in the OECD area that the use of economic instruments, in particular environmentally related taxes and tradable permits, is generally preferable to regulation for addressing environmental issues such as excessive CO_2 emissions. More rigid measures, such as technology-prescriptive regulations, limit the availability of firms' options for addressing environmental pressures, while market-based instruments, such as carbon taxes or tradable permits, provide a greater range of potential options for individual agents.

Environmentally related taxes levied directly on harmful polluting activity may be an efficient means to encourage pollution abatement. Depending on their design, environmentally related taxes may encourage various abatement approaches on the part of firms, including non-technology based approaches (*e.g.* output reduction, fuel switching), wider use of existing technologies, and the development of new green technologies through R&D. Indeed, in many areas, innovation is central to addressing ambitious environmental challenges in a cost-effective way.

The interaction of environmentally related taxation and R&D support (discussed further below) forms an interesting intersection of two externalities. In general, environmentally related taxes are intended to address pollution externalities. However, the development of new green technologies may be hindered by an environmental tax that addresses pollution externalities but not R&D spillovers. Support for R&D (*e.g.* R&D tax credits) may be used to help encourage R&D activity, for green and other types of innovation, by compensating for spillovers effects. At the same time, R&D tax credits alone may provide limited incentive to undertake R&D on new green technologies (particularly if there is little incentive for adoption).[3] However, in combination, these two instruments may provide strong incentives for green innovation.

Combined use of environmental taxes and targeted R&D support may also be considered when addressing international competitiveness concerns. In particular, officials may be confronted with business concerns over a loss of international competitiveness resulting from a high environmental tax burden if such a tax is not levied elsewhere. Policy makers may therefore be encouraged to use some percentage of environmental tax revenues to partially compensate affected sectors; however, maintaining incentives to abate that arise from environmental taxes, while not over-compensating polluting sectors *vis-à-vis* less pollution-intensive sectors may be difficult. Implementing a targeted R&D tax credit to encourage the development of lower-cost abatement technologies, while also helping overcome the spillover effect, may help address competitiveness concerns while also supporting environmental objectives and innovation.

At the same time, radical or breakthrough innovations (*e.g.* nuclear fusion in a carbon-free economy) may be required in certain cases to achieve a desired environmental objective at reasonable cost. Long time horizons, policy and market uncertainty, large research costs and financing constraints may impede private research efforts in these areas, even with environmentally related taxes and R&D tax credits. Therefore additional financing arrangements aimed at basic research might be needed, such as direct public funding or incentives to firms to co-operate with universities or public research institutions.

Public- and private-sector instruments to facilitate innovation

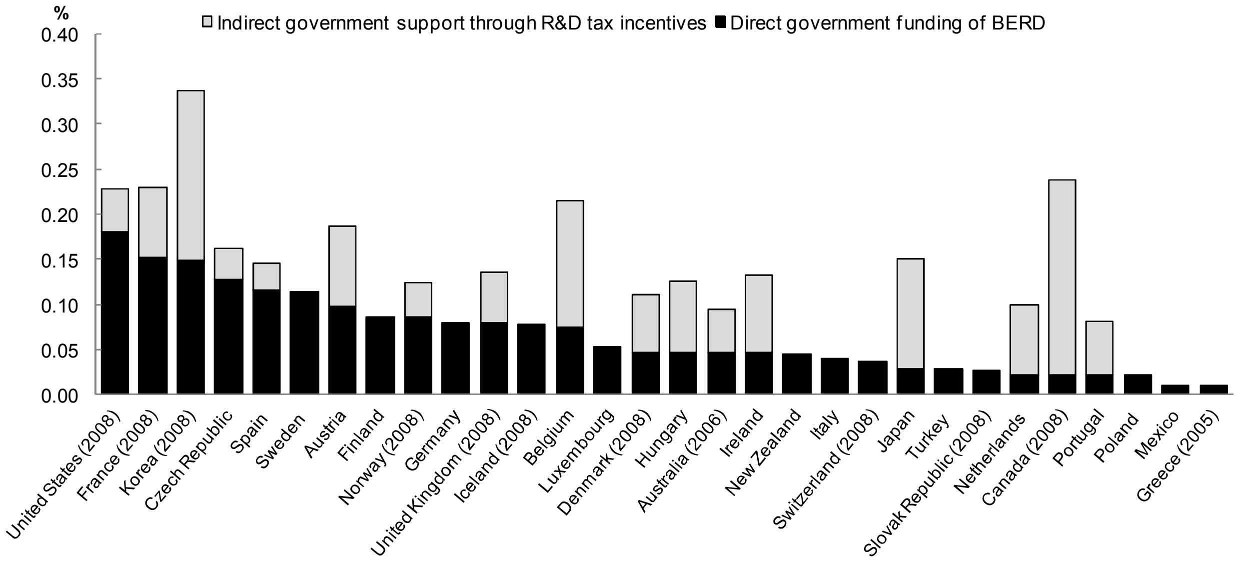
The public sector plays an important role in fuelling access to finance for entrepreneurs. In the United States, the federal government launched the Small Business Innovation Research programme in 1958. In Finland the first public investment vehicle was created in 1967 (FORA, 2009). The recent financial crisis and the resulting scarcity of financial resources have also heightened policy makers' attention to venture capital. In addition to public funding, tax incentives are increasingly used to encourage high-growth companies: young innovative company schemes, tax credits for angel investors and reduced capital gains taxes for investors.

Clearly, public funds should only be utilised if a tangible or imminent market failure in the private sector is evident and schemes should be designed in line with the market needs as much as possible. Public funding should be channelled through existing market-based systems and adopt a clear market approach. In addition to providing finance for companies, policy makers need to focus on the development of the venture capital market itself. The sustainability of (private) venture capital markets in several countries is hampered by insufficient exit opportunities for investors. In order to assess the accuracy and efficacy of government intervention, a periodic review should take place and adjustments made as needed.

Public-sector financing instruments to facilitate innovation include direct financial support, tax incentives and credit guarantees, each of which has specific advantages and disadvantages. Direct grants are the dominant form of public financial support to business R&D in many countries (Figure 4.4). While tax credits are market-based firm-level policy tools that reduce the marginal cost of R&D activities and allow private firms to choose which projects to fund, direct R&D grants/subsidies represent project-specific support tools. They offer public bodies the possibility to target projects perceived to have high marginal social rates of return (David *et al.*, 2000). Governments also provide direct lending to young and small businesses or start-up subsidies for the unemployed.

Figure 4.4. Direct and indirect government support for business R&D (BERD), 2008 (or latest available year)

As a percentage of GDP



Notes: The estimates of R&D tax expenditures do not cover sub-national R&D tax incentives. The Austrian estimate covers the refundable research premium but excludes other R&D allowances. The estimate for the United States covers the research tax credit but excludes the expensing of R&D. For Turkey, a calculation by the Scientific and Technological Research Council of Turkey indicates foregone tax revenue of TRY 593 million (or 0.06% of GDP) in 2008. Italy and Greece offered R&D tax incentives in 2007, but estimates of the related foregone tax revenues are not yet available.

Source: OECD (2010), *Measuring Innovation: A New Perspective*, OECD, Paris, based on OECD R&D tax incentive questionnaire, January 2010; and OECD, Main Science and Technology Indicators Database, March 2010.

The likelihood of financial constraints is especially high for (potential) new entrants into the research process, since they have no history of successful research and often only limited means of internal finance. Credit constraints for these firms are due to risks arising from information asymmetries between lenders and borrowers. Lenders are unable to separate worthy from unworthy businesses and an increase in the interest rate charged by the lender may only increase the share of high-risk firms in the pool of borrowers (adverse selection) since only they would be willing to pay the high rate to obtain a loan. Moreover, it is hard for lenders to be sure that once the loan is obtained, entrepreneurs will not take excessive risks or misuse the funds (moral hazard). One way for lenders to overcome the problems associated with information asymmetries is to require collateral. This helps lenders to screen borrowers and reduces adverse selection problems but also moral hazard because in case of misuse borrowers would lose their collateral. However, it may not be possible for entrepreneurs and young innovative firms to provide collateral, especially if their main assets are intangible. Such firms are thus likely to be credit-constrained, independently of their project quality and growth potential.

Easing access to finance for new and innovative small firms involves both debt (in most cases the main source of external funding for all enterprises, including innovative ones) and equity finance. In the current economic context, the financial system's fading support for firms – and for new entrants in particular – is a major source of concern. Aversion to risk and the lack of exit opportunities for investors such as banks, business angels and venture capital firms are drying up many sources of seed, early-stage and growth capital.

Debt financing involves the acquisition of resources with an obligation of repayment; the investor does not receive an equity stake. It includes a wide variety of financing schemes: loans from individuals, banks or other financial institutions; selling bonds, notes or other debt instruments; and other forms of credit such as leasing or credit cards (OECD, 2008d).

Direct public support

Direct subsidies may raise the private marginal rate of return to R&D and relieve firms of (some) R&D and innovation costs, thus modifying their marginal cost of capital. They may also raise R&D efficiency, improve the risk-return pattern on other projects, allow firms to conduct further R&D projects at lower cost, and help firms to update their know-how. This may in turn result in knowledge spillovers that ultimately benefit other firms (Klette *et al.*, 2000). In addition, direct R&D subsidies may also have positive indirect effects at the micro level. For example, in the case of (small and/or young) firms, government R&D funds may have a certification effect (Lerner, 1999), thus lowering these firms' external cost of capital.

Normally grants are provided to firms in a competitive manner rather than automatically. This is especially the case for innovation activities (*e.g.* the US Small Business Innovation Research [SBIR] programme). This selection process has an additional positive effect for firms that receive support as it provides a screening device for lenders and therefore goes some way towards solving the adverse selection problem (Takalo *et al.,* 2007; Takalo and Tanayama, 2010).

Some studies suggest, however, that public support for R&D may crowd out private investment. This may occur when public funds are provided for R&D that firms would undertake even in the absence of public support or when limited resources, such as scientists, are displaced from use in privately funded to publicly funded projects (Lach, 2002). In sum, the findings are mixed. Some studies have provided evidence of additionality while others have found that direct subsidies partially or fully crowd out private investment (Garcia-Quevedo, 2004; Cerulli, 2008).

Recent developments in this area aim at applying more market-friendly approaches that avoid "picking winners" but encourage competitive selection of investments that are likely to have the highest social return. This has been accompanied by a move away from unspecific, single-firm, project-based grants to more sophisticated designs, leaving basic public support to tax incentives for R&D, and towards consolidation and streamlining of public support schemes. These developments have given rise to a reconfiguration of the overall policy mix in many countries.

R&D tax provisions

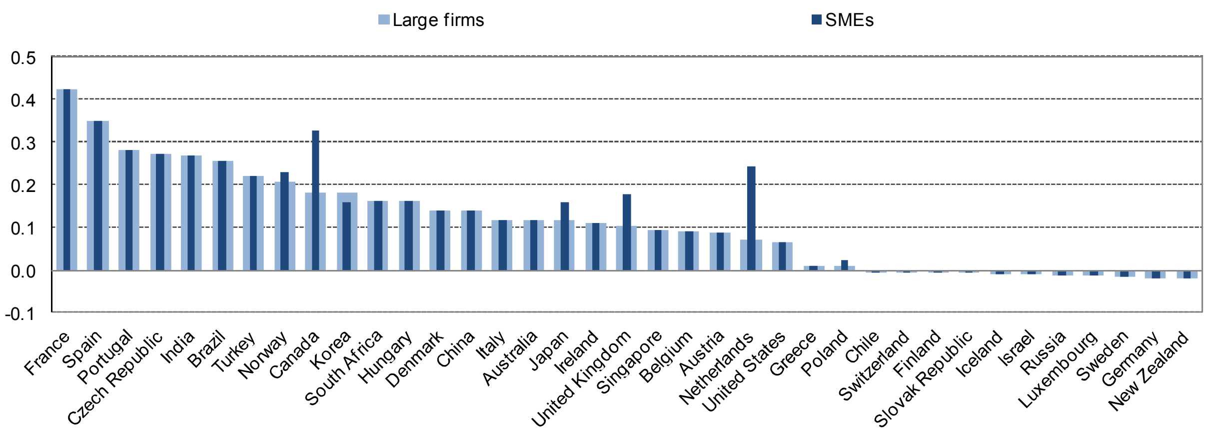
Tax provisions for R&D are widely used as a policy measure to foster private investment in innovation in OECD countries. R&D involves inputs such as labour (*e.g.* the wages of scientists), materials (*e.g.* test tubes), machinery (*e.g.* microscopes), buildings (*e.g.* laboratories), overhead costs (*e.g.* utilities or salaries and wages for support staff, marketing expenses), licensing costs of tangible and intangible capital (*e.g.* software) and costs for services (*e.g.* external consultation regarding the feasibility of the R&D project). The characteristics of these inputs differ: they may be considered either current expenses or capital investment and they may receive different tax treatments.

Tax treatment of R&D expenditure includes immediate write-off of current R&D expenditures and various types of tax relief, such as tax credits or allowances against taxable income, and depreciation allowances. Countries may:

- levy a reduced corporate income tax rate on profits generated by intangible investments;
- implement accelerated tax depreciation allowances, immediate expensing of R&D investment or allow an additional deduction;
- provide assistance for the financing of R&D investment by allowing for more favourable interest deduction arrangements; and
- reduce labour taxes on gross earnings of employees involved in the creation of intangibles (OECD, 2009c).

As of 2008, 21 OECD countries had provisions for tax credits for R&D, up from 18 in 2004. However, the scheme introduced in New Zealand in 2008 was discontinued in 2009. France and Spain provide the largest subsidies and make no distinction between large and small firms (Figure 4.5). Canada and the Netherlands are more generous to small firms than to large ones. Emerging economies are also using these policy instruments to encourage R&D investments. Brazil, the People's Republic of China, India and South Africa provide a generous and competitive tax environment for investment in R&D (OECD, 2009d).

Figure 4.5. Tax subsidy rate for USD 1 of R&D, large firms and SMEs, 2008



Note: The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Source: OECD (2009), *Science, Technology and Industry Scoreboard 2009*, OECD, Paris.

The case for R&D tax credits is not always clear. The policy may be questioned on a number of grounds, including the fact that R&D credit programmes can impose a significant administrative burden on governments (*e.g.* to identify qualifying R&D activity), depending on the efficiency of the bodies administering the programme (*e.g.* tax administration) and the design of the instrument. The market failure argument is also sometimes difficult to translate into active policy. Spillover benefits are generally hard to measure, as is the additional (incremental) amount of R&D activity that is triggered by tax relief. It is also difficult to ensure that tax relief is directly linked to the qualifying R&D activities.

Nevertheless, R&D tax credits may be more attractive than R&D discretionary grants, to the extent that fewer public resources are needed to administer the programme. R&D performers may also be better able to decide the best use of funds under a tax incentive programme. However, depending on the robustness of auditing practices for R&D tax claims, the scope for subsidising non-targeted R&D may be greater than with a discretionary grant scheme. R&D tax credits may also be more attractive than greater tax allowances or deductions for qualifying current and capital R&D costs, in that the amount of relief provided is not fixed to the personal or corporate income tax rate. Volume-based measures offer certain advantages relative to "incremental" tax credits, despite the generally larger windfall gains associated with the former. At the same time, even with incremental credits, much of the tax support may go to R&D that would have been undertaken in the absence of the tax relief.

In assessing the overall amount of tax relief in support of R&D, it is important for policy makers to consider not only the tax treatment of R&D expenditures, but also the tax burden on returns to R&D investment. In certain cases, firms performing tax-assisted R&D can largely avoid domestic corporate income tax on returns to R&D such as patents. For example, through special cost-sharing agreements between domestic parent companies and foreign subsidiaries and the application of non-arm's-length prices on inter-affiliate transactions (so-called "transfer prices"), profits from the exploitation of R&D may be shielded from domestic home country tax. Such structures may also be used to artificially reduce host country taxable profits earned on other business activities. This can occur if a foreign company that holds the IP licenses it to its parent or loans capital derived from offshore licensing activity to its parent, and charges non-arm's-length prices (OECD, 2009c).

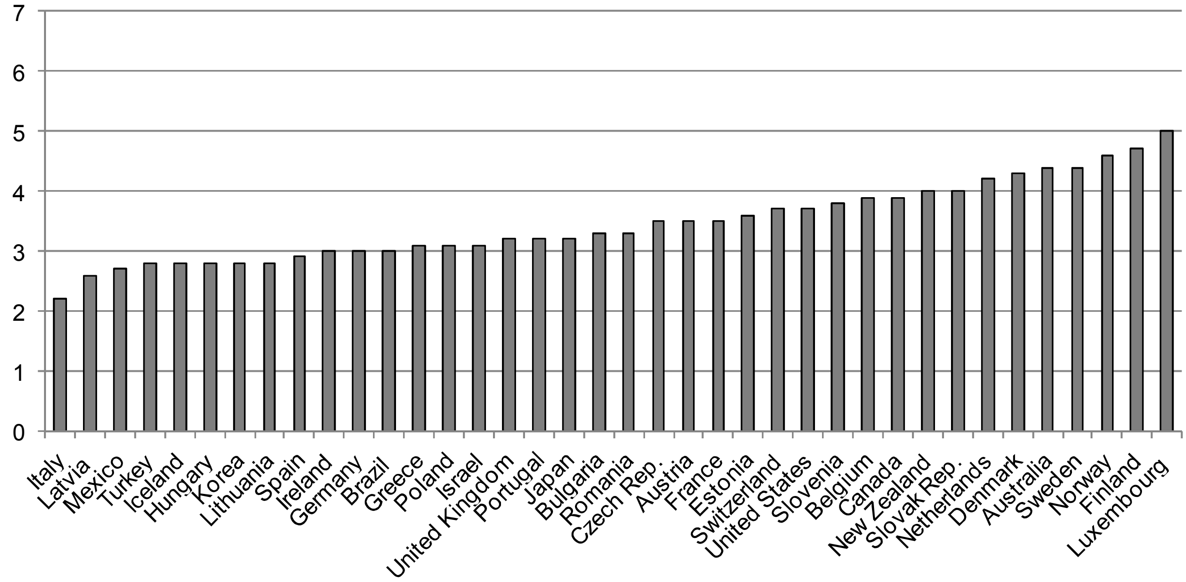
Credit guarantees

Firms have recently found it more difficult to get loans (Figure 4.6). In the wake of the financial crisis, banks have become less ready to approve companies' loan applications. Ease of access to loans is also perceived rather differently across countries, suggesting important differences worldwide in companies' ability to attract financial resources.

Credit guarantees are a type of public support programme which facilitates access to external finance. They serve as a form of insurance to lenders against the risk of default. In particular, they can alleviate problems deriving from young firms' lack of collateral and may therefore lead to higher start-up rates and higher growth for young innovative firms. They may also be socially desirable since they can foster relations between banks and entrepreneurs (Petersen and Rajan, 1995).

Figure 4.6. Ease of access to loans, 2009

1 = impossible, 7 = easy



Note: The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Source: OECD (2009), "Measuring Entrepreneurship: A Collection of Indicators", based on World Economic Forum, *Global Competitiveness Report 2009*.

Credit guarantees do not solve the problem of adverse selection since they do not help identify "worthy" borrowers. They do not necessarily lower the *ex post* risk of moral hazard among borrowers and they may even raise that risk among lenders, since the programme lowers the costs of default by insolvent firms. Two features of credit guarantee programmes may affect their effectiveness in this respect. The first is the payment of an insurance premium by the borrower. It should be high enough to discourage unconstrained firms from applying but low enough for constrained firm to be able to apply. The second is the share of the loan guaranteed by the programme. A higher share might allow more constrained borrowers who lack collateral to get more external financing, but it might have a negative impact on lenders' screening and monitoring efforts. Therefore, credit loan guarantees may increase the number of borrowers who receive finance, but may also raise the bankruptcy rate among those who do did not receive the guarantee, both because of adverse selection and moral hazard.

Evidence on the effectiveness of these widely used programmes is scarce and mixed. Evaluations have mainly focused on additionality, *i.e.* the extent to which the programmes have benefited firms that would not otherwise have been able to obtain loans, and on the level of default. Recent evidence from French firm-level data stresses differences in the effectiveness of these programmes for the growth of newly founded firms and the creation of new firms (Lelarge *et al.,* 2008).

Public-private partnerships

All countries have limited resources and some degree of prioritisation is needed to focus efforts, notably on areas that may have particularly large social returns. Public-private partnerships (P/PPs) for R&D and innovation offer a framework for the public and the private sectors to join forces in areas in which they have complementary interests but cannot act as efficiently alone (OECD, 2004). They have become increasingly popular in R&D and innovation because they can effectively address shortcomings in innovation systems (*e.g.* the lack of interaction between industry and public research and a lack of long-term, "strategic" co-operation); increase the efficiency of public policy in addressing certain market failures that affect innovation processes (*e.g.* the high costs and risks of pre-competitive research); and address the new needs of society, especially when this requires long-term multidisciplinary research (see Chapter 7).

Deriving such potential benefits challenges governments' ability to use P/PPs for the right purposes and manage them efficiently. P/PPs are being used in the context of priority areas, including R&D for societal challenges. Competitive calls are effective means to reveal information on new, innovative combinations and emerging forms of co-operation of various types of actors. Overall, P/PPs help to increase the responsiveness of innovation policy to changing business needs.

Entrepreneurship

Entrepreneurship is increasingly recognised as an important driver of economic growth, productivity, innovation and employment, and it is widely accepted as a key aspect of economic dynamism (OECD, 2009a). Entrepreneurs fuel innovation by developing new or improving existing products, services or processes. New technologies and their applications stimulate the growth of new firms and improve the efficiency and productivity of existing ones. However, the links between entrepreneurship and its potential impacts are not fully understood. This knowledge gap largely reflects the lack of internationally comparable definitions for, and indicators on, entrepreneurs, entrepreneurship and entrepreneurial activity (Box 4.2).

Box 4.2. Defining and measuring entrepreneurship

The OECD, with the support of the Kauffmann Foundation, launched the Entrepreneurship Indicators Programme (EIP) to develop standard definitions and concepts for the collection of policy-relevant entrepreneurship statistics. Eurostat became a partner in this activity in 2007 and the EIP is now a joint OECD-Eurostat Programme.

The following definitions of entrepreneurship have been established by the EIP.

- *Entrepreneurs* are those persons (business owners) who seek to generate value through the creation or expansion of economic activity, by identifying and exploiting new products, processes or markets.
- *Entrepreneurial activity* is enterprising human action in pursuit of the generation of value through the creation or expansion of economic activity, by identifying and exploiting new products, processes or markets.
- *Entrepreneurship* is the phenomenon associated with entrepreneurial activity.

Source: OECD (2009), "Measuring Entrepreneurship: A Collection of Indicators", OECD, Paris.

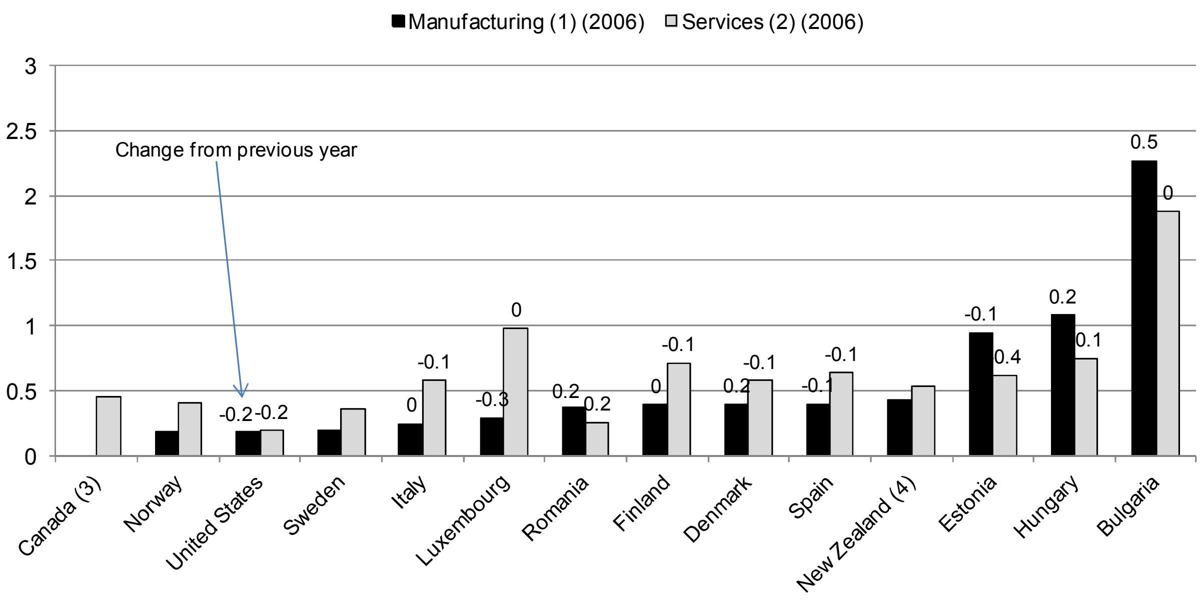
Rapid technological change and the constant need for businesses to adapt have drawn increased attention to the dynamism and flexibility of entrepreneurship. Innovative firms need access to international markets not only to increase their revenue but also to develop the knowledge, skills and networks necessary for long-term growth and competitiveness. Tariff and non-tariff trade barriers can hinder entrepreneurship by limiting opportunities for internationalisation, which is important for enterprises of all sizes – large firms expanding across borders, SMEs integrating global supply chains and entrepreneurial ventures seeking high growth.

In an effort to build the skills needed for operating in an international environment and help SMEs reach their growth potential, entrepreneurship policies have broadened their scope to include the establishment of one-stop shops, training programmes, networking activities, counselling services and support for internationalisation. While the provision of these services is growing, it is not evident that they are always reaching the target audience or providing an adequate quality level of services.

At present, there are few young fast-growing enterprises, or gazelles (a term first used by Birch, 1979), in most countries (Figure 4.7), although they make an important contribution to GDP and employment growth. Research has shown that new and young firms have been the primary source of new jobs in the United States over the past three decades (Stangler, 2009). Analysis of US Census Bureau data has shown that companies less than five years old created nearly two-thirds of net new jobs in 2007 (Haltiwanger *et al.,* 2009).

Figure 4.7. Share of gazelles (employment definition), 2006

As a percentage of all enterprises with 10 or more employees



Notes: 1. Mining and quarrying; Manufacturing; Electricity, gas and water. 2. Wholesale and retail trade; Hotels and restaurants; Transport, storage and communications; Financial intermediation; Real estate, renting and business activities. 3. Employer enterprises with fewer than 250 employees. 4. 2008.

Source: OECD (2009), *Main Science and Technology Indicators 2009/1*, OECD, Paris.

Although the importance of high-growth entrepreneurs is widely acknowledged, governments face a number of challenges for designing policies explicitly aimed at high-growth entrepreneurship (and which address more than the business environment). In particular, it is difficult to identify and therefore target specific individuals/start-ups with growth potential.

The dynamics of firm creation

The process of entry and exit of firms, *i.e.* the process of creative destruction, is an important element of countries' aggregate employment and productivity growth (OECD, 2009e; Bartelsman *et al.*, 2009a). Market selection leads to the exit of less productive firms and the success of the more productive. Young firms play a crucial role in these dynamics, which shape aggregate productivity growth.

Experimentation, learning and selection underlie young firms' dynamics, which are characterised by high rates of gross job creation and destruction. Young firms are more likely to exit and have high levels of jobs churning; but those that survive grow more rapidly than mature firms. This "up or out" dynamics (Bartelsman, *et al.*, 2009a; OECD, 2009e) has been found in several countries and suggests that firm creation and young firms' dynamics are important for understanding and quantifying the processes underlying countries' differences in aggregate employment and productivity growth. For example, a recent study for the United States shows that business start-ups account for roughly 3% of total US employment in any given year (relative to the average net flow of 2.2% a year).

The extent to which creative destruction contributes to growth differs across countries, however, even when taking into account differences in the sectoral composition of economies. Existing evidence highlights large differences in entry rates (size of firms at entry) but also in the post-entry performance of young firms. Such differences are likely to reflect the role of regulatory and institutional frameworks and market structure, which will affect reallocation dynamics in various ways. For example, high barriers to entry, subsidies to incumbents or policy measures that can delay the exit of failing firms may stifle competition and slow the reallocation process relative to an economy without barriers (Bartelsman *et al.,* 2009a). Local regulations, agreements between incumbent market players (suppliers or distributors), limited access to local input resource, bankruptcy laws and labour market regulations also contribute to reducing the rate of entry of new firms (*i.e.* entrepreneurship). These barriers affect competition and entre-preneurial activities in a given sector and hence have a strong influence on industrial renewal and innovation (Aghion *et al.*, 2005).

In all countries the contribution of new firms to productivity growth and employment growth is much stronger and positive in higher-technology industries, and there is extensive evidence that entrepreneurs are particularly crucial in industries with technological opportunities. Examples of such industries are those that are addressing global challenges such as climate change (clean technologies; renewable energies, etc.) and health (*e.g.* bio-technology).

The effect of the economic crisis

In November 2009, the OECD published the first indications of how the economic slump had affected entrepreneurship in a number of countries in 2008 and into 2009 (Figures 4.8 and 4.9). The report showed that firm formation had declined and exits had increased (OECD, 2009a), with potentially significant implications for job creation. While exits are a normal part of business activity, the study shows a concurrent increase in exits and decrease in business formation throughout the OECD area. This highlights the urgency of encouraging and supporting business start-ups to create new jobs and sustain a worldwide economic recovery.

Figure 4.8. Firm entries, 2005 to first half 2009

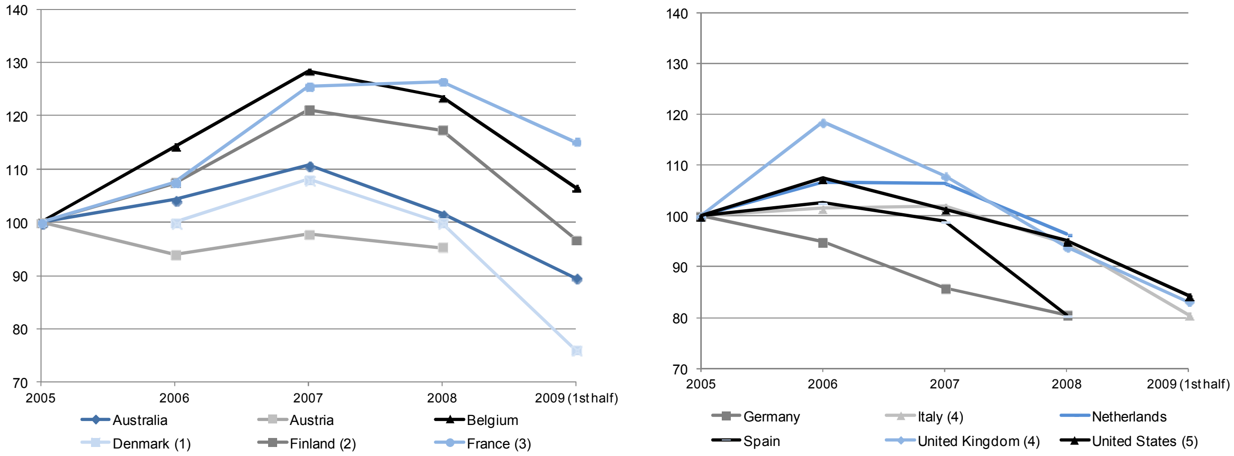
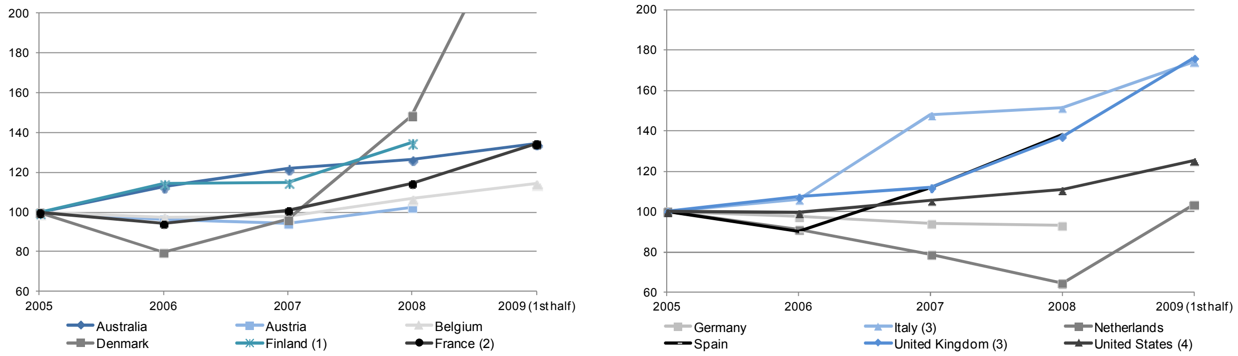


Figure 4.9. Firm exits, 2005 to first half 2009



1. Data for Denmark only available from 2006 onwards (hence 2006 = 100). 2. Data refer to the first quarter of each year. 3. Data for France exclude registrations of self-employed in order to mitigate the bias in the 2009 results as a consequence of a change in data collection (régime de l'auto-entrepreneur). 4. 2009 data based only on the first quarter. 5. Data refer to first quarter of each year.

Source: OECD (2009), *Main Science and Technology Indicators 2009/1*, OECD, Paris.

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The effects of the crisis are mixed. On the one hand, evidence suggests that recessions provide firms with an opportunity to restructure at low cost (Hall, 1991; Davis and Haltiwanger, 1990; Cooper and Haltiwanger, 1993; and Caballero and Hammour, 1994). On the other hand, the "liquidationist" view would suggest the existence of a silver lining because recessions facilitate the reallocation of resources from least to most productive units. However, a surge in job destruction may not be matched by a surge in employment creation (Caballero and Hammour, 2005). In previous crises the surge in destruction has not been matched by a surge in employment or business creation (Davis *et al.,* 1996). However, it is still too early to assess the long-term impact of the current crisis.

The regulatory burden

Market entry regulations

Certain aspects of regulatory frameworks matter particularly for entrepreneurship, as they have a disproportionate impact on start-ups and new firms: they are business registration for new firms, bankruptcy/insolvency, taxation and labour market regulations.

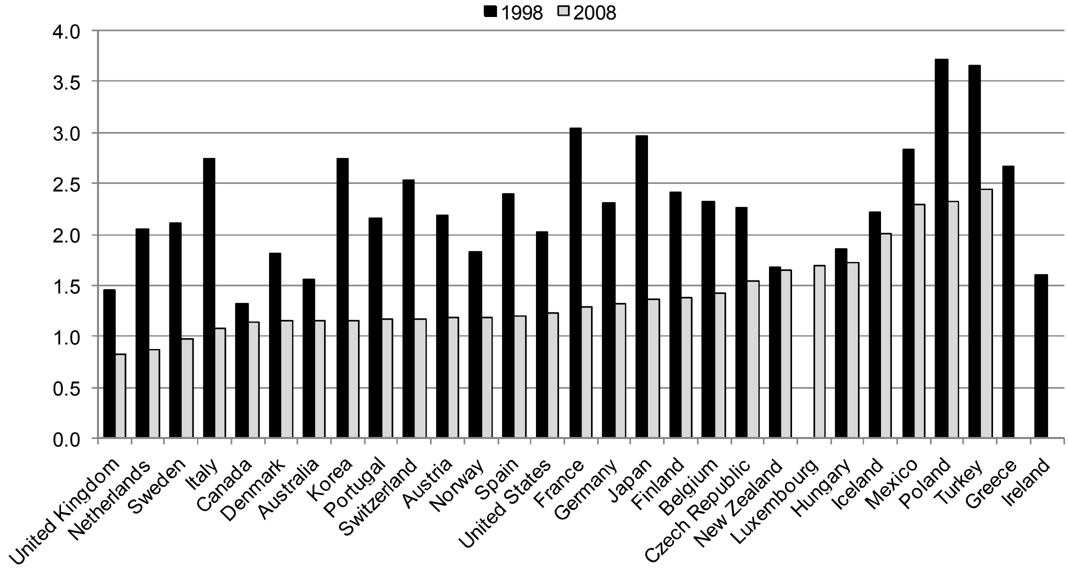
New and small firms pay a disproportionate tribute to red tape, which imposes significantly higher burdens on them than on larger firms (OECD, 2001). The monetary costs incurred by the entrepreneur for opening a business (Fisman and Sarria-Allende, 2010; Klapper *et al.*, 2006) and the delays caused by entry regulations (Ciccone and Papaioannou, 2007) are associated with lower entry rates. Countries in which the legal status to operate a firm is obtained more cheaply and quickly see significantly higher entry rates in industries that should naturally have more firm entry (Klapper *et al.*, 2006; Ciccone and Papaioannou, 2007).

Market entry regulations affect not only the entry rate of new businesses, they also have an impact on the average size of entrants and the growth of young firms. They may force new entrants to have a certain size and incumbent firms in high-growth industries to grow more slowly (Klapper *et al.,* 2006). More generally, microeconometric cross-country evidence confirms that strict regulatory environments for both labour and product markets have a negative impact on business entry as they dampen the positive effects on entrepreneurship of social networks and business skills while amplifying the role of attitudes towards risk. These effects are particularly strong for "Schumpeterian entrepreneurs" who follow a business opportunity (Ardagna and Lusardi, 2008). Increases in product and labour market regulation are also associated with an increase in the size of the informal sector (Loayza *et al.*, 2006); this may affect the growth of young firms, especially in developing countries.

Figure 4.10 provides details on barriers to entrepreneurship in OECD countries. The data cover a broad definition of barriers, including administrative burdens to open a business, legal barriers to entry, bankruptcy laws, property right protection, investor protection and labour market regulations (Wolfl *et al*., 2009). As the figure shows, most countries have significantly reduced these barriers over the recent period, although large differences remain.

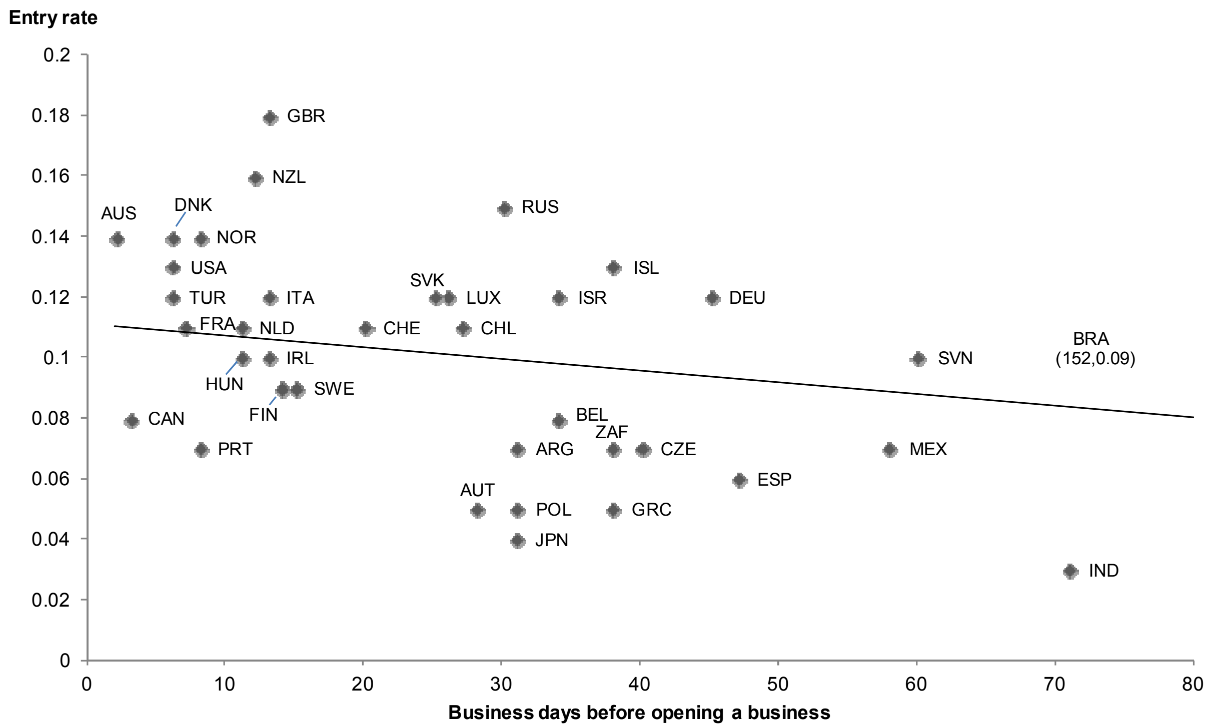
Figure 4.10. Barriers to entrepreneurship

Scale of 0-6 from least to most restrictive



Source: A. Wölfl, P. Holler, M. Morgan and A. Worgotter (2009), "Ten Years of Product Market Reform in OECD Countries – Insights from a Revised PMR Indicator", *OECD Economics Department Working Papers*, No. 695, OECD, Paris.

Figure 4.11. Number of days needed to open a business and entry rate, 2007 (or latest available year)



Notes: Data for Argentina, Belgium, Chile, Czech Republic, Finland, France, India, Indonesia, Israel, Norway and Poland refer to 2006. Data for Brazil, Germany, Japan, Luxembourg, Mexico, Netherlands, South Africa and the United States refer to 2005. Data for Greece refer to 2004. The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Source: OECD calculations based on World Bank *Doing Business* data and World Bank Group Entrepreneurship Survey 2008.

Large differences also still exist in the number of days required to start a business. The number of days estimated to be necessary to start a business has implications both for firm creation and for the informal economy. In developing countries in particular official licensing procedures often represent an important constraint on entrepreneurial activity, with implications in terms of opportunities for corruption (De Soto, 1990). Various technological means, including the use of electronic business registers, can help reduce these constraints and facilitate the switch from the informal to formal economy (Mullainathan and Schnabl, 2009; Klapper, Amit and Guillen, 2009). As Figure 4.11 shows, there is a negative correlation between the number of days that it takes to open a business and the entry rate of businesses, measured as the number of newly registered limited liability corporations divided by the number of total registered corporations. Streamlining procedures would appear likely to raise entry rates.

Cutting red tape to improve the quality of regulations is also important for facilitating business creation. This includes the use of guillotine laws to reduce unnecessary regulations and one-stop shops to facilitate access to information and reduce paperwork. To this end, countries have engaged in a wide range of programmes (OECD, 2003c, 2006b). Some have implemented programmes to compute the total cost of red tape, using the Standard Cost Model pioneered in the Netherlands and now widely diffused. In terms of regulation generally, but also more specifically tax administration, compliance, inspections, etc., targets for reducing red tape help facilitate the opening and management of SMEs.

Bankruptcy

For entrepreneurs the risk of bankruptcy and its costs are especially tangible during downturns. Figures from the Creditreform (2009) show that in 2008 corporate insolvencies in Europe (EU15 plus Norway and Switzerland) amounted to more than 150 000, *i.e.* on average 83 out of 10 000 businesses failed, a rise of 11% from 2007 when 135 000 filed for bankruptcy. In the United States, 40 000 firms filed for bankruptcy in 2008, an increase of 41% from the previous year. Japan had 12 700 bankruptcies and an increase of 12.7% relative to 2007.

More generally, bankruptcy rules play a key role in managing the risks of the entrepreneurial process and can help reduce the stigma of failure associated with bankruptcy. This often requires adjusting insolvency rules to allow for orderly closure or company restructuring, as these can affect entrepreneurs’ decision to open a business or engage in a risky investment.

Strong bankruptcy laws will hamper entrepreneurship as they place a greater burden on entrepreneurs in case of failure. At the same time, they imply a strong guarantee for investors and therefore make access to credit easier and cheaper and might increase entry. The expected impact of tougher bankruptcy rules is therefore uncertain, because of the opposing effects of the trade-off between the insurance against business failure and the credit supply effects of bankruptcy laws. Empirical evidence on the impact of bankruptcy laws on firm entry and entrepreneurship is scarce, and results from studies of individual countries are mixed. Recent cross-country evidence suggests that countries with less forgiving bankruptcy regimes have lower entrepreneurship rates (Peng *et al.,* 2009; Armour and Cumming, 2008). The impact of bankruptcy laws is also amplified by restrictions on access to limited liabilities such as minimum capital requirements. Recent evidence shows that the impact of stringent bankruptcy laws is much more severe in the presence of high minimum capital requirement for incorporation (Armour and Cumming, 2008).

The design of bankruptcy laws may also affect the rate at which failed entrepreneurs can start up a new business. In some countries entrepreneurs who have been bankrupted cannot start a new business before a certain lapse of time. The cost may be high: a study on the performance of Europe's fastest-growing companies shows that repeat entrepreneurs have higher turnover and employment growth than companies run by entrepreneurs who have never failed (Rowe *et al*., 2002).

Taxation

Through general taxes (personal income, corporate and capital gains tax rates, social security contributions) and targeted tax policies (tax incentives targeted to start-ups, young firms and SMEs), taxes and tax policy affect individuals' decision to engage in entrepreneurial activities. Taxes on business income affect after-tax returns on investment and therefore firms' investment decisions and potential entrepreneurs' decisions on whether to invest. The way gains and losses are treated in the tax system, non-linearities in the tax schedules and the extent of loss offset provisions also play a role in shaping the risk-taking behaviour of entrepreneurs. Limited loss offset provisions can discourage entrepreneurs from undertaking risky projects with potentially high returns, such as innovation, towards less risky activities with lower returns are effectively taxed at a lower rate (OECD, 2009c, 2009f; Vartia, 2008).

Finally, capital gains taxation also affects entrepreneurship. If entrepreneurial activity inherently generates more capital gains relative to other employment or investment choices, lower capital gains tax rates may increase entrepreneurial activity. Capital gains tax rates also affect the supply of venture capital to start-up firms (Poterba, 1989). However, exempting capital gains from taxation may create opportunities for tax avoidance and create unintended distortions (OECD, 2009f).

Cross-country studies on the impact of taxation on entrepreneurship are affected by the difficulty of calculating comparable tax rates. Djankov *et al.* (2008) calculate comparable tax rates that are applicable to the same standardised domestic firms in 85 countries in 2004. The findings show that an increase in the first-year effective corporate tax rate is associated with lower official entry rates and reduces business density. A recent study examines possible tax distortions created by personal and income taxation and social security contributions ("all in" tax rates) on two margins: the decision to move from dependent employment to self-employment and the decision between an unincorporated or incorporated legal form. This latter decision is likely to affect growth prospects of young business since incorporation is generally associated with easier access to outside capital. The report shows evidence from four OECD countries (United Kingdom, Sweden, Norway and New Zealand) for 2007 based on the impact of comparable all-in average statutory tax rates (ASTRs). The evidence shows that high level of personal income tax and lower level of capital gains tax and of corporate tax are associated with higher level of entrepreneurship.

Labour market regulations

Labour market regulations also affect entrepreneurship. They affect an individual's choice to become an entrepreneur since they affect the degree of risk involved. Labour market regulation and benefits associated with paid employment may make employed work a much less risky option than self-employment. At the same time, strict hiring and firing rules, minimum wage provisions and administrative extensions of collective agreements increase the adjustment costs of potential entrepreneurs, who might therefore be discouraged from becoming employers. Moreover, labour market regulations, if they apply to firms above a certain size, may distort entrepreneurs' incentives to grow beyond that threshold. Empirical work based on cross-country harmonised firm-level data shows that stringent employment protection legislation (EPL), such as strict hiring and firing rules, slow down reallocation via entry and exit of firms (*e.g.* Haltiwanger *et al.,* 2008; OECD, 2009e, Chapter 2) and is negatively correlated to job entry (Autor *et al.*, 2007, for the United States).

Labour market regulations are also likely to affect the growth of young innovative firms and their investment decisions. EPL is negatively associated with productivity (*e.g.* Bassanini *et al.*, 2009; Bartelsman, Perotti and Scarpetta, 2008) and discourages risky and innovative investment because of high firing costs in case of failure (Bartelsman and Hinloopen, 2005; Bartelsman, Gautier and de Wind, 2009). The costs are likely to be particularly important in sectors of rapid technological change which require quick adjustment, such as ICT sectors (Samaniego, 2006).

Information on the effect on the creation of young and innovative firms of policies that restrict labour mobility of skilled workers is scarce. Recent US evidence suggests, however, that legal constraints on mobility – *e.g.* employee non-compete agreements – affect inventors who specialise in narrow technical fields (Marx *et al.,* 2009). The threat of legal proceedings can prevent employees from finding employment at a new employer and also makes it difficult for start-ups to build experienced teams quickly. This might also discourage potential entrepreneurs from starting a business given potentially high legal costs in case of a lawsuit.

Idiosyncratic features of countries' social security systems may also affect workers' incentives to engage in entrepreneurial activities. Recent evidence suggests entrepreneurs are likely to have worked as employees and are therefore likely to be affected by the design and transferability of health insurance and of social security contributions. This issue has not yet been widely explored. US evidence on the possible "entrepreneurship lock" due to the financial and health costs associated with losing employer-based health insurance remains scarce and is not conclusive although recent empirical evidence seems to suggest that such a lock exists (Fairlie *et al.,* 2008). This evidence therefore suggests the importance of transferability of social security contributions nationally and internationally to facilitate mobility.

The role of demand for innovation

In many OECD countries there is growing recognition that traditional supply-side innovation policies – despite their importance – cannot on their own improve innovation performance and productivity. Demand-pull theories suggest that the ability to produce innovations is often widespread and flexible but requires market opportunity (*i.e.* demand). For example, innovative solutions for global challenges such as climate change and energy security are hampered not only by technological barriers but also by the lack of supporting market conditions. Getting prices right, as in the case of climate change, or reforming regulations to foster new market opportunities are among the most powerful tools that can be used to strengthen markets for innovative products and services.

Demand-side policies can involve a range of policy instruments from procurement to standards setting, require highly specialised knowledge and competencies, as well as good alignment of the incentives of the different stakeholders (Box 4.3). Consumers have also become an important source of demand for innovation.

Box 4.3. Examples of demand-side innovation policies

Demand-side policies are attracting increased attention in both OECD and non-member economies. They operate at the tail end of innovation cycle and often involve regulations, standards, pricing or public procurement. The following are examples of demand-side initiatives that specifically target demand for innovation.

EU: The European Commission's Lead Market Initiative (LMI) identifies e-health, protective textiles, sustainable construction, recycling, bio-based products and renewable energies as areas in which a combination of procurement, regulations and standards can strengthen the competiveness of leading firms in these markets.

Finland: The national innovation funding agency, Tekes, finances public procurement of innovation to lower risks associated with the development of innovative goods and services. In the first stage, planning of procurement, the government funds between 25% and 75% of the project's total expenses. In the second stage, procurement or implementation, Tekes provides financing support for the procurer and for suppliers' R&D and innovation expenses.

France: Article 26 of the French Economic Modernisation Act of March 2009 promotes procurement of innovation from SMEs. It reserves 15% of small technology contracts for innovative SMEs. The article applies to all firms eligible for FCPI (*Fonds commun de placement dans l'innovation*) funding, *i.e.* SMEs which spend 10-15% of their expenditures on R&D or meet other conditions related to innovation.

Netherlands: The Dutch Launching Customer Scheme is an awareness and information scheme on the use of public procurement by government procurers and suppliers. The Dutch Innovation Agency, SenterNovem, complements this scheme by advising municipalities and other agencies on how to promote innovation through tendering.

Korea: The New Technology Purchasing Assurance scheme requires public agencies to give preference to the procurement of goods and services from SMEs, which also receive a new technology guarantee from the government. Under this programme, the Korean Small & Medium Business Administration finances the technological development of SMEs, and public institutions purchase the products for a certain period.

United Kingdom: The United Kingdom aims to make government procurement more conducive to innovation. Government departments are required to establish and develop an Innovation Procurement Plan. The procurement agency (OGC) and the innovation ministry (BIS) provide practical advice to procurers on how to ensure that innovation is incorporated into procurement practices.

United States: In 2003, a total of USD 95 billion in public procurement contracts was awarded to SMEs in the framework of the US Small Business Act, which targets 23% of direct contracts and 40%of subcontracts to SMEs. Agencies must measure and communicate their annual results to the Administrator of the Small Business Administration and the President of the United States.

The public sector, as a large-scale purchaser of goods and services, can promote innovation by being an informed and demanding buyer. Public procurement is perhaps the largest and most visible of the discrete instruments available to countries in this respect. Estimates suggest that public procurement accounts for between 10% and 15% of GDP on average in OECD countries (OECD, 2009g). The mechanisms by which public procurement supports innovation include signalling acceptance of innovations as early or lead users and creating new markets.

Regulatory and institutional frameworks under which procurement agencies operate may not encourage the procurement of innovative goods, services or works. A tension arises between public procurement and innovation because procurement is positioned as a transactional rather than strategic activity in public agencies. Clear guidance, tools and support can help clarify the scope for public agencies to foster and benefit from public procurement of innovation (*e.g.* considering functional specifications in market studies, examining lifecycle costs, including innovation in selection and evaluation criteria, etc.). However, guidance and best practices are not enough to ensure more public procurement of innovation. Stronger incentives may be required to change inertia and risk-averse attitudes of public procurement officials.

For young and small enterprises access to public procurement can be more difficult than for larger businesses. Bidding for government contracts is typically more expensive than bidding for comparable private-sector contracts. Contract bundling, driven by efforts to reduce civil administrative works can also inhibit SMEs' participation in bidding for very large contracts because of a lack of sufficient supply capacity (Clark and Moutray, 2004). Inadequate access to relevant information on forthcoming contracts, burdensome documentation, the time and costs involved in preparing offers, and standards specifications have also been noted as obstacles to the involvement of small firms (Fee *et al.,* 2002). Many governments are working to remedy the inherent bias against SMEs in public procurement, especially where selection and award criteria favour established enterprises over new innovative firms and start-ups. Australia and the United States set quotas for SMEs. In Korea, the New Technology Purchasing Assurance scheme requires public agencies to give preference to procurement of products from SMEs, which also receive a New Technology guarantee from the government. In the EU the recently proposed Small Business Act (SBA) does not envisage quotas for SMEs but proposes changes in national public procurement procedures that aim at levelling the level playing field.

One step towards overcoming some of these problems is the use of e-procurement practices which facilitate access to information and lower the administrative burdens of accessing and responding to tenders. Countries may also consider ways to guarantee access for SMEs. Measures exist to address risk aversion and information gaps among public procurers of innovation and potential suppliers (see Finland, Box 4.3).

Despite all these developments and the growing use of public procurement to drive innovation, there is a risk that public procurement of innovation may be at odds with good governance. Innovation goals must be balanced with integrity. In pursuing public procurement of innovation, OECD countries should adhere to national competition and public procurement rules as well as related international standards and obligations (*e.g.* OECD Council Recommendation for Enhancing Integrity in Public Procurement, the World Trade Organization's Government Procurement Agreement, the EC Directive on public procurement for procurement within the EU, etc.). Attention should focus on what constitutes public procurement of innovation as opposed to smart purchasing decisions. Specific mechanisms may also be established to monitor public procurement of innovation, given the different risks associated with pre-commercial goods and services.

Regulatory policies and standards can also help "pull" innovation. In several areas, market failures and distortions are best corrected with regulatory approaches that impose decisions on business choices and operations or on consumer products, either through technology standards – requiring operators to use a specific technology – or through performance standards, which set specific targets. These approaches should not be overly prescriptive but should encourage the private sector to innovate and apply the best technologies and approaches. In the environmental field, this includes the adoption of new standards and regulations that require operators to respect low-carbon, high-efficiency policies and practices such as the imposition of a minimum percentage of biofuel in the overall fuel mix of passenger vehicles. Unlike other demand-side innovation policies such as public procurement and regulation, standards policy sometimes has the added difficulty of an international dimension which requires standards that are compatible and enable technological interfaces across borders.

As consumers and users become catalysts for innovation, by creating demand and facilitating the diffusion of innovation, their role has grown in importance (see Chapter 3). Consumer policy regimes and consumer education play a role in fostering innovation in key innovative markets and in strengthening competition. Bottlenecks such as Internet fraud, lack of consumer education or product safety risks can significantly slow innovation by affecting demand and require attention from government.

Initiatives to promote consumer education and awareness can help improve transparency and help consumers to develop the skills, knowledge and confidence needed to improve market outcomes, thereby encouraging innovation and increasing consumer welfare. This is an important policy instrument that can help improve the flow of information between users and developers. To be effective, education and awareness strategies must go beyond addressing information asymmetries in individual transactions; they should help promote the critical and active engagement of consumers generally.

Like supply-side policies, demand-side innovation policies represent an important area for policy development, but they are not without risks. For example, public procurement of innovation may inadvertently harm competition, reduce transparency in procurement procedures, decrease value for money, and increase the public sector's vulnerability to fraud. In all cases, government policy needs to carefully consider the rationale and efficiency of policy actions.

Moreover, demand is not independent of supply since restrictions such as the relative inelasticity of the supply of researchers, skill mismatches, physical capacity, or the costs of financial capital can limit the leverage effect of demand. In contrast to supply-oriented innovation policies (R&D subsidies, etc.) demand-oriented policies are in most cases not administered by "innovation" ministries but by governmental departments or sectoral ministries responsible for areas such as the environment, consumers, energy, ICT, health, defence and transport. This requires policy co-ordination and coherence among the actors.

In many cases, demand-side policies may be better able to foster incremental innovation by strengthening incentives for firms to engage in particular areas of innovation, whereas supply-side policies, such as public investment in R&D, may be better in fostering more radical breakthroughs.

Key findings

The foundations on which innovative activity relies must be sound if firms are to participate in innovation and if its benefits are to spread throughout the economy and society. A policy environment based on core framework conditions – sound macro-economic policy, competition, openness to international trade and investment, tax and financial systems – is fundamental. The importance of a country's framework conditions has increased in recent years as businesses and capital seek the most favourable environments and become more mobile. Reaping the benefits of innovation at the national, regional and local level increasingly requires governments and other stakeholders to undertake the investments and policy reforms that provide a good environment for engaging in innovation. Access to finance is a key constraint as business-led innovation is inherently risky and may require a long-term horizon.

Despite the increasing variety of actors in the innovation process, firms remain the pre-eminent means of translating good ideas into jobs and wealth. New and young firms are particularly important, as they often exploit technological or commercial opportunities that have been neglected by more established companies. Improving the innovative capabilities of small and medium-sized firms is an important policy challenge in many OECD countries, as is the expansion of existing firms. Both market entry and exit are indispensable for the experimentation that leads to the development of new technologies and markets.

Governments play a fundamental role in determining demand-side policies that can affect innovation, such as regulations, standards, pricing, consumer education, taxation and public procurement. Because demand is necessarily linked to supply, policies that affect both need to be better harnessed to drive long-term innovation and growth. In most countries, the demand for innovative products and services that meet social and global needs can be further encouraged. Well-designed demand-side policies are less expensive than direct support measures, are not directed at specific firms, and reward innovation and efficiency. At the same time, government itself plays an important role through efficient public investment in the long-term drivers of change, well-designed standards and regulations, and innovative ways of leveraging public procurement. Public procurement provides important signals on future demand to the private sector. It can be effective in certain markets, in particular those in which the government is a large consumer.

The policy principles that emerge are:

1. Ensure that framework conditions are sound and supportive of competition, conducive to innovation and are mutually reinforcing.

a) *Ensure macroeconomic stability.* A sound macroeconomic framework supports investment in innovation through low and stable inflation rates and by reducing the level and volatility of real interest rates. High and stable rates of output growth provide better conditions for business firms to pursue activities with a medium- to long-term time horizon such as investment in R&D or demanding forms of product, process and organisational innovation.

b) *Foster competition.* Open and competitive markets are essential drivers of innovation. There is considerable scope at national and internationals level to open markets to competition. Eliminating anti-competitive product market regulation is a powerful way to stimulate investment in innovation.

c) *Open markets to trade and investment.* Keeping markets open to trade in goods and services and to international investment contributes to a positive environment for innovation. Governments should consider the quality of their policy frameworks for investment, as these play an important role in determining how much investment an economy receives and the extent to which this investment contributes to economic development and drives innovation.

d) *Foster sound regulatory policy.* Sound regulatory policy is essential to avoid excessive and burdensome regulations that impede innovation. Regulations intended to reduce the incidence of hazardous events also have the potential to impede risk-taking activity, with implications for innovation. It is necessary for the benefits of regulation to fully justify the costs. Risk assessment and risk management need to be integrated into regulatory impact assessment.

e) *Adopt tax policies that are conducive to long-term growth and innovation.* To encourage innovation and the diffusion of innovative processes, policy should ensure that the tax system does not impede investment in innovation, for example through the tax treatment of R&D.

f) *Foster demand for innovation.* Getting prices right and reforming regulations can help foster markets for innovation. Regulations, standards and public procurement can all be used to reduce fragmentation in markets and to "pull" innovation in a market-friendly way that does not harm competition.

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2. Mobilise private funding for innovation, by fostering well-functioning financial markets and easing access to finance for new firms, in particular for early stages of innovation. Encourage the diffusion of best practices in the reporting of intangible investments and develop market-friendly approaches to support innovation.

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a) *Foster well-developed financial markets.* Financial markets needs to encourage a better balance between the search for return and prudence with regard to risk. Well-functioning venture capital markets and the securitisation of innovation-related assets (*e.g.* intellectual property) are key sources of finance for many innovative start-ups.

b) *Ease the access to finance for new and innovative small firms* both with respect to debt (the main source of external funding for all enterprises) and equity finance. This is particularly important in the current crisis.

c) *Support early-stage financing for innovation* as well as networks for venture capital and business angels. Seed capital and start-up financing play a key role in enabling entrepreneurial individuals to turn new ideas into new products. Access to such sources can provide more than funding, they also help start-ups to develop as businesses by providing advice and potentially on-the-ground management expertise.

d) *Encourage the diffusion of best practices in financial reporting.* Governments need to encourage the diffusion of best practices. Given the wide range of intellectual assets held by firms in different industries, and the comparatively early stage of development of reporting frameworks, the approach to improved disclosure should remain principles-based.

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3. Foster open markets, a competitive and dynamic business sector and a culture of healthy risk taking and creative activity. Foster innovation in small and medium-sized firms, in particular new and young ones.

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a) *Reduce red tape to facilitate firm creation and the growth of new firms.* Simplifying and reducing start-up regulations and administrative burdens can reduce barriers to entry. Low regulatory barriers can help ensure that high-growth firms do not spend the capital needed to support their growth on overcoming bureaucratic obstacles. Policy should address the administrative, social and tax requirements that tend to rise with the size of the company, as these increase the cost of growth.

b) *Improve bankruptcy laws.* Both firm creation and destruction are indispensible for the experimentation process needed to develop new technologies and markets. Since firms entering the market may know little about their chances to survive, costly exit discourages firms from entering. Bankruptcy laws can be made less punitive for entrepreneurs and should offer more favourable conditions for the survival and restructuring of ailing businesses in certain countries, with due regard to risk management and the need to avoid moral hazard.

c) *Review tax systems to ensure they do not impede entrepreneurship.* Personal income tax, corporate income tax and social security contributions play an important role in decisions to move from wage employment to establishing a business and in the structure of such businesses (incorporated or unincorporated). Changes that provide more neutral tax treatment should be considered.

d) *Leverage public procurement to foster innovation.* Government procurement policies should strengthen their capacity to deliver innovative solutions to public needs that are in line with good governance, transparency and accountability. When special measures for SMEs are considered, they must be fall within the framework of national competition policies and international standards and obligations.

Notes

1. The section on competition explores the role of product market regulation for innovation, whereas other sections discuss the impact of labour market regulations on innovation, as well as the role of administrative regulations on entrepreneurship.

2. The European Commission has issued guidelines to assess the competitive effects of patent pools, which focus on the complementarity of the patents in the pool. In the United States, while there are no explicit guidelines, reviews of patent pools by the Department of Justice point to several factors likely to safeguard competition that may be taken into account when setting up pools: the patents in the pool be essential (*i.e.* the patents are complements and none has a substitute outside the pool) and each patent holder be allowed to license its technology outside the pool.

3. More details on the role of direct support and tax relief for private R&D follow.

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Chapter 5

Creating and Applying Knowledge

Government plays an essential role in creating and applying knowledge and in fostering public and private investment in innovation. This chapter focuses on the wide array of support that is needed for innovation. It examines the public research system; investment in knowledge infrastructure and general purpose technologies; the importance of knowledge flows, networks and markets; and how governments can be innovative actors in the delivery of public services.

Introduction

Innovation requires public and private investment in the infrastructure and networks that support innovation, as well as in R&D and other intangibles, and governments play an important role in fostering private as well as public investment in innovation. Private investment may be below a socially optimal level, mainly because returns are uncertain or innovators cannot appropriate the optimum benefits of their investment. In areas such as basic science, private investment may be limited or absent because of the time before results are obtained or because of the lack of direct applicability for products and services. This chapter examines various dimensions of investment in innovation: public research, investment in knowledge infrastructure and general purpose technologies, knowledge networks and markets, and the role of the public sector in fostering innovation.

Public research is essential to strong innovation performance

The public research system can be loosely defined as the institutions that depend on various forms of public support and carry out basic and applied research as well as experimental development. These institutions include world-class research universities, small regional universities, colleges of technology, public hospitals and clinics, government research laboratories and government establishments engaged in activities such as administration, health, defence and cultural services as well as technology centres and science parks. Some are mainly involved in the production of knowledge, others are more closely tied to firms and industrial innovation, and still others deal with public goods, such as standards, weather forecasting or developing test methods.

The public research system plays many roles in innovation systems including education, training, skills development, problem solving, creation and diffusion of knowledge, development of new instrumentation, and storage and transmission of knowledge. They perform much "blue sky" science or basic research and undertake activities that support innovation, such as development work, certification, testing, monitoring and measurement, find new uses of existing knowledge, create links between scientific fields and establish multidisciplinary knowledge bases, such as gene banks and quality-assured scientific collections. Public research has been the source of significant scientific and technological breakthroughs that have become major innovations (Box 5.1). The public research base can also shape a region's capacity to innovate, as its institutions act as a magnet for high-technology firms or the research and development (R&D) facilities of multinational enterprises (MNEs).

Box 5.1. Public research and innovation

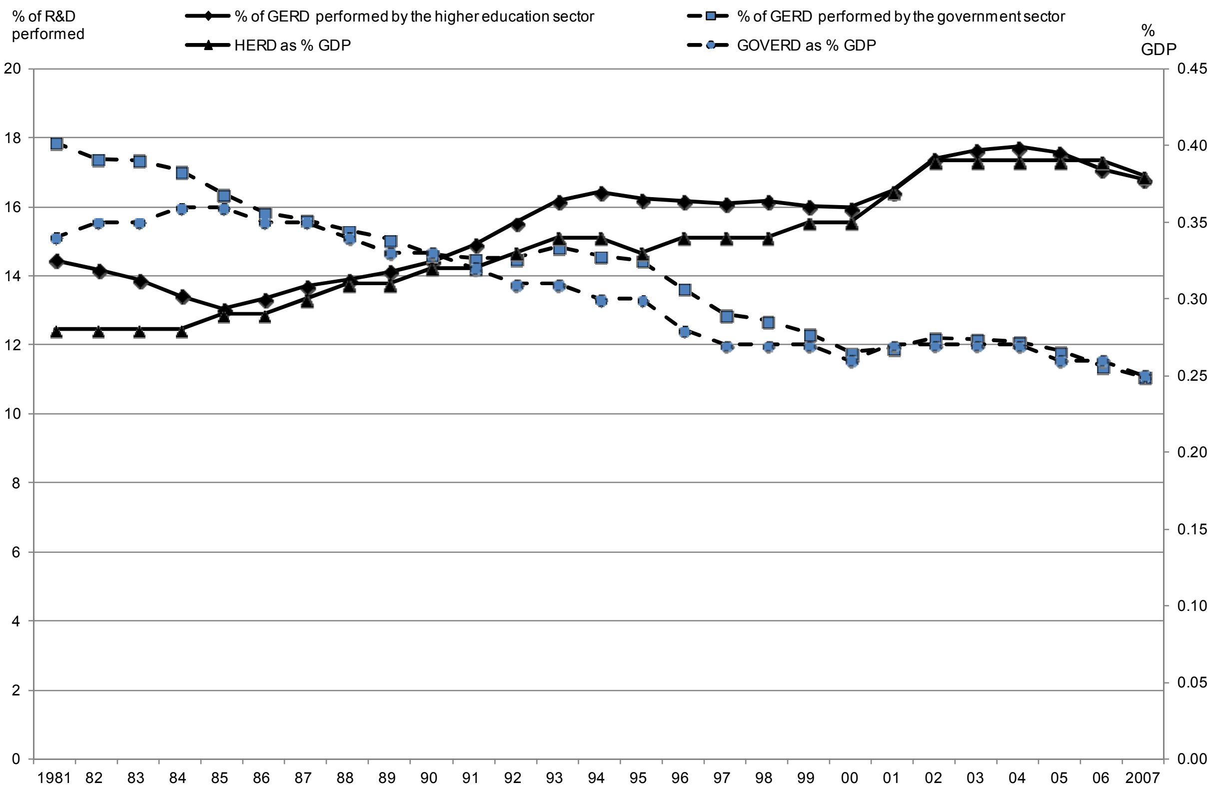
Many of today's innovations are based on knowledge generated in the public sector. Well-known examples include recombinant DNA techniques and the Internet (Ruttan, 2001; Faulkner and Senker, 1995). While it is inherently difficult to quantify the impact of public R&D, it has been suggested that around a tenth of innovations would have been delayed in the absence of academic research (Mansfield, 1991) although in some sectors – such as pharmaceuticals and semiconductors – innovation is far more dependent on public research. The contribution of public research to innovation often stems from spillovers and unintended effects or applications of scientific research in areas very different from the original intention. For example, public-sector research has led to the development of instrumentation such as the scanning electron microscope and superconducting magnets which have been widely taken up by industry (Salter and Martin, 2001). Moreover, industry-financed R&D in the public sector is usually aimed at obtaining up-to-date knowledge, solutions to specific problems and access to students (Mansfield and Lee, 1996).

The private sector draws on the results of public research in different ways. In sectors such as pharmaceuticals, the link is direct and is apparent in citations to publications and patents. In others, such as the automotive industry, it is more indirect and occurs through the movement of students (Salter and Martin, 2001). Linkages also occur through joint research projects, training, consultancy and contract work, attendance at conferences, staff mobility between workplaces and informal co-operation between researchers. Public infrastructure and other shared resources are also avenues for interaction. There is however considerable diversity in terms of the range and forms of linkages. Research has shown that a small number of researchers are involved in a large number of interactions (Balconi, Breschi and Lissoni, 2004), and linkages differ in different scientific disciplines (D'Este and Patel, 2007).

To expand their countries' science and innovation capabilities, several governments have increased funding for public-sector research. As countries' GDP has grown, total public R&D expenditures (*i.e.* the sum of higher education R&D and government R&D) in the OECD area remained roughly constant as a share of GDP between 1981 (0.62%) and 2007 (0.63%). Since then, the financial crisis had led to the introduction of economic stimulus packages in 2009 and many countries have introduced additional R&D spending and investment in green technologies (OECD, 2009a). It remains to be seen at what level expenditure will settle after exit from the stimulus packages – but any decline from pre-crisis levels could have long term negative consequences.

In the past decade, public expenditure on R&D has climbed from USD 159 billion to USD 207 billion (in constant 2000 PPP USD) (OECD, 2009b), with most of the growth in the higher education sector. In the OECD area between 2000 and 2006, government R&D budgets grew on average by 3.8% a year in real terms. Figure 5.1 shows the changing trends in OECD public R&D expenditure and the reallocation of resources between sectors. The long-term effects of this reorientation are not clearly understood at the present time.

Figure 5.1. OECD public R&D expenditures and sectors of performance, 1981-2007



Note: HERD = higher education expenditure on R&D; GERD = gross expenditure on R&D; GOVERD = government intramural expenditure of R&D.

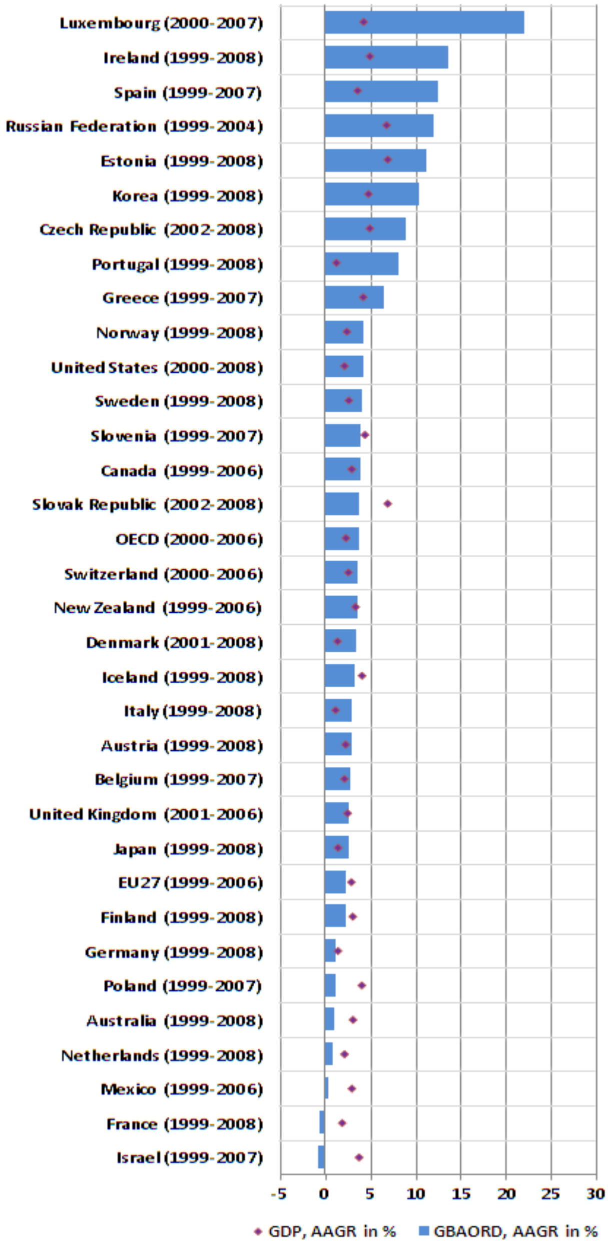
Source: OECD (2009), *Main Science and Technology Indicators 2009/1*, OECD, Paris.

In most countries, government funds committed for R&D grew at the same pace or even faster than national GDP (Figure 5.2). In addition to direct support, governments also finance business R&D indirectly through the use of tax incentives, an alternative to direct spending for achieving government policy objectives (see Chapter 4). The cost of these tax credits, in terms of foregone revenue, do not usually appear as R&D support in government budgets, although they may be significant (see Figure 4.4).

While the amount of government funding for R&D is a determinant of the outcomes of R&D, more public funding does not always lead to stronger outcomes. In the United States, for example, resource inputs per publication in the top 200 academic R&D institutions increased by approximately 30% from 1990 to 2001 (NSB, 2010, pp. 5-47). The pattern of increasing inputs required to yield the same quantity of publication outputs is apparent across the entire US academic system. Reasons suggested include greater complexity of research, staff and equipment costs rising faster than average inflation rates, and increased communication costs due to collaboration (NSB, 2010).

Figure 5.2. Change in government R&D budget and GDP, 2000-2008 (or latest available year)

Average annual growth, percentage



Note: The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Source: OECD (2009), *Main Science and Technology Indicators 2009/1*, OECD, Paris.

The role of science in innovation

Much of the world's scientific knowledge is produced by the academic and government research sectors, generally with strong government support. It is largely the connection between science and technological and economic development that has provided the core rationale for this support. The knowledge produced by publicly supported research has public good characteristics and also allows for the partial appropriation of spillovers by entrepreneurs and firms through intellectual property rights. Governments have therefore long supported investment in public research and the diffusion of the knowledge generated throughout the economy. This remains true today, although there is increasing emphasis on the need for science to demonstrate its contributions to economic growth and social welfare.

The aim of innovation is to meet private and public demand through the development and commercialisation of new products, processes and services. To do so, it has often turned to science. At the same time, innovation need not always draw on scientific knowledge. Indeed, as discussed throughout this report, innovation draws on a range of activities or knowledge that may have less to do with science and more to do with market research, technical development or entrepreneurship. Survey data of firms, for example, routinely cite suppliers and customers/users as the main sources of innovation. However, innovation is not a linear process and science and other sources of innovation should not be seen wholly as unconnected.

Indeed, the link between science and innovation is far from straightforward. For the past 40 years, academic research on innovation has challenged the "linear" view of innovation, according to which basic science is translated into manufactured products or services in the market place. While the debate on the relevance of the linear model continues, a great deal of theoretical and empirical evidence supports a chain-linked model of the relationship between science and innovation wherein "innovation draws on science, but also the demands of innovation force the creation of science" (Kline and Rosenberg, 1986, p. 285). More recently, this model has been extended to encompass a multi-channel, interactive learning model "where research aiming at understanding markets and organisations appears on an equal footing with scientific research aiming at developing new technology and where experience-based learning is recognised as a prerequisite for transforming scientific knowledge into economic performance" (Caraça *et al*., 2009).

However, if the relation between science and innovation is complex, it is nevertheless clear that innovation, especially at the frontier, increasingly depends on scientific progress. Advances in science more and more determine advances in technology, as illustrated by developments in information and communication technologies and, more recently, biotechnology and nanotechnology, where science and technology are inter-twined. This increasing interconnectedness of science and innovation parallels the blurring between academic and applied research. Indeed, bibliometric studies and other data on science-patent linkages demonstrate the intensity of the contribution of science to innovation, particularly in emerging and growth sectors such as information technology, health (pharmaceuticals and biotechnologies) and environmental technologies.

Public research faces challenges and reforms are under way

National public research systems differ greatly in their efficiency in turning funding into research outcomes, and many countries are working to reform their public research system to increase its efficiency and responsiveness to social needs. This is particularly relevant in a context of severely constrained public finances. Public research institutions are increasingly faced with the challenges of globalisation, competition, the commercialisation of research results, and greater demand for quality and relevance. Adjusting to these pressures has led to changes in governance structures, priority-setting processes and funding allocation mechanisms (OECD, 2008a; 2008b). While countries have taken different approaches, reflecting the characteristics of their science systems, there are some common trends:

- Countries are restructuring institutional mechanisms for financing public research, in part to facilitate funding of multidisciplinary research. This has usually involved establishing or reforming the research councils or similar bodies that operate at the interface of government ministries and research-performing institutions. It has also been achieved through better co-ordination between funding agencies and government and through funds that create incentives for interdisciplinary collaboration or for research in certain priority areas.
- Governments are also adapting their research-financing mechanisms, *e.g.* by making greater use of competitively awarded project funding. They are seeking to overcome rigidities in the discipline-based research system to facilitate funding of interdisciplinary research and areas that reflect national priorities. They are exploring tying funding more closely to specific objectives and missions. They have also sought to foster more competition for students and faculty.
- More emphasis is being placed on the quality and relevance of institutions' research activities and their contribution to improving the innovative capacity of the country. In this regard, funding is being linked to assessments of institutions' research performance.
- The commercialisation of public research results through licensing, patenting and the creation of spin-offs continues to be emphasised.
- Public research institutions are being encouraged to forge more links, notably with industry and across international borders, and "centres of excellence" have emerged strongly.

How these reforms affect the long-term operations and functioning of public research systems is an important policy issue, given the latter's contribution to innovation and the need to ensure their long-term sustainability.

As noted, there is still strong policy emphasis on making publicly funded research more commercially oriented. Policy mechanisms include strengthening IPRs through the Bayh-Dole Act in the United States and its equivalent in other countries and the establishment of technology transfer offices (TTOs) to commercialise university research results. According to the OECD *Tertiary Education Review* (OECD, 2008b), many countries have developed national guidelines on licensing and strong incentive structures to promote the commercialisation of public research. However, it has become clear that there are complex trade-offs between stronger public-sector IPRs and increasing knowledge transfer from the public sector to industry (Mowery, Nelson and Martin, 2009), and in the area of licensing of genetic inventions – for example – OECD countries have adopted guidelines that aims to encourage broad licensing (OECD 2006).

Nonetheless, the main motivation behind public research is to fund and perform basic research that often has a long time horizon and carries high risks with uncertain returns. While business invests in some basic research, it continues to rely on public research and knowledge spillovers. Increasing access to research data deriving from public funding is gaining support in many countries (Box 5.2). Around 58% of basic research is performed in the higher education sector and 22% in the government sector (Figure 5.3). Basic research as a percentage of GDP has been generally stable over the past two decades in the OECD countries for which data are available. In the United States, for example, basic research represented 0.45% of GDP in 1997 and 0.47% in 2007. In Japan the figures were 0.34% and 0.40%, respectively (OECD, 2009b).

Box 5.2. Access to research data from public funding

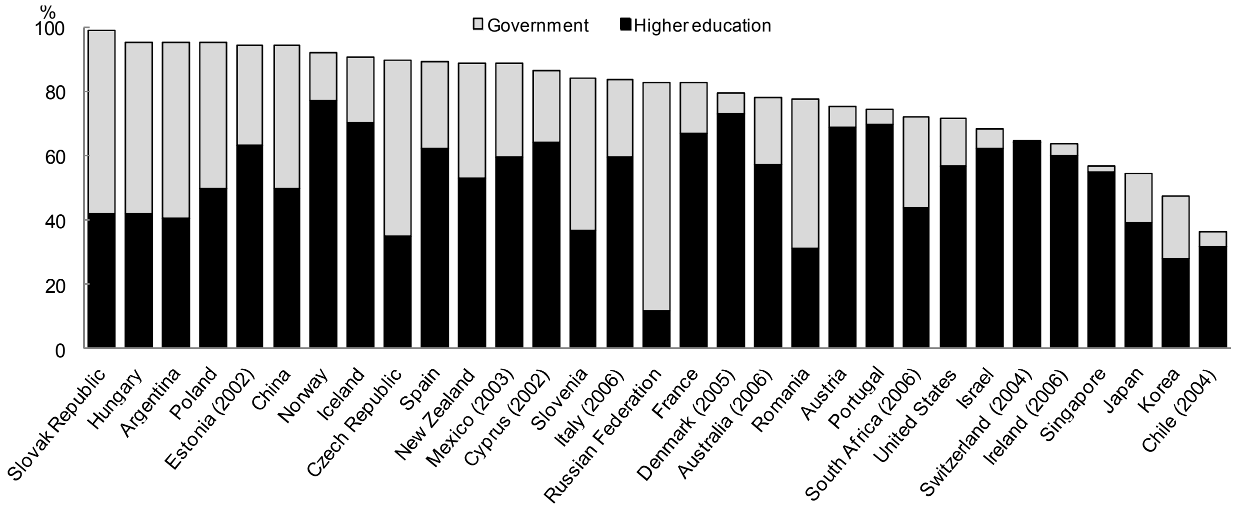
In 2004, governments of OECD countries and of the People's Republic of China, Israel, the Russian Federation and South Africa adopted a Declaration on Access to Research Data from Public Funding. In 2006 the OECD Council endorsed a Recommendation on Access to Research Data from Public Funding. The Recommendation, including accompanying Guidelines and Principles, was subsequently published in 2007 and applies to research data that are gathered using public funds for the purposes of producing publicly accessible knowledge. The aims and objectives are to: promote a culture of openness and sharing of research data among the public research communities within member countries and beyond; stimulate the exchange of good practices in data access and sharing; raise awareness about the potential costs and benefits of restrictions and limitations on access to and the sharing of research data from public funding; highlight the need to consider data access and sharing regulations and practices in the formation of member countries' science policies and programmes; provide a commonly agreed upon framework of operational principles for the establishment of research data access arrangements in member countries; offer recommendations to member countries on how to improve the international research data sharing and distribution environment.

In 2009 the OECD Committee for Scientific and Technological Policy (CSTP) conducted a review of the implementation of access to research data from public funding. While the survey responses were qualitative in nature and were not based on representative samples within countries, the results demonstrated a wide range of policies and views. Countries differed in terms of the practices adopted and the stage of implementation of the Principles and Guidelines. Some have introduced laws and comprehensive policies while others have position statements or are still in the planning phase. Despite these differences, the responses indicated that most countries view the initiative positively, particularly in terms of accelerating scientific progress and optimising efficiency and scientific transparency. The few concerns raised mainly focused on IPRs and the cost of implementation. Very few countries have evaluated the impact of data access policies so it is difficult to identify best practices at the present time.

Public research policies could consider how to benefit from the growing use of ICT in research. With the development and application of large-scale and usually collaborative research networks, the term "e-science" is sometimes used to refer to distributed global collaboration enabled by the Internet, using very large data collections, tera-scale computing resources and high performance visualisation and analytical tools, notably modelling and simulation. In many areas of science, research communities use powerful computing resources across new infrastructures, often called "grids" to access very large data sets for use in real-time experiments. Unresolved questions include how and who should fund collaborative research infrastructures, such as networks, databases, sensor networks, etc., how should transnational infrastructures be funded where there are issues of "diversion" of research funding towards infrastructure, and whether collaborative infrastructure for multiple projects may require different funding mechanisms from competitive processes used in traditional research funding.

Figure 5.3. Basic research performed in the higher education and government sectors, 2007

As a percentage of national basic research



Notes: Total cost (current and capital) included for all countries except Norway, Estonia, Poland, Spain, Russian Federation and United States, where only current costs are included. The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Note by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

Note by all the European Union Member States of the OECD and the European Commission: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

Source: OECD (2010), *Measuring Innovation: A New Perspective,* OECD, Paris, based on OECD, Research & Development Database, December 2009.

Priority setting for research has become common

Priority setting is a difficult task that requires not only political vision and clear goals but tools and "a feasible methodology for the identification, selection and definition of thematic priorities or specific technologies" (Gassler, Polt and Rammer, 2007). Polt (2008) categorises three main dimensions of the priority setting processes:

- *types* of priorities: thematic priorities (scientific, technological, societal missions) or functional/generic priorities;
- *levels* of priority setting (national priority-setting exercises, institutional priority setting, etc.);
- *nature* of the priority setting process (*e.g.* top-down/expert-based vs. bottom-up/participatory, degree of formalisation, mechanisms for implementation, evaluation).

Priority setting can take many different forms. At the macro level it can be expressed in government white papers, national innovation strategies or national S&T plans. At the operational level, priorities can be expressed via the missions of institutions, or through more flexible structures such as centres of excellence. Governments have increasingly used instruments such as research and technology programmes, performance-based contracting and public-private partnerships (P/PPs) as more flexible ways of influencing the research agenda of research institutions. Funding instruments also serve to adjust or set national priorities. Industry financing of public research or P/PPs can also shift or align public priorities for research with business strategies for the longer as well as the shorter term (OECD, 2010a).

There are also important international dimensions to national priority setting. First, foreign priority setting affects national priority setting exercises both directly and indirectly. The most direct impact is via competition among scientists to create new knowledge. Strength in knowledge production in one country – specialisation – can influence the direction of specialisation in another country with different financial and intellectual resource endowments. Foreign funding of research by MNEs or public research organisations may also indirectly affect the direction of research in the receiving country by signalling user demand in a given area. EU Structural Funds and Regional Funds have arguably shaped the direction of research priorities in the new member states.

Another international dimension concerns the setting of priorities for regional or global challenges or for large research infrastructures which require international co-operation to shoulder the high development costs (see Chapter 6). The creation of the European Research Area has increased the focus on ways to better co-ordinate member states' national research programmes. This ranges from the definition of agreed priorities as set out in the Lisbon Strategy and European Framework programmes to the implementation and monitoring or evaluation of national and common programmes. The challenge in setting priorities for international collaboration is to balance a co-ordinated approach with a differentiated approach according to the type of research. Furthermore, the different technological specialisations of partnering countries, the need to foster both competition and co-operation among research teams and between bottom-up research initiatives and top-down strategic guidance also need to be taken into account (OECD, 2010a).

Many countries have established and implemented research priorities and are building centres of excellence as a means of creating critical mass. On the one hand, these measures are being used to alleviate resource constraints, and, on the other, they aim to raise research quality, enhance outcomes and facilitate co-operation. This has increasingly concentrated public research funding in a limited number of institutions, and research priorities often focus on specific scientific and/or technological fields. Until recently countries often selected the same areas – usually biotechnology, ICT and nanotechnology; they more rarely focused on their national areas of technological specialisation, but the scope of research priorities is now widening in some countries.

Critical mass depends on the goals to be achieved and the nature of the field concerned by the R&D. For example, nanoscience and nanotechnology both are multi-disciplinary and interdisciplinary and often require facilities and expertise in a wide range of disciplines. However, critical mass may also be achieved in a single laboratory or project or by a partnership involving a small number of facilities with complementary expertise and equipment. Alternatively, it may necessitate new buildings, state-of-the-art equipment and bringing together large numbers of expert researchers and support staff.

Given the considerable diversity of countries' industrial structures and technological fields, priority setting is an important issue for further work. Policy makers also need to ensure that the public research sector retains sufficient diversity to respond to future needs in the innovation system (see Chapter 7).

The funding of public research is changing

Funding and the methods used to allocate resources are a central element of the governance of public research. The two main government allocation methods are institutional and project funding. Institutional funding is generally a block grant that is not directed towards particular projects or programmes; project funding is a project- or programme-based grant which is attributed to a group or an individual to perform a research activity limited in scope, budget and time, normally on the basis of the submission of a project proposal (Lepori *et al.,* 2007a, 2007b). A further distinction is between competitive and non-competitive funding which can be either institutional or project-based. Institutional funding, including for infrastructure, is critical for long-term research capacity while project-based funding is used to promote competition within the research system. Liefner (2003, p. 480) argues that one of the positive aspects of stable core funding is that it enables researchers to "follow new ideas and concentrate on pure research". It should be remembered, however, that the allocation of institutional funding may also be competitive. A combination of funding mechanisms should be used to counterbalance the negative effects of a single type of funding.

Project-based funding is used extensively in many countries to fund research in tertiary education institutions (OECD, 2008b). Although much less is known about the funding of government institutions, preliminary results from OECD work indicate the prevalence of project-based funding. Because it has been difficult to quantify the distribution of funding and changes over time across countries owing to the lack of internationally comparable data, the OECD has launched an international project on the public funding of R&D (Box 5.3).

Box 5.3. Public funding of R&D: The first internationally comparable indicators

Only a few indicators on public R&D funding are currently used for international purposes (e.g. government R&D funding by socioeconomic objectives). However, more can be done with existing statistics to assist policy makers. To fill this gap, the OECD started in 2008 a project to develop new indicators on government R&D funding. A pilot exploratory phase involved six countries; it has been extended to include more than 15 OECD and non-OECD economies.

The general aim of the project is to make better use of the potential of government R&D data (GBAORD) to compare research funding systems across countries. The project focuses on:

- government R&D funding allocation (block funding vs. project-based focus);
- type of instruments used (investigator-led, policy-oriented, innovation-related);
- degree of autonomy of funding institutes (research organisation, policy-based ministry, etc.); and
- share of public funding to international organisations.

Preliminary results show:

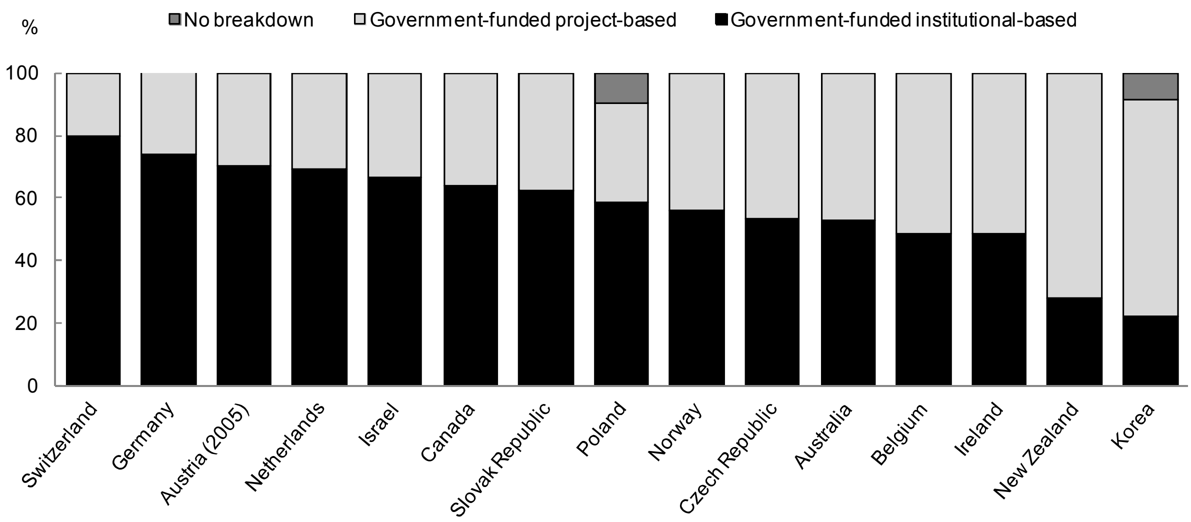
- Country funding schemes vary widely. Austria, Germany and Switzerland mostly use institutional funding (around 70%), while Belgium, Ireland, Korea and New Zealand devote more than 50% of public funding to project-based funding (Figure 5.4).
- In the higher education sector, general university funds (GUF) are an important part of overall funding (considered as institutional funding), but Belgium, Canada and Ireland still provide substantial additional funding to project-based, peer-reviewed projects.

Box 5.3. Public funding of R&D: The first internationally comparable indicators *(continued)*

- A large part of project funding is managed by independent agencies (such as research councils) except in the Czech Republic, Israel and Poland, where centralised research ministries or other sectoral ministries provide most of the project-based funding.
- The long-term trend of public R&D funding seems to favour project-based funding over institutional funding (Lepori *et al.,* 2007b), but over the short period studied so far (2000-08), countries' funding modes are relatively stable.
- Public funding of international organisations continue to be a minor component of national public R&D funding (usually less than 5%) except for Belgium and Switzerland, which devote more than 10% of public R&D funding to such organisations,

These findings are based on experimental indicators and should be interpreted with caution. Consolidation of these preliminary findings will take place in 2010-11.

Figure 5.4. Government-funded R&D by type of funding, 2008



Notes: This is an experimental indicator. International comparability is currently limited. The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Source: OECD, Working Party of National Experts in Science and Technology (NESTI) microdata project on public R&D funding, 2009.

The shift toward more project-based and competitive research funding raises a number of issues that need to be considered in relation to the long-term development of research and innovation systems. Competitive funding may lead to more *ad hoc* and short-term research if evaluation mechanisms and incentive structures focus on quantifiable and "immediate" outputs. This may make researchers reluctant to engage in research that will not produce results rapidly. In addition, because project-based funding is competitive, sustained funding is not guaranteed. If project-based funding is of short duration, researchers may have to spend time more often preparing applications to secure funding. Atkinson (2007, p. 19) remarks that young faculty in particular spend an excessive amount of time preparing project proposals.

Liefner (2003) found that competitive or performance-based funding can affect the type and field of research because some academics avoid research with riskier outcomes. Likewise, Geuna (2001, p. 623) notes that short-term and less risky research may reduce the likelihood of "scientific novelty". Geuna and Martin (2003, p. 296) argue that research may become "homogenised" because "safer" research is rewarded. Morris and Rip (2006) point out that the stage of a researcher's career needs to be considered in relation to the type of research undertaken. They raise some questions: "Does the researcher need quick results to bolster his or her next job application? Is he or she senior enough to get a five-year rather than a three-year grant?" (Morris and Rip, 2006, p. 256). These are pertinent questions in a context of project-based funding. These studies focus on the higher education research sector (OECD, 2008b) but are equally relevant to the government research sector (OECD, 2010b).

Public research infrastructure, instruments and equipment need to be maintained and updated regularly – both the basic teaching, routine research and storage functions structure of the public research system[1] and the more specialised large scientific facilities. The replacement of large infrastructures must be carefully planned internationally, nationally and in individual institutions. However, there may be a trend towards declining funding for infrastructure relative to other R&D costs in the public research sector. Data show that expenditure on major instruments and equipment acquired for the performance of R&D, as a proportion of all spending on R&D in higher education institutions and government research institutions, has fallen over the past decade in most countries (OECD, 2008b).[2] These decreases may represent a drop in the cost of instruments and equipment relative to other such as salaries for R&D personnel, other current costs (*e.g.* water, electricity, subscriptions to libraries, administrative costs, etc.), and land and buildings. Alternatively, expenditure on instruments and equipment may simply be decreasing. While the reasons for the decline are not clear, changing funding practices may have a bearing on investment in equipment.

A comparative study of large-scale research equipment purchase and use in UK and US universities found that limited funding and purchase delays could impede international competitiveness. The authors found that problems were more pronounced in the United Kingdom because the funding of research infrastructure was largely piecemeal and involved the submission of independent and successive research grant applications. Uncertain and short-term funding exacerbated these issues. In addition, support costs (*e.g.* maintenance, support personnel, etc.) were excluded from some grants (Flanagan *et al.*, 2002).

Project-based funding may also affect the training of researchers. It was noted above that one of the key functions of the public research system is competence building and research training. No major study has yet been undertaken on the effects of governance reforms on such training. However, research in Australia has shown that the introduction of performance indicators can have an impact on teaching. For example, Taylor (2001) found that some academics encouraged their research students to undertake easier projects to ensure that the research is completed in a short period of time.

Evaluation of public research has grown

Evaluation of publicly funded research has become a central concern of policy makers for two main reasons. First, there is growing demand for evidence-based policies and for evaluation of the results of public investments. More precisely, governments increasingly seek to determine how much they should invest in science, technology and innovation, where to invest to enhance social returns, and how to raise research quality. Ideally, evaluation should help determine the economic effects of public investment in R&D and innovation, such as the contribution to growth, and the social impacts, such as better health outcomes. Moreover, policy makers increasingly want public investment to help meet global challenges, such as energy, security and climate change. Second, the demand for evaluation has expanded because OECD countries have increased public investment in R&D despite budget constraints.

Attention has therefore turned towards efforts to investigate the relation between funding inputs and a wide range of possible outcomes. However, it is difficult to determine and measure the various impacts of public R&D and the most important challenges are discussed in Box 5.4. Over the past decade, national governments and academics have developed new analytical techniques for assessing the impacts of public R&D investment, such as econometric analysis, data linkages approaches and case studies. Further work is needed on integrating different approaches and methodologies to create coherent impact assessment practices (OECD, 2008a).

Box 5.4. The main challenges for analysing the economic and non-economic impacts of public R&D

Causality. There is typically no direct link between a research investment and an impact. Research inputs generate specific outputs that can affect society. This relation is always indirect and therefore difficult to identify and measure. It is also almost impossible to isolate the influence of a specific research output on a given impact, which is generally the result of several factors and thus difficult to control for. As a result, any "causality" between research outputs and impacts cannot be easily demonstrated.

Sector specificities. Every research field and industry creates output and channels it to the end user in a specific way. This makes it difficult to develop a single framework for assessment.

Multiple benefits. Basic research may have various impacts, not all of which can be easily identified.

Identification of users. It can be difficult and/or costly to identify all beneficiaries of research outputs, especially those of basic research.

Complex transfer mechanisms. It is difficult to identify and describe all the mechanisms for transferring research results to society. Studies have identified transfer mechanisms between businesses or between universities and businesses. The models are mainly empirical and often do not reveal the full impact on society.

Lack of appropriate indicators. Given the lack of the needed categories of beneficiaries, transfer mechanisms and end users, it is difficult to define appropriate impact indicators for measuring specific research outputs.

International spillovers. The existence of knowledge spillovers is well documented and demonstrated (Jaffe, 1986; Griliches, 1979). As a result, specific impacts may result partly from international research rather than from national investments.

Time lags. Different research investments may take more or less time to have an impact on society. Particularly in the case of basic research, it may sometimes take longer for the research to generate its full impact.

Interdisciplinary output. Research outputs have various impacts, and it may be difficult to identify them all in order to evaluate the contribution of a specific output, l*et al*one that of the research investment.

Valuation. In many cases, it is difficult to give a monetary value to impacts in order to make them comparable. Even if non-economic impacts can be identified, they may be difficult to value. There have been attempts to translate some of these impacts, e.g. the economic savings associated with a healthy population, into economic terms, but these have typically been partial and subjective.

Source: OECD (2008), *OECD Science, Technology and Industry Outlook 2008,* OECD, Paris.

Despite the difficulties associated with evaluating the impact of public research, it is necessary to ensure that the system is efficient and effective. Many governments have therefore developed funding models based on performance criteria. However, there are important questions regarding the strengths and weaknesses of the different models. For example, linking funding to quantifiable output measures, such as publications and patents, can have unintended effects on the quality of research (Butler, 2002, 2003, 2007; Henderson, Jaffe and Trajtenberg, 1998). This suggests that a broad range of robust performance indicators should be developed and used to ensure that the quality of public research is maintained and enhanced. Indicators can also be supplemented by other evaluation mechanisms such as peer review. Particular care needs to be taken to ensure that research assessments capture differences among disciplines and take account of time lags. Policy makers need to be mindful of the complexities, unintended side effects and long-term impacts. Evaluation is now taking place in a more complex environment and new demands are being placed on evaluation exercises. Ensuring that these can take account of the overlapping roles and responsibilities of stakeholders, multidisciplinarity, globalisation and more complex funding arrangements will be essential if evaluation is to remain a useful tool for policy makers. In addition, administering assessments can entail considerable costs.

Knowledge production is a cumulative process which often entails very long time lags between discovery and application. Public research policies must therefore take a long-term perspective to ensure that the system is able to contribute to future economic growth, technological progress and sustainable development. In particular, the public research sector has an important role to play in terms of understanding and developing solutions to global challenges including those involving the environment, health and energy. Moreover, because these public research institutions play multiple roles in knowledge economies, their governance cannot focus on one-dimensional or short-term needs (see Chapter 7).

An innovation-supporting knowledge infrastructure

Infrastructure takes many forms and is a vital complement to public and private research. At its most fundamental, research infrastructure comprises roads and communications, particularly around physical clusters or technology hubs. It needs to be complemented by sustained public funding for more specific infrastructure – basic scientific capacity for public purposes, such as forecasting, response to health outbreaks, policy support, libraries and databases. Public policy and funding are necessary to provide an efficient, well-networked infrastructure for scientific capabilities to meet public needs, and many countries include support for the infrastructure underpinning innovation in their stimulus packages.

The scientific and technological infrastructure and technology platforms built around general purpose technologies (GPTs, Box 5.5) are also important for innovation. ICTs play a prominent role in the current debate on innovation, but other GPTs, such as biotechnology and perhaps nanotechnology, are of growing importance, as is the convergence between them.

Box 5.5. General purpose technologies

General purpose technologies (GPTs) have been defined as technologies which are pervasive, have a widespread productivity impact on a range of industries, show continuous improvement and productivity growth and cost reduction in their own industry, and stimulate product and process innovation in application sectors (Bresnahan and Trajtenberg, 1995; Ruttan, 2008). GPTs often lead through secondary effects to significant innovation in applications by reducing costs and changing geographic cost structures, by facilitating significant organisational change (*e.g.* workflows), changing scale economies and facilitating information exchange.

Electricity, the combustion engine and the steam engine were early GPTs. More recent examples include ICTs (Inetworked computing and the Internet in particular). Many have seen ICTs as the reason for the acceleration in productivity in the United States and other OECD countries since the mid-1990s. Biotechnologies, and more recently nanotechnologies, are viewed as emerging GPTs. GPTs usually require building up of new skills sets which can take time.

Given the potential impact of GPTs on growth and productivity, it is important to better understand the conditions that lead to their development and diffusion across the economy. In the case of ICTs many developments benefited from public expenditures. For example, DARPA, the US Defense Advanced Research Projects Agency, funded Internet development and the main Internet standard, TCP/IP. Diffusion was stimulated by the National Science Foundation and by the use of the Internet by some major universities in the United States as a communication and information sharing platform. The fact that TCP/IP was an open standard is often cited as having had a beneficial role in stimulating diffusion. The early stage of Internet diffusion coincided with the opening of telecommunication markets to competition; this stimulated adoption by a number of new market entrants seeking a low-cost platform to compete against entrenched incumbent telecommunication operators. The concentration of knowledge (Silicon Valley) linking university research with firm development activities as well as an active venture capital market undoubtedly also played a large part in stimulating inter-industry spillovers in the development and use of ICT applications.

The extent to which biotechnology, and indeed nanotechnology, will evolve into GPTs comparable to ICTs and provide a platform for innovation in many industries, will also depend on the degree to which innovation policies and other institutional frameworks can facilitate their further industrial uptake and diffusion. These technologies are converging rapidly with ICTs and the interdisciplinary and broad-based nature of these developments raises some new challenges for commercialisation, including questions about the extent to which new business models and new types of alliances and industrial organisation may be required. It is still unclear whether new or incumbent companies will be the main innovators as the field develops further. Better understanding of convergence between technologies is needed.

Sources: E. Helpman (ed.) (1998), *General Purpose Technologies and Economic Growth,* The MIT Press, Cambridge, MA; R.G. Lipsey, K. Carlaw, and C.T. Bekar (2005), *Economic Transformations: General Purpose Technologies and Long Term Economic Growth*, Oxford University Press, Oxford; V. Ruttan (2008), "General Purpose Technology, Revolutionary Technology, and Technological Maturity", *Staff Paper P08-3*, Department of Applied Economics, University of Minnesota, April; OECD (2008), *OECD Information Technology Outlook 2008*, OECD, Paris.

ICTs support innovation

The Internet, enhanced with high-speed broadband connections, vastly increases the functionality of ICT capital and has created a platform for innovation across the economy and society. Today, high-speed communication networks support innovation throughout the economy much as electricity and transport networks spurred innovation in the past. Future innovations in many sectors will be linked to the availability of high-speed, competitive data networks and the new applications they support. However, for the full potential of new network technologies to be realised, the market will require that they have universal, or close to universal coverage, and the full potential of networks is only likely to be achieved if markets are effectively competitive and there is adequate coverage of most geographic areas.

Software plays an important role in enabling the strong contribution of ICTs to innovation (OECD, 2009c). Efficiency-enhancing processes and structural innovations, such as inventory and supply chain management or e-commerce, have been enabled by innovative software systems. As communications technology continues to converge across different electronic platforms and wireless networks, new opportunities for software innovation are constantly being created. This is particularly the case for industries in which embedded software plays a prominent role such as automotive, robotics, mobile phone, household appliances, etc., or in which it leads to process or organisational innovations in other branches (OECD, 2009c, 2008f).

Many innovative services tied to broadband are emerging today in electricity, health, transport and education.

In the areas of electricity, ICT hardware and software and data networks can serve as the foundation of new, smart electrical grids. Consumers can have a vision of overall supply and demand and of their electricity consumption in real time and thus adjust their consumption based on price signals. For the electricity provider, the smart grid allows operators to stabilise demand by monitoring and influencing consumption in real time either through technical intervention or variable demand-based pricing. ICTs can also facilitate distributed energy generation from renewable sources, intelligent load management, effective electricity storage and large-scale electric car infrastructures.

Adoption of ICTs in the health sector is increasingly seen as part of the process of modernisation of health care. Many estimate that this will result in care that is of higher quality, safer and more responsive to patients' needs as well as more efficient (appropriate, available, and less wasteful). ICTs can help improve primary care, generally by improving the management of widespread chronic diseases such as diabetes or heart failure, which are strongly associated with preventable hospitalisations. In areas with large rural or remote populations, broadband is enabling increasing use of telemedicine to overcome the impact of the shortage of physicians and improve access to care. This is particularly important as the percentage of the population over age 65 rises significantly.

ICTs are also substantially increasing the safety of medical care by improving clinical staff actions and workflows and by bringing evidence-based, patient-centred decision support to the point of care. Electronic health records can make medical information on individual patients readily available and can be used to follow the effects of disease and therapies on the patient over time and to detect and prevent medication errors (OECD, 2010c).

For their part, transport planners struggle to understand traffic flows because there are not sufficiently robust means to collect traffic data, analyse and model it in real time and then pass the results along to all concerned drivers and commuters to help them alter their routes. Broadband networks and access to the resources they provide can form a foundation for collecting and distributing timely transport information. This information, provided to traffic control systems and delivered to commuters to aid in route planning can help reduce traffic congestion, lower fuel consumption and help users avoid accidents.

In addition, intelligent infrastructure systems can be used to measure the intensity and fluidity of traffic and to control traffic lights. Further examples of ICTs for intelligent vehicles include: *i)* driverless metro systems that use sensors to control the velocity and location of trains as well as stops; *ii)* buses that detect whether doors are open; and *iii)* cars with embedded systems for fuel-efficient driving or with systems for vehicle-to-vehicle communication (OECD, 2008c).

ICTs are also having a significant impact on education and e-learning by improving access to digital learning resources; encouraging communication among schools, teachers and pupils; promoting professional education for teachers; and linking local, regional and national databases for administrative purposes or supervision.

New high-speed broadband networks are also affecting other sectors of the economy. Broadband has become the leading delivery system for the newspaper, music and video industries. More generally, high-speed broadband networks are also the foundation of innovations in cloud and grid computing which efficiently centralise computing power and resources across the Internet and enable the rapid scalability of services in sectors such as transport and education. They have transformed financial services in developing countries.

The process of ICT implementation is, however, a complex and expensive undertaking. At each stage of the implementation/adoption/use cycle, various social and economic factors can disrupt the process. Government action and leadership is proving necessary to help overcome barriers. Governments can provide motivation for high-performing projects through targeted incentives aimed at unambiguous public priorities with clear benefits and that may not be achievable without ICTs. Governments also occupy a central position in the development and enforcement of reliable and coherent privacy and security frameworks which are essential to establish the high degree of public confidence and trust needed to encourage widespread adoption of ICTs.

Broadband development and innovation: a role for government

Innovation thrives on open platforms with expansive bandwidth for new applications. Government should promote the network technologies and topologies that are the most flexible, create the most opportunities for competition, offer the highest potential for innovation and can provide the most bandwidth in the future. Policy makers and networks planners should focus on developing a broadband platform which easily supports capacity upgrades to match the bandwidth demand of new applications as they appear. Bandwidth constraints should not inhibit innovation.

The OECD recently put forward a new approach to evaluating the costs of building the most forward-looking network platform for innovation by evaluating the short-term cost savings (benefits) that would have to be achieved in other key economic sectors to justify the investment. On average, a cost savings of between 0.5% and 1.5% in electricity, health, education and transport over ten years directly due to the new broadband network could justify the cost of building a national point-to-point, fibre-to-the-home network. If the cost savings in these and other industries are potentially large enough to justify the investment, governments have an incentive to find ways to encourage rollouts to capture the social gains.

At the same time, certain roadblocks and bottlenecks may hinder implementation in some sectors and minimise the impact of broadband even when it is available. Broadband investment with the goal of cost savings should be coupled with initiatives to ensure a smooth transition from existing service models and address bottlenecks that might hinder innovation. For example, there are concerns that networks deployed by incumbent telephone companies may make it difficult to maintain effective competition in markets. Regulators need to examine the options available to ensure competition, for example through access to facilities, access to passive facilities, or policies promoting inter-modal competition. Moreover, the roll-out of high-capacity networks may create asymmetries in access between urban and rural and remote areas. This raises the question of whether alternative technologies might be used to provide high-speed access to rural and remote areas. In addition, the question of whether new network developments should be reflected in universal service obligations should be reviewed.

ICT has become a world-wide repository for information that facilitates co-ordination and co-operation, and provides new ways of disseminating information (*e.g.* via the participative web, social networking tools and virtual worlds, and new open access repositories for scientific and technical data). Its low cost and growing ubiquity represents a change in how innovation is performed where it occurs and who participates.

Upholding the scalability of the Internet

The Internet has been remarkably successful in scaling up from a small community of technical users to a global network supporting more than a billion users. Because it is such an efficient platform for communication and innovation, it is drawing in an increasing number of people (and their devices). Devices such as handheld devices and integrated IP appliances and utilities increasingly use the Internet and thus require unique addresses. However, the number of available addresses under the current system (IPv4) is quickly running out and is expected to be exhausted by 2011-12.

If it becomes significantly more difficult and expensive to connect a device or computer to the Internet and if new entrants cannot readily interoperate with the rest of the Internet, innovation is likely to suffer. IPv6 is a newer version of the Internet protocol that widely expands the available addresses, but take-up has been extremely slow. In the absence of visible competitive differentiators – beyond future risk – or of customer demand, service providers operating in a deregulated commercial environment have somewhat reluctant to make the necessary investment.

Governments have a critical role to play in the transition to IPv6 by *i)* leading by example and demonstrating government commitment to its adoption; *ii)* working with the private sector and other stakeholders to increase education and awareness and reduce bottlenecks; *iii)* pursuing international co-operation and monitoring IPv6 deployment, and; *iv)* considering the applicability of other traditional public good solutions that might facilitate the transition.

Life sciences infrastructure

The advent of genomics and the application of computational techniques to the wealth of data coming from this area of science has brought into sharp focus the need for a strong and diverse infrastructure. Pertinent examples include:

- *Human biobanks and genetic research databases*: Access to high quality human genetic data and human tissue samples is increasingly at the core of modern clinical research. This must be balanced with rigorous quality control and scrupulous oversight of patient confidentiality and privacy. A number of countries/ regions have developed large-scale human biobanks and the OECD has been instrumental in developing principles and best practices for their governance and management (OECD, 2009d).

- *Biological resource centres:* Biological resources (microbes, plants, human cell lines, etc.) provide a vital underpinning for life science research. An OECD initiative developed best practices for ensuring the quality of such resources and for guaranteeing the security of their exchange. The German government has since led in financing a global network of centres that store and exchange such resources and meet OECD best practices (OECD, 2007).
- *SNPs consortium:* SNPs (single nucleotide polymorphisms) are one of the most valuable tools available for linking the genetics of individuals to the onset and treatment of disease. They therefore play an essential role in drug discovery and development. The consortium was set up on a non-profit basis by industry and the public sector to pool research data and provide simple and rapid access to knowledge.

Because the governance of such infrastructure initiatives needs to keep pace with developments, it often develops along with the infrastructure itself. There is consensus that there is a need for better foresight regarding the prioritisation of infrastructure for the life sciences – perhaps particularly where these converge with other technologies – and for the development of best practices around governance.

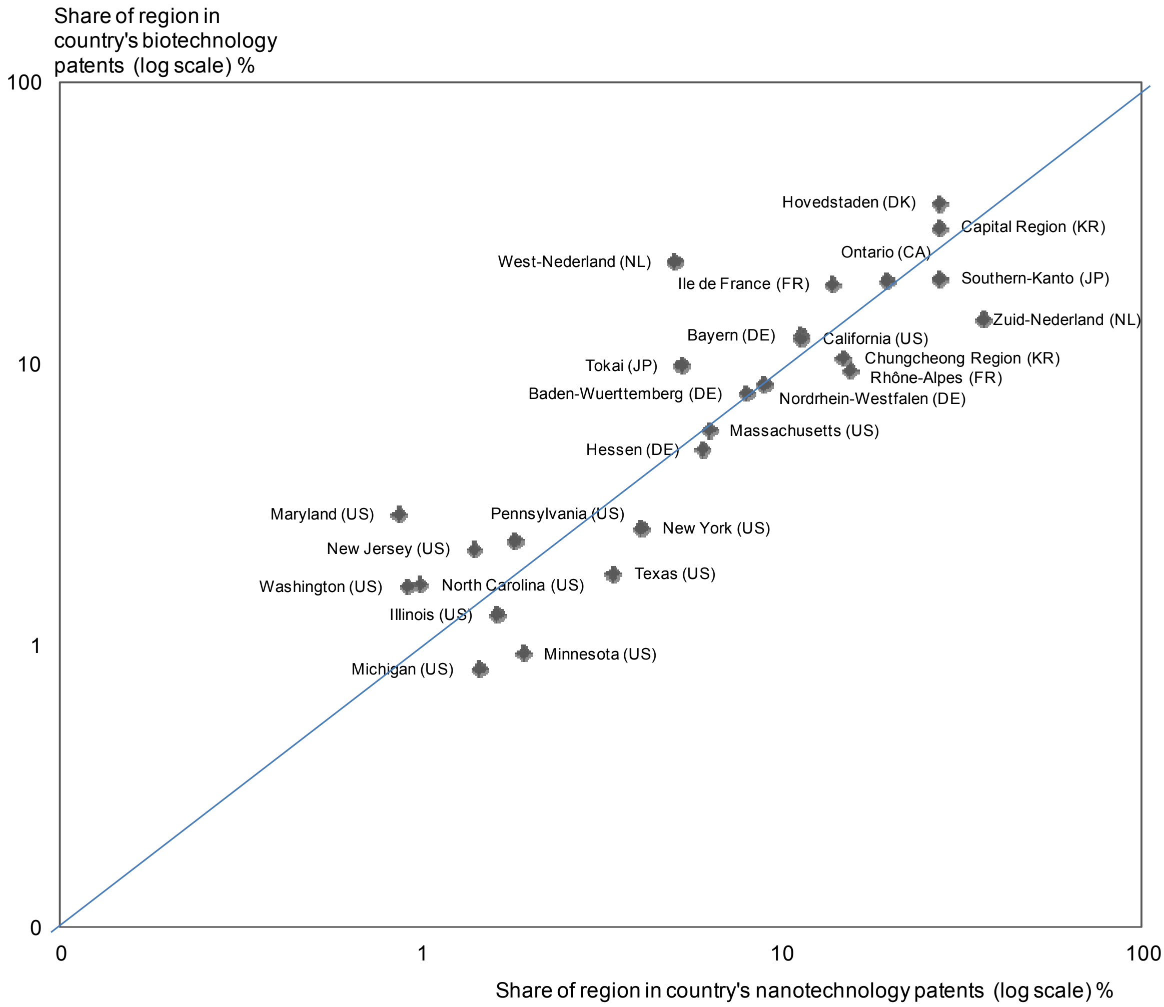
Advanced technologies are converging

The increasing complexity of some technological innovations and the evolution towards bringing to the market products that rely on convergence of different technologies such as ICTs, life science technologies and nanotechnology have been accompanied by the rise of so-called "technology platforms". Broadly speaking, these are areas at the boundaries of different technologies which provide the basis for a range of new products and processes. In biotechnology, platforms are developing around research tools for molecular genetic testing, for drug discovery and other applications in industrial biotechnology. ICT platforms are increasingly becoming intertwined with life sciences platforms in genetics and synthetic biology. Some of these infrastructure projects are creating new collaborative mechanisms for sharing and easing access to IPRs while ensuring fair returns to rights holders (OECD, 2010d). As Figure 5.5 demonstrates, centres of technology convergence are evident. The development of such platforms opens up opportunities for innovation but also present challenges. Platforms tend to be followed by standardisation, which may have uncertain impacts on the developments of alternatives.

According to many analysts nanotechnology may lead to further advances in both ICT and biotechnology as it continues to cross-pollinate and even converge with these fields. Examples of converging areas include nanoelectronics (DNA or quantum computing, biomolecules for electronic and data storage) and various applications related to health care such as drug-delivery systems, biomolecular motors, sensors and new types of cost-efficient diagnostics. It is sometimes suggested that these convergent developments may lead to the partial fusion of nanotechnology, biotechnology, information technology and cognitive sciences (OECD, 2008c). Merging ICT research with other scientific disciplines and applications opens up new possibilities, such as ICT-enabled biomarkers and biosensors to improve medical diagnostics, brain-computer interfaces to operate computers and other applications via brain activity, bio-computing using living tissue for information processing, quantum cryptography for Internet security.

Figure 5.5. Top patenting regions in biotechnology and nanotechnology, 2005-07

As a % of patents in biotechnology and nanotechnology of the country



Note: Data relate to patent applications filed under the Patent Co-operation Treaty (PCT) in biotechnology and in nanotechnology. Patent counts are based on the priority date, the inventor's region of residence and fractional counts. The regional breakdown used is based on OECD's Territorial Level 2.

Source: OECD (2010), *Measuring Innovation: A New Perspective,* OECD, Paris, based on OECD REGPAT database, January 2010.

Advances in computational power have had a profound impact on life sciences at every stage of the value chain. Were it not for enhanced ICT capabilities, the sequencing of the first draft of the human genome, along with the sequencing of all other genomes from plants, animals, bacteria and viruses, would not be possible. Indeed the hand-in-hand relationship between biotechnology and ICTs has given rise to the field of bioinformatics. This provides both a source of significant opportunity for innovation but also often a bottleneck for researchers attempting to analyse patterns of genetic variation and identify the underlying causes of disease. Most diseases are not caused by single genes but by a multiplicity of genes interacting with one another and with the environment (both inside and outside the human body) (OECD, 2009e). The challenge of managing this information also affects regulators and other policy makers who can no longer regulate the new diagnostics and therapeutics for safety and efficacy through legacy information systems architecture.

Fostering knowledge flows: the role of networks and markets

Knowledge drives economies. Its creation and application are crucial to the ability of firms and countries to thrive in an increasingly competitive global economy. Investing in knowledge creation and enabling its diffusion are therefore essential to create high-wage employment and enhance productivity growth. Knowledge is a source of future and sustained growth that cannot be exhausted and is often non-rival. Unlike any other factor of production, knowledge can be used by many firms and countries at the same time to foster sustainable economic growth.

Knowledge is proprietary when it is controlled by one or more parties that can exclude others from accessing or using it. Knowledge is non-proprietary when it can be accessed without limit by any party willing to do so at no or low cost. Proprietary mechanisms are often associated with IPRs which compensate for the costs of knowledge production through the transfer of knowledge or the marketing of a product or service based on that knowledge. Non-proprietary mechanisms require compensating the costs indirectly (by taxes, donations or any type of free contribution). This section first examines the role of intellectual property rights (IPRs) in the context of innovation, and then the role of knowledge markets and networks in the innovation process.

The circulation of knowledge: the generation and implementation of ideas

The circulation of knowledge is essential to innovation. New ideas emerge from the combination of existing knowledge from various sources. Circulation of knowledge make it possible to confront, mix, test and improve ideas, to share and exploit data sources, and to transfer basic knowledge to contexts in which it can be developed and applied. It allows knowledge producers to specialise in their respective fields of expertise and results in efficiency due to specialisation, economies of scale, learning, etc.

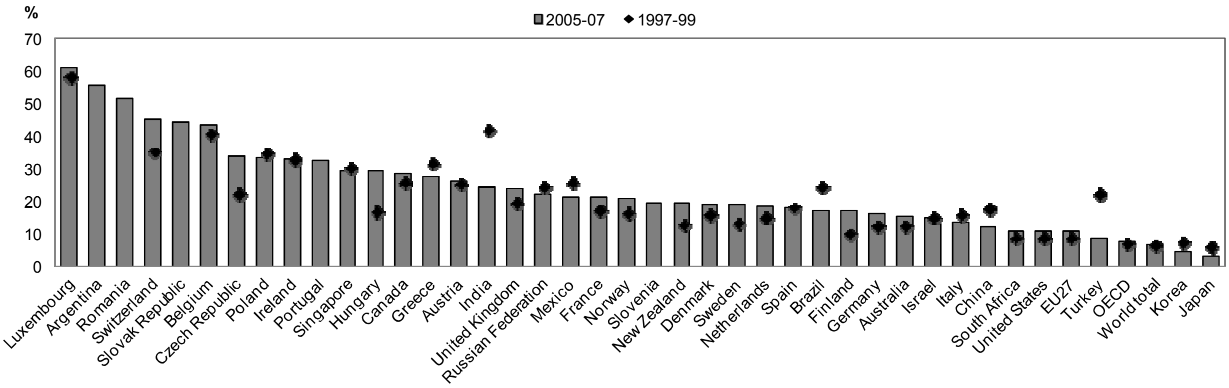
The circulation of knowledge is also essential to productivity growth. Productivity in firms increases through the application of knowledge from elsewhere. Many new products, especially complex products such as mobile phones or cars, require components based on knowledge resulting from inventions made in various places. Some firms are good at inventing but have no comparative advantage in implementing their inventions, and vice versa. This again requires the circulation of knowledge.

The circulation of knowledge plays a vital role in the organisation of innovation known as open innovation (see Chapter 2). Open innovation commonly involves partnerships with external parties (alliances, joint ventures, joint development, etc.) and acquiring/selling knowledge (contract R&D, purchasing, licensing). It is also increasingly realised through corporate venturing (equity investments in university spin-offs or in venture capital investment funds). Companies also use venturing to find external partners to commercialise innovations that are not used internally (divestments, spinning out, spinning off).

Evidence shows that the circulation of knowledge has increased over time (see Chapter 2). For example, data on trade in technology cover the transfer of techniques (through patents and licences, disclosure of know-how); the transfer (sale, licensing, franchising) of designs, trademarks and patterns; services with a technical content, including technical and engineering studies, as well as technical assistance; and industrial R&D. They show that technology flows (defined as the average of technological payments and receipts) for OECD countries increased from 0.4% of GDP in 1997 to more than 0.6% in 2007, a 50% rise in recorded international transfers of knowledge (OECD, 2009f). The international co-invention of patents has also increased, as a result of co-operation between researchers of the same enterprise in different countries. The average share of patent applications filed under the PCT that involved international co-invention increased from 7% in 1997-99 to 7.3% in 2005-07 (Figure 5.6).

Figure 5.6. PCT patent applications with co-inventors located abroad, 2005-07

Percentage



Notes: Patent counts are based on applications filed under the Patent Co-operation Treaty, at international phase, by priority date and inventor's residence country. Figures only cover countries/economies with more than 150 PCT filings over the periods. Share of patents with at least one co-inventor located abroad in total patents invented domestically. The EU is treated as a country; intra-EU co-operation is excluded. The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law. It should be noted that statistical data on Israeli patents and trademarks are supplied by the patent and trademark offices of the relevant countries.

Source: OECD, Patent Database, February 2010.

The role of intellectual property rights

IPRs are legal titles giving exclusivity on certain uses of intellectual assets to individuals, firms, universities or other entities. They include patents (for inventions), copyright (for material such as software, writing or the arts), design and trademarks (for brands, logos, etc.). These various rights are heterogeneous in terms of their content and purpose. They all rely however on the assumption that market exclusivity can potentially provide owners with more revenue than purely competitive markets and thus provide an incentive to invest to build the corresponding asset. Hence IPRs create a trade-off between static efficiency (pure competition bringing down prices) and dynamic efficiency (giving incentives to invest, notably in innovation). The proper management of this trade-off is at the core of IPR policies.

Patents endow their owner with a set of exclusive rights over an invention (a product or process that is new, involves an inventive step and is capable of industrial application) as defined by the "claims" described in the patent document. The legal protection conferred by a patent gives its owner the right to exclude others from making, using, selling, offering for sale or importing the patented invention for the term of the patent, which is usually 20 years from the filing date, and in the country or countries concerned by the protection. These rights provides the patentee with a competitive advantage (OECD, 2009g, p 18).

Patents also serve to disseminate knowledge regarding the protected inventions. The right is granted under the condition of disclosure: the contents of the invention must be publicised in a way that allows it to be understood and implemented by a "person skilled in the art". Hence patent libraries and databases are a major source of technological information that is broadly and freely accessible. In addition patents, by giving a legal guarantee to their holder that they will not easily be deprived of the invention, might encourage them to market an invention instead of keeping it secret. Indeed, in some jurisdictions patents can be challenged if they are not "worked". Hence patents should not be seen only as providing exclusivity for products and processes, but also as encouraging the diffusion of knowledge.

Various empirical surveys (*e.g.* Cohen, Nelson and Walsh, 2000) have shown that patents are extensively used in high-technology industries: in the pharmaceutical industry they ensure exclusivity for drugs, and in the information technology (IT) industries they are used by companies to share technology through licensing and cross-licensing. An OECD study based on innovation surveys (OECD, 2009h) showed that an increase in the proportion of patenting firms would actually increase the proportion of innovating firms as well, although to a different extent across countries and across industries.

Patents are particularly important for new, small firms (start-ups) which have no other means of protecting their inventions, unlike large established firms which have manufacturing facilities, distribution networks, a brand name, etc., which give them some *de facto* protection. By protecting new entrants against incumbents, patents can in such cases enable entry on innovative markets and thus boost dynamic competition. The traditional trade-off between static and dynamic efficiency does not fully capture this, as patents can in certain cases serve *both* static and dynamic efficiency (incumbents will reduce prices in order to hamper new entry: this strategy has been observed *e.g.* in consumer software markets).

Between the early 1980s and the mid-2000s patent laws were strengthened worldwide (Martinez and Guellec, 2004). Steps included the creation of specialised courts which more often find against alleged infringers and judge patents to be valid; an increase in the damages granted to patent holders in case of infringement; as well as an expansion of the explicit patent subject matter in certain countries (*e.g.* genetic inventions, software inventions and business methods). A particularly important step was the signature of the TRIPs agreement in 1994, which established common standards for patent law in all signatory states. This implied a strengthening of patent laws in most countries, notably developing countries, and for the first time provided for international sanctions against states which did not comply with their IPR-related commitments. At the same time legal standards, *e.g.* regarding non-obviousness, were eased, either explicitly by courts decisions[3] or in practice by overburdened patent offices.

Some further adjustment seems to have occurred in recent years. For example, stricter standards regarding the inventive step are being established, notably in the United States and Europe. The impact on the number of patent filings or on innovation is not yet clear. The latest data regarding patent filings tend to show a sharp slowdown in Europe and, for primary filings, in the United States. Recent growth in the United States is essentially due to "requests for continued examination" (Torres, 2009). The slowdown in European filings and in primary filings in the United States could be due to the global economic crisis. The longer-term trend has been steady growth across most major jurisdictions.

What role for patent policies?

Whereas markets for most products and for most inventions are global in scope, patent offices are still national or at most regional (in the case of the European Patent Office, EPO) and provide protection in the corresponding jurisdiction, whatever the residence of the owner of the invention (domestic or foreign) though in the case of the EPO it should be noted that a single European patent does not yet exist. The national character of patent policies raises a risk of inconsistent decisions across jurisdictions, and also increases the cost of processing patent applications. The Patent Co-operation Treaty (PCT, implemented since 1979) aims to co-ordinate procedures across offices. Further worldwide consolidation may be possible, but will require further convergence in patenting laws and standards.

Because international co-ordination of patent policies is important, patent standards are part of several international agreements, the most important of which is the TRIPs (Trade-related Aspects of Intellectual Property Rights). The issue of enforcement is frequently raised in international discussions between developed and emerging countries, as patent legislation can meet international standards but ineffective enforcement can be associated with counterfeiting. However, emerging countries have been strengthening their patent systems, notably regarding capacity and enforcement, as they have expanded their innovative activities over the past decade.

The legal framework sets standards for inventions that are patentable and the rights and obligations assigned to patent holders, *i.e.* the "strength" of the patent. Strong patents are usually understood as endowing their holder with strong rights, which strengthen the private economic value of the patent. Stronger can mean broader (close substitutes to the invention are excluded), longer, more strictly enforced, more often upheld in courts (seldom revoked), and/or giving right to higher damages in case of infringement. Such characteristics put the holder in a position to generate more value from the patent. However, strong patents may exclude other firms from the market or result in higher than necessary prices for customers. A patent system should take account of the interests of all parties: inventors, competitors (actual and potential) and customers. This typically involves policy areas beyond patent policy, including competition policy and sectoral policies (*e.g.* health) that may establish market prices or otherwise regulate specific industries. A "patent thicket" may also protect incumbents from competition from new entrants and thus deter innovation (Shapiro, 2002; OECD, 2002). In some cases (such as genetic inventions used in health care), specific measures have been adopted to discourage the development of such thickets and encourage broad licensing of patents (OECD, 2006).

Patent quality is an important aspect of patent policy. If patents are awarded to weak inventions, a proliferation of patents on trivial matters may raise barriers to the diffusion of technology, shift innovation towards marginal improvements, and increase uncertainty and unpredictability, thereby lowering incentives to invest in inventive activities. Recent decisions by the US Supreme Court and the European Patent Office (EPO) have raised the bar for the granting of patents.

A major difficulty in patent policy comes from the diversity of technology and market characteristics across industries. The ability of patent systems to accommodate this diversity is limited, as the patent statute is unitary: the same legal standards are applied to all industries. This helps explain disagreements between industry representatives around patent reforms, as changes that would favour innovation in certain industries might hamper it in others.

With the expansion of knowledge networks and markets (see below) and the diffusion of collaborative innovation (see Chapter 2) the production of new knowledge is increasingly distributed. At the level of patent management, this has been accommodated to date by setting up various arrangements within the existing patent legal framework: licensing, cross-licensing, patent pools, etc. (OECD, 2010e). This can go a long way towards accommodating changes in inventive processes, but consideration may need to be given at some point to adapting the legal framework itself, for example by differentiating the rights and obligations of the rights holder on a menu from which inventors could choose their preferred option (*e.g.* the "soft IP" proposal of IBM, 2007).

Knowledge networks and markets

Knowledge networks and markets (KNM) are arrangements which govern the transfer of various types of knowledge, such as intellectual property, know-how, software code or databases, between independent parties. Well-designed KNM can reduce transaction costs, enable new knowledge transfers and make existing transfers more efficient. KNM are extremely varied: some are essentially based on prices and direct monetary transfers (*i.e.* markets); others are based on structural relations or networks; still others are a mix of the two (Box 5.6). The main types are discussed below.

Box 5.6. Collaborative mechanisms, knowledge networks and consortia in the life sciences

A more open architecture for innovation in health technologies is emerging. Collaborations, public-private partnerships, consortia, innovation networks, brokerage facilities, prizes and data sharing/exchange platforms are increasingly used to access, interpret and share widely dispersed sources of data, information, know-how, materials, compounds, software, methodologies, expertise and patented innovations. In the era of genomic medicine – increasingly known as personalised medicine – these open models will take on added importance. Given the vast size of the human genome (over 3 billion base pairs of As, Cs, Ts and Gs), improved access to and exchange of biological samples and the research and clinical data associated with those samples is critically important to building the scientific and medical knowledge base needed to address global needs in human health. As assets are externally distributed, organisations derive value from the ability to access, manage and exploit knowledge from multiple sources. Open or networked health technology innovation requires organisation, frameworks, financing, quality information, asset management and vision. These are essential for both public and private research organisations. There is no single model for distributed knowledge networks in health technology. Success depends on a variety of factors, including the goals of the network, the partners involved, financing, administration and governance. The following are some of the collaborative mechanisms, knowledge networks and consortia that help advance research in the life sciences to move these discoveries into the clinic.

…/…

Box 5.6. Collaborative mechanisms, knowledge networks and consortia in the life sciences ***(continued)***

The Genetic Association Information Network (GAIN). Gain is a public-private partnership of the Foundation for the National Institutes of Health, Inc. (FNIH) and includes partnerships with the US National Institutes of Health (NIH) and the private sector. GAIN supports a series of genome-wide association studies (GWAS) designed to identify specific points of DNA variation associated with the occurrence of a particular common disease. Investigators from existing case-control or trio (parent-offspring) studies were invited to submit samples and data on roughly 2 000 participants for assay of 300 000 to 500 000 single nucleotide polymorphisms designed to capture roughly 80% of the common variation in the human genome. Specific genes involved in disease processes can be identified once particular areas of the genome are associated with the occurrence of disease. The GAIN initiative has officially concluded, and the resulting data have been deposited in the database of Genotype and Phenotype (dbGaP) at the National Library of Medicine at the NIH for the broad use of the research community. Access is controlled by the GAIN Data Access Committee.

The Innovative Medicine Initiative (IMI). The IMI is a joint technology initiative of the European Commission and the European Federation of Pharmaceutical Industries and Associations (EFPIA). It was launched in 2005. It has a total budget of EUR 18 million of which two-thirds is contributed by the Commission. The IMI aims to enhance Europe's competitiveness by ensuring that the biopharmaceutical sector remains dynamic. IMI stated purposes are to improve predictivity of drug safety evaluation, improve predictivity of efficacy evaluation, and improve knowledge management as well as education and training. But the research agenda of IMI indicates that an important part of its activity is devoted to the discovery, development and validation of biomarkers. This shows the importance given to biomarkers in large-scale projects. The discovery, development and acceptance of biomarkers and the commercialisation of biomarkers-related products is seen as essential to improve country competitiveness in pharmaceuticals and diagnostic-related activities.

CollabRx. CollabRx is a privately held NetPortofolio company which builds "virtual biotechs to help slash the time, cost, and risk of developing new therapies", and provides tools to patient groups and virtual biotechnologies to accelerate the development of treatments for diseases that do not attract major pharmaceutical company research funding. This web-based collaborative research platform gives different types of participants in a research system (*e.g.* genomic and proteomic profiling, combinatorial drug screening, mouse) access to all the data, knowledge and resources they need to function as a team. Scientific advisory board members can use the system to prioritise research opportunities in a funder's portfolio. Project managers can co-ordinate and track all activities, and foundations can monitor progress and allocate resources in real time. A specific service in this initiative has been dedicated to personalised medicine delivery for cancer patients. Working on behalf of a limited set of cancer patients and their physicians, CollabRx is developing CollabRx ONE. This project aims to identify specific mechanisms of carcinogenesis based on a patient's tumour samples and to provide hypotheses for compounds that target those mechanisms.

InnoCentive: breakthrough innovation for biomarker discovery. InnoCentive is a broker that connects companies, academic institutions, public-sector and non-profit organisations that are looking for innovative solutions, with a global network of more than 160 000 problem solvers all over the world. InnoCentive is built on the idea of crowd-sourcing. Crowd-sourcing typically involves allowing a mass of people to help a company or a group accomplish its goals. InnoCentive exploits this strategy to solve specific questions for its clients in areas ranging from business and entrepreneurship to mathematics and life sciences. These questions, turned into "challenges", are posted online and those who provide a valuable solution are awarded a prize (ranging from USD 5 000 to USD 1 million). So far, InnoCentive has posted more than 700 challenges, over 250 of which have been solved. Finding biomarkers of complex diseases is one of these challenges – *e.g.* finding biological targets for obesity, developing a synthesis method for a new tuberculosis drug, finding biomarkers of amyotrophic lateral sclerosis.

IP marketplaces

IP markets and IP aggregating mechanisms are concerned with the exchange or sharing of existing knowledge protected by IPRs. They often involve licensing contracts negotiated on a bilateral or multilateral basis. Examples of IP marketplaces include: patent clearing houses; patent auction houses (*e.g.* Ocean Tomo); licensing markets (IPX, to be launched in Chicago in 2010); brokers (*e.g.* specialised Internet portals such as Yet2.com); technology transfer offices of universities that license university patents and monitor the associated knowledge transfer; as well as technology platforms (like those of Apple or Nokia) that allow inventors of applications compatible with a particular standard to sell their invention to any user of the standard.

IP aggregating arrangements bundle complementary pieces of IP and offer access to the pool. They are often created when many inventions, owned by distinct parties, are needed to manufacture products or invent new ones: grouping the rights on these inventions and offering the bundle on the market reduces transaction costs. Examples of IP aggregators include patent pools (which pool the various essential and complementary patents protecting a particular technology or standard); as well as patent funds (*e.g.* Intellectual Ventures), which gather patents associated with particular technical fields and license them as a bundle (Yanagizawa and Guellec, 2009; OECD, 2010d).

These arrangements aim to replace *ad hoc* approaches to licensing by collective mechanisms to conduct negotiations in a standardised way at reduced transaction costs. Most transactions are quite traditional, but they are structured in a new way and at a larger scale. In recent years, many new business models have emerged; most, however, are still at an early stage and have to demonstrate their viability over time. Because they reduce cost, these mechanisms may boost licensing activity and other types of IP transactions. They may therefore have a positive impact on innovation performance, although they also raise specific competition issues. For example, patent funds might gather a significant interest in an entire technology field.

Non-commercial networks and knowledge communities

Not all knowledge networks are developed for commercial purposes. Some groups of individuals or organisations share or exchange knowledge and data at no cost or for non-commercial purposes. Access to this knowledge is sometimes provided to non-participants as well. Examples of such communities include: open source (mainly for software, *e.g.* Linux); expert networks (sharing knowledge of common interest, *e.g.* Spineconnect); consortia of research institutions that share databases or other research tools (CaBIG in US cancer research); patent clearing houses and patent pools that provide developing countries access to health technologies (*e.g.* GSK patent pool).

Such arrangements aim at leveraging the public good nature of knowledge. They do not compensate the knowledge provider directly and monetarily. As there is no direct monetary incentive, there have to be other reasons for participants to share knowledge such as an incentive relating to reputation (*e.g.* in the case of scientific communities) or expected reciprocity. The resources of these communities include free labour, revenue generated downstream by the provision of specialised services or selling of applications, and contributions by businesses that benefit from the network or by government as part of their science and innovation policies.

Research consortia

Research consortia are groups of research entities which enter into various types of interactions in order to produce new knowledge, separately or jointly, generally for commercial purposes. Examples include: R&D joint ventures between two or more companies as well as R&D agreements between businesses or between businesses and universities. They can also be extended and complex mechanisms involving a large number of entities under common governance rules as part of a same "innovation eco-system". Most university/industry agreements are of this type. Whereas knowledge communities may be open to non-participants, research consortia usually take a proprietary approach, as the long-term goal is generally commercial.

Research consortia can involve a variety of interactions among their members: sharing of common infrastructure, mobility of researchers, and agreements regarding IP. When set up on the basis of public policy initiatives, such clusters will also benefit from public funding and the provision of certain services (consultancy, etc.) by public entities. The licensing and commercialisation strategy of universities is increasingly part of a broader approach which takes into account all types of knowledge transfer and the complementary mechanisms needed for a dynamic entrepreneurship milieu (*e.g.* finance or business consultancy). For large firms the benefits of being in a research consortium include having access to more exploratory research than what they tend to do internally (thanks to start-ups), having access to basic knowledge, and maintaining a more flexible research agenda.

Knowledge brokerages

Not all knowledge that has value can be protected by patents or copyright. Knowledge such as that derived from failed clinical trials of drugs or underutilised experimental data do not currently have ready markets. However, a number of new knowledge brokerage facilities – such as InnoCentive in the United States (see Box 5.6) – are bringing suppliers and consumers of such knowledge together. Further developments in using computational techniques are needed to value and exchange such knowledge and to link early-stage data to possible downstream benefits.

Policies for knowledge networks and markets

KNM are of interest to governments because they directly affect the performance and diffusion of innovation and are reactive to certain policy instruments. Efficient KNM reduce the cost of accessing knowledge for their participants; they must strengthen, or at least not weaken, the conditions and incentives for producing new knowledge in a co-operative or distributed context. Government policies include both the provision of adequate conditions for the development of efficient KNM and direct contributions to the creation of KNM when this can serve policy objectives.

For patent-based markets and aggregators, a number of policy concerns need to be addressed, apart from those related to patents addressed above:

- *Valuation of IP and other intangible assets:* The valuation of intangible assets is very difficult, especially for entities (SMEs or universities) which lack the resources and expertise to do this. A lack of references hampers the ability of markets to converge to reliable prices, and this may deter potential participants. Significant public and private efforts are currently under way to work out standard and transparent methods for valuing patents, and a proposal (from the German standards administration DIN) has been submitted to the International Organization for Standardization (ISO). However, in view of the difficulty of evaluating IP and patents, standards should be open, flexible and voluntary. As a first step, governments could develop and diffuse tools for valuing patents and other intangible assets.

- *Competition policies*: In certain technical fields rights may be very highly concentrated. This may lead to anticompetitive conduct that restricts access to knowledge and increases prices. Competition authorities therefore need to establish policies, *e.g.* defining the conditions which guarantee fair competition and those under which they will intervene in various knowledge transfer arrangements. Competition policy is also important for research consortia, *e.g.* for examining the competition aspects of pre-competitive versus competitive research.
- *Global aspects of KNM*: Cross-border knowledge transfers are a source of innovation and productivity both for the recipient and the emitting countries. Restrictions and obstacles to cross-border knowledge deals, such as international differences in rules and regulations governing licensing, may restrict knowledge exchange.
- *Access mechanisms:* Safeguarding non-monetary incentives and ensuring adequate resources for non-commercial entities participating in knowledge communities or in research consortia will ensure that access conditions are sufficiently open where necessary. The scientific community should in general provide access to its discoveries on a non-discriminatory basis and on a non-commercial basis if the benefits from commercialisation are not clear. Governments have a strong policy interest in making data, information and knowledge more accessible and in maintaining scientific resources over the longer term.
- *Investing in infrastructure*: Governments need to provide significant financial and human capital investments to assure the sustainability of research infrastructure. Information technology is the backbone that allows the network of disparate databases and knowledge repositories – *e.g.* everything from basic genomic research to clinical data to patient outcomes – to exist and, more importantly, to communicate with one another. When building IT infrastructure for scientific purposes, system designers should strive for “technological neutrality” or open standards so that platforms are adaptable and do not limit the future scope of research or collaboration.

The use of KNM to serve particular innovation policy goals should be more systematically explored by government. This includes the following areas:

- *Promoting knowledge transfers from universities:* The KNM approach consists in using the various tools available (IP licensing, spin-offs, contract research, co-operative research) in an integrated way and on a broad scale, with a view to enhancing the quantity and quality of knowledge flows to society and industry. Governments can encourage better access to the output of publicly funded research through legislation, regulation, policy guidelines and conditions for funding grants. Specifically, they may want to consider policies to encourage research organisations and grantees to give access to publicly funded research outcomes in the early stages of discovery. Additionally, guidelines can encourage appropriate behaviour in the licensing and transferring of inventions and discourage the frequent use of restrictive, exclusive licences that limit follow-on inventions.

- *Encouraging entrepreneurship*: KNM are of interest to smaller actors who have little internal capabilities to create or commercialise their inventions. KNM can allow small firms to access global knowledge, as well as distant suppliers and customers.

KNM are among the infrastructures needed to co-ordinate innovative activities in an age where innovation is increasingly the work of groups of independent parties. Ensuring their development and use for societal goals will be key for innovation in the coming decades.

Unleashing innovation in the public sector is a priority

Because of their size, governments should also be innovative actors for the delivery of public services. Governments provide many services in OECD countries and their contribution to national wealth and expenditure is considerable. Demographic pressures, burgeoning demand, higher public expectations and ever-tighter fiscal constraints mean that the public sector needs innovative solutions to enhance productivity, contain costs and boost public satisfaction. The "innovation imperative" is therefore equally strong for the public sector. Several recent national innovation strategies include provisions for more innovation in the public sector (*e.g.* Australia, Finland, the Netherlands, Norway and the United Kingdom).

Public service innovation today differs considerably across OECD countries, from modest incremental changes to quite radical transformation. The tools being used to improve and transform services reflect different traditions, economic circumstances and starting points. Examples include a dedicated strategy for public-sector innovation, e-government and web 2.0; user-centred innovative approaches such as multi-access to information and services or design and re-design of services through service design principles and tools; citizen involvement in service design and delivery; partnerships with the private sector or not-for-profit sector; use of public service innovation organisations; use of incentives for innovation; and dedicated funding for innovation. In addition, there is growing interest in enhancing access to and use of public sector information (Box 5.7).

Box 5.7. Enhanced access and more effective use of public sector information

In 2008, the OECD Council adopted a Recommendation for Enhanced Access and More Effective Use of Public Sector Information. Public organisations produce and hold a large amount of information to fulfil their core public tasks. This information is generated, created, collected, processed, preserved, maintained, disseminated, or funded by or for the government or public institution. For the information it produces, the public sector exclusively determines the conditions of access and re-use. Some content is also held by the public sector for which the IPRs reside with other parties (*e.g.* films in film archives). An increasing share of public sector information is digitised or produced in digital form and is increasingly accessible and available as information products and services for potential users to find, access, re-use, and further develop for both individual and commercial purposes.

The growing interest of governments in facilitating access to and promoting further use of public-sector information by other public-sector organisations, businesses and individuals is based on the expectation that enhanced flows and re-use of information, greater competition and the increased economic activity associated with non-commercial and commercial use contribute to improving government efficiency, economic growth, and citizen welfare.

Box 5.7. Enhanced access and more effective use of public sector information *(continued)*

Examples of the large potential of digital information and content produced or held by the public sector when put to wider use include the variety of new private-sector services based on meteorological and cartographic data. They also include on-demand online access to video archives of national broadcasters, and new applications that show virtual guided tours through national art galleries or the detailed geology and physiology of a rare fossil in a natural history museum. While access, further development and commercial and non-commercial re-use of public-sector information and content is generally becoming more open, a number of obstacles impede its efficient and effective use. Difficulties faced by potential users include restrictive or unclear rules governing access and conditions of re-use; discouraging, unclear and inconsistent pricing of information when re-use of information is chargeable; complex and lengthy licensing procedures; inefficient distribution to final users; and barriers to development of international markets.

The OECD Recommendation is designed to tackle these obstacles, to improve access, make access more competitive, clarify copyright conditions, improve pricing transparency, provide public-sector information at the marginal cost of maintenance and distribution, ensure clear redress mechanisms, and exchange best practices. The principles aim to promote more efficient distribution of information and content as well as the development of new information products and services through market-based competition among re-users of information.

Source: National Research Council (2009), "The Socioeconomic Effects of Public Sector Information on Digital Networks: Towards a Better Understanding of Different Access and Reuse Policies", workshop summary, US National Committee for CODATA in collaboration with the OECD Working Party on the Information Economy.

Cross-border provision of higher education is another recent innovation. It has grown quickly in the past decade and plays a role in knowledge flows at the global level. It has the potential not only to improve educational offerings in host or receiving countries (including developing countries), but also to contribute to the formation of innovative clusters of activity (Box 5.8).

Box 5.8. Cross-border tertiary education: a tool for capacity building in innovation

The cross-border mobility of tertiary educational programmes and institutions has surged over the past decade in both OECD and non-OECD countries. From a relatively low starting point, it has grown very quickly, under a variety of contractual arrangements and "business models". Tertiary education institutions generally partner with local institutions when they deliver their programmes abroad, but they sometimes open branch campuses, turn their institutions into a multi-campus institution, or network with other foreign institutions to operate abroad.

Cross-border higher education represents a potential capacity development tool for the host countries, by providing quality benchmarks to their institutions thanks to incoming and outgoing mobility, by supplementing local capacity in the training of qualified manpower, by helping students and academics benefit from cutting-edge knowledge, or by inducing positive organisational or cultural change within their higher education sector. For example, in the frame of its Partnership for the Future initiative, Portugal recently invited MIT, Carnegie Mellon, University of Texas at Austin and the German Fraunhofer Society to partner with Portuguese higher education institutions to develop postgraduate and R&D programmes and improve its research capacity.

Increasingly, cross-border education is explicitly becoming part of innovation strategies. Foreign institutions may be grouped in clusters encompassing businesses as part of regional innovation clusters (and strategies): the Knowledge Village in Dubai, the Education city in Qatar, and the Kuala Lumpur Education City in Malaysia are examples of these new innovation clusters.

Source: OECD/World Bank (2007), *Cross-border Tertiary Education: A Way Towards Capacity Development*. OECD, Paris.

Public engagement and user-driver innovation are important

Involvement of citizens in service delivery is a source of innovation. Over time, governments have moved from delivering standard services to giving users more choice, to personalising services to a greater degree and even to designing services together with users. Today, initial pilots based on co-design and co-production are rapidly evolving toward more direct management by users of certain public services. For example, self-directed budgets for social care allow disabled people to better choose the kind of support they need and from which service provider. Benefits in terms of increased satisfaction and cost reduction can be realised when service users are involved in decisions on services which directly affect their lives rather than placed in plans designed by professionals. The rewards of "open innovation" and the potential for "crowd sourcing" new ideas by harnessing leading-edge users of public services are gaining recognition and contribute to transforming relations between service users and professionals.

Involving citizens in the design and delivery of public services opens new opportunities but also raises important challenges such as maintaining a high level of probity and accountability when responsibility for delivery is transferred outside government departments. Governments must ensure an inclusive approach to involvement while avoiding "capture" by particular groups. The real costs and benefits for government and citizens therefore need to be assessed carefully.

Early evidence from OECD country pilot projects to date indicates that citizen involvement in service delivery can bring cost reduction and enhance quality of service delivery. Some of the benefits of working with service users can be seen in sectors such as education, health and social care. In education, collaborative approaches between school officials, teachers, parents and community members (*e.g.* through community conversation groups) have been used in the United States to address achievement gaps among students from different social backgrounds. Peer mentoring schemes have been used in schools in the United Kingdom to fight bullying: they involve students who are trained as anti-bullying counsellors and are a source of advice and support for others. However not all services are amenable to participatory schemes (*e.g.* self-directed service models are less suitable for collective services). User involvement seems effective for complex issues requiring a behavioural change in the user (*e.g.* dealing with a chronic illness). In the health-care sector, innovative approaches include reducing user reliance on experts and cost by training service users to become more knowledgeable about their condition and manage their own care on a day-to-day basis. Such initiatives are being used in the United States and Canada.

The Internet is increasingly the platform of choice for the provision of public services. E-government investments have forced governments to rethink business processes and public service delivery. It has challenged them to reconsider responsibilities and organisation within and across levels of government in order to harvest "whole-of-public-sector" benefits. Today, recovery from the financial and economic crisis has drawn governments' attention to the need to realise the long-promised benefits from e-government investments. This involves an equal focus on cost saving and better quality of public services. Public-sector use of participative web tools (such as wikis, blogs and social bookmarking) is growing, both within government (to improve knowledge management and efficiency) and externally (to provide additional channels for interaction with citizens and business).

Building a culture of innovation in the public sector is essential

In many countries, government is the largest employer, and in some it is often the direct employer of many researchers and school teachers. Many OECD countries have implemented reforms in their employment arrangements in order to favour risk taking and innovation by public servants. Policies aiming at increasing diversity in public organisations are also being promoted not only to ensure equity, but also to foster productivity and innovation. Much more can still be done, although employment arrangements also have to take into account the need to focus on due process and continuity in the delivery of public services.

One way to build an innovation culture in the public sector is to measure public-sector innovation. It would signal the importance of innovation for improving public service delivery and provide an important tool for evaluating innovative practices (Box 5.9).

Box 5.9. Measuring innovation in the public sector

A major gap in the current measurement framework for innovation concerns innovation in the public sector and in the delivery of public services. Public policy in many OECD countries increasingly aims to improve the quality of public services and enhance value for money. To support such policy initiatives with sound evidence will require better measurement of public sector innovation. Recent initiatives in the United Kingdom and in the Nordic countries provide important input into an OECD project on measuring innovation in the public sector. This longer-term project will involve building a conceptual and statistical framework, pilot testing and development of statistical guidelines for data collection. The OECD's Governance at a Glance project will also progressively move towards including measurement of the performance of public services and the impact of innovation.

Promoting a culture of innovation in the public sector raises capacity challenges in addition to those involving human resources. New approaches and new technologies can help solve problems and improve how services are designed and delivered by increasing responsiveness, saving time and money and improving transparency. However, they also create new constraints and risks. In promoting a culture of innovation, governments cannot adopt the same risk-taking culture in their management processes as private companies. Finding the right balance between continuity and stability, on the one hand, and innovation and risk taking, on the other, both in government and in its interaction with private companies, is a continuing challenge.

Key findings

The creation, diffusion and application of knowledge are essential if firms and countries are to innovate and thrive in an increasingly competitive global economy. Most basic research still takes place in the public sector, predominantly by higher education establishments or government research institutions. While public research and the science base have always been at the heart of innovation and remain vital, they have come under increasing scrutiny and reforms are under way. Setting priorities for research and the evaluation of its impacts have become common and take many different forms. The funding of public research has also shifted towards more project-based and competitive methods.

Infrastructure is a vital complement to public and private research, and innovation also requires a supportive knowledge infrastructure. For example, broadband networks provide a platform for the development and diffusion of smart infrastructures (energy, health, transport, education). Governments should promote this symbiotic relationship and ensure that broadband is available throughout their territory. In addition to hardware and software, ICT infrastructure includes information that is publicly generated or funded. Provision of this information at no or low cost can stimulate innovation and improve the transparency and efficiency of government.

The development of fully functioning knowledge networks and markets can have a significant impact on the efficiency and effectiveness of the innovation effort. So far, however, knowledge networks and markets are much less developed than product, labour and financial markets, though they have become increasingly common in certain settings and sectors. Their development is important for stimulating innovation and improving its efficiency by reducing transaction costs. Some good practice exists (for example, in networking R&D for emerging infectious diseases) but significant scale-up is required.

An important contributor to building such networks and markets is the recognised ability to own certain kinds of knowledge through intellectual property rights. IPRs provide an important incentive to invest in innovation by allowing firms to recover their investment costs. IPRs should be well protected and appropriately enforced.

However, the protection of knowledge needs to be combined with policies and mechanisms that facilitate access and transfer. Excessively strong IPRs may hamper the appropriate use of protected knowledge and discourage follow-on research and research in adjacent areas, to the detriment of both competition and innovation. To encourage innovation and the diffusion of knowledge, IPR regimes should be of high quality and balanced. Patent systems need to be properly tailored to ensure the proper balance between incentives for innovation and the public benefit that flows from dissemination of the knowledge into the marketplace.

Because of their size, governments should also be innovative actors, particularly in delivering key public services, such as education or health.

The policy principles that emerge are:

1. Provide sufficient investment in an effective public research system and improve the governance of research institutions. Ensure coherence between multi-level sources of funding for R&D.

a) The governance of research institutions and higher education institutions should be such that it enhances excellence, with better linkages to other innovation actors and stakeholders. This includes restructuring the institutional mechanisms for financing public research to better facilitate funding of multidisciplinary research, and increasing their ability to work more closely with industry to bring ideas to market. It could also involve tying funding more closely to societal objectives and missions such as sustainability and global challenges.

b) Governments should adapt their mechanisms for financing research, for example by balancing competitively awarded project funding with other forms of funding, and giving greater autonomy to universities and public research organisations to enable them to enhance quality.

c) Policy should remove barriers and regulations that limit the effective interaction between universities, firms and public laboratories and foster collaborative arrangements that can facilitate the formation of networks.

d) Public information should remain open, to eliminate exclusive arrangements and allow innovative commercial and non-commercial re-use, as noted in the 2008 OECD Council Recommendation on Public Sector Information.

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2. Ensure that a modern and reliable knowledge infrastructure that supports innovation is in place, accompanied by the regulatory frameworks which support open access to networks and competition in the market. Create a suitable policy and regulatory environment that allows for the responsible development of technologies and their convergence.

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a) Foster the development of next-generation, high capacity broadband networks. These provide a platform for the development and diffusion of smart infrastructures (energy, health, transport, education). Governments need to ensure that broadband is universally available.

b) The potential to drive safe and successful innovation based on a broad range of technologies, including through convergence, is evident. Governments need to ensure that their infrastructure policies capture the benefits of such interactions and effectively co-ordinate ICT policies with innovation polices more generally.

c) Infrastructure development needs to support access to centres of technology convergence so that knowledge generated in high-technology hubs can be exchanged and maximum value extracted.

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3. Facilitate efficient knowledge flows and foster the development of networks and markets which enable the creation, circulation and diffusion of knowledge along with an effective system of intellectual property rights.

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a) Promote knowledge transfers. Policy should remove barriers and regulations that limit effective interaction between universities, firms and public laboratories and foster collaborative arrangements. Ensuring that researchers, public research institutions and higher education institutions have incentives and opportunities for collaborating with industry is important and vice-versa. In this context, research performance evaluation criteria should be adjusted to reflect the multiple missions of research institutions, including knowledge transfer where appropriate.

b) Encourage value creation from intellectual assets. Policies should encourage the use of and value creation from IPRs and non-IPR-based mechanisms. A variety of collaborative mechanisms and brokerages can facilitate access to and use. This may require a differentiated regime which takes into account the specificities of particular sectors.

c) Foster knowledge markets. Policies should foster the development of "knowledge networks and markets" both for commercial and non-commercial exchanges. This will require improving market transparency and competition, and supporting standards development that can improve the valuation of intellectual assets as well as mechanisms for the exchange of knowledge.

d) Protect and enforce intellectual property rights. Adequate and effective protection of IPRs provides important incentives for innovation, investment and trade. Competition authorities play an important role in ensuring that patenting procedures are not abused and that patents are not used anti-competitively.

4. Foster innovation in the public sector at all levels of government to enhance the delivery of public services, improve efficiency, coverage and equity, and create positive externalities in the rest of the economy.

a) Develop coherent innovation frameworks for the public sector. Governments need to articulate systemic innovation strategies for their main public services, such as education or health, that go beyond the funding of small pilot or experimental programmes.

b) Design data systems for innovation. Data systems that allow the linking of outcomes to resources and use of these resources can support innovation in the public sector and inform policy making. Measuring innovation in the public sector can help inform policy making and contribute to a more innovative culture.

c) Turn public information into a resource for innovation. Openness of public information should be the default rule as a way to eliminate exclusive arrangements and allow innovative commercial and non-commercial re-use. Unnecessary restrictions on the ways in which information can be accessed, used, re-used, combined or shared should be removed.

Notes

1. For example, scientific collections include plants, animals, microbes, biomedical samples, rocks, minerals, ice cores, fossils and so on. They are an integral part of the infrastructure of all countries with strong research enterprises [OECD (2007), Best Practice Guidelines for Biological Resource Centres", OECD, Paris; OECD (2008), "Global Science Forum Second Activity on Policy Issues Related to Scientific Research Collections: Final Report on Findings and Recommendations", OECD, Paris].

2. Calculations for the government sector from OECD, *Research and Development Statistics (RDS) Database*, February 2009.

3. Court of Appeals for the Federal Circuit and its implementation of the "teaching-suggestion-motivation test" in the United States.

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Chapter 6

Addressing Global and Social Challenges through Innovation

This chapter examines a number of global challenges currently facing governments: including addressing climate change, meeting global health issues and bridging the gaps in economic development. Innovation is crucial to tackling these public challenges and a mix of policy instruments may be necessary to reach sustainable solutions. The chapter therefore discusses the importance of bilateral and multilateral international co-operation strategies as well as the need for more concerted approaches to accelerate technology development and diffusion.

Introduction

Innovation is increasingly perceived as essential for tackling global challenges. Wherever they originate, the effects of greenhouse gas (GHG) emissions are universal, and any solutions that reduce these emissions will benefit all countries. Similarly, most infectious diseases have no regard for national borders, and new medicines can benefit many countries if they are affordable and accessible. High food prices and food security are also an important issue for developed as well as developing countries. Solutions to these challenges and more all require global action.

Global challenges are defined by the need to co-operate worldwide to create a public good (mitigation of climate change, health) or protect the global commons (the environment, fisheries). However, the need to invest in innovation to help address these challenges and maximise their impact raises corresponding challenges in the policy context. These concern international co-ordination of research needs and priorities; financing levels and provision of other incentive mechanisms or reward systems for innovation; evaluation; mechanisms to ensure technology transfer, equity and sharing of benefits; capacity building to enable countries to absorb innovations and benefits from them; and governance frameworks that establish and legitimate policy actions.

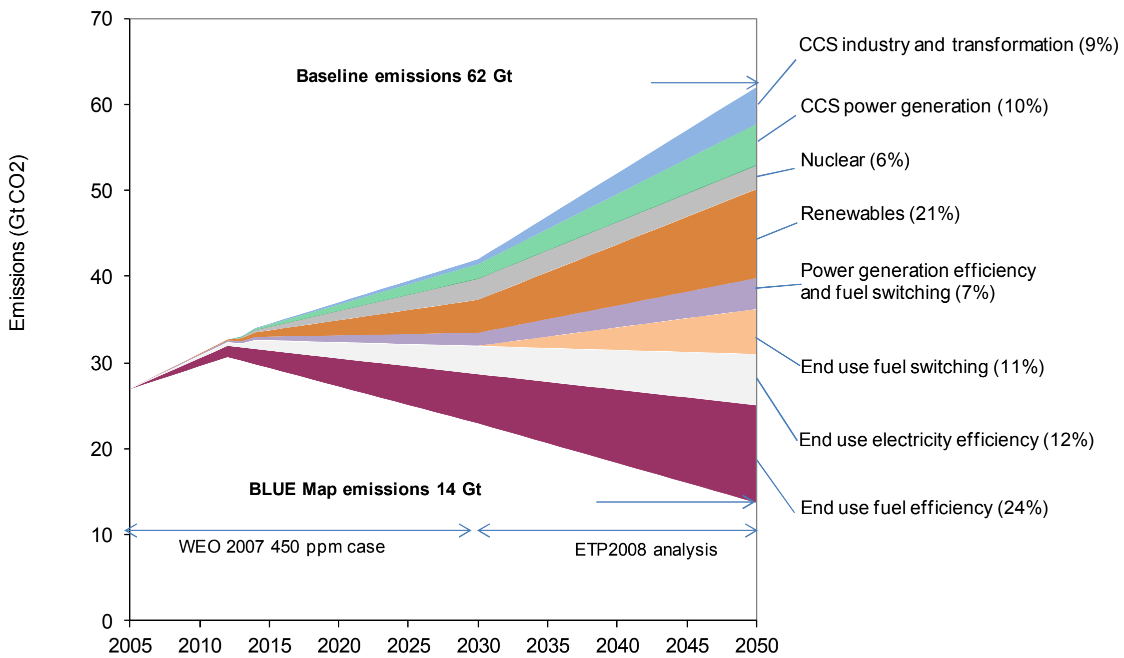
Co-operation is necessary because: *i*) no single country can successfully address the problems alone; *ii*) individual countries may not be willing to bear the costs of addressing global challenges because they cannot appropriate the benefits; and *iii*) the uncoordinated efforts of many countries are likely to be more costly and less successful than co-ordinated, co-operative efforts.

Addressing climate, health and food security issues

Tackling climate change

A lack of policy action to address climate change can mean significant economic costs (OECD, 2008a). The estimated costs vary widely, but may be as much as the equivalent of 14.4% of per capita consumption when all market and non-market impacts are taken into account (Stern, 2007). Innovation can reduce these costs by a shift to energies that create less greenhouse gas. The International Energy Agency's *Energy Technology Perspectives* (IEA, 2008) simulates a technological trajectory in which a 50% reduction in CO_2 emissions is achieved through aggressive innovative activities across a range of areas, *e.g.* carbon capture and storage (CCS), nuclear energy, renewable energy, and end-use efficiency gains (Figure 6.1). However, the scenario is based on optimistic assumptions about the progress of key technologies and requires deployment of technologies costing up to USD 200 per tonne of CO_2 saved when fully commercialised. If these technologies fail to reach expectations, the costs may be as much as USD 500 per tonne.

Figure 6.1. Potential contributions of various energy technologies to CO_2 emission reductions, 2005-50



Note: WEO refers to the IEA's *2007 World Energy Outlook*.

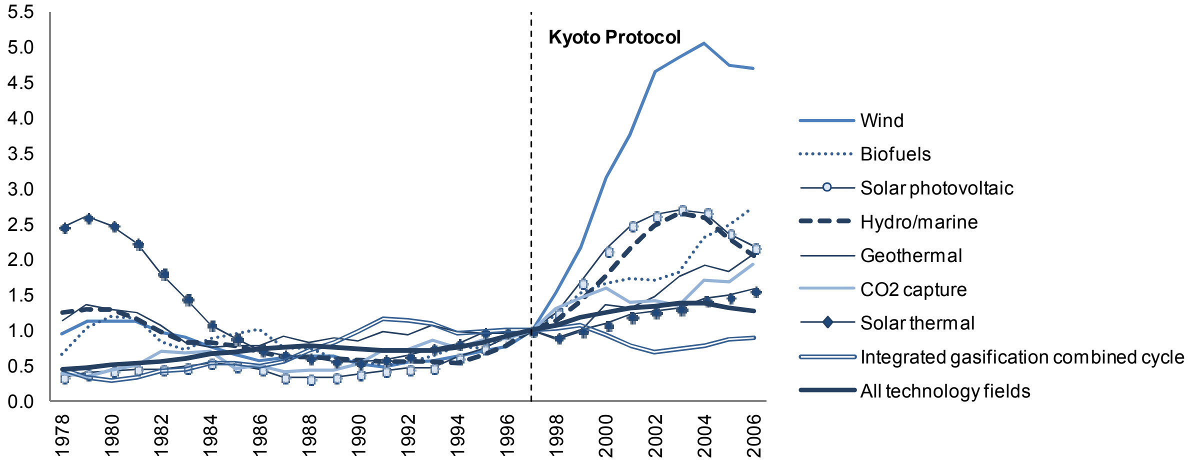
Source: International Energy Agency (2008), *Energy Technology Perspectives 2008: Scenarios and Strategies to 2050*, IEA, Paris.

Fortunately, there is evidence that innovation in climate change mitigation technologies is accelerating. Figure 6.2 presents trends in high-value patents ("claimed priorities") for a number of climate change mitigation technologies relative to the rate of innovation in general. A sharp increase in such innovations since the late 1990s coincides approximately with the signing of the Kyoto Protocol. Empirical work has shown that increases in fossil fuel prices, targeted R&D expenditures, as well as policy measures such as feed-in tariffs, investment grants and obligations can be a significant inducement to innovation in renewable energy technologies (OECD, 2008b; Johnstone, Haščič and Popp, 2010).

There is scope for expedited examinations and differentiated fee structures for patents covering technologies with public good aspects (*i.e.* medicines, abatement technologies), while encouraging greater mutual recognition of examination results. Faster examinations result in longer patent length, but do not actually extend the endpoint of protection as would formal extensions. Instead they offer efficiency gains so long as the average quality of the examinations does not go down (Maskus, 2010). Intellectual property offices in a number of countries (Australia, Japan, Korea, United States, the People's Republic of China and United Kingdom) have recently introduced expedited review for 'green' patents.

Figure 6.2. Innovation in climate mitigation technologies, patents compared to all sectors

Index 1980=1.0, Annex 1 ratification countries



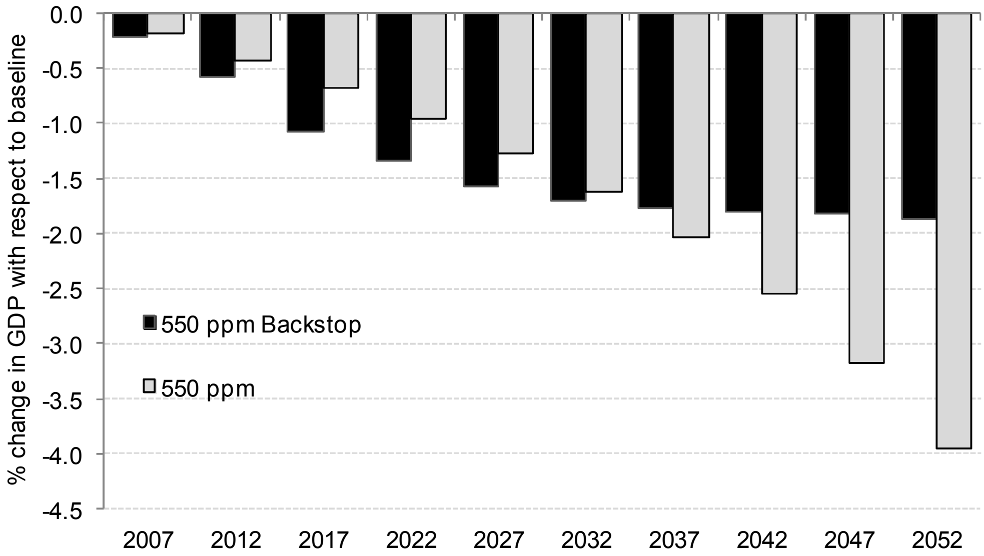
Source: OECD Project on "Environmental Policy and Technological Innovation" (*www.oecd.org/environment/innovation*). Data based on search strategies developed in collaboration with the European Patent Office, see *www.epo.org/topics/news/2009/20091125.html*.

Simulations of future trends has found that setting a price for CO_2 and other greenhouse gases (through tradable permits or a carbon tax) is necessary to bring about emissions-reducing innovation. Flexible market-based instruments provide incentives to identify optimal solutions to reduce environmental impacts and avoid the danger of technology "lock-in". Moreover, since they penalise emissions across the full range of outcomes, they provide rewards for continual improvement. However, to ensure that the technological trajectory is optimal, such measures should be targeted wherever possible as close as possible to the environmental externality itself (*e.g.* pollution emissions), rather than a proxy (*e.g.* fuel use). Design details are, therefore, important (OECD, 2009a).

Government support for R&D on mitigation technologies is an important complement to emissions pricing (OECD, 2009b). Owing to uncertainties (market and policy) and the public good aspects of innovation in this area, a particularly strong case can be made for targeted support for R&D. Such support can take the form of direct investment in basic research, provision of tax credits for private R&D expenditures, and public/private research partnerships (IEA, 2007).

More generally, to reduce uncertainty for investors it is necessary to provide potential innovators with a stable long-term policy horizon. This is particularly important for less mature "breakthrough" technologies, since the necessary planning horizon may be very long and a lack of predictability can raise costs sharply. As Figure 6.3 shows, costs (measured as a percentage of GDP) rise steeply in the absence of so-called backstop technologies (*e.g.* advanced biofuels, solar and nuclear technologies, etc.).

Figure 6.3. Projected world GDP costs under a 550 ppm GHG concentration stabilisation scenario, with and without backstop technologies



Source: OECD (2009), *The Economics of Climate Change Mitigation*, OECD, Paris.

Clear policy signals are important not only to induce R&D but also to encourage early adoption of new technologies. Political uncertainties surrounding the policy framework can be detrimental to low-carbon investments and are likely to be most acute in emitting industries with large and irreversible fixed costs, such as electricity supply and transport (OECD, 2009a). For a discussion of this issue in the context of environmental taxation see Box 6.1.

While setting a "price" on carbon and investing in R&D are necessary to induce innovation, policies on the demand side also play a role. One instrument is inducement "prizes" which offer financial or other rewards for achieving innovation mitigation objectives that are specified in advance (Newell, 2009). Public procurement can also play a role, particularly in markets characterised by network externalities (*e.g.* the infrastructure for electric/hybrid vehicles) or where demonstration effects are important. In such cases, initial barriers to market creation are high but can be overcome through public demand (OECD, 2003).

Box 6.1. The (in)stability of Japan's charge on SOx emissions

In the 1960s, Japan began to seek to control emissions of sulphur oxides (SO**x**) which are generally created through the combustion of oil and coal for power generation. Regulations relating to emission rates, fuel usage and smokestack height, for example, were put in place and contributed to significant declines in emission levels. At the same time, victims of diseases related to air pollution sought compensation from the government and industry. As a result, a charge on SO**x** emissions was enacted in 1974 and the proceeds were used to compensate victims of air pollution. The rate was not based on the marginal damage of an extra unit of pollution in the present but on the amount of revenue needed to compensate victims injured by earlier emissions. As the number of victims and their compensation varied significantly and emission rates continued to drop, the rates of taxation per unit of emission skyrocketed.

Abatement technologies, particularly flue-gas desulphurisation, were adopted by regulated firms to reduce their tax liability. However, patent activity related to SO**x** emissions declined as tax rates rose. This suggests that the tax did not create an environment in which innovative activities were profitable. Two possible reasons are:

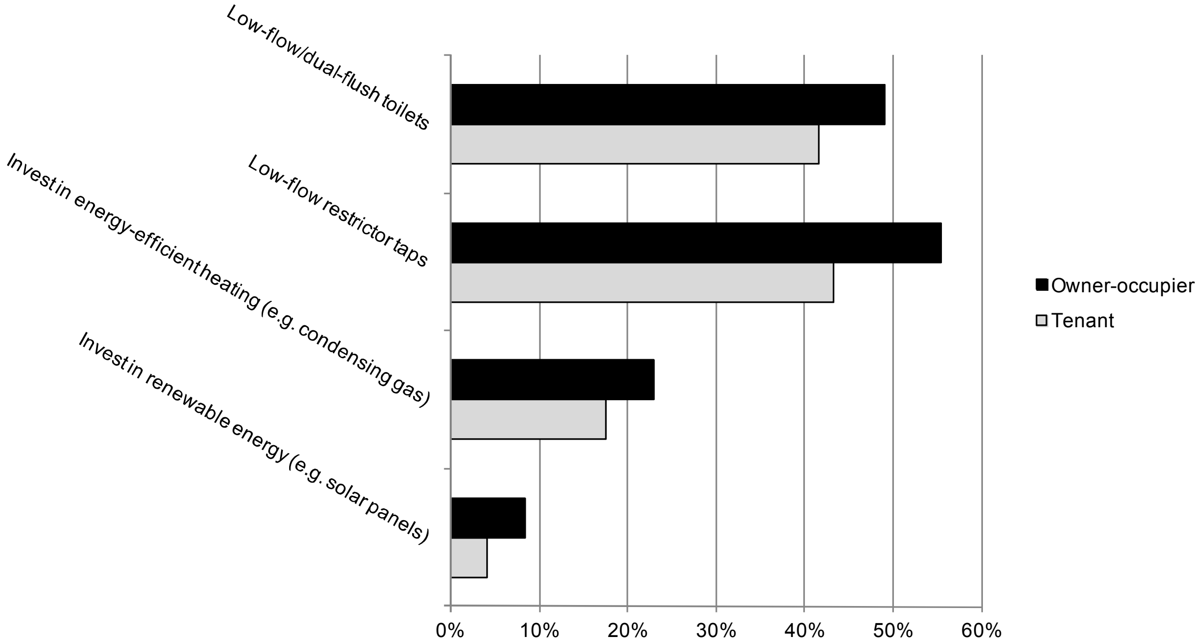
- First, the factors determining tax rates were unpredictable. The level of the tax was a function of industry-level emissions (and, to a smaller extent, those of motor vehicles), the number of victims of air pollution and the average compensation per victim. This year-to-year uncertainty in the means by which the tax was calculated discouraged R&D investments.
- Second, with tax rates rising quickly and reaching very high levels, it became apparent that the current system was fundamentally flawed and there was significant political pressure to reform it. As a consequence investors did not see the policy as credible, which may have significantly deterred investments in long-term R&D efforts. Installing off-the-shelf technologies appeared more prudent.

This example underscores that the specific characteristics of policy instruments can have appreciable impacts on the predictability and credibility of the policy environment and thereby whether the climate is conductive to technology adoption and innovation.

Source: OECD (2010), *Taxation, Innovation and the Environment*, OECD, Paris.

While environmental and climate policy largely focuses on the corporate and public sector, household activities also contribute significantly to climate change and other environmental damage. As in other sectors, attaching a "price" to such activities will encourage households to adopt innovative or "cleaner" products and appliances. An OECD study of a sample of over 10 000 households also indicates that information can be a very effective complement because it allows consumers to make decisions that reflect their desire for environmental quality. However, structural market factors can constrain the adoption of innovations. For instance, split incentives can result in lower take-up even of simple innovations by tenants than by owner-occupiers (Figure 6.4).

Figure 6.4. The adoption of energy and water efficiency innovations by households



Source: OECD (2010), *Environmental Policy and Household Behaviour: A Survey of OECD Countries*, OECD, Paris.

While addressing global challenges such as climate change requires a mix of policy instruments, relations among instruments and their impacts on innovation need to be assessed carefully. An accumulation of policies can generate inconsistencies as well as synergies. As a general rule, each policy should address a specific market failure or barrier. Since different government ministries (*e.g.* environment, energy, housing, transport, research) are responsible for different measures, a whole-of-government approach is clearly called for, a challenge addressed in the recent OECD Global Forum on Eco-Innovation (*www.oecd.org/environment/innovation/globalforum*).

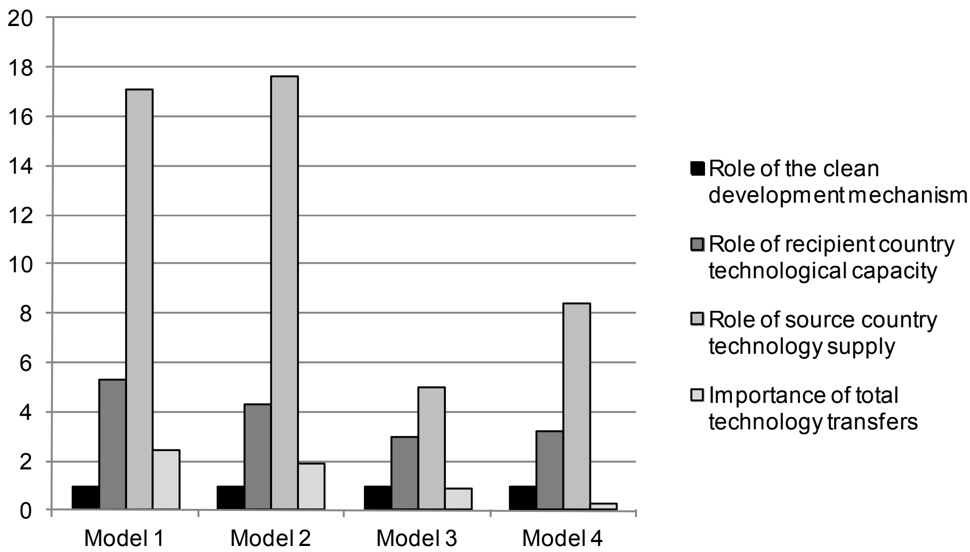
In addition, while much of the policy debate has focused on the development and promotion of environmental technologies, its scope is increasingly broadening to fostering sustainable societal change based on a combination of technological and non-technological innovation (OECD, 2010a). For example, empirical work on a sample of manufacturing facilities indicates that the introduction of organisational innovations such as advanced environmental management practices (*e.g.* environmental accounting) can result in better environmental performance and complement technological innovations (OECD, 2007; Johnstone, 2007).

Incentives to adopt appropriate mitigation technologies can be created through built-in mechanisms which oblige less developed countries take on more stringent commitments (or actions) as their income levels converge to those of developed countries. This would help to alleviate the need for frequent renegotiation of targets and reduce uncertainty about the global response to climate change (OECD, 2009b).

Technological development, adoption and transfer are at the core of current discussions surrounding the post-Kyoto agreement. The 2007 Bali Road Map cites technology development and diffusion as strategic objectives and leads to a discussion of appropriate policies and means of facilitating implementation, such as the Clean Development

Mechanism (CDM). Haščič and Johnstone (2009) find that host country involvement in the CDM has encouraged the transfer of climate change mitigation technologies. However, and not surprisingly, CDM plays a relatively small role in encouraging such transfer compared to other factors. In particular, domestic absorptive capacity appears to be the main driver: countries with strong domestic technological capacity are more likely to import technologies from abroad (Figure 6.5).

Figure 6.5. What is driving transfer? The case of wind power



Notes: Model 1: sample is 1988-2007; Model 2: sample is 2000-2007; Model 3: sample is 1988-2007 with country fixed effects; Model 4: sample is 2000-2007 with country fixed effects and without China.

Source: OECD (2010), *The Invention and Transfer of Environmental Technologies*, OECD, Paris.

Meeting global health challenges

Improving the health of the world's population is an enormous policy challenge that requires both national and international policy action. A number of health challenges are directly linked to environmental issues and need to be addressed through preventive measures. Examples include clean water, waste handling and sustainable urban development. Over the coming decades, innovation – both technical and organisational – will play a major role in the delivery of more personal, predictive and preventive health care products and will radically change how medicine is practised and health care is delivered.

Health challenges in terms of the prevalence of chronic diseases such as diabetes are on the rise in developed and developing countries alike. This has led governments to seek both to contain the costs of treatment and to find new approaches to prediction and prevention. Ageing societies are also putting cost and delivery pressure on health-care systems, forcing governments to consider new ways to deal with long-term care. Age-old infectious diseases such as malaria and tuberculosis continue to threaten significant portions of the world's population, and emerging infectious diseases, such as the flu caused by the H1N1 influenza virus, coupled with a highly mobile population, raise the spectre of potential pandemics. Amid all these challenges, government health-care costs continue to rise at alarming rates and consume an increasing share of GDP, creating a situation that is neither politically nor economically sustainable over the long term.

There are significant opportunities to improve the quality of human health dramatically by harnessing the results of current scientific discoveries. The era of genomic medicine, launched by the sequencing of the human genome, promises a major shift in health care, with life increasingly understood, and medicine increasingly practised, on a molecular level. Understanding genetics, genomics and their interaction with environmental factors, as well as new technologies such as next-generation genomic sequencing, leads to earlier, more accurate diagnosis and intervention, *i.e.* the practice of personalised medicine.

Electronic health records and biomedical data collections (*e.g.* human biobanks and genetic research data bases) (see Chapter 5) are examples of innovations designed to reduce costs, increase efficiency and optimise the use of research outcomes. Entirely new therapies are being developed via technologies based on stem cells, nanotechnology and synthetic biology. Emerging fields such as industrial biotechnology and environmental biotechnology can also affect human health and well-being. Neglected infectious diseases are also being addressed (Box 6.2).

The rapid pace of scientific and technological advances in the life sciences, the complexity and heterogeneity of knowledge relevant to health innovation across fields and subfields, and the need to integrate vast amounts of scientific and clinical data all combine to create challenges for achieving the interoperability, knowledge integration and accumulation necessary to efficiently harvest the full benefits of the existing knowledge base.

New models of health innovation and knowledge management are proving necessary for achieving a number of objectives:

- to improve the efficiency of biomedical research and facilitate incremental innovation (getting more use from knowledge and more organisations and individuals involved in research);
- to improve the translation of research from academia to industry;
- to increase evidence-based treatment options and deliver on the promise of personalised medicines and targeted therapies, to deliver better public health in general (across a broad range of disease groups and a broad range of the population) rather than better private health for a select few; and
- to tackle new diseases and treatment paradigms, including high value-added diagnostics, antibiotics and neglected infectious diseases.

Some of the changes in business models are driven by technological opportunity. The move away from dependence on blockbuster drugs for treating whole populations and towards therapies tailored for treating individual patients may be facilitated by broader use of biomarkers to make early go/no-go decisions in the development process and to better define diseases at the molecular and genetic levels.

A further issue relates to the vast amounts of data, information and knowledge in the health and biotechnology industries that are proprietary but not part of the core business. They could be exchanged for the benefit of buyers and sellers (examples include pre-competitive research data, data about research and clinical failures, in-house materials and databases) through newly emerging knowledge networks and markets (see Chapter 5). In fact such exchanges (*e.g.* see Box 5.6) are some of the most rapidly developing and promising forms of knowledge networks and markets currently in evidence.

Box 6.2. Innovation to combat neglected infectious diseases

Infectious diseases have both health and economic consequences and do not recognise national borders. They are one of the primary causes of mortality in the developing world and a major barrier to economic development, social progress and human health. Innovations in health care to help diagnose, prevent and treat disease have not been successful in tackling infectious diseases such as tuberculosis and malaria that primarily affect the developing world. The World Health Organisation (WHO, 2004) estimates that between 14 and 17 million people die each year from infectious diseases. Nearly all live in developing countries but less than 1% of the drugs that have entered the market since 1975 were developed for infectious diseases that predominately affect these countries.

The Noordwijk Medicines Agenda (NMA), which was developed by over 200 high-level officials from OECD and developing countries (including representatives from industry, research, funders, academics, philanthropic foundations, international and non-governmental organisations), lays out policy options and concrete actions to make the world's innovation systems more efficient and promote international collaboration in order to combat some of the most challenging infectious diseases.

Recognising the importance of scaling up and expanding new for-profit and non-profit models of innovation for tackling neglected diseases in the developing world, the Noordwijk Medicines Agenda calls for several changes to present-day health innovation systems:

- prioritise R&D needs and align research to a common purpose;
- assess the viability of a global virtual network for drug development that draws on and scales up existing research networks and is more open;
- create incentives for R&D through alternative policy mechanisms to reward innovation;
- facilitate the development and operation of a sustainable architecture for sharing and exchanging knowledge, data and research tools;
- identify the infrastructure necessary for a global virtual collaborative network;
- explore collaborative mechanisms for IP management;
- promote the transfer of technology, knowledge and technical skills to strengthen innovation systems in developing countries;
- support efforts led by developing countries to provide their own health, local production and research systems;
- forecast the demand for medical technologies for neglected and emerging infectious diseases;
- support and provide incentives to new for-profit and non-profit partnerships between developing and developed nations to accelerate R&D for neglected diseases.

Source: www.oecd.org/sti/biotechnology/nma.

The financial incentives for developing new technologies are influenced by both the regulatory environment and pricing policies. Measures need be taken to develop stable and transparent regulatory frameworks that facilitate long-term planning, provide sufficient incentives for risk-taking investment, and promote market access for goods and services based on innovative technologies.

Reducing the cost of health products by streamlining clinical trials to make them smaller and faster is a shared government-industry goal. Work needs to be done to simplify, co-ordinate and process the permissions needed for clinical trials; to make advice consistent and standardised; to create model contracts; and to develop early warning systems for problems.

Early interaction between regulators and companies is critical to build support for the development of new clinically valid endpoints – biomarkers essential to personalised medicine, clinical practice and genetic databases – in order to improve clinical trials. Discussions between regulatory agencies and industry can help establish stable, predictable, transparent regulatory pathways; improve biomarker validation and pave the way for regulatory acceptance; take on the challenge of personalised medicines and targeted therapies; tackle methodologies for the design of next-generation clinical trials; and create safe havens for new approaches to knowledge sharing and risk sharing.

Diagnostic biomarkers will require educating physicians and health-care providers and giving them statistical training to understand tests and results. Information about the clinical utility of biomarkers will also be needed at point of care as it may affect the process of care and effective implementation.

Payers (*e.g.* governments and insurers) will need to better understand the advantages and disadvantages (*i.e.* cost-effectiveness) of using biomarkers as diagnostic tests when establishing their payment and reimbursement plans.

New tools, frameworks and processes for evaluating new technologies may need to be developed to capture aspects such as increased effectiveness and cost effectiveness. Pharmaco-economic assessment offers promise for achieving socially optimal outcomes, in terms of promoting the right level and type of R&D investment, through better signals to industry as to which innovations are most highly valued. It can also be used to establish market-based incentives for investment in treatments for rare conditions.

Public acceptance and trust is a critical factor in uptake and diffusion. Establishing clear policies with regard to the privacy and security of personal data is fundamental for a wide range of health technologies (*e.g.* genetics and genomics, electronic health records). Similarly, the public is concerned with equity of access. Governments have a central role to play in finding a balance between individual rights and public health/research priorities.

Direct-to-consumer tests and services are increasingly available. There is no consensus on whether and what oversight and governance are needed. This is a subject that calls for further consideration by governments.

Meeting global health challenges has spurred innovative approaches to inter-firm collaboration, access and use of intellectual property (IP), and financing mechanisms. These experiments may yield lessons for a lower-cost approach to innovation in health care. Governments should identify the lessons contained in these innovative approaches to global health challenges and should try to apply them to health innovation more generally.

A variety of push and pull mechanisms are being used to bring new health technologies for neglected diseases onto the market. They complement traditional development programmes rather than compete with them. Because no individual tool (*e.g.* public-private partnerships for product development, advanced market commitment, prizes, etc.) can be used to address all problems, governments need to better understand the available mix of approaches in order to achieve different policy goals.

Meeting public health priorities will also require alternative approaches to forming capital for R&D, such as bond issues or better uses of philanthropic programmes, in order to finance health innovation programmes. Governments should be better aware of the options and their relative merits.

Integration and coherence of innovation policies in areas such as health, science, development, trade and industry would be of enormous help in addressing public health priorities. This is difficult to achieve, however, owing in part to institutional barriers to co-operation in policy making and implementation. Governments may also want to facilitate patients' and/or their organisations' more active role in innovation policy and policy making related to clinical trials and access to new products. Patients are important sources of innovations which remain underutilised. New modes of communication and networking between health systems, end users and innovators are emerging that may provide a better match between global health objectives and investment in R&D. These need to be better understood by governments.

Addressing food security

The world's capacity to supply food has grown faster than its population and income-driven demand at least since the 1930s. Consequently, real prices have trended steadily downward, substantially improving the affordability of food, a critical dimension of food security. The world's growing capacity to produce food is largely attributable to productivity-enhancing innovations flowing from public and private investments in agricultural research, extension and education.

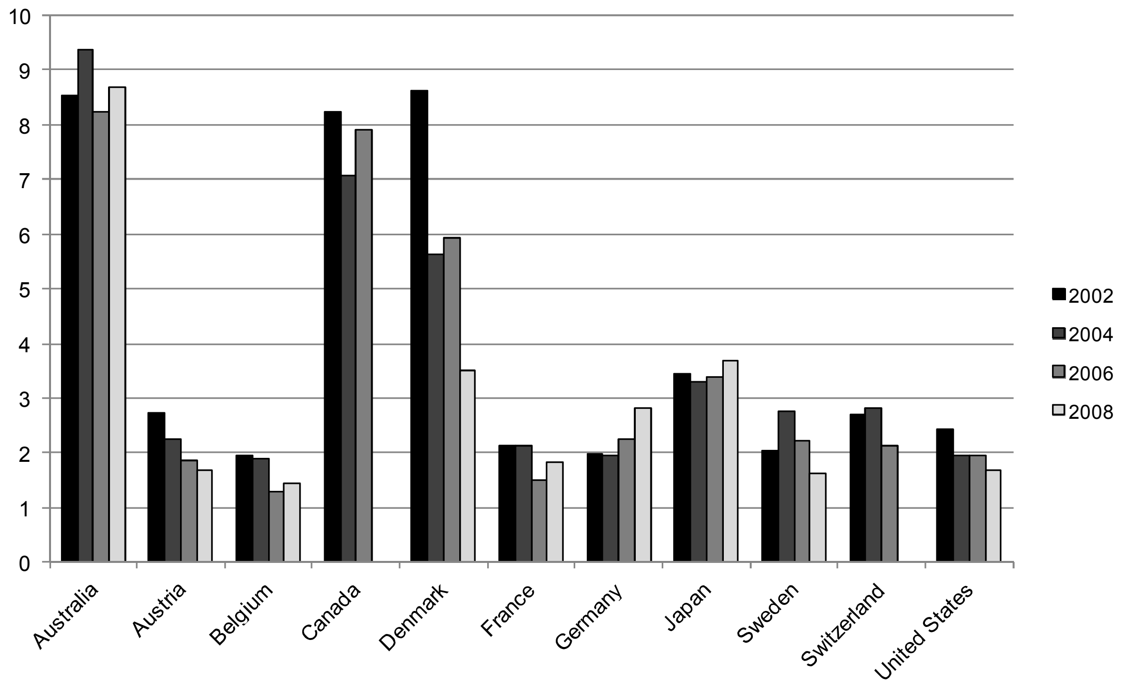
However, steep increases in the prices of major food crops in 2008 raised widespread concerns about the fragility of the food supply in many underdeveloped countries and even caused some citizens in rich countries to worry whether there would be a sufficient supply of food in the future. The underlying causes of the price spike are complex and below-trend production levels proved temporary. Nonetheless, according to the Food and Agricultural Organization of the United Nations (FAO), the number of hungry and malnourished people in the world is now higher than ever before (FAO, 2009). Many live in countries well-endowed with agricultural resources that are under-exploited relative to their potential. Fully reaching that potential requires developing, adapting and adopting innovations that have fuelled agricultural achievements in other parts of the world.

However, public, private and international investment in developing country agriculture is far below that in developed countries. These low levels do not bode well for prospects of achieving food security through advances in agricultural productivity in the developing world. The general failure to achieve sustained rates of agricultural productivity in recent decades, especially in Sub-Saharan Africa, can be attributed to inappropriate market and trade policies in African but also in OECD countries; inadequate institutions and services; failures to invest in appropriate infrastructure; and failures to invest in the development of the human, social and natural capital that agricultural households need to achieve higher productivity.

Even in developed countries there are fears that agricultural productivity will not continue to grow at the robust rates of the past. A recent study by the United States Department of Agriculture confirmed that productivity growth, as opposed to increased use of inputs, has been responsible for increased output over the past half century (Fuglie, 2008). However, public investment in agricultural research as a share of total government spending in OECD countries shows signs of declining (Figure 6.6). Such investments take a long time to affect productivity levels on farms.

Figure 6.6. Public R&D expenditures for agricultural production and technology

Government budgets and appropriations on R&D, % of total expenditure



Source: OECD Research and Development Database 2009.

Climate change and vanishing water resources also are seen as constraints on agricultural productivity. New demands, for example for biofuel feedstocks, put further pressure on supply. It is argued that global warming leads directly to a greater incidence of negative yield shocks and sustained pressure on production in heat-stressed climatic zones. As yields may increase in regions with moderate climates, the net effect on world production is uncertain.

Increased investments in R&D, technology transfer and extension services, particularly in less developed economies, could do much to increase productivity and output. The use of genetically modified organisms (GMOs) also offers the potential to improve productivity, to enhance the attributes of crops destined for either food or non-food uses, and to enhance the resilience of crops against stresses such as drought.

The largely policy-driven nature of the rapid increase in demand for biofuels warrants close review. OECD/IEA analysis suggests that the energy security, environmental and economic benefits of biofuel production based on (first-generation) agricultural commodity feedstocks are modest and unlikely to be delivered by current policies. Approaches that encourage reduced energy demand and GHG emissions, provide for freer trade in biofuels, and accelerate the introduction of "second-generation" production technologies that do not rely upon current commodity feed stocks offer potentially greater benefits without the unintended impact on food prices (OECD/FAO, 2009).

To address food security, there is a fundamental need to foster growth and development in poor countries. In some of the poorest countries, investment in agriculture and agricultural research, extension and education, may be the best way to reduce poverty and stimulate economic activity. In other situations, there may be a need to diversify the structure of the economy and make investments that improve the overall environment in which agriculture operates – basic governance systems, macroeconomic policy, infrastructure, technology, education, health, etc.

Closing the economic development gap

While larger emerging economies have been able to mobilise foreign direct investment (FDI), trade and human capital to build technological and innovation capacity, this is much less true of low-income developing countries, where support for innovation is more of an issue. Their infrastructure – water and reliable electricity supply, roads, ports, basic telecommunications services and broadband Internet access – may be insufficient to facilitate business activities. Framework conditions, such as courts, education, stable governance, health services, security and tax systems, may not be conducive to innovation in the private sector.

Indeed, developing economies may lack a strong business sector. In these countries, innovation often takes place in small firms or in the informal economy with limited support from the infrastructure. Such firms, which may be individual entrepreneurs, often lack the absorptive capacity to seek and absorb knowledge. These firms may focus more on innovation for survival than on formal knowledge creation through R&D activities (Gault, 2010). The focus in developing countries should therefore be on encouraging all forms of innovation and on adapting existing technologies to address local social and economic needs. While the business sector may be small, the agriculture sector may be quite large and a fruitful domain for innovation policies and their application. In fact, agriculture in developing economies can be part of the global knowledge economy.

Particularly in the agriculture sector, enhanced productivity, entrepreneurship and value added can drive poverty reduction in rural economies. Agriculture is a knowledge-intensive productive sector, yet in many poor countries, farmers, small and medium-sized enterprises (SMEs) and research centres do not interact to move beyond low value-added subsistence agriculture. Strengthening rural innovation systems, developing clusters that can add value to unprocessed raw materials, and promoting value chains across sectors such as horticulture, food processing, packaging, storage, transport, safety standards, distribution systems and exports are all central to moving beyond subsistence agriculture, generating growth and moving towards prosperity. An agricultural innovation system has to link the public and private sectors and create close interaction between government, academia, business and civil society. Knowledge-based institutions will need to integrate research, university teaching, farmers' extension and professional training, and become directly involved in the production and commercialisation of products.

Accessing existing technologies through trade and FDI may help address the imbalance between the capacity of and the need for innovation and technology in developing countries. OECD countries can foster technology transfer through trade and FDI and, in cases of market failure, through approaches such as export credits targeted at developing countries and public and private partnerships (P/PP) that help reduce the risk that the private sector will not engage in technology transfer activities when the social benefits would exceed private economic gains. In particular, as noted in the WTO TRIPS Agreement (Article 66.2), developed countries are to provide enterprises and institutions in the least-developed countries incentives to promote and encourage technology transfer.

Other means of addressing the need for innovation and technology in developing countries include arrangements that grant free rights to unutilised patents for developmental purposes and solutions for making available critical technologies needed to address challenges such as food security, infectious disease, water and sanitation. Government-funded research collaboration between OECD and developing countries to address local needs or as part of efforts to address global challenges can also be effective for knowledge diffusion along with training of local personnel. In addition, steps to boost absorptive capacity in developing countries may help to facilitate the process of technology transfer (*e.g.* through the removal of trade and investment barriers or development co-operation in support of institutional development).

Because technology markets and other market-based innovation infrastructure such as financing for innovation are either non-existent or very poorly developed in developing countries, there is a greater need for alternative ways to fill the gaps or provide the missing conditions. Public/private partnerships (P/PPs) can in many cases provide better solutions than government interventions. They can be particularly important in developing countries because government resources are more limited and the need for public intervention often greater than in OECD countries. P/PPs can be a cost-effective and sustainable solution.

Given the formal sector's limited ability to meet the innovation and technology needs of developing countries, the engagement of local players and local resources can make a real difference. Activities to foster innovation should include local entrepreneurs, women, local products and indigenous knowledge and expertise. This requires combining government- and donor-led top-down and bottom-up approaches, including learning and importing from outside and innovative adaptation using local knowledge and resources (Box 6.3). Creating entrepreneurship and facilitating private-sector development should be high on the agenda to promote the autonomy needed to translate opportunity into prosperity. This should be seen as an investment in itself, with carefully tailored incentives and risk-sharing approaches supported by government.

Donors can play an important role in terms of agenda setting and priority setting but also in terms of operations and implementation. This requires links and greater coherence between development policy and innovation policy. Donors should use their resources to leverage those of developing country governments and the private sector. Donor priorities may include support for capacity building in terms of innovation skills through general and specialised education and training, and policy and institutional capacity building, as well as public/private partnerships for north-south and south-south technology and knowledge transfers.

Box 6.3. Pro-development innovative applications in Africa

Africa shows that innovation does not always come from R&D-intensive activities. With the liberalisation of the ICT sector, user-driven innovation has proliferated through the interaction of local practices and technologies. This interaction is creating value in the form of new products and services.

By 2009, four out of ten Africans had a mobile phone and thus a means to circumvent traditional market bottlenecks. Mobile phones deliver value-added services for the first time to much of Africa's population. Services that are rapidly scaling up include mobile payments, which reduce transaction costs, and e-agriculture, which enables matching supply and demand.

In the short term, there is a significant potential for growth in these innovative ICT applications. International connection prices in Sub-Saharan Africa have started to fall since August 2009. As the decrease in rates reaches consumers in coastal areas, investment should concentrate on connecting landlocked consumers.

Mobile payments

In Kenya, mobile phones allow users to send money inside the country to owners of other mobile phones. This payment system has formalised Sente's1 informal practice in Uganda, where money is sent from one person to another by using public phone kiosks and trusted networks.

In less than two years, Kenya´s mobile payment system attracted over 5 million consumers in a country where only 26% of the population has a bank account. The service sharply reduces transaction costs, particularly for the transfer of small amounts of money, a common practice between urban and rural areas. Following this example, similar projects have been announced in ten Sub-Saharan and in three North African countries.

E-agriculture

In Ghana, mobile phones have brought farmers and consumers together by enabling timely and affordable access to production information. As grain markets typically take place once a week, traders and farmers have historically travelled long distances to markets to obtain production information. This requires not only the cost of travel, but also the opportunity costs of traders' time.

The arrival of mobile phones in Ghana provides an alternative and cheaper source of information for grain traders, farmers and consumers. Users can sign up to receive weekly text messages alerts on commodities for a fee and the cost of the message. Users can also upload offers to buy and sell products via mobile phone and make price requests on products.

As a result, grain traders operating with mobile phones search a greater number of markets, have more market contacts and sell in more markets than their non-mobile phone counterparts. This suggests that traders with mobile phones are better able to respond to surpluses and shortages, thereby allocating grains more efficiently across markets and dampening the price differences.

1. The Sente service is an informal means of sending money from one individual to another using mobile technology in Uganda.

Source: OECD/African Development Bank (2009), *African Economic Outlook 2009.*

There is a particular need to put innovation on the development agenda and into the development process and to promote co-operation between developed and developing countries (OECD, 2010b). A joint OECD-UNESCO workshop (UNESCO, 2009) outlined the following priorities:

- partnerships and networks, including networks of excellence, should be developed and supported to promote co-operation, production and sharing of information and promotion of innovation;
- case studies and indicators monitoring evaluation of innovation are required to provide evidence of good practice, success stories and lessons learnt, and the factors promoting and impeding innovation, including policy effectiveness;
- publication and dissemination of information is needed to promote the sharing and exchange of studies and research on innovation at the practitioner, programme and policy levels, including examples of case studies, guidelines, strategies, policy instruments and frameworks;
- assessment of human and institutional capacity needs and capacity building are required to promote innovation at the practitioner, programme and policy levels;
- promotion of wider awareness and public understanding of innovation at the practitioner, programme and policy levels is required to put innovation more effectively on the development agenda, into development plans and poverty reduction strategy papers, and into the development process.

A second workshop on innovating out of poverty made recommendations for developing agriculture as a knowledge-based industry (OECD, 2009a).

Strengthening global scientific co-operation

In recent years, there has been a growing political consensus that responding to global challenges calls for international and multilateral co-operation to develop global solutions. International science and technology co-operation will need to be strengthened. Increasingly multidisciplinary approaches to research also encourage different fields and expertise to come together – foundations, public authorities, industry, civil society organisations and, most importantly, universities – to work in partnership. It is essential to identify and implement policies, frameworks, and governance mechanisms that can deliver rapid scientific and technological progress and lead to rapid and wide diffusion of subsequent innovations. Existing schemes of co-operation in science, technology and innovation may have to be evaluated and improved. Box 6.4 provides examples of international initiatives that specifically aim to address key global challenges.

Proven co-operation strategies include joint investment in basic research; mapping of R&D needs; collaborative research in international networks; technology transfer initiatives; and scholarships and fellowships for the international mobility of researchers. However, current challenges require more concerted approaches in order to accelerate technology development and diffusion. Perceived benefits include: creating economies of scale, reducing redundancies, utilising complementary expertise and pooling resources for research funding. Co-operation can also help create a common pool of knowledge, *e.g.* the pre-competitive stages of research, which can be utilised by all firms and countries involved in technology development. It can also help strengthen and accelerate technology development and diffusion by combining the strengths of different countries.

Box 6.4. International S&T co-operation for global challenges

Initiatives that address global challenges include:

- *The Intergovernmental Panel on Climate Change*; *(ICCP),* an intergovernmental scientific body involving thousands of scientists from across the globe in international co-operation for "providing the world with a clear scientific view on the current state of climate change and its potential environmental and socioeconomic consequences";
- *The Consultative Group on International Agricultural Research (CGIAR)*, a strategic partnership with 15 international research centres to foster growth of sustainable agricultural, involving industrialised and developing countries, co-sponsors and 13 other international organisations;
- *The Earth System Science Partnership (ESSP)*, composed of researchers from diverse fields from all over the world, is a "joint initiative of four international global environmental change research programmes for the integrated study of the Earth System, the changes that are occurring to the system and the implications of these changes for global and regional sustainability";
- *The Group on Earth Observation (GEO)*, a voluntary partnership of governments and international organisations, linking all Earth observation systems, whose purpose is to foster new joint projects, strategies and co-ordinated investment and to ensure that Earth observation data and information remain accessible as a global public good; and
- *The United Nations Framework Convention on Climate Change (UNFCCC)*, under which "industrialised countries have agreed to share technology with less advanced nations".

Global challenges have many dimensions: the nature of the scientific and technical problems; the innovator communities involved; the involvement of private sector and/or non-governmental actors; the types of funding available and needed; the social and economic context; the number and types of solutions sought; and the organisation and governance of the international community. Different approaches are therefore needed.

Nevertheless, some common strategies are emerging: greater involvement of the private sector, non-governmental organisations, philanthropic organisations, and other stakeholders in the prioritisation and delivery of science and innovation and the use of new financing mechanisms (*e.g.* securitisation, risk sharing) to provide incentives for global and local innovations. They call for closer involvement of the developing world and a build-up of these countries' research and technology capacity. To accelerate the diffusion of innovation, mechanisms to enhance technology transfer to developing countries are under discussion (*e.g.* patent pools and other collaborative mechanisms for leveraging IP). Multilateral agreements, such as the United Nations Clean Development Mechanism, can be used to encourage technology transfer and reach public objectives at less cost. Academic partnerships and cross-border higher education can also facilitate technology transfers and lead to spillovers in the local innovation system.

Because global challenges need to be addressed collectively a new governance model for multilateral co-operation on international science, technology and innovation should be explored. It could focus on priority setting, funding and institutional arrangements, procedures that ensure access to knowledge and transfer of technology, capacity building, and delivery of new innovations into widespread use. Because further work is needed to identify successful aspects of governance approaches and mechanisms for co-operation in science, technology and innovation, the OECD, in co-operation with non-members, is working to bring forward agreed principles underpinning such governance.

Empowering new players to address global and social challenges through innovation

Non-governmental organisations, private, often philanthropic, foundations and social entrepreneurs which often are driven by non-profit motives can play an important role in catalysing innovation to solve social problems that are insufficiently addressed by governments or the market.

Philanthropy

Philanthropy is often overlooked but can play a key role in fuelling innovation. Foundations, in particular, fund and support innovation in a number of ways. They have the freedom to experiment and try new approaches to solving social challenges, and their work can provide new insights and guidance for future policy. Many foundations also directly fund a significant amount of research, including scientific and technological research. They should be an integral part of the innovation system.

Foundations have become increasingly active in seeking new, innovative approaches to fulfilling their missions. They have also become more engaged in partnering with other foundations, locally and internationally, to address challenges of mutual interest. By leveraging their competitive advantages of independence, cross-sector networks, creative problem solving and flexibility, foundations can play an important role in research and innovation policy discussions (European Foundation Centre, 2008).

Innovation to address social challenges

The last few years have seen a burst of interest in steering research and innovation to address social challenges. This interest reflects the rise of "social innovation", the use of innovation to address social problems. Many of today's social challenges, such as those associated with ageing populations and environmental sustainability, as well as long-standing problems such as poverty, education and migration, have resisted conventional government or market solutions.

Innovation that seeks to address social challenges faces specific barriers (*e.g.* risk, low rates of private return) which lead to under-investment. Many social challenges are long-term phenomena requiring long-term responses. They involve a variety of intertwined issues, some of which have dimensions of both public and private goods. Traditional innovation concepts and models are inadequate for distinguishing socially driven innovation from profit-driven innovation. The small size and fragmentation of markets for social goods also discourage firms from investing in and committing resources to these areas. This does not mean that socially and economically oriented innovation are necessarily at odds. They can in fact be complementary, but this will require changes to the way policy makers promote innovation, for example by involving stakeholders so as to link social demands with research agendas.

Research and innovation systems can certainly help respond to social challenges. However, the disciplinary focus of academia and public research limits opportunities for bringing disparate sources of knowledge together to deal with a common problem. Given the multidisciplinary nature of many social problems, research to address them must bring together the natural and social sciences.

Several OECD countries have developed national strategies to mobilise public funding to address social problems. The Netherlands explicitly combines social and economic challenges in research funding decisions as it sees opportunities for dealing with the two objectives simultaneously. Canada, Finland, Germany, Italy, Japan and Norway have implemented more targeted research initiatives to solve particular social problems such as population ageing or crime. Access to data from publicly funded research can also help social actors (*e.g.* patient groups) mobilise innovation to address social challenges.

Companies and entrepreneurs also address social problems. They have integrated social concerns primarily through the prism of corporate social responsibility (CSR), but they also see business opportunities in this area. In particular, social entrepreneurship, which generally refers to entrepreneurship aimed at providing innovative solutions to unsolved social problems, has emerged. It is often linked with social innovation and plays an increasing role around the world (Box 6.5).

Box 6.5. The emerging role of social enterprises

In recent years, the term "social enterprise" has become familiar to academic and policy audiences and increasingly to the general public as a new innovation business model that meets both social and economic objectives by contributing to labour market integration, social inclusion and economic development. Increasingly governments, the private sector and other stakeholders are partnering with organisations in the social sector. For example, US President Obama recently announced the establishment of an Office of Social Innovation in the White House; Australia and New Zealand are both setting up centres for social innovation; Spain is setting up a "Social Silicon Valley"; and Korea's Hope Institute has been at the forefront of using the web to link citizen ideas to government.

Source: OECD (2009), *The Changing Boundaries of Social Enterprise*, OECD, Paris.

Governments can help these efforts by providing funding, tax credits and encouraging the development of the emerging social finance market, removing regulatory barriers and providing the infrastructure (*e.g.* ICT) and incentives to encourage firms and entrepreneurs to address social challenges (OECD, 2010c). A wealth of experiments enlisting various stakeholders in different learning spaces is already in place, but these are often dispersed and uncoordinated. They can provide lessons on which to build future policy actions (OECD, 2009c). However, the mechanisms for stimulating social innovation – and especially how to scale initiatives in order to enable local stakeholder involvement and ownership – need to be better understood in order to inform policy.

Key findings

Innovation offers a means of addressing global and social challenges at both the global and the local level. For many of these challenges, market failures – including the simple absence of a market – limit investment and the development and deployment of products and services. Global challenges are by nature large-scale and complex and need to be addressed collectively at international level through the development of comprehensive solutions and bilateral and multilateral co-operation. They cannot be addressed by any one nation alone nor solved by any single policy intervention. A mix of policy instruments is necessary to reach sustainable solutions.

Climate change is a global challenge which can only be addressed effectively through massive innovation. Pricing of environmental externalities, such as carbon emissions, will be an important trigger for the development and diffusion of green technologies and innovations. Tax policies, standards or other economic instruments can provide such a signal and foster markets for innovation as can the removal of environmentally harmful subsidies. At the same time, investment in long-term research and innovation will be needed to develop breakthrough technologies that private initiative alone will not undertake. Governments will need to take the lead in areas that are too risky and uncertain for firms through investment in public research and well-designed support for pre-competitive research in the private sector. Fostering the growth of new firms will be essential, as they are often the source of the most radical innovations.

Breakthroughs in science and in the organisation of innovation also offer opportunities to address challenges such as global health. Scientific discoveries, the growing availability of data, and the rapid development of new techniques in drug design and delivery (so-called personalised medicine) provide the beginnings of the technology push that can help address unmet needs. Innovative approaches based on inter-firm collaboration, access to and use of intellectual property, along with new financing mechanisms, may lead to a lower-cost approach to innovation in health care, which could be applied to health innovation more generally.

Volatile food prices and food security have also become important issues in both developed and developing countries. Innovations are needed both in the area of global food security and world agricultural supply. Investments in R&D, technology transfer and extension services, particularly in less developed economies, could do much to increase productivity and output.

Low-income countries face specific challenges for making innovation the source of economic development, such as poor framework conditions and low human and social capital. They should therefore be supported in strengthening their framework conditions and educational attainment. Improving rural productivity requires significant investments in basic infrastructure, including transport, rural energy and irrigation.

The policy principles that emerge are:

1. Improve international scientific and technological co-operation and technology transfer, including through the development of international mechanisms to finance innovation and share costs.

a) *Improve international science and technology co-operation.* Proven co-operation strategies include joint investment in basic and pre-competitive research; mapping of R&D needs; technology transfer initiatives; and scholarships and fellowships for international researchers and students. But the current global challenges require more concerted approaches to accelerate technology development and diffusion that can help create economies of scale, reduce redundancies, and create a common pool of knowledge, *e.g.* for the pre-competitive stages of research. This may also involve mechanisms to share costs across countries and actors and engage in joint investments, such as the International Energy Agency's "Energy Technology Agreements".

b) *Foster international technology transfer, e.g.* by removing trade barriers that limit technology transfer across borders, as well as by developing mechanisms that enhance technology transfer (*e.g.* voluntary patent pools and other collaborative mechanisms for reducing transaction costs to use IP). Multilateral agreements can also be used to encourage technology transfer, allowing for the realisation of public objectives at least cost (*e.g.* the Clean Development Mechanism). Academic partnerships and cross-border higher education can also facilitate technology transfers between universities, and lead to spillovers in the local innovation system.

c) *Use new financing mechanisms* (*e.g.* risk sharing) to provide incentives for global and local innovations that can help address global challenges. New modes of financing and managing innovation borrowed from the venture capital sector are being used by philanthropies and foundations to raise funding for research projects around global challenges. International public-private partnerships are another tool used by governments to address financing gaps in the areas of infrastructure, research or technology development.

d) *Develop the appropriate international platforms to support the mobilisation of innovation for global challenges*. International technology platforms and consortia, bringing together firms and national governments, can help address issues, such as standard-setting and technological deployment, that arise when developing innovative solutions to problems that cross markets and borders.

e) *Increase the involvement of the private sector, civil society, non-governmental organisations, philanthropic organisations* and other stakeholders in the prioritisation and delivery of science and innovation and in the development of policies to address global challenges and in support of developing countries, especially those with low income.

2. Provide a predictable policy regime which provides flexibility and incentives to address global challenges through innovation in developed and developing countries, and encourages invention and the adoption of cost-effective technologies.

a) *Use economic incentives to get prices right.* Better pricing will be one of the best triggers for the development and diffusion of green technologies and new forms of sustainable production and consumption. Tax policies or other economic instruments can provide such a signal and can foster markets for new innovative solutions in areas where there are important externalities. Removing environmentally harmful subsidies also provides a powerful incentive in the case of climate change.

b) Due to uncertainties (technological, market and policy) in order to bring forward the breakthrough technologies that will be needed to address climate change complementary *long-term research and innovation measures* are necessary.

c) To the extent feasible, *use technology-neutral policies* which give the private sector incentives to identify the most promising means of addressing environmental problems. This will involve providing a flexible policy regime which encourages innovators to “search” for the most innovative technologies and solutions, and adopters to invest in the most cost-effective technologies.

d) *Target policy instruments as directly as possible to the policy objective.* This will ensure that resources are devoted to finding the solutions to the problems themselves, rather than some indirect "proxy". For instance, a tax on carbon will be more effective at inducing optimal innovation paths than a tax on fuel use.

e) *Provide predictable policy signals.* Since many of the investments needed to address climate change involve significant up-front investments, it is important to give potential innovators (and adopters) a predictable and credible long-term policy horizon in order to bear the risk of undertaking such investments.

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3. To spur innovation as a tool for development, strengthen the foundations for innovation in low-income countries, including affordable access to modern technologies. Foster entrepreneurship throughout the economy, and enable entrepreneurs to experiment, invest and expand creative economic activities, particularly around agriculture.

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a) *Strengthen the foundations for innovation in low-income and emerging economies.* Policies should focus on strengthening framework conditions and enhancing educational attainment. Improving rural productivity also requires significant investments in basic infrastructure including transport, rural energy and irrigation. Likewise, encouraging foreign direct investment and enabling trade can offer significant opportunities for accessing technologies that provide opportunities for innovation for emerging and low-income economies.

b) *Foster entrepreneurship and agricultural productivity as drivers of innovation and poverty reduction.* Low-income countries should be supported in transforming agriculture into a modern sector through a locally adapted approach where entrepreneurship, agricultural productivity, and value addition become drivers of poverty reduction and green growth. This entails linking research, university teaching, training, extension work, production, processing, packaging, safety standards, infrastructure, distribution systems, marketing, and exports in value chains. Policies to consider should take account of the important role of women as drivers of growth in these economies, as well as the role played by the informal economy.

c) *Enable the use of ICTs as a key tool for innovation.* Policies should urgently address the need in low income countries for affordable access to communications services for individuals, as well as broadband Internet connectivity for centres of learning, such as universities and technical colleges. Support should also be given to the creation of good land registration systems using digital technology to ensure land ownership or mobile banking to secure financial transactions, thereby boosting investments in agriculture and businesses. In this context, OECD countries could accelerate the transfer of ICT technology and intellectual property rights to low-income countries by pursuing policy coherence for development.

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Chapter 7

Improving Governance and Measurement

This chapter focuses on the key role of governance and measurement of innovation performance. It examines how governance arrangements and policy practices have changed over the past two decades, and which challenges have been emerging, both as a result of processes such as globalisation and regionalisation, and new developments and innovations in the organisation of government and policy design and delivery. Key areas in which governance needs to be improved are discussed, including mobilising actors and resources for innovation; improving co-ordination and coherence of policies and different layers of government; addressing worldwide the great societal challenges that need to be faced on a global scale; setting priorities in resource allocation accordingly; and improving the measurement of innovation.

Introduction

Evidence from the OECD area provides ample evidence that countries' innovation performance depends in part on the quality of the governance of science, technology and innovation (STI), *i.e.* the set of largely publicly defined institutional arrangements, incentive structures, etc., that determine how the various public and private actors engaged in socioeconomic development interact in allocating and managing resources devoted to STI.

As the preceding chapters have illustrated, governments play a key role in providing the supporting institutions and infrastructure that enable successful innovation on a broad scale. This includes creating and maintaining favourable framework conditions for – and removing barriers to – innovation, as well as dedicated policies to foster innovation on a broad base: enhancing technology absorption and capacity building, notably in SMEs, fostering networking and clustering, and leveraging research and development (R&D) in various ways. Yet, governance of innovative activity is not provided by government alone. Actors from the research and the business sectors, as well as other stakeholders, play an important role in many aspects of STI governance. For example, a society's accumulated "social capital" can make an important contribution to innovation by reducing transaction costs. However, this chapter focuses on the role of government and public policy.

High-quality governance is essential

A stylised presentation of policy making typically involves three stages: *i)* an agenda-setting stage in which policies are formulated and instruments selected in response to perceived social or economic needs; *ii)* an implementation stage in which actors and resources are mobilised to realise policy targets; and *iii)* an evaluation (or reflection) stage in which the effectiveness, efficiency and continuing appropriateness of policies and policy instruments are assessed and the results fed back into another round of agenda setting. STI governance involves developing capabilities in each of these areas.

A number of factors impinge on the efficiency of STI governance*, i.e.* the extent to which policy processes have the greatest effect with a given use of resources. It must be acknowledged that overall efficiency is not easily defined and measured in a multi-objective, multi-actor world. However, evidence from the OECD area indicates that efficient governance depends, among others, on certain qualities:

- *Legitimacy.* To be perceived as legitimate, the policy actors and approaches adopted in policy processes have to be widely accepted as appropriate for the tasks at hand. Legitimacy can also refer to the extent to which policy addresses issues in the public interest. Definitions of the public interest may vary among actors, be contested and evolve over time. The degree to which policy processes accommodate platforms for consultation and confrontation among stakeholders is therefore an important dimension of the quality of governance.
- *Coherence.* In order to achieve their goals, the different strands of innovation policy and associated policy instruments must fit together. In practice, this often means co-ordinating the activities of different agencies responsible for formulating, implementing and evaluating policies and instruments. As innovation policy today tends to be framed in broad terms and policies and instruments become more differentiated, coherence and co-ordination have become more pressing concerns for policy makers. They are difficult to achieve, particularly in regard to policies whose primary objectives are other than innovation, such as many of those that shape the framework conditions for innovation (*e.g.* competition policy, product market regulation, immigration policy, etc.) discussed in Chapter 4.
- *Stability.* Innovation – famously characterised by Schumpeter as a process of creative destruction – requires sufficiently stable framework conditions, institutions and policies. Stability and predictability are particularly important for risky activities with a long time horizon such as R&D and innovation. Excessive instability may inhibit innovation by increasing uncertainty for innovators. It may lessen the effectiveness of policy instruments by weakening the incentives they provide. In addition, it reduces the opportunity for learning and developing evidence-based policy practices. While there are manifold sources of unwarranted discontinuities, political instability and fiscal problems, often related to policy cycles, are a common cause.
- *Adaptability.* As the environment for innovation and innovation itself keep evolving – sometimes at an accelerated pace or abruptly – STI governance actors need to be able to adapt. This ability can be enhanced in various ways, such as exposure to competitive forces or provisions for evaluation. It also requires broad-based discourse and openness to new ideas. Adaptability is needed to keep abreast of fast-changing environments. Lack of adaptability can result in policies and

governance arrangements that trail behind developments in innovation systems and the challenges they face. It can thus act as a barrier to needed change.

- *Ability to steer and give direction.* A related capability is the STI governance system's ability to provide direction to actors and steer the innovation system as a whole. Countries that have succeeded in catching up technologically would generally not have been able to do so if they had not developed such capabilities. Steering and setting direction can be incremental or involve more radical choices. In the latter case there is a risk of locking into trajectories that may prove less than optimal. Monitoring and governance arrangements that allow for sufficient adaptability will be needed in order to reverse unwise decisions quickly.

These qualities of governance are rooted in the overall policy environment in which they operate and tend to be difficult to change quickly and deliberately. For this reason, weaknesses in the qualities of governance are often a source of persistent failure in innovation policy. The challenges discussed below need to be tackled so as to strengthen these qualities, which are related in various ways. While some are complements and can give rise to synergies, others may involve trade-offs. For example, adaptability and the capacity to steer the innovation system can reinforce each other. In contrast, too strong an emphasis on stability may adversely affect the system's adaptability.

STI governance has changed dramatically

Governance arrangements and policy practices are evolving and have changed profoundly over the past quarter of a century (OECD, 2005a). Changes have been driven and shaped by developments in the economic environment and in the policy sphere. The following discussion reviews some of the major developments that have affected STI governance in OECD countries: changing perspectives on innovation and a better understanding of innovation systems which have modified the rationale for and perceived scope of policy intervention; globalisation and regionalisation; a "strategic turn" in STI; changes in the way government operates, including the rise of new public management; and the increasing popularity of public/private partnerships (P/PPs) as a vehicle for investment and service delivery in general and as an instrument of STI policy in particular. Taken together, these changes highlight tensions in the governance of STI concerning the respective role of public and private actors, horizontal and vertical co-ordination, arrangements across different layers of government, top-down steering and bottom-up self-organisation, technocratic and democratic modes of governance, and consideration of the short and the longer term.

The overall result of these changes has been a broader and more differentiated set of policies and a proliferation of programmes and instruments.

Changing perspectives on innovation have broadened the scope of STI policy

The idea that market failure leads to under-investment in research has been the principal rationale for public funding of R&D for half a century (Stoneman, 1987; Metcalfe, 1995). This analysis was developed in the framework of neo-classical welfare economics. Arrow (1962) highlighted three fundamental causes of this failure: indivisibilities, uncertainty and externalities: *i)* R&D activity often incurs high fixed costs and economies of scale, while learning-by-doing gives rise to dynamic economies of scale; *ii)* investment in R&D is inherently risky and information asymmetries abound in markets for knowledge and technology, where they exist; and *iii)* because knowledge has properties of a public good as performers of R&D can only imperfectly appropriate the results of their effort and the use of knowledge does not preclude its simultaneous use by others. The lack of appropriability is reflected in positive externalities (evidenced by a wealth of empirical studies), with social returns exceeding private returns. Under these circumstances, under-investment in the production of new knowledge will occur. Traditional responses to market failure due to non-appropriability of the results of R&D include: strengthening intellectual property rights (notably the patent system), R&D subsidies to private producers of knowledge, and capturing externalities through (horizontal) R&D co-operation (Geroski, 1995).

Owing to advances in the understanding of innovation systems and processes, the rationale of STI policies has been revisited since the 1990s (OECD, 1998). The innovation systems approach, which highlights interactions among institutional actors (business firms, universities, research organisations) in the production, diffusion and use of knowledge, gave rise to the notion of systemic failure. Systemic failures block the functioning of the innovation system, hinder the flow of knowledge and technology, and reduce the overall efficiency of the system-wide R&D and innovation effort. Systemic failures can arise from mismatches between different components of an innovation system, such as incompatible incentives for market and non-market institutions, *e.g.* enterprises and the public research sector (and the people operating within them). Other failures may result from institutional rigidities, asymmetric information and communication gaps, and lack of networking or mobility of personnel (OECD, 1999). It can be argued that systems are better able to identify where public support should go (Smith, 2000). It is important to note, however, that market and systemic failures can occur simultaneously, and policies to address them are not necessarily mutually exclusive. Indeed, market failure remains the basic rationale for innovation policy in many areas. At the same time the need for innovation policy to address systemic failures has become widely accepted.

The rise of the innovation system framework has been complemented by the emergence of a more comprehensive view of innovation processes. Reflecting on the policy implications of a broader approach to innovation in business firms as well as the innovation system as a whole, Arnold (2004) identified the following four types of failure:

- *Capability failures*: Innovation capabilities may be lacking, for example, through managerial deficits, lack of technological understanding, learning ability or absorptive capacity to make use of externally generated technology.
- *Failures in institutions*: Failure to (re)configure public institutions such as universities, research institutes, etc., so that they work effectively within the innovation system.
- *Network failures*: These refer to problems in the interaction among actors in the innovation system and relate to phenomena such as weak links between system actors, missing complementary assets in clusters, etc.
- *Framework failures*: Deficiencies in regulatory frameworks (*e.g.* health and safety rules), as well as in other background conditions, such as the sophistication of demand, culture and social values, can have a negative effect on innovation and economic performance.

Not all potential failures in innovation systems make government intervention necessary or desirable. There is no guarantee that government policy will address a market or systemic failure in a way that effectively improves the outcome, *e.g.* in welfare terms. Even where governments may improve welfare in principle, they may lack the means to do so in practice. Governments' space of action may be limited; in fact, policy or government failures are often the result of the same (*e.g.* informational) constraints as those faced by private actors. However, governments can, in principle, make a difference by funding basic and strategic research, supporting innovative SMEs,*e.g.* by helping them to develop their absorptive capacity, fostering networks and other system linkages, and providing strategic intelligence as a public good to inform actors throughout the innovation system. Awareness of the possibility of government failure and rigourous *ex ante* evaluation of policies help limit the risk of costly but ineffective intervention.

STI policy has become more strategic

Over the last two decades, many OECD countries' STI policy has become more strategic because of concerns about competitiveness and societal issues as well as global challenges. It is increasingly informed by explicit expectations regarding outputs and outcomes, which are themselves framed in a broader context. This context is determined not only by an assessment of current needs and opportunities but also by anticipation of what these may be in the medium term. Various forms of strategic *ex ante* evaluation, such as technology assessment and technology foresight, are increasingly used. They involve a multitude of actors in forums where alternative futures are debated. Other widely used instruments are meta-evaluation and system reviews, which tend to provide a joined-up horizontal view of the system under consideration.

While these processes generate a lot of information, additional efforts are needed to convert it into intelligence. The strategic reflection processes associated with foresight activities can help in this regard. However, to make full use of them, organisations must be able to sort through, process and make sense of the available data.

Globalisation and regionalisation are adding to the complexity of governance

In transforming the world economy, globalisation has affected governance in many ways. For example, governance arrangements that were well-suited to (partly) sheltered national economies have become obsolete, and new ones have emerged. For example, multinational enterprises (MNEs) have expanded their R&D and innovation activities across the world; this has given them greater prominence in many national STI policy contexts, including in emerging economies. As national (and regional) governments compete to attract investments for R&D and innovation and, more generally, seek to maximise the benefits from globalisation, national STI policy is increasingly framed with reference to the evolving global environment. Economic globalisation has been accompanied by the expansion of the role and scope of international organisations and frameworks, *e.g.* the WTO TRIPS Agreement, the Kyoto Protocol. The European Commission plays a prominent role in supporting research and innovation agendas, mostly at the European level, but also at the sub-national level, and provides platforms for the co-ordination of national policies. How these levels interact needs to be better understood.

At the same time, the regional dimension of innovation is gaining in importance. A key policy debate is whether it is better to concentrate resources in leading regions or to use innovation-targeted resources to trigger catch-up in other regions. The arguments in favour of the former tend to emphasise efficiency and higher returns from research excellence; the counterarguments emphasise regional development and/or tapping into new ideas and innovative research. As interest in regional innovation hubs increases, it seems likely that more effort will be made to harness research capacity outside traditional research centres. In turn, policy makers are looking for examples showing that regions can successfully develop new specialisations or increase their engagement in innovation.

Many OECD countries have moved towards increased regionalisation, with more competencies and resources devolved to sub-national authorities. Decentralisation has led to the emergence of regional innovation and science agendas in order to promote local socioeconomic development. These tend to focus upon nurturing regional clusters and capability building among local knowledge producers, as regional policy makers may be better placed than their national counterparts to understand local conditions and to tailor interventions accordingly. Sometimes they have attempted to correct for shortcomings in national framework conditions and drawn on their greater flexibility to pioneer innovations in their country's STI governance system. In sum, new policy actors and agendas have emerged, adding to the complexity of the overall governance system. In practice, there is no neat division of labour between the various levels and actors, and overlaps and gaps are often evident. Moreover, governance arrangements are rarely well co-ordinated, despite their often obvious interdependence. This may adversely affect the effectiveness of policies at different levels and become a source of inertia. This highlights the importance of improved co-ordination and coherence of the overall system of governance.

Changes in the way governments function raise challenges for policy coherence

There has been a profound shift in the perception of the appropriate role of government and how it should be organised and perform its activities, in terms of cost efficiency and the quality of services delivered to clients. Since the 1980s, and first under the influence of new public management (NPM) approaches, many governments in OECD countries have delegated authority to lower management levels and created government agencies. In STI governance, this has included establishing agencies for a mix of service delivery tasks, including research funding, innovation support and even research performance. The operating autonomy given to agencies was meant to induce them to innovate and improve performance (Schick, 2002). This delegation of managerial authority and the resulting increased managerial discretion were accompanied by stronger reporting requirements on the outputs and outcomes of public policies. This has in fact helped increase the accountability of lower hierarchical levels (Box 7.1). The move towards delegation also highlights the need for ministries to strengthen their steering capacity and calls for greater emphasis on evaluation and performance.

Box 7.1. Applying and adapting new public management principles

Luxembourg provides a good example of the need for and usefulness of NPM principles in order to improve the steering and funding of public research organisations (PROs) (OECD, 2007a). At the same time, New Zealand's experience suggests the need for some degree of pragmatism (OECD, 2007b). Too rigid application of the customer-contractor principle to public funding of R&D may lead to overlooking the fact that the contractor (PROs, business) may be better placed than the customer (government agencies) to define societal, business or even government needs, and the further fact that the capabilities needed to satisfy the customer can only be built up over a period of time and in expectation of a regular flow of future work. Time-consuming vertical relationships imposed by the purchaser-provider model should not be at the expense of horizontal co-ordination.

Source: OECD (2007), *OECD Reviews of Innovation Policy: Luxembourg* and *OECD Reviews of Innovation Policy: New Zealand*, OECD, Paris, *www.oecd.org/sti/innovation/reviews.*

These developments have affected the coherence of STI policy in two opposing ways. While the focus on outputs and outcomes should help create a more coherent set of STI policies, the delegation of managerial authority to a vast array of actors makes it difficult to maintain policy coherence. There have, as a result, been calls for greater attention to whole-of-government issues. The increasing complexity of the STI policy system, which involves a wide array of (sometimes competing) ministries together with non-governmental actors such as business firms further complicates the situation. Under these conditions, principal-agent relations are much less clear-cut. Instead, a network-oriented polity can be said to be emerging in which the power of would-be orchestrators may reside more in their ability to convince than in their power of coercion.

Attention should be paid to (vertical) steering and accountability mechanisms. For public research, ministries can, in principle, steer through the allocation of budgetary resources. In practice, their steering capacity is often limited in the short and medium term. For its part, the scientific community tends to guard its autonomy to decide which research to fund. Intermediary agencies, such as research councils or R&D promotion agencies, have found ways to preserve a margin for steering, through research programmes aligned on socioeconomic needs. These leave scientific autonomy largely intact, with peer review used to select projects, but help to link scientific efforts to broader social goals. Additional levers available to influence R&D and innovation in the business sector include regulation, procurement, and direct grants and fiscal incentives. Yet, top-down steering is inherently limited, as governments have only partial leverage on business firms, notably MNEs.

Public/private partnerships have emerged as a new instrument of policy delivery

The past 15 years have seen a strong increase in contracting out and the use of public/private partnerships, a trend that has accelerated with the stimulus packages put in place to foster recovery from the recent financial and economic crisis. The widespread use of P/PPs can be seen as part of a more general movement towards redefining the role of government and its relation to the private sector. P/PPs are formal relationships or arrangements, over some period of time, between public and private actors, in which both sides interact in decision making and co-invest resources such as money, personnel, facility, and information in order to achieve specific objectives. P/PPs offer a framework in which the public and the private sectors can join forces in areas in which they have complementary interests but cannot act as efficiently alone. Traditionally used for building physical infrastructures, they have become increasingly popular in R&D and innovation policy because they can fill certain gaps in innovation systems more effectively than other policy instruments (OECD, 2004). They can take a variety of forms and be used to address various policy objectives, but their major contribution in the area of STI is in developing the infrastructure for knowledge and technology diffusion and in supporting more long-term, strategic collaboration on R&D between private firms and public research organisations (PROs).

Governments have been eager in recent years to reap broader economic and social benefits from investments in public research by: *i)* improving the leverage of public support to business R&D through cost and risk sharing; *ii)* securing higher-quality contributions by the private sector to government mission-oriented R&D; *iii)* fostering the commercialisation of results from public research; and *iv)* upgrading knowledge infrastructures. P/PPs develop as a response to the partial failure of other policy instruments to achieve these objectives in an environment characterised by the changing nature of R&D

and innovation processes (*e.g.* increased scientific content of technological development, higher dependency of innovators on external sources of knowledge and know-how), and rapidly evolving business R&D strategies and social needs (*e.g.* health, security, environment).

STI governance requires improvement

Overall, good governance is necessary to secure well-functioning markets and to provide organisational and physical infrastructure in areas in which markets cannot play their role. Although governance arrangements and policy practices have changed significantly – including, as illustrated above, in the area of STI – they need to be continuously adapted in order to maintain effective public policies in a changing environment. The following paragraphs discuss some major challenges for STI governance. The examples used to illustrate current and emerging policy practices are drawn from the OECD country reviews of innovation policy (see *www.oecd.org/sti/innovation/reviews*), which cover both OECD member and non-member economies. They span a wide field in terms of economic development, size, institutional features, etc., and thus offer fertile ground for identifying shared features as well as differences in policy challenges and responses.

Innovation policy needs to be better co-ordinated and more coherent

In an increasingly complex innovation landscape, developing effective governance requires better co-ordination at and among the local, regional, national and international levels. With the broadening of innovative processes, players and locations, the systems of governance that provide for their proper functioning become even more important. As no single actor has the knowledge and resources to tackle the innovation challenge unilaterally, all countries – in one way or another – face the task of better co-ordinating actors in formulating and implementing policy.

Governments find co-ordination and coherence difficult since their traditionally departmentalised structures are generally ill-suited to deal with cross-cutting policy issues such as innovation. Coherence involves not only co-ordination of a multitude of policy actions in the core set of innovation policies such as S&T and education, but also an evaluation of their possible interaction with policies pursuing other primary objectives, *e.g.* tax policy, competition laws and regulations, *i.e.* the framework conditions for innovation (Chapter 4). For example, attracting foreign students or university staff requires close co-ordination between education and immigration policies. Fostering innovation and a cleaner environment to help guide economies towards greater sustainability requires closer integration of multiple policies, *e.g.* in transport, energy, environment, etc. Such policies may, in some instances, be inherently complementary, but in others they may be incompatible; this can reduce their overall effectiveness.

In recent years, the concept of policy mix has emerged to frame the challenge of achieving greater coherence of innovation policies that remain compartmentalised in different departments and agencies. The value of this concept is to force attention to the trade-offs between policy instruments in attempts to achieve policy goals (Flanagan, Uyarra and Laranja, 2010). Accordingly, a number of arrangements for increasing the overall coherence of policies, programmes and instruments across a range of departments and agencies have emerged, some of which are discussed below.

Box 7.2. S&T policy councils

Most countries attempt to co-ordinate science and innovation policy. This co-ordination is implemented and institutionalised in different forms, and the resulting stringency varies considerably across countries. Science and innovation policy councils have become a key element in these co-ordination efforts:

- The Finnish Science and Technology Policy Council, headed by the Prime Minister, has been a reference for many similar institutions around the world.
- Canada's Science, Technology and Innovation Council brings the public and private sectors together to advise the government on priority setting. It produces a biennial State of the Nation report to track the impact of policies.
- Korea has made persistent efforts to better co-ordinate its STI policies. It established a National Science and Technology Council, which has been progressively strengthened to play a pivotal role in policy co-ordination. Among other functions, it is responsible for improving coherence between rival ministries' programmes.
- The advisory Swiss Science and Technology Council focuses on science and higher education. Unlike comparable councils in other countries its membership comes largely from academia.
- The Supreme Council for Science and Technology in Turkey steers the innovation system forward while diffusing developments on STI policies and establishing ad hoc committees to provide policy recommendations.
- Norway lacks a strong institutionalised co-ordination arena but holds that this is partly compensated for by relatively strong informal co-operation among the ministries involved in STI policy.
- Hungary's Science and Technology Policy Council (chaired by the Prime Minister) has a varied history. In recent years it stopped convening, and thus has not played a decisive role in important strategic policy decisions.
- Mexico, too, had a council that has not yet been fully functional; a new inter-ministerial co-ordination mechanism was established recently.
- Chile has established an advisory National Innovation Council for Competitiveness which has succeeded in developing a national strategy and deploying a cluster initiative. The Council has triggered changes in the governance system, including the creation of an Inter-ministerial Committee for Innovation, the advisory Council's counterpart in the executive branch. There has been some initial uncertainty concerning its composition and its actual role in allocating resources from the Innovation for Competitiveness Fund (which was established along with a levy on mining revenues).
- The People's Republic of China's State Council Steering Group for Science, Technology and Education headed by the Prime Minister is a top-level co-ordinating mechanism on strategic matters. There is a lack of a co-ordination covering the design and implementation of STI policy, and co-ordination between the central and provincial levels, and among regions, remains weak.

Horizontal co-ordination

A comprehensive innovation policy requires co-ordination of a wide range of actors and government ministries such as science and technology, education, competition, trade, communication, migration, employment, environment, health and foreign affairs. This can be achieved in different ways, *e.g.* through the establishment of a high-level policy council. In fact, recent years have seen a proliferation of councils modelled on what has been perceived as international best practice, above all the Finnish Science and Technology Council with the Prime Minister at the helm. Such councils can play an important role in agenda setting, prioritisation and as an overall policy co-ordination platform (Box 7.2). However, it has become evident that simply establishing such a council is not a panacea. The role and performance of existing councils has sometimes been limited because of more deeply rooted problems. Its tasks may have been ill-defined in the context of the country's innovation system, or policy makers may not have been prepared to take on the role they were assigned (OECD, 2009). This highlights the need for precision about the concrete role of councils and the need to gear them to the strategic needs of the respective innovation system and social and political realities. There are some general lessons to be drawn from international experience, *e.g.* concerning the involvement of councils in the budg*et al*location process. The council's composition, too, needs to be considered in view of the strategic tasks to be fulfilled by the national innovation system. This includes ensuring an adequate degree of openness, including to the outside world (*e.g.* nomination of members from beyond national boundaries) and to newly emerging actors in innovation in the country.

Other approaches for achieving greater policy coherence include the merger of institutions and/or the formulation of strategic, long-term policies and visions that provide a legitimate framework and direction for priority setting. But it can also be achieved through joint programming and the like. The need for the latter is accentuated by the proliferation of government agencies, since NPM-inspired arrangements, with their strong focus on vertical co-ordination and tightly bound service missions, have sometimes tended to inhibit horizontal co-ordination. Of course, effective horizontal integration tends to result in a loosening of control and the introduction of greater complexity into policy implementation processes.

Recent years have seen many attempts to improve horizontal co-ordination across the STI policy system. Some OECD countries have taken an ambitious whole-of-government view and have encouraged the main players to better co-ordinate their policy interventions, *e.g.* through the establishment of high-level policy councils or through the articulation of a strong guiding national vision or strategy. Others have been more modest in their ambitions for various reasons, with most co-ordination tending to occur between two or more ministries or agencies around a particular issue or policy instrument.

Co-ordination across different levels of government

In addition to horizontal co-ordination, co-ordination of different layers of government merits more attention, in view of the growing importance of (sub-national) regions and local authorities in STI policy making. As discussed in Chapter 2, regional policy makers are sometimes better placed than their national counterparts to understand the local landscape and tailor interventions accordingly. Furthermore, leading regions can provide a testing ground for new policy initiatives and governance arrangements, including in the area of STI. On the other hand, excessive federalism can reduce the efficiency of the overall system by a suboptimal allocation of resources (*e.g.* failure to achieve critical mass and exploit economies of scale of research facilities) and can incur large transaction costs (*e.g.* by creating obstacles to the mobility of resources).

There are different institutional options for the delivery of policy (Boxes 7.3 and 7.4). Federal or strongly decentralised countries typically have some form of constitutional arrangement that devolves powers for certain dimensions of innovation policy to sub-national units. The central government maintains a role in providing funding for key sectors or technologies and usually retains a guiding influence over science policy and major funding streams for scientific research. This is the case in the United States and Germany, for example. In other countries, where decentralisation is more recent or ongoing, innovation policy is more of a joint responsibility. In Italy, for example, responsibility for innovation policy has been shifted to the regions, but the central government ministries still have important functions.

In more centralised countries, the regional dimension of innovation policy remains strongly driven by the centre, with the regions involved in business support delivery (*e.g.* cluster policies) or more real-estate actions such as science parks. The UK government has established arm's-length agencies to improve policy delivery while maintaining central government control over how resources are spent (OECD, 2008).

In most countries, regions manifest a strong desire to be more active in innovation policy and innovation has a central place in regional strategies. This has led many regions and cities to establish their own innovation support agencies, sometimes growing out of SME or cluster support bodies or local development agencies. Prominent examples of such agencies include SPRI in the Basque Country, ASTER in Emilia-Romagna and Bretagne Innovation in Brittany.

National and regional authorities have recently attempted to design policy frameworks that support positive externalities by improving the efficiency with which partners interact and share knowledge and by systematising their relationships. In this context, it is crucial to clarify the general "rules" that determine the management of innovation policy across levels of government. Evidence from OECD regional reviews of innovation and regional policy reviews suggests that the respective roles of national and regional policies can be broadly described as follows:

- *National policy* sets an "anonymous" framework of regulations and institutions that is designed to shape the policies and initiatives of a wide range of actors towards some general economic and specific S&T related objectives.
- *Regional policies* relate to more or less direct collaboration among identifiable actors, by implementing policy in specific places to achieve specific targets. The role of regional authorities is to offer services and other mechanisms that augment the linkages among these actors.

Box 7.3. The emergence of a regional dimension to innovation policy in Chile

Chile has made progress towards a territorial approach to regional development. Between 2006 and 2007 the Chilean government established regional development agencies (RDAs) based on co-operation between the private and public sectors. Fifteen RDAs have been established, one for each region. The process was directed by the Chilean Economic Development Agency (Corfo), and was co-financed by the Inter-American Development Bank (IADB). One of the main roles of the RDAs is to develop bottom-up regional agendas for productive development based on each region's assets, strengths and opportunities. They represent a promising means of creating regional frameworks for business development and public/private partnerships. Within the same context, some programmes are trying to spread the benefits of Chile's innovation system (strongly concentrated around the capital, Santiago) to the regions. In 2000, the National Commission for Scientific and Technological Research (Conicyt) launched the regional programme on science and technology, which now supports 11 scientific and technological centres in different regions of the country. The objective of this initiative is to stimulate the development of centres of excellence in disciplines or specific areas of research that are consistent with regional assets and advantages. In addition, the launching of the Competitiveness Innovation Fund of Regional Assignment in 2008 appears as a major effort to improve innovation in the regions. The 2008 budget of the Competitiveness Innovation Fund amounted to CLP 80 907 million (more than USD 154.5 million), or close to 30% of total public investment for innovation in 2008. Regions assign 25% of these resources and thus participate in decisions on the use of public resources for innovation, giving them the opportunity to link innovation investment to regional priorities.

Source: OECD (2009), *Territorial Review of Chile,* OECD, Paris.

Box 7.4. Supporting regional innovation systems: national and regional examples

National approaches

- *Encouraging the development of a regional innovation strategy*: France, in response to EU evaluations, has been providing technical assistance to different regions to better tailor their innovation strategies to specific regional situations. The United Kingdom offered seed funds to help its Regional Development Agencies develop regional innovation strategies.
- *Decentralising innovation support responsibilities*: Through a series of legal changes, Italy has devolved authority for innovation policy to the regions. In practice, only some regions have actively taken on this new role, notably Piedmont and Lombardy. In Spain, decentralisation of responsibilities has also included supporting science and technology and the Autonomous Communities increasingly finance business R&D, public research institutions and technology parks and centres.
- *Supporting innovation hubs*: Finland and Norway have funded regional centres of expertise to act as hubs for regional innovation systems in different regions. Other programmes in OECD countries to support increased collaboration between knowledge generators and firms include the NRC Technology Clusters Initiatives in Canada, the Innovative Cluster Cities in Korea and the VINNVAXT programme in Sweden.

Regional approaches

- *Co-ordination*: The regional level (as opposed to the national level) is more suited to bringing actors together in defining a strategy. While one region may have a few key actors or leaders in the innovation system, in others the landscape can be very complex.
- *Adapting instruments*: National level instruments tend to focus on setting up the overall framework, whereas regions focus on instruments that are closer to the market in order to help firms translate knowledge into products and services. Mexico, with one of the highest intra-regional disparities in productivity of all OECD countries, requires differentiated regional responses.
- *Filling gaps*: One of the roles for a particular region is to identify and fill in gaps within the region's innovation system. In the north of England, the North East region has a thin institutional landscape in terms of firms and has some strong universities but was missing intermediaries. Through its Strategy for Success, the region has supported the development of private closer-to-market, translational, scale-up and demonstration facilities.

Source: OECD Territorial Reviews and *OECD Reviews of Regional Innovation.*

Pressures for prioritisation in STI have increased

As discussed in Chapter 5, there are pressures to prioritise public spending on STI. Emerging societal issues and global challenges, on the one hand, and fiscal constraints, which will become more acute as governments face the task of fiscal consolidation in the aftermath of the economic crisis, on the other, have led governments to seek to focus research efforts. Countries with a relatively small-scale research system, such as small countries and catching-up economies in their initial phases, cannot afford to cover all areas of science. But even larger countries are in need to concentrate effort, in some cases across national borders, in order to achieve the scale and capacities required for reaching their objectives, Prioritisation raises two basic questions: What areas of research should be supported? Who should be funded to carry out the research?

In practice, prioritisation in science has often been implicit, with a high degree of path dependency and lock-in typically shaping budget portfolios. In some respects, this has been reinfoirced by the autonomy of the scientific community and the reliance upon peer review for project selection. While this process undoubtedly has strong merits, it is also known for its inherent conservatism and is unsuitable for selecting among areas of science. For this reason, more explicit prioritisation exercises to guide the selection of research areas have been put in place in many OECD countries. The rationale is the need to identify and exploit emerging opportunities and to consolidate research efforts in order to create a critical mass of activities.

Every priority-setting exercise must deal with an array of generic issues, including the scope, the level of detail, the criteria, the institutional positioning and the identity of those involved. Several related trade-offs are apparent: the desire to specialise *versus* the desire to diversify; a concern with harnessing high-technology sectors *versus* a concern with meeting the innovation needs of established industries; adopting a science-driven *versus* a market or society-driven approach; and a focus upon meeting short-term needs *versus* a focus upon long-term opportunities. Many formal prioritisation processes tend not to meet the often unrealistic expectations of their sponsors owing to system inertia and the medium-term commitment of most resources to existing lines of work. Countries have taken very different approaches to priority setting (Box 7.5). It appears that some countries which are reluctant to provide direct public support for R&D to industry in order to avoid "picking winners" are prepared to engage in priority setting in science.

Box 7.5. Priority setting

- Korea uses a mix of instruments for priority setting, including technology foresight and technology road-mapping. The processes are distributed across various ministries and agencies and create a cacophony of competing priorities and visions. Some efforts have been made to consolidate these into a total R&D map.
- China is setting priorities in science and technology as part of its medium- and long-term planning, and has proven its ability to mobilise resources to achieve its goals. The approach to priority setting is still largely top-down and is biased towards high technology.
- Norway has set broad priorities in science and technology. It has a strong social consensus on issues relating to sustainable development as well as strong capabilities in associated areas of science and technology. This creates a unique opportunity to use this combination as a mobilising device.
- Switzerland has exercised a considerable degree of thematic priority setting in science. The reform of higher education includes portfolio management, fostering strengths and profiles, and allocation of much university investment to a few selected fields. Targeted investments of the Federal Institutes of Technology and National Research Programmes have a long tradition. The Innovation Promotion Agency (CTI) also engages in funding priority areas in key technologies such as nanotechnology and medical technologies.
- Chile has started to develop more selective policies through the cluster initiative launched by the National Innovation Council for Competitiveness.

Source: OECD Reviews of Innovation Policy, www.oecd.org/sti/innovation/reviews.

Recent developments include the extension of the application of competitive mechanisms to proposals for areas of technology, clusters and consortia. Experience with P/PPs for research and innovation indicates that they can be an effective focusing device for the allocation of resources with industry participation, and thus contribute to priority setting in new ways. The approach may be (partly) top-down, *e.g.* defining certain thematic areas (sometimes in rather broad terms), or it may adopt thematically open, bottom-up procedures which have proven fruitful in revealing developments within the innovation system, *e.g.* through the appearance of multidisciplinary consortia engaging in novel types of joint research.

Finally, support to innovation has paid more attention to so-called structural priorities (research infrastructure, tertiary education, industry-academic links, financing innovation, IPR protection regimes, etc.) (OECD, 1991; Gassler *et al.*, 2004). There is of course a strong link between thematic and structural priorities, as the latter can improve the chances of success of the former. Structural priorities closely relate to discussions of "policy mixes", which emphasise achieving an appropriate blend of measures.

STI governance needs to better integrate the international dimension

The growing international dimension of STI governance discussed in Chapter 6 has several aspects.

- First, issues related to agenda setting, priority setting, and co-ordination and engagement with stakeholders are not insulated from developments beyond national borders. The globalisation of trade and investment, the international mobility of human resources, and the internationalisation of R&D and innovation, as well as the global rules-setting agenda in areas such as IPRs, redefine the space in which national STI policies and governance structures operate.
- Second, the pursuit of national agendas and the need for critical mass in research, specialisation or technological competitiveness can require policies at the international level. The co-ordination of European Union policies in the area of research, development and technological innovation, for example, extends beyond national borders. The development of international research infrastructure is also a way to leverage national efforts but requires changes in or new modes of governance.
- Third, governance issues arise in relation to international S&T co-operation on specific global challenges. There is a growing consensus among governments and various stakeholders that global challenges such as climate change, energy or food security require global solutions involving both OECD members and non-members, and that science, technology and innovation must play an important role (see Chapter 6). The challenge for national governments is efficient institutional and multi-level co-ordination in international arenas. A related issue is the role of international stakeholders in this process.

Bringing these various strands together and improving STI governance is clearly an area that requires further work.

Evaluation and benchmarking for accountability and learning needs to be improved

Modern public management approaches highlight the need for effective monitoring and evaluation, more from the perspective of accountability than of learning. Yet, the main strength of evaluation may reside in its capacity to provide insight and understanding. Thus, while arrangements aimed at enhancing accountability offer the prospect of institutionalising evaluation and monitoring, they need to be formulated so as to encourage learning across ministries, agencies and their clients.

Traditions and cultures of accountability have evolved differently in different national settings and influence performance assessment measures and processes. In many OECD countries, performance indicators are used to measure the quantity (and sometimes quality) of services provided by agencies (OECD, 2010a). They are also increasingly used in steering public research organisations (see Chapter 5) and invariably change the behaviour of those who are held accountable. In some respects, that is their purpose: to raise performance levels. However, agencies may focus on achieving specific targets and give too little attention to overall improvements. Unfortunately, many performance indicators focus on aspects of performance that are measurable quantitatively but do not cover many (sometimes more essential) intangible effects. In this sense, performance indicators are blunt instruments of control, which, inappropriately used, may have undesirable effects on the system that is monitored. Such effects can be minimised by a good understanding of the system and broad agreement on a set of performance indicators that are sufficiently nuanced.

Evaluation – typically of institutions, programmes and instruments, but recently also more comprehensively of the overall policy mix or public funding system – is essential to improve STI governance and enhance the effectiveness and efficiency of innovation policies. It may be systematic or *ad hoc* (OECD, 2010a). Its general purposes are:

- To learn about the effectiveness and efficiency of policy and programme interventions *ex post*, or to anticipate them *ex ante*, with a view to shaping and justifying future interventions.
- To offer opportunities to a range of stakeholders – particularly users and beneficiaries – to reflect upon the performance of the policies and programmes evaluated and to make suggestions for improvements.
- To provide one way to hold policy makers and programme managers accountable for their actions (and inactions).

Effective evaluation is also crucial for the legitimacy and credibility of government intervention in support of innovation activity. Factors to keep in mind include a programme's or policy's additionality, *i.e.* the extent to which desirable outcomes would have occurred without public intervention. Additionality may concern inputs, outputs and behaviour (OECD, 2006a).

In many countries, evaluations of government support programmes and instruments have become an important tool of evidence-based STI policy making. Challenges for evaluation include the need to keep pace with the broadening scope of innovation policy:

- Evaluation remains constrained by available the methodologies, data and indicators. While governments collect and standardise data on inputs into the innovation process, measures of outputs remain limited (except for outputs such as scientific publications and patents). This calls for moving the measurement agenda forward (see below).
- Feeding the outcomes of evaluation back into policy also remains a challenge. Utilisation of evaluation results is often indirect. While *ex post* evaluations are increasingly used to improve programme design and implementation, they are not always readily available or communicated to policy makers at the strategic decision-making level.

Demand for effective evaluation tools to inform decisions on funding and impacts will increase in line with public investments in innovation to enhance competitiveness and improve innovation capacity but also in line with demands for greater accountability and more effective public support. As a result, learning through international benchmarking and co-operation has become more important. International organisations have played an active role in offering advice on best practices and in providing forums for mutual learning between policy actors. For example, the OECD and UNESCO have been active in this area since the 1960s, and the European Commission has considerably expanded its support for STI policy making since the 1980s.

Despite a trend towards convergence inspired by international experience, evaluation practices vary strongly across countries and significant obstacles to international learning remain. First, the necessary absorptive capacity is often missing or under-developed. Even when countries are eager to transfer practices and arrangements used elsewhere, they may lack the means to do so effectively. This is because countries' history, institutional cultures and dynamics, patterns of relations and trust in networks and communities, among others, provide specific contexts that it is impossible, and often undesirable, to reproduce elsewhere. Yet, these contextual factors often explain the success or lack thereof of policy interventions. It is difficult to understand these characteristics fully, but certain principles can usually be derived and transferred to other contexts. The recent success of catch-up economies demonstrates that international learning can be very effective but requires appropriate adaptation to the new context (Rodrik, 2008).

In developing their innovation policies, governments need to consider policies that can be adapted to the evolving needs of innovation actors. Mechanisms that enable learning and policy development can help ensure that government is meeting the innovation needs of society. Most OECD governments have also sought to better understand what is happening in the wider STI policy system through periodic stock-taking exercise and to identify bottlenecks and gaps and improve players' broader awareness of activities elsewhere.

Mobilisation of actors and resources

An important factor of success in setting and implementing an STI agenda is the ability to mobilise a broad spectrum of actors to follow a desired line of action and to make the necessary resources available. This becomes increasingly important as systems become more complex, cross borders, and require partnership and co-operation. Successful mobilisation will depend on factors such as the available power bases (*e.g.* monetary resources, persuasive arguments, etc.), the autonomy of actors in the institutional landscape, the nature and extent of existing network linkages (social capital), and the effectiveness of leadership.

As the spectrum of countries engaged in science, technology and innovation broadens (Guinet, Hutschenreiter and Keenan, 2009), it becomes clear that STI policy, like other policy areas, is sometimes dominated by narrow elites who wield considerable influence. For example, it is not uncommon to find powerful scientific elites dominating national STI agendas, particularly in countries with a less mature innovation system. This can become a serious obstacle to developing policies that could set the innovation system on a more dynamic path. OECD countries are not immune to this type of lock-in, although they tend – to varying degrees and depending on the policy area – to involve various interest groups in agenda-setting and decision-making processes. The greater involvement of business actors and organised interests in public policy formulation and implementation has to some extent resulted in blurring of the public-private distinction. Finally, some STI policy arenas see a greater role for direct citizen participation in agenda setting, although this remains relatively rare.

Vision – communicating goals and roles in a comprehensive manner – can help to mobilise and align system actors, notably in segmented institutional landscapes. It can contribute to linking S&T activities to current and emerging socioeconomic agendas. In some countries, it has become an important means of co-ordination and mobilisation. Broad participation in the vision-building process can induce strong commitment to the vision and its action pathways. However, vision alone will not induce actors to follow particular paths; other features, such as leadership, are also important. Experience indicates that leadership in STI governance – by distinguished individuals, ministries or innovative business enterprises – helps to mobilise actors and resources. Therefore, an intermediate goal in STI policy making is often to enrol the support of high-level leaders – a president, prime minister or minister of finance – who can take a broader perspective on science and innovation policy agendas and help maintain their overall coherence.

Improving the measurement of innovation

The measurement of innovation needs to reflect current innovation processes

As the notion of innovation policy becomes broader and more inclusive, measuring innovation across different policy domains is a huge challenge that calls for reconsidering the framework for measuring innovation. In the shorter term, the challenge is to render statistical systems more flexible and responsive to the introduction of new and fast-evolving concepts. Ways of doing this include experimenting with satellite accounts, adding questions to surveys, or adding topic-specific modules to main survey vehicles every *n* years. Experimental and flexible approaches can progress at different speeds according to countries' specific priorities and resources. This will require co-ordination to prevent geographically fragmented research efforts over the long term and ensure that the results of successful experimentation in a limited number of countries are taken up by the international community.

In the longer term, the challenge for the statistical community is to redesign surveys to address the relevant unit of innovation analysis. Should data be collected at the level of research laboratories to address questions about basic research? Is the enterprise group a more relevant unit of analysis than the enterprise when looking at innovation activity? Should innovation surveys use the establishment as the unit to look at the diffusion of new process technologies? Another challenge is to restructure data collection to maximise data-linking opportunities for research and the analysis of impacts. This also means finding ways of providing researchers with access to micro-data while respecting confidentiality requirements.

The development and implementation of measurement framework and its components require a relatively long time frame. It requires the efforts of the statistical community but also the engagement of policy makers to define user needs and of researchers to use the data, analyse impacts and feed into the development of the right metrics and data infrastructures. It also requires the engagement of organisations, businesses, universities and the public sector, because the statistical system can only collect what it is feasible to measure inside organisations.

The work undertaken as part of the OECD Innovation Strategy has engaged the international community and has helped to move the measurement agenda forward. *Measuring Innovation: A New Perspective* (OECD, 2010b) presents some “experimental” indicators and highlights some of the gaps in the current measurement framework, as well as some of the initiatives under way to address such gaps. A number of recommendations have emerged from this work and are presented below. In addition, Box 7.6 provides a summary of the key actions needed to take the measurement agenda forward.

Measuring innovation more broadly

The increasing recognition of innovation as a driver of economic growth and structural change has drawn greater attention to its nature, role and determinants. Innovation entails investment aimed at producing new knowledge. It is the result of a range of complementary intangible assets – not only R&D but also software, human capital and new organisational structures. In itself, innovation is not an objective. It needs to be placed in the broader context of its contribution to aggregate economic performance. The ability to explain productivity differences is what drives and informs policies designed by ministers of finance or of the economy.

STI surveys need to be redesigned to take a broader view of innovation. Survey and administrative data need to be aligned with aggregate economic measures and become a visible part of the System of National Accounts (SNA). The goal is to help recognise the important role of STI policies in promoting economic growth. The business, statistical and research communities are therefore encouraged to work to measure and value intangible assets, revisit the measurement framework for innovation to identify and prioritise areas for survey design and re-design, and align survey and administrative data with economic aggregates to enable productivity analysis.

Going beyond targets and aggregates: understanding why and how innovation happens in firms

Targeting levels of spending on certain dimensions of innovation activity, such as R&D, has been a widely used policy tool in recent years. Spending on R&D is well measured, but it is important to know how to reach the target and what that target means in terms of innovation outcomes and impacts. R&D surveys can provide information about some of the inputs to innovation but give little information on the outputs of these processes. They tend to be more useful for measuring technology-based activities, which are only a subset of what is included in the broader concept of innovation, and they are often more relevant for manufacturing than for services. Similarly, patent data are useful for understanding certain innovation-related strategies, but they cannot measure the full extent of innovative activities and suffer from some well-known limitations. Innovation surveys were therefore developed to increase knowledge about innovation in firms with a view to developing effective innovation policies. They collect information about types of innovation, reasons for innovating (or not), collaboration and linkages among firms or public research organisations, and flows of knowledge, as well as quantitative data on sales from product innovations and spending on a range of assets beyond R&D. However, knowing, for example, that 60% of a country’s firms have introduced some type of innovation does not help to understand why and how innovation happened, what its impacts are on the economy and how it can be encouraged.

Sound evidence-based policy advice calls for a comprehensive, high-quality data infrastructure. Its backbone is a reliable business register. It is important to be able to link different data sets and exploit the potential of administrative records. For example, the ability to link innovation survey data to business practice surveys, ICT surveys or administrative databases on firm-level capital investment, earnings, value added and employment can substantially improve empirical research on the impacts of innovation. This can also reduce respondent burden if questions do not have to be repeated in the innovation survey.

However, there is no point to a first-class data infrastructure if it is not available to the research community. It is researchers who formulate relevant research questions and analyse the data. Of course, this requires measures to ensure data confidentiality in order to protect respondents and to avoid any real or perceived conflict of interest on the part of researchers.

In this area, governments, the statistical and the research communities are encouraged to focus on improving business registers; exploring the statistical potential of administrative records; building a data infrastructure which exploits data linkages across datasets and over time; and improving the research community's access to such infrastructure, while ensuring data confidentiality.

Going beyond traditional actors: addressing the role of government in innovation

As discussed in this chapter, governments, including central and local government and various agencies, provide services to people and to businesses. They also define the boundaries within which innovation takes place through regulation of domestic activity and trade, and they play a major role in fostering innovation. Yet while universities and firms are covered by conventional indicators, current measures do not fully take account of the roles of individuals, consumers and government in the innovation process. There are several compelling reasons for developing metrics and definitions for innovation in the public sector and measures of policy efforts to foster innovation. There is a need to account for the use of public funds for innovation, to deal with the rising cost of health services, or to improve learning outcomes and the quality of the provision of education or other public services.

Internationally agreed concepts and comparable metrics for studying innovation in the public sector do not yet exist. A framework for the measurement of public sector innovation that is analogous to, but appropriately different from, the one used for business innovation (the *Oslo Manual*, OECD and Eurostat, 2005) would provide a basis for a more innovative approach to public activities and services and allow for comparisons and benchmarking. Because the concept of "public sector" encompasses very different organisational units (*e.g.* the public administration, the health sector, the education sector), it may be necessary to develop new concepts, such as innovation in education (see Chapter 5) and different metrics to encompass the public welfare aspects of innovation.

Governments and the statistical and research communities are therefore encouraged to develop a measurement framework for innovation in the public sector that: examines the extent to which concepts and metrics used in the context of business innovation can be used and adapted; considers whether basic concepts and tools are relevant in light of the specificities of the public sector, in particular its complexity and heterogeneity, and its organisational and incentive structures; and recognises that the public sector has multiple objectives, including innovation for social goals, which may require radically new thinking about what innovation is and how it takes place in that context.

New metrics are also needed to guide public policies that support innovation. As already mentioned, *Measuring Innovation: A New Perspective* (OECD, 2010b) presents experimental indicators on the mix of direct and indirect public support to R&D, as well as measures of public funding "modes" (*e.g.* institutional versus project funding). More work is needed to improve the international comparability of these indicators, as well as to develop metrics of support to broader innovation (beyond R&D).

The policy, research and statistical communities are encouraged to promote the development of indicators that capture the nature, direction and intensity of policy actions for innovation at national and regional levels. This will make it possible to study the linkages between them and innovation performance and the relevance of policies in different innovation system contexts.

Capturing knowledge interactions

The production of new knowledge is often a collective process involving a significant number of individuals and organisations which requires communication and co-ordination. Knowledge produced in such a complex but structured way may have public good aspects. Such interactions or "networks" may be usefully tracked as part of the innovation measurement framework. Networks can be a means for "collective intelligence", and policies that seek to influence the rate and orientation of innovation have to take networks into account. For instance, technology transfer between universities and industries implies two-way communication. A clever and linked use of bibliometric, patent and other administrative data can help reveal how these multidisciplinary, transnational networks are evolving.

However, while science and innovation activities increasingly rely on dispersed networks of actors, they sometimes tend to cluster in certain places or around certain institutions (*e.g.* a leading university or a research laboratory of a multinational corporation). To analyse the changing landscape of science, technology and innovation is likely to require new units of analysis with different geographical scope.

Finally, rapidly developing enabling technologies such as ICT, biotechnologies and nanotechnologies draw on interdisciplinary research and tend to be general purpose technologies (see Box 5.5) that can be used across a broad range of industries. A consistent measurement framework across technologies would make it possible to compare their impacts.

The design of innovation policy should take into account the characteristics of technologies, actors and locations, as well as the linkages and flows among them. New methods of analysis are needed to understand innovative behaviour, its determinants and its impacts at the level of the individual, the firm and the organisation.

The statistical and research communities should consider developing interdisciplinary approaches to data collection and new units of data collection; improving the measurement of innovative activity in complex business structures, organisations and networks; and promoting joint measurement of emerging and enabling technologies.

Going beyond economic goals: innovation for social goals and social impacts of innovation

Innovation may be part of a policy framework that addresses societal issues that go beyond day-to-day business innovation. This may require a concept of "policy-driven" innovation which can also respond to social challenges or address social needs. Some innovations that generate income for firms may, of course, reduce environmental impacts and improve social well-being. However, the current measurement framework focuses on the role of innovation in economic performance and has limited capacity to measure innovations that help address social goals, such as those associated with an ageing population or climate change. Moreover, the current framework does not cover the social impacts of innovation. For example, to analyse the effects of policies that foster innovative workplaces, it is necessary to measure both the adoption of innovative practices by companies and the impact of these practices on workers. It would be possible to do so, for example, through linked employer-employee surveys.

It is important to promote the development of concepts and measures of innovation that reveal their impact on well-being or their contributions to achieving social goals. The statistical and research communities are thus encouraged to work towards developing concepts and measures of innovations that address social needs; and devising measurement tools that bridge the economic and social impacts of innovation activities.

Key findings

A country's innovation performance depends greatly on the overall quality of its governance of science, technology and innovation. Over the past two decades, changes in perspectives on innovation have shifted the rationale for and scope of STI governance. With a more strategic approach to STI policy, STI activities are increasingly subject to criteria of relevance in addition to the traditional criterion of excellence. Globalisation and regionalisation have affected STI policy, and the application of new public management principles has profoundly influenced how governments are organised and deliver services.

Despite ongoing adaptations in organisation, policy design and implementation, STI policy needs to be better co-ordinated and made more coherent. Globalisation and regionalisation have given rise to a multi-level governance architecture. And while new public management practices have increased the efficiency of government, they have induced a proliferation of agencies and a more fragmented system. New perspectives on what innovation involves have widened the relevant policy areas. The result has been of the fragmentation of a multitude of STI policies across a wide array of ministries, agencies and levels of government.

Better co-ordination and greater coherence are therefore urgent. Despite the overall trend towards complexity and fragmentation, the demand for effective and coherent collective action is in fact increasing. Policy makers have become more aware of the role of framework conditions for innovation beyond STI policy (market competition, the regulatory environment, etc.). Stakeholders rightly demand integrated responses to societal challenges that cross national borders and disciplines. Pressures to prioritise public spending on STI are strong. The international dimension has also become an essential aspect of STI governance. To underpin responses and keep policy adaptive, evaluation, accountability and international learning need to be fostered and actors and resources mobilised.

Box 7.6. A measurement agenda for innovation: key actions

1. Improve the measurement of broader innovation and its link to macroeconomic performance

Science, technology and innovation surveys need to be redesigned to take a broader view of innovation and improved measurements are needed to link science, technology and innovation policies to economic growth. Key actions:

- Measure and value intangible assets;
- Revisit the measurement framework for innovation to identify and prioritise areas for survey design and re-design; and
- Align survey and administrative data with economic aggregates.

2. Invest in a high-quality and comprehensive data infrastructure to measure the determinants and impacts of innovation

Sound policy advice needs to rely on a high-quality and comprehensive data infrastructure, including at the sub-national level. The backbone of such infrastructure is a high quality business register. The ability to link different data sets and exploit the potential of administrative records will improve understanding and reduce respondent burden. Key actions:

- Improve business registers;
- Exploit the statistical potential of administrative records;
- Improve the data infrastructure at the sub-national level; and
- Establish a data infrastructure which combines data linkages with good researcher access to the data, while protecting business and individual confidentiality.

3. Recognise the role of innovation in the public sector and promote its measurement

There is a need to account for the use of public funds, measure the efficiency of producing and delivering public policies and services, and improve learning outcomes and the quality of the provision of public services via innovation. Key actions:

- Develop a measurement framework for innovation in the public sector for the delivery of public services, health and education; and
- Devise indicators that capture the nature, direction and intensity of public support for innovation, at national and regional levels.

4. Promote the design of new statistical methods and interdisciplinary approaches to data collection

Design of policies for innovation needs to take into account the characteristics of technologies, people and locations, as well as the linkages and flows among them. New methods of analysis that are interdisciplinary in nature are necessary to understand innovative behaviour, its determinants and its impacts at the level of the individual, the firm and the organisation. Key actions:

- Develop interdisciplinary approaches to data collection and new units of data collection;
- Improve the measurement of innovative activity in complex business structures, organisations and networks;
- Promote the measurement of the skills required in innovative workplaces; and
- Promote the joint measurement of emerging and enabling technologies.

5. Promote the measurement of innovation for social goals and of social impacts of innovation

The current measurement framework fails to measure the social impacts of innovation. The development of measures that provide an assessment of the impacts of innovation on well-being, or their contributions to achieving social goals, needs to be promoted. Key actions:

- Develop measures of innovation that address social needs; and
- Devise measurement tools that bridge the economic and social impacts of innovation activities.

Improving measures of innovation is essential for policy making and evaluation and for promoting innovation in businesses, the public sector and society at large. However, current innovation indicators focus on the inputs of the innovation process rather than on its outcomes, and the aggregate numbers or indices available do not adequately reflect the diversity of innovation actors and processes and the links among them. Continuing efforts in this area are needed.

The policy principles that emerge are:

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1. Ensure policy coherence by treating innovation as a central component of government policy, with strong leadership at the highest political levels. Enable regional and local actors to foster innovation, while ensuring co-ordination across regions and with national efforts. Foster evidence-based decision making and policy accountability by recognising measurement as central to the innovation agenda.

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a) *Ensure policy coherence.* A whole-of-government approach to policies for innovation requires stable platforms for co-ordinating actions, a focus on policies with a medium and long-term perspective, and attention from policy makers at the highest level. It also involves coherence and complementarities between the local, regional and national levels.

b) *Foster innovation at the regional level.* National policy should enable regional actors to foster innovation in their own context, building on local strengths and established frameworks. Regional policies may help capture positive externalities by improving the efficiency with which partners interact and share knowledge and by strengthening their relationships. Regions may be able to work closer to the "market" by targeting locally-based stakeholders such as research and higher education institutions, specific sectors or types of firms.

c) *Involve stakeholders in policy development.* The growing range of stakeholders in the innovation process and the growing impact that innovation has on society increasingly requires the involvement of stakeholders in shaping policies for innovation. This can help to develop a shared vision of goals and can make policies more effective in meeting societal demands.

d) *Evaluate policies and improve their effectiveness.* Evaluation of policies is essential to enhance the effectiveness and efficiency of policies to foster innovation. Effective evaluation is also key for the legitimacy and credibility of government intervention in innovation processes. Improved approaches and methods for evaluation are required to capture the broadening of innovation, as is better feedback of evaluation into the policy making process.

e) *Improve the measurement of innovation.* A better evidence base for policies to foster innovation will require progress on a wide range of measurements to capture investment in intangible assets, measure outputs and impacts and understand the process of innovation, including its spatial dimension. Such efforts will require investments to enhance data infrastructure and linkages.

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Chapter 8

The Way Forward

This chapter draws attention to the broad multidisciplinary perspective of this report, which builds on OECD work in the area of innovation. It outlines some elements of the future agenda for analysis and policy making in the area of innovation.

Introduction

Over the past decades, the OECD's work on innovation and economic performance has focused on assessing national innovation performance and the effectiveness of framework conditions and individual policy interventions through the prism of a national innovation systems framework. This framework takes account of the relations among the various actors and has increasingly considered the governance of innovation systems at a whole-of-government level. More recently, the globalisation of R&D and the changing nature of innovation have become a central focus. This report builds on a wealth of OECD work and brings a new perspective, broader and multidisciplinary, to bear on the analysis of innovation and the policies that help drive it.

The preceding chapters have shown that a strategic approach to fostering innovation is necessary to achieve the core objectives of public policy. As countries emerge from the economic downturn, and with other sources of growth declining in importance and global challenges mounting, innovation needs to be harnessed more effectively. Innovation has been, and must continue to be, a driver of rising living standards.

To be effective, innovation policy must take account of how innovation takes place today. Innovation encompasses a wide range of activities. It involves R&D, organisational changes, firm-level training, testing, marketing and design. Innovation also rarely occurs in isolation; it is a highly interactive process involving a growing and diverse network of stakeholders, institutions and users around the globe.

This report offers a broad, system-wide approach to achieving stronger innovation, bringing together policies that can help drive innovation in a mutually supportive manner. Together, the five priorities outlined in the preceding chapters, and summarised in Box 8.1, can help underpin the development of national and collective strategies for policies that make innovation work for people and help meet the major challenges of the 21st century. They can be applied in different contexts and settings, taking account of specific strengths and needs.

Box 8.1. Policy principles for innovation

1. Empowering people to innovate

- Education and training systems should equip people with the foundations to learn and develop the broad range of skills needed for innovation in all of its forms, and with the flexibility to upgrade skills and adapt to changing market conditions. To foster an innovative workplace, ensure that employment policies facilitate efficient organisational change.
- Enable consumers to be active participants in the innovation process.
- Foster an entrepreneurial culture by instilling the skills and attitudes needed for creative enterprise.

2. Unleashing innovations

- Ensure that framework conditions are sound and supportive of competition, conducive to innovation and are mutually reinforcing.
- Mobilise private funding for innovation, by fostering well-functioning financial markets and easing access to finance for new firms, in particular for early stages of innovation. Encourage the diffusion of best practices in the reporting of intangible investments and develop market-friendly approaches to support innovation.
- Foster open markets, a competitive and dynamic business sector and a culture of healthy risk-taking and creative activity. Foster innovation in small and medium-sized firms, in particular new and young ones.

3. Creating and applying knowledge

- Provide sufficient investment in an effective public research system and improve the governance of research institutions. Ensure coherence between multi-level sources of funding for R&D.
- Ensure that a modern and reliable knowledge infrastructure that supports innovation is in place, accompanied by the regulatory frameworks which support open access to networks and competition in the market. Create a suitable policy and regulatory environment that allows for the responsible development of technologies and their convergence.
- Facilitate efficient knowledge flows and foster the development of networks and markets which enable the creation, circulation and diffusion of knowledge, along with an efficient system of intellectual property rights.
- Foster innovation in the public sector at all levels of government to enhance the delivery of public services, improve efficiency, coverage and equity, and create positive externalities in the rest of the economy.

4. Applying innovation to address global and social challenges

- Improve international scientific and technological co-operation and technology transfer, including through the development of international mechanisms to finance innovation and share costs.
- Provide a predictable policy regime which provides flexibility and incentives to address global challenges through innovation in developed and developing countries, and encourages invention and the adoption of cost-effective technologies.
- To spur innovation as a tool for development, strengthen the foundations for innovation in low-income countries, including affordable access to modern technologies. Foster entrepreneurship throughout the economy, and enable entrepreneurs to experiment, invest and expand creative economic activities, particularly around agriculture.

5. Improving the governance and measurement of policies for innovation

- Ensure policy coherence by treating innovation as a central component of government policy, with strong leadership at the highest political levels. Enable regional and local actors to foster innovation, while ensuring co-ordination across regions and with national efforts. Foster evidence-based decision making and policy accountability by recognising measurement as central to the innovation agenda.

Policy challenges differ across countries, depending on their economic structure, level of development, culture and institutions. The priority assigned to each of these principles depends on the nature and state of the system of innovation in each country, as "one size does not fit all". However, because of the interactions within the innovation system, attention must be given to all policy areas to improve its operation. The message of this report is that with a mobilising vision – and the ambition to achieve it through policy coherence and effective co-ordination – governments around the world can use innovation as a tool to improve economic performance, address societal challenges and enhance welfare. This demands both horizontal and vertical co-ordination of policies. With the right set of policies in place, innovation will result in win-win outcomes and greater well-being at both the national and global levels.

The broader approach to innovation described here makes particularly important a balance between policies aimed at the creation of new knowledge and innovations and those aimed at fostering its uptake and diffusion in the economy. It is only through a coherent and comprehensive approach, which matches the supply of knowledge and innovation to demand by firms and individuals, that innovation performance can be improved in an enduring way and optimised to meet society's needs.

The future agenda and way forward

Now more than ever, a strategic approach to fostering innovation is needed to achieve the core objectives of public policy. As countries emerge from the downturn, and with other sources of growth declining in importance and global challenges mounting, innovation needs to be harnessed more effectively.

The OECD Innovation Strategy offers a broad, system-wide approach to bringing together policies that help drive innovation in a mutually supportive manner. Together, the five priorities outlined above can help underpin the development of national and collective strategies for policies that will make innovation work for people and help meet the major challenges of the 21st century. They can be applied in different contexts and settings and take specific strengths and needs into account.

The broad concept of innovation embraced in this report emphasises the need for reaching across the borders of institutions, sectors, fields of training, academic disciplines and countries. This emphasis on building bridges diverges from the many innovation policies that are vertical in nature and target a particular field, sector, technology or locale. This broader vision of innovation necessitates concerted efforts to create a better match between supply side inputs and the demand side, including the role of markets, and to meet the expectation of consumers and society at large.

The OECD Innovation Strategy recognises that countries' policy challenges differ, depending on their economic structure, level of development, culture and institutions. Its message is that a mobilising vision – and the ambition to achieve it through policy coherence and effective co-ordination – can help governments around the world to use innovation as a tool to improve economic performance, address societal challenges and enhance welfare. This requires both horizontal and vertical policy co-ordination. With the right set of policies in place, innovation will result in greater well-being at both the national and global levels.

Policy coherence is also needed so that countries can capture value from innovation at the national, regional and local levels. In a highly interconnected global economy, firms and governments will need to make choices and establish priorities for areas in which they can achieve excellence and critical mass. Local strengths, such as strong human capital, knowledge institutions and networks, well-developed local services, social factors and job opportunities, are the key to attracting firms, including multinational firms, and talent to specific locations and countries and to developing local clusters of activity. These are the foundation on which collaboration with other firms and countries can be built, and strategic and selective choices have to be made.

In this broader approach to innovation, it is particularly important to balance policies aimed at the creation of new knowledge and innovations with those aimed at fostering its uptake and diffusion in the economy. Policy actions also need to reflect the changing nature of innovation. This implies an emphasis on the following areas:

- A more strategic focus on the role of policies for innovation in delivering stronger, cleaner and fairer growth.
- Broadening policies to foster innovation beyond science and technology in recognition of the fact that innovation involves a wide range of investments in intangible assets and actors.
- Education and training policies adapted to the needs of society today to empower people throughout society to be creative, engage in innovation and benefit from its outcomes.
- Greater policy attention to the creation and growth of new firms and their role in creating breakthrough innovations and new jobs.
- Improved mechanisms to foster the diffusion and application of knowledge through well-functioning networks and markets.
- New approaches and governance mechanisms for international co-operation in science and technology to help address global challenges and share costs and risks.
- Frameworks for measuring the broader, more networked concept of innovation and its impacts to guide policy making.

This system-wide approach elicits many questions, and further comparative analysis is needed to better understand the ongoing shifts in innovation processes and how policy can best respond. In particular, efforts are needed to address some of the tensions between certain framework conditions and targeted policies for innovation. For example, as open innovation models proliferate and lead to more collaboration by firms, opportunities arise for anti-competitive collusion that can reduce incentives to innovate. Efforts to engage in demand-led innovation must avoid protectionism and preserve competition. In addition, the governance of multilateral co-operation on innovation will require increased attention as the international community seeks collective solutions to global problems. The OECD will continue to explore and foster debate in these areas in the coming months and years.

The OECD stands ready to help governments and international instances to use the Innovation Strategy to design their approaches to finding national and global solutions. This work will also contribute to the OECD's Green Growth Strategy, requested by Ministers in 2009, and the OECD Project on Measuring the Progress of Societies. Implementing the Strategy will be an evolving process and will benefit from monitoring, peer review and the exchange of experiences and good policy practices.

In the coming months, the OECD may develop a policy handbook to provide operational advice and guidance to countries as they seek to implement an innovation strategy. It has also produced a compendium of indicators (*Measuring Innovation: A New Perspective*) that may help countries assess their performance and monitor implementation of the Strategy by governments. The construction of robust innovation indicators is a long-term endeavour which needs to continue and be supported at national and international level.

As mentioned in the introduction to this report, the development of the OECD Innovation Strategy has benefited from consultations with policy makers and stakeholders in national capitals. The OECD will continue to support a dialogue within governments, among various actors and between countries in the area of innovation.

Annex A

Consultation

This annex summarises the involvement of OECD Committees and Working Parties in the project, the stakeholder consultation process and events contributing to the OECD Innovation Strategy.

OECD participation

The Council of the OECD and working bodies from science and technology; industry and entrepreneurship; information and communications; statistics; public governance; territorial development; consumer policy; trade; investment, competition, tax; development, environment; and education and skills took part in the work.

Expert advisory group

An expert advisory group met three times over the course of the project and provided advice and feedback on the plan, performance and outputs of the Innovation Strategy. These experts were nominated by member governments and other selected governments. In addition, the Business and Industry Advisory Committee to the OECD (BIAC) and the Trade Union Advisory Committee to the OECD (TUAC) provided feedback and advice on the project.

A list of representatives is available at *www.oecd.org/innovation/strategy*.

Innovation strategy roundtables

In order to obtain feedback on the draft principles and the Strategy, ensure that they reflect national realities and explore how they can be applied in different national contexts, a series of high-level roundtable discussions were held in selected OECD capitals from November 2009 to January 2010. In several cases, the roundtables brought together representatives from several countries in the same geographic region. As of 31 March 2010, 13 innovation strategy roundtables had been held in Mexico, Spain, Japan, France, Nordic countries, Austria, Canada, Australia, Korea, Belgium, Italy and the Czech Republic, representing 25 countries.

Workshops/seminars

Over the course of the project nearly 100 workshops, seminars and conferences were held around the world covering a wide range of issues. A complete list is available at: *www.oecd.org/innovation/strategy*.

Innovation portal

A web-based portal (secure website) was created to enhance the development of the Innovation Strategy by fostering a rich, open and informal exchange of ideas among the broader IS community. It provided a single meeting place to pool knowledge and collaborate in real time via an interactive discussion board.

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