OECD Science, Technology and Industry Outlook

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OECD

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Foreword

The OECD Science, Technology, and Industry Outlook 2010 *is the eighth in a biennial series designed to examine trends, prospects and policy directions in science, technology and industry across the OECD area and major non-member economies. In addition to synthesising the latest available information on major policy developments, it contains a chapter on the design and assessment of innovation policy: the "policy mix". It also provides individual profiles of the science and innovation performance of countries and relates these to their national context and current policy challenges.*

In 2011, the OECD is celebrating its 50th anniversary. To mark the occasion, the STI Outlook *contains a special chapter looking at how science policy has evolved since the 1960s, and describing the pioneering role played by the OECD Directorate for Science, Technology and Industry.*

The main report was prepared under the aegis of the OECD Committee for Scientific and Technological Policy (CSTP), with input from its working parties. Chapters were prepared by several members of the OECD Directorate for Science, Technology and Industry (DSTI), including Ester Basri, Sarah Box, Mario Cervantes, Gernot Hutschenreiter, Nils de Jager, Michael Keenan and Sandrine Kergroach.

Ester Basri served as the overall co-ordinator of the publication. Claire Miguet prepared the statistics. Marion Barberis and Stella Horsin provided secretarial support and Joseph Loux supervised the publication process. The report benefited from substantive input and comments from delegates to the CSTP and its Working Party on Innovation and Technology Policy, as well as from members of the Secretariat.

OECD at 50

Science and technology are everybody's business

In 2011 the OECD celebrates its 50th anniversary, and to mark the occasion we'll look briefly at how science and technology have evolved since the 1960s, how the OECD contributed to this evolution and the prospects for the 21st century.

Scientific issues are often sensationalised, trivialised, or misunderstood. The stories chosen by the media usually fall into one of three categories: breakthrough, silly or scare. Scare stories give a poor image of science, reinforcing the stereotype of the "mad scientist" whose research is dangerous for human health or the environment. Likewise, trivia such as the scientific formula for how to eat ice cream or write a sitcom present scientists as eccentrics and their research as futile. Breakthrough stories give an image that is positive, but just as inaccurate as scares and trivia, ignoring the way ideas and intuitions emerge, are formulated as hypotheses and then tested, vindicated, revised or rejected over a period of time.

Scientific ignorance among the media and public impoverishes debate about serious choices facing society (presenting the GMO debate as Frankenstein food *versus* obscurantism, for example) but can also have dangerous consequences in a more direct manner. In 1998, the UK media widely reported a study that associated the MMR (measles, mumps rubella) vaccine with autism and bowel disease in children. The reports gave the impression that the scientific community was evenly divided as to the safety of the vaccine, whereas the research in question was widely criticised, no other studies corroborated its findings, and 10 of the 12 authors of the paper rejected the conclusions. Nonetheless, the rate of vaccination dropped dramatically, and in June 2006 British paediatricians issued an open letter criticising the scare stories and calling on parents to vaccinate their children – national coverage was down to 83%, while 95% coverage is needed to provide protection to the whole community, and the number of measles deaths was rising.

Public interest

One encouraging sign of public interest in science and technology is the expanding market for books dealing with science and technology. Stephen Hawking's *A Brief History of Time*, first published in 1988, has sold over 9 million copies (although how many of them were actually read is a different matter) leading publishers to devote more resources to the sector. As with other sections of publishing, much of the output is formulaic, derivative and uninspired, but books about science can both stimulate public debate and foster vocations.

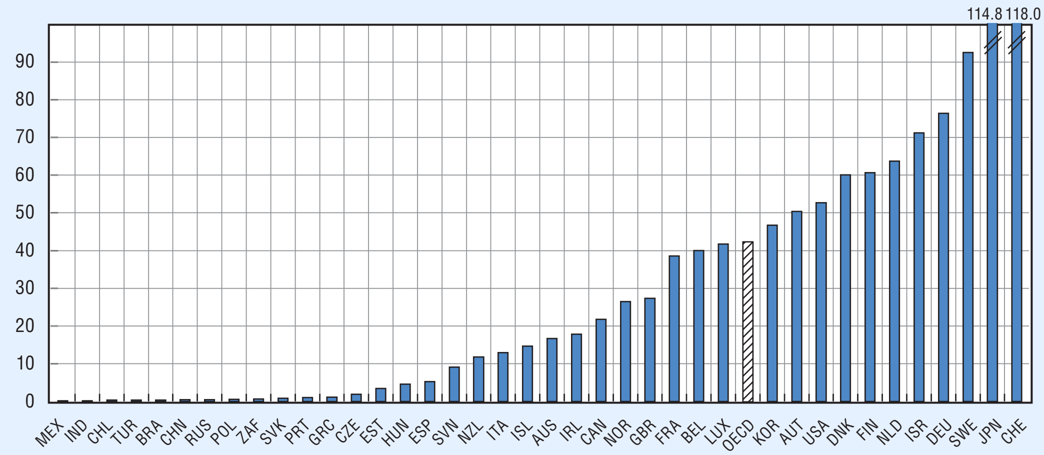
The OECD plays an important role in promoting a better understanding of what science and technology do and could do, as well as the factors shaping how research is carried out and how that research is then used. Often this is controversial, so objective data, analysis and advice will become even more precious as new knowledge is created, and new possibilities and dangers are debated.

In 1961, the year the OECD was created, Soviet cosmonaut Yuri Gagarin became the first human being to orbit the Earth. Only eight years later, Neil Armstrong walked on the Moon. Astronautics was the most spectacular proof that the pace of change in science and technology had accelerated dramatically, but every area of science and technology seemed to be achieving major breakthroughs. The genetic code was cracked. The notion of quarks was developed. The world's first solar power station opened. Other ideas would have to wait until technology caught up with imagination, for instance Alan Kay's Dynabook, a portable device to give children access to digital content, but it was clear that science, technology and intellectual assets in general would play a major role in the economy emerging from post-war reconstruction.

Making daily life better

The big projects like exploring the origins of the Universe or probing the workings of the brain capture our imagination, but science and technology are also about making daily life better. Look at the basics – food, clothing and shelter.

Patents per million inhabitants, 2007



StatLink http://dx.doi.org/10.1787/820878701421

The US and EU27 had around 30% each of patents in 2007, Japan 28%, and the rest of the world 12%. Switzerland, Japan, Sweden and Germany are the four most inventive countries in 2007, with the highest values recorded in Switzerland (118 per million habitants) and Japan (115). Conversely, China has less than 0.5 patent families per million population.

Malthus would have been right about the Earth not being able to feed a bigger population if extending the area of farmland had remained the main way to increase production. Thanks to a series of innovations in animal and crop science, as well as fertilisers and pesticides, the world now produces more than enough to feed everybody (to the point where obesity is the main problem in many places) and hunger exists because of economic reasons, not agricultural ones.

In the 19th century, Gogol could write a credible story about a man who dreams of a new overcoat, whereas today, in OECD countries at least, people throw away used clothes rather than mend them, and the same is true for far more sophisticated goods too because factories can churn out products at a fraction of the cost they once did, in part because of advances in production technology.

A favourite article in 1950s magazines was the home of the future, and while the atomic vacuum cleaner and helicopter in every garage have not materialised, many products and services we take for granted were barely known half a century ago. Some of these seem very low-tech, like stain-proof carpets or non-stick frying pans (which, contrary to a popular myth, were invented in 1954, and were not a spin-off from the space programme), but there is complicated science behind them, and equally complicated technology to turn the discovery into a useful product.

Information and communication technologies have seen rapid advances too. A year before Apollo 11's Moon landing captivated the world's imagination, Douglas Englebart presented e-mail, hypertext, word processing, video conferencing, and the computer mouse for the first time. The computers he used were too expensive for most businesses, even if they could have found the experts needed to run them, but one of the greatest changes of the industrial age was underway. In fact, you could argue that the industrial age was coming to an end in the decade that would see the birth not only of space flight, but of the Internet, computer games, video cassettes, the ATM, and a host of other inventions ranging from artificial hearts to the bar code scanner.

Atomic age, space age, information age…

The impact of dominant technologies, and their relative importance, was even reflected in popular language, with the atomic age giving way to the space age that would then be replaced by the information age. Government thinking would have to change too, and many would agree with Harold Wilson, Britain's future prime minister, that the type of country being "forged in the white heat" of the scientific and technical revolution would need different ways of dealing with the potentials and problems of the new discoveries. However, policymaking often lags behind the pace of change in science and technology, and the OECD's Committee for Scientific and Technological Policy (CSTP) wouldn't be created until 1972, long after Committees overseeing other areas such as agriculture or tourism.

The new Committee would start work just as the post-war boom started to falter. However, although the pace of economic growth slowed in OECD countries, science and technology continued to expand rapidly, even though most scientific discoveries that would prove crucial would have seemed insignificant to all but a few specialists. Putting *E. coli* cells in a cold calcium chloride solution doesn't sound exciting, but they then become permeable to nucleic acid fragments, allowing scientists to carry out numerous genetic engineering operations. This illustrates a dilemma for science and technology policy makers. They are faced with demands to finance "useful" research, but it's practically impossible to predict where science will lead, and which technologies will ultimately make the most money.

Value for money?

Ornithology provides a striking example of the limits of "value for money" thinking regarding scientific research. You could make a convincing case that bird watching is a fascinating hobby but governments shouldn't be paying people to do it. It doesn't have much economic value, except as a minor tourist attraction. Then along comes avian influenza, and the possibility that some national poultry industries could be wiped out, or that the virus could even mutate and infect humans. Suddenly, migration patterns, nesting habits and so on become vital pieces of information.

A funding approach that relies on spotting winners ignores the role that unforeseen connections and insights play in science and technology. To take another example. Researchers in Italy studying toads discovered that the toads abandoned breeding behaviour and fled their usual habitat in the days before the Aquila earthquake. The scientists weren't looking for anything remotely to do with seismology, but the finding could turn out to be a "useful" contribution to predicting Earth tremors.

From investment to outcomes

One of the OECD's main contributions to how science is done relates to the concept of national innovation systems – turning investment in science into profitable and socially beneficial outcomes. For a national innovation system to be successful, an understanding of science and technology is necessary not only for those whose livelihood depends on it directly, but also for the policy makers whose decisions influence what is done and how. It's also important for any citizen who wishes to make informed choices about questions ranging from stem cell research to climate change, and the issues that are bound to emerge in the years to come. At the same time, there is this concern that science and technology are evolving more quickly than our ability to understand them or design policy to govern them.

The OECD addresses these concerns through a wide-ranging programme of work that looks at specific industries; the interactions of science and technology with factors shaping the world economy generally, such as the globalisation of markets; and ways to protect consumers while promoting the benefits of innovation. The aim is to give policy makers and anyone else interested in science and technology an objective understanding of the most important issues shaping the field as a whole, as well as the specific concerns of key disciplines.

Convergence and co-operation

Foremost among the latter are nanotechnology and biotechnology. Each is fascinating in itself, offering wide range of benefits, such as providing renewable energy and clean water or improving health. However, unlocking this potential will require a co-ordinated approach to ensure that potential problems are addressed at the same time as the technology is developing. Here the OECD with its wide range of technical competence, policy expertise and reputation for objectivity is playing a unique part in shaping the governance of the new technologies. Nanotechnology and biotechnology illustrate one of the major characteristics of modern science: convergence. We still tend to think in terms of traditional disciplines such as mathematics, physics, chemistry and so on, but many of the most promising new discoveries come about by combining numerous strands of research and technology.

For example, nanotechnology could have many applications in medical and life-sciences due to the fact that nanoscale devices are a hundred to ten thousand times smaller than human cells and are similar in size to large biological molecules (biomolecules) such as enzymes. Nanodevices could easily enter most cells, and some could be made small enough to move out of blood vessels as they circulate through the body. In cancer treatment, this means that it could be possible to inject into the body devices capable of bypassing biological barriers to deliver multiple therapeutic agents directly to cancer cells and those tissues that play a critical role in the growth and metastasis of cancer. Designing and manufacturing such devices though requires co-operation across a number of scientific and technological fields from molecular chemistry to engineering.

> **"The OECD has played a key role in the evolution of the understanding of [science, technology and innovation] policy… It is certainly one of the best sources for internationally comparable data on science technology and innovation. Data are accessible through regular publications in the form of periodical policy reviews and through data bases that are regularly up-dated. But it is also interesting to follow the policy discourse organized at the OECD secretariat. What has been said at OECD meetings and recommended by its expert groups might not always be transformed into practical use in member countries but it reflects the new ideas."**
>
> Lundvall, Bengt-Åke and Susana Borrás
> in *Innovation Handbook,* Oxford University Press, (2005).

Ideas like this show how converging advances in nanotechnology, biotechnology, robotics and computing are creating unprecedented capacities to manipulate nature. This is even changing what "natural" means, both as regards human beings and other life forms, raising a number of ethical issues. For example, some countries already ban xenotransplants, the use of animal organs such as pig kidneys to replace damaged human organs. Researchers are working on "humanising" these organs via genetic modification, but also on growing them from stem cells in countries where such research is permitted. Other research explores, for example, the possibility of growing human egg cells in animals for retransplantation into infertile women, or the use of hybrid animal-human embryos in developing cures for Alzheimer's and other diseases.

The future meaning of life

The question is further complicated when boundaries not only between species, but between living and non-living start to become blurred. In Korea, the government drew up a robots ethics charter, while according to a strategic review for the UK armed forces, an implantable information chip could be wired directly into a human user's brain by 2035. Information and entertainment choices would be accessible through cognition and might include synthetic sensory perception beamed direct to the user's senses. Cochlear implants to treat deafness, and deep brain stimulators to treat Parkinson's disease are already on the market, and a "bionic eye" is being tested. Implantable brain-machine interfaces have primitive artificial vision systems and mind-controlled robot prosthetics. But these devices are designed to correct defects, while in the longer term, technology convergence may permit enhancement of healthy people. Primitive forerunners of this are treatments such as Prozac, Botox, Viagra, cosmetic surgery or doping of athletes, that change the body but are not designed to combat an illness.

The science of science policy

Despite the dazzling, or worrying, prospects opened up by the rapid and profound changes of the past 50 years, some of the basic demands on science and technology have not changed much since the 1960s – creating knowledge and understanding and transforming it into useful concepts and objects. As intellectual assets grow in importance in the global economy, a solid basis in science and technology will become ever more vital for competitiveness. In the future though, just as the boundaries between different scientific disciplines have become blurred, the definition of what constitutes a legitimate domain for scientific intervention will become broader.

The way science is done has been changed radically by the connectivity offered by the Internet and other communication tools. This allows scientists and technologists to interact better with each other, and it also allows scientists and technologists to take advantage of other types of expertise to develop the tools and foster the innovation required to meet emerging economic, sustainability and even social challenges.

This means that what has been called the science of science policy will have to change too. The OECD will have a role to play in this. As in the past, it will be expected to spot emerging issues and provide the data, analyses, and policy recommendations needed to make the most of them, and to provide a forum where the problems, contradictions and differing aspirations can be debated in an objective, productive fashion.

Better policies for better lives

As the following examples show, the OECD has been a major influence on how governments approach science, technology and innovation, and how economics as a discipline tries to understand these phenomena.

National Innovation Systems

In 1963 already, *Science, economic growth and government policy* convinced governments that science policy should be linked to economic policy, while in 1971 *Science, growth and society* anticipated many of today's concerns by emphasising the need to involve citizens in assessing the consequences of developing and using new technologies.

For many experts though, the major contribution was the concept of national innovation systems, presented in 1992 in a landmark publication, *Technology and the Economy: The Key Relationships*. The origins of the concept go back to the 1970s crisis, which had provoked an in-depth re-examination of previous economic thinking on how growth came about and why growth in productivity was slowing. A 1980 OECD report, *Technical Change and Economic Policy*, is now widely recognised as the first major policy document to challenge the macroeconomic interpretations of the 1970s crisis, and to emphasise the role of technological factors in finding solutions, for instance, innovation can be more powerful than wage competitiveness in stimulating an economy.

Economists working at the OECD were pioneers of a new approach that saw innovation not as something linear but as a kind of ecosystem involving interactions among existing knowledge, research, invention; potential markets; and the production process. And contrary to the dominant thinking in policy circles in the 1980s and early 1990s, they also saw it as something that governments should play a central role in – hence the term *national* innovation strategy.

This continues to be the case today, even though we now talk of globalisation rather than internationalisation, and the emphasis of new innovation strategies has now shifted to services.

* * *

Governance of biotechnologies

Bakers and brewers have been using biotechnologies for millennia, but today scientists are manipulating organisms, and their basic components, with ever greater precision. This raises concerns about the ethics and safety of the new biotechnologies. At the same time, even people who are worried about the dangers may recognise the benefits of better drugs or other products. Researchers and firms developing the applications have additional concerns: they want access to the new knowledge, as well as recognition of their rights regarding their ideas and inventions.

In such an innovative domain, legal precedents for protecting intellectual property may act as a guide, but are often inadequate to deal with the precise issues at stake. In the early 1980s, the debate was often presented as being about the right to patent life. The OECD argued that discoveries regarding chemical processes could be accorded protection as intellectual property. Its 1985 publication *Biotechnology and Patent Protection* became the basis for patent systems in OECD countries and beyond.

Firms then knew that they could invest in developing biotech applications without the fear that a rival would simply use their work without paying. We tend to think of the spectacular side of biotechnologies, but many mundane, but useful applications followed, such as enzymes that allow detergents to work at low temperatures and with far less water than before.

The OECD defined a new framework again in 1986, this time regarding recombinant DNA, and once again governments everywhere followed the lead. However, there was also a risk that too many patents would be granted, giving patent holders too much power. For instance, a company that developed a genetic test for cancer wanted to keep complete control of the testing and the databanks built up while doing it.

The *OECD Guidelines for the Licensing of Genetic Inventions* came out strongly against this, saying that yes, intellectual property should be protected, but it should also be shared. Health benefits should not be restricted by patent protection. Likewise, strict privacy guidelines were defined to protect the rights of the public.

Today, synthetic biology is challenging us to rethink the science of science policy. Synthetic biology promises tools to design and construct new biological parts, devices and systems which do not exist in the natural world, and to redesign existing biological systems to perform specific tasks. The science is so new that we don't have all the answers, but the various guidelines developed by the OECD since the 1980s now provide the framework for biotechnology governance worldwide and offer an approach to dealing with emerging issues that has proved its worth and will no doubt be called on again in the decades to come.

* * *

Rights and trust in the age of Internet

In 1980, ten years before Tim Berners-Lee developed all the components of what would become the Web, the OECD published its *Guidelines on the Protection of Privacy and Trans-border Flows of Personal Data*, the first internationally-agreed statement of core privacy principles. They address the twin concerns of protecting privacy and individual liberties, while minimising the economic costs of privacy-related restrictions on trans-border data flows. Over the years the *Privacy Guidelines* have been remarkably influential. Today nearly every OECD country has a privacy law, whereas only one-third of members had such at the time of their adoption. And the impact can be seen well beyond the OECD borders: the 21 economies of APEC have also agreed a privacy framework modelled explicitly on OECD's *Guidelines*.

As the Web emerged and Internet began to develop, forward-looking thinkers began to see that the initial vision of the Net's commercial potential as mainly a platform for business to business exchanges could be bypassed if shopping and other activities could be as simple and reliable online as in more traditional forms. Trust is the basis for any commercial transaction, but how can you trust somebody you'll never meet to supply goods you'll only see when (and if) they're delivered? And how can a seller be sure online customers will pay? If there's a dispute, who should arbitrate?

The 1999 OECD *Guidelines for Consumer Protection in the Context of Electronic Commerce* ("*E-commerce Guidelines*") help to ensure that consumers are just as protected when shopping on-line as when buying through more traditional means. The *Guidelines*, which set out the characteristics of effective consumer protection for on-line business-to-consumer transactions, call for global enforcement co-operation among OECD countries and non-member economies through enhanced information sharing on consumer protection issues. These were followed in 2003 by *Guidelines for Protecting Consumers from Fraudulent and Deceptive Commercial Practices Across Borders* and the 2007 *Recommendation on Consumer Dispute Resolution and Redress*.

As new challenges have emerged – email scams or phishing for example – the OECD has reacted to give people tools to combat them. And because the OECD had already worked on consumer issues for many decades, and had experience in adapting to new developments, a lot of the groundwork was already done, enabling governments to move swiftly to get the most out of new technologies.

* * *

Cheap communications for everybody

In 1985 when Midge Ure was organising Live Aid with Bob Geldof, he didn't have a phone in his flat in London and had to call from the street or from friends' places. Like many other people in the UK and elsewhere, he was on the waiting list of the only telephone company in the country. Calls charges were calculated by distance and length of time. Today, unlimited calls to numerous parts of the world are part of many standard Internet deals, and free calls are available via VoIP. The OECD played a part in this, arguing over the years that by breaking up the big monopolies and allowing different service providers to compete, prices would fall and technological progress would be encouraged.

The OECD's pioneering role in liberalisation of telecommunication markets led to an *OECD Statement of the Benefits of Telecommunication Infrastructure Competition* in 1994. The statement represented a milestone, in that for the first time OECD governments agreed on the benefits of liberalising the sector, even though the majority still had monopolies. In the coming years the sector was rapidly transformed, as predicted, with rapid growth in mobile telephony, the Internet, and broadband. Liberalisation, in turn translated into greater choice and lower prices for consumers. In undertaking this work the OECD also developed a framework for trade in telecommunication services which served as a basis for the agreement on a General Agreement on Trade in Services as applied to telecommunication.

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Innovation can play an important role in the economic recovery

Science, technology and innovation must be at the core of a sustained recovery

In the wake of the financial crisis, science, technology and innovation (STI) will make a vital contribution to a sustainable and lasting recovery and to the longer-term growth prospects of OECD and non-OECD economies. STI can open new avenues to meet some of the major challenges facing societies: demographic change, global health issues and climate change. To deliver on these agendas, it is essential for countries to maintain productive investments in knowledge. STI has never been more important.

But the current economic environment is challenging…

However, the economic events of the past two years have been the source of serious difficulties for STI. Firms have faced weaker demand as well as problems of credit availability which hamper their efforts to maintain innovative activity. Sharp declines in trade, foreign investment and access to international financing have also had negative impacts which have affected the global value chains that provide companies with technical expertise, market intelligence, business contacts and international partners.

… and OECD country policies show signs of diverging

OECD countries have responded to these pressures in different ways. Some have announced cuts in their annual budget provisions for research and development (R&D) and tertiary education, and others look poised to follow. This reduces resources for public research and private R&D activities in the short term, and could lead, over the longer term, to declines in the human resources available for innovation. However, others, including Austria, Germany, Korea and the United States have recently increased investment in the science base, strengthening public research and human resources in order to improve future innovation and growth prospects. In the medium term, the need for broader fiscal consolidation may place yet further pressure on the ability of some OECD governments to maintain their investment in STI.

Overall investment in R&D has slowed in OECD countries…

In the OECD area, real growth in R&D spending slowed between 2007 and 2008, with annual growth falling from over 4% in recent years to 3.1%. Patent numbers grew steadily at an average annual rate of 2.4% from 1995 to 2008, though growth has weakened in recent years, and the number of OECD-area (triadic) patents fell in 2008. Similarly, trademarks, which measure product or marketing advances, fell by 20% in 2008. To some extent the drop in the quantity of patents could be offset by a rise in quality, and firms may be using other approaches to protect their knowledge base, such as trade secrecy or collaborative IP mechanisms. More positively, all OECD countries except the United States increased their output of scientific articles between 1998 and 2008. However, there remains some concern about the extent to which the withdrawal of temporary fiscal stimulus – which in some cases has been used to strengthen the science base – could dampen investment and output.

… while science and innovation performance in emerging economies continues to expand…

The situation in some non-OECD economies is brighter. Worldwide, STI activities are intensifying and expanding across more regions. Non-OECD economies continue to increase their expenditures on R&D and have become important players. China's real gross domestic expenditure on R&D in 2008 was equivalent to 13.1% of the OECD total, up from around 5% in 2001. The Russian Federation's R&D spending of USD 17 billion (constant 2000 dollars, PPP) in 2008 was equal to 2.2% of the OECD total, close to the shares of Canada and Italy.

… with growing focus on environmental technologies

Such increases matter. Non-member BRIICS economies (Brazil, Russia, India, Indonesia, China and South Africa) are making significant investments in environmental technologies, a dynamic area with enormous growth potential and clear practical relevance for global challenges such as climate change, water and food. In 2007 the BRIICS countries were already focusing more on renewable energy applications than the global norm, as seen in their higher than average patent applications.

The growth by the BRIICS creates opportunities and challenges for OECD countries

The rise of STI in non-member economies presents both opportunities and challenges for OECD countries. The big emerging economies offer large consumer markets, new sources of skilled people and ideas, and new opportunities for collaboration. At the same time, the resulting reorganisation of production and research pushes OECD countries to adopt policy frameworks that support the reallocation of resources to new activities and help businesses to adjust to new opportunities and markets. Just as the improved STI performance of individual OECD countries is a source of combined strength and an opportunity to expand the global stock of knowledge to drive growth and meet social challenges, the increased activity and proficiency of non-member economies can ultimately deliver global benefits.

Science, technology and innovation policies evolve towards green

As policies evolve with globalisation…

At first glance, the national innovation strategies of OECD countries appear broadly similar, focused on strengthening innovation to improve industrial competitiveness, especially by raising productivity growth, as well as on jobs and living standards. Emerging and other non-member economies also see innovation as a means to modernise economic structures and to achieve sustainable growth. However, just as R&D investments are diverging, policies for STI continue to evolve and can vary substantially even among OECD members.

… national research agendas are becoming "greener"

In parallel with what seems to be happening in many of the BRIICS countries, recent policy trends in many OECD countries point to a "greening" of national research and innovation strategies. Countries are placing environmental issues, climate change and energy high on their national science and innovation agendas. Health and quality of life are also among their important priorities.

Building capacity through international collaboration is becoming more important…

Improving international collaboration to address global challenges is high on national agendas. Much of the focus appears to be on better governance. Some countries have reorganised ministerial or departmental functions to strengthen links between R&D and higher education or between industry and research. Others have broadened structures to involve community stakeholders. Germany and the Nordic countries have also launched strategies to internationalise their public-research sector and build their capacity for multilateral collaboration on STI.

… as are efforts to target policy support

At the same time, countries maintain their focus on key research areas and enabling technologies such as biotechnology, nanotechnology, ICT, new materials and advanced manufacturing. While most countries support research in these technologies, there is a growing effort to improve policy support at different stages of the innovation value chain (for example by providing incentives for R&D via grants or tax credits, fostering specific technology clusters or development of venture funds) in order to enhance firms' ability to capitalise on public and private investments in these emerging technologies.

Indirect support is growing…

More countries are using tax incentives than a decade ago and the schemes are more generous than ever. Today, more than 20 OECD governments provide fiscal incentives to encourage business R&D, up from 12 in 1995 and 18 in 2004. Among those that do not, Germany and Finland are currently discussing their introduction. Non-OECD countries such as Brazil, China, India, Singapore and South Africa also provide a generous and competitive tax environment for investment in R&D. China provides generous (general) tax reductions for R&D firms located in certain new technology zones or investing in key areas such as biotechnology, ICT and other high-technology fields.

… however, direct funding remains the predominant tool

Nevertheless, direct public funding through grants, subsidies and loans remains the most frequent form of support to business R&D, with an increased focus on competitive and merit-based programmes. The balance between direct funding and indirect measures such as R&D tax incentives varies according to factors such as a country's industrial structure, the presence of large R&D-intensive firms, R&D intensity and specialisation.

Governments must co-ordinate policy at regional, national and international levels

Public support to the "supply side" of research and innovation remains a key aspect of STI policies, although attention to the "demand" side, such as public procurement, standards and involvement of users to "pull" innovation, continues to gain ground. Changes in innovation processes, especially those driven by the broadening of innovation, the rise of new global players and global value chains, and technological convergence also affect how governments design, develop and implement policies to support STI performance. This puts pressure on governments to monitor and adjust the effectiveness of national STI governance structures and policies to ensure co-ordination and coherence at the regional, national and international levels.

Support for non-technological and user-driven innovation is rising, especially in services

Government support for non-technological and user-driven innovation is increasing in some countries, in recognition of the importance of non-technological innovation, design and branding for competitiveness, especially in service-sector firms. In particular, Chile, Denmark, Finland and the United Kingdom, and non-member Brazil as well, are trying to raise awareness of this area and encourage non-technological innovation alongside technological innovation.

The innovation "policy mix" concept needs to be applied to improving co-ordination and coherence

Finding an appropriate policy mix is challenging…

New objectives and rationales for policy intervention have opened up a larger policy instrument "toolbox". This has created an even more complex policy landscape, thereby increasing the challenge of achieving balance and coherence in the policy mix. The good news is that during the past few decades, a growing number of countries have made significant efforts to assess and evaluate programmes and instruments aimed at fostering STI. Yet, developing a "policy mix" that combines a range of policies that is well adapted to the prevailing environment and national objectives remains a real challenge. This challenge will persist, since the scope and content of government policies evolve over time, driven by changes in external factors such as globalisation and technical advances as well as economic and institutional development.

… and needs to take account of interaction among the various instruments

The key question in assessing a policy mix is whether it is appropriate, efficient and effective. Ideally, a policy mix takes into account possible interactions among instruments (positive and negative) and ensures balanced support for the range of challenges faced by a country's innovation system. Policy mixes need to be adapted to national circumstances – industry structure in terms of activities and firm size, the role of universities and government research laboratories, etc. Policy coherence can be improved through the establishment of multi-actor forums supported by information systems and advanced analytical capacities.

OECD Science, Technology and Industry
Outlook 2010

Chapter 1

Key Trends in Science, Technology and Innovation

This chapter provides an overview of the main trends in science, technology and innovation across the OECD area and in selected non-member economies. Using the latest available data and analyses, it highlights changes in R&D investment and skilled human resources, and explores their impact on scientific and innovative activity. It also analyses trends in globalisation and looks at the future potential of non-OECD economies in the innovation arena. Against the backdrop of the financial crisis and economic downturn, and to provide a forward-looking component, the chapter also uses available data and evidence to discuss the future growth prospects of OECD and selected non-member economies, future challenges facing societies, and emerging areas in science, technology and innovation.

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.

The economic events of the past two years have laid down what is perhaps the biggest challenge to have faced OECD governments for several decades and the effects will be felt for some time to come. Much faith has been placed in science, technology and innovation as a means to move towards a sustainable and sustained recovery. Against that turbulent backdrop, this chapter presents the latest available data and analyses on investment in research and development (R&D), human resources, scientific and innovation outputs, and globalisation. It also discusses the potential for R&D to contribute to societal challenges, the impact of the downturn and expectations for the future, and the growing role of non-member economies in the science, technology and innovation landscape.

A turbulent backdrop to recent trends in science, technology and innovation

At the time of writing of the 2008 *Science, Technology and Industry Outlook*, the global economy was unsettled, and in most OECD economies weak growth was predicted for the near future. Problems in the sub-prime mortgage sector in the United States had created turbulence in OECD financial markets and, combined with high commodity and energy prices, had led to a slowdown in activity. Employment growth had fallen, turning negative in some OECD areas (notably the United States). Yet the outlook was not totally pessimistic – the odds that the financial turmoil had passed its peak were improving, although uncertainty remained, and the case for boosting economies via fiscal stimulus was regarded as weak (OECD, 2008a).

However, in September 2008 the macroeconomic situation worsened dramatically. The (actual and threatened) failure of an increasing number of large, systemically important financial institutions in the United States and Europe set off a full-blown financial crisis. This triggered a deep economic downturn, with output and trade volumes declining, unemployment rising, equity prices plummeting and credit drying up (OECD, 2008b). Few countries were left untouched by the downturn; emerging market economies felt the effects through their financial and trading ties to major OECD markets, although they had limited direct exposure to the origins of the crisis. Governments took strong policy measures, including the introduction of unprecedented levels of support for financial markets and, in some cases, large fiscal stimulus packages.

By the end of 2009, growth had resumed in the OECD area, driven by exceptional levels of policy support as well as an upturn in demand from non-OECD economies. OECD economic projections undertaken in May 2010 (Table 1.1) were more optimistic than those of late 2009; they suggested that real GDP growth in the OECD area could reach 2.8% by 2011 (after a 3.3% contraction in 2009). However, unemployment is projected to stay high throughout 2010, and global recovery still faces several substantial risks, particularly relating to sovereign debt in a number of OECD economies. The crisis has battered government budgets but it has also led to greater awareness and concern about underlying structural deficits. A number of countries are in need of substantial fiscal consolidation, although this requires careful consideration of the impacts on recovery and the ability of

Table 1.1. **Economic projections**

	2009	2010	2011
Real GDP growth			
United States	–2.4	3.2	3.2
Japan	–5.2	3.0	2.0
Euro area	–4.1	1.2	1.8
Total OECD	–3.3	2.7	2.8
Unemployment rate[1]			
United States	9.3	9.7	8.9
Japan	5.1	4.9	4.7
Euro area	9.4	10.1	10.1
Total OECD	8.1	8.5	8.2
Fiscal balance[2]			
United States	–11.0	–10.7	–8.9
Japan	–7.2	–7.6	–8.3
Euro area	–6.3	–6.6	–5.7
Total OECD	–7.9	–7.8	–6.7
World trade growth	–11.0	10.6	8.4

Note: Real GDP growth and world trade growth (the arithmetic average of world merchandise import and export volumes) are seasonally and working-day adjusted annual rates. The cut-off date for information used in the compilation of the projections was 18 May 2010.

Note on Chile: Chile became a member of the OECD on 7 May 2010. The projections of OECD aggregates in this table include Chile for all years, including pre-2010, provided sufficient data exist.

1. Percentage of the labour force.
2. Percentage of gross domestic product (GDP).

Source: *OECD Economic Outlook,* May 2010 (OECD, 2010a).

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other policies to support growth. They must also maintain their credibility in financial markets and with households.

The macroeconomic environment has presented challenges for research and innovation

The broader economic and policy environment has presented a number of challenges for firms' recent research and innovation activities, and this chapter provides some early estimates of the quantitative impact on R&D investment. Many stimulus packages included measures aimed at supporting businesses and bolstering household consumption through various tax breaks, welfare packages and specific industry assistance schemes, and around three-quarters of OECD countries introduced new R&D tax credits and subsidies (OECD 2009a, 2009b). Responses to the policy questionnaire for Chapter 2 of this publication showed that governments have maintained support for firms' R&D and innovation as a means to foster economic growth in the longer term, with a number of countries introducing or expanding support for small and medium-sized enterprises (SMEs), for example. Nevertheless, firms have faced weaker demand conditions as well as problems with credit availability which hamper efforts to maintain innovation activity. The sharp declines in trade, foreign investment and access to international financing affect the global supply chains that provide companies with technical expertise, market intelligence, business contacts and international partners (OECD, 2009c).

In the public sector, the initial impact of the downturn on investment in research and innovation may have been more muted. Stimulus packages frequently carried funding to improve the national infrastructure (for example, roads, energy networks, information and communication technologies), with preservation of resources and sustainability often critical considerations (OECD, 2009b). A number of countries also bolstered public R&D through funding for university R&D and government research institutions, the establishment of new laboratories and the acquisition of new research equipment (see Chapter 2). "Green technologies" have attracted particular attention in many countries in this regard. Increasing public investments in education also appeared to be an integral part of a number of stimulus measures, as indicated in an OECD education survey conducted in June 2009 (Karkkainen, 2010; see also OECD, 2009b). Education and skills development were explicit priority areas in some countries, while infrastructure investments (such as school refurbishment and repairs) also received some attention. OECD countries set high priority on human resources for science and technology (HRST) to support innovation and many have implemented policies to raise interest in science and create a culture of innovation, as well as improve education and employment conditions (see Chapter 2). Nevertheless, in all these areas of expenditure, it is not straightforward to distinguish how much of the recent growth in spending was supplementary and how much was related to ongoing investment plans and reforms. Where planned expenditure has been brought forward, there may be falls in spending in later years.

Risks and uncertainties continue…

Looking ahead, there remain risks and uncertainties in the R&D and innovation environment. In the short term, the withdrawal of temporary fiscal stimulus may dampen demand for the goods and services of innovative firms, both directly (if firms have received subsidies or other policy support) and indirectly (as cuts elsewhere flow through the economy). OECD projections suggest that exit from fiscal support must start now, or by 2011 at the latest, at a pace contingent on specific country conditions and the state of public finances (OECD, 2010a). Some countries have also announced cuts in their annual budget provisions for R&D and tertiary education. These will reduce the resources available for public research and private R&D activities in the short term, and will potentially affect the human resources available for these activities over the longer term.

In the medium term, the need for broader fiscal consolidation may put pressure on the ability of some OECD governments to maintain their investment in R&D and innovation (as well as key support areas such as education) and may also contribute to overall weaker demand (Box 1.1). The need for many households to "rebuild their balance sheets" through higher savings and lower expenditures will add to this effect. At the same time, however, a lack of consolidation may also affect research and innovation negatively. In particular, the accumulation of high levels of public debt may push up long-term interest rates; this would affect firms' ability to access capital and might also depress demand and consumption. With respect to financial markets, the medium-term impact of an improved regulatory and supervisory framework is unclear and would depend on the exact measures taken by countries, both independently and collectively.

While there is much uncertainty about how macroeconomic influences on R&D and innovative activity in the private and public sectors will play out, there are some positive trends. Non-OECD economies are experiencing stronger growth and trade is recovering; they provide potential sources of demand for innovative outputs and are helping to reinvigorate the global supply chains that spread knowledge and innovation from one country to another. For example, OECD projections expected Brazil's growth to rebound to 6.5% a year in 2010 and 5% in 2011 and the economy of the People's Republic of China

Box 1.1. **Fiscal consolidation and R&D**

The need for fiscal consolidation in many OECD countries is now well recognised. Budget deficits are expected to reach historic highs in 2010 in several countries, boosted by recession-driven fiscal support and cyclical changes in tax revenues and social spending (Table 1.1 gives estimates of fiscal balances for 2010 and 2011). In the absence of consolidation, countries will find it more difficult to deal with future age-related costs, have less scope to use counter-cyclical policies in any future downturn, put pressure on interest rates as government borrowing rises, and be less able to spend on growth-enhancing programmes.

However, countries' problems with fiscal deficits and debt are not entirely due to the financial crisis and the subsequent downturn; they also reflect existing imbalances and unsustainable fiscal trajectories. Most of the deficit for the OECD area as a whole, and specifically for the United States, Japan and the euro area, is structural, meaning that it will not be eliminated as countries move back to an environment of positive economic growth. For example, the OECD projected that the underlying balance for the United States in 2010 (that is, the government's fiscal balance adjusted for the business cycle and one-off items) would be –8.9% and would drop only slightly to –8.1% in 2011. Large deficits will lift government debt to disturbing levels in several countries in the next few years, but debts are also projected to continue to rise in the medium term.

In OECD economies structural deficits and rising debt levels are partly due to underlying trends related to the costs of population ageing and health care, and serious attempts to reform these areas must be part of consolidation. They are also a function of the disappearance of exceptionally high tax revenues, partly owing to the reversal of asset price gains. In general, fiscal consolidation should focus on instruments that minimise adverse impacts on trend growth, and should also incorporate structural reforms that lift countries' future growth potential. OECD studies suggest that exploiting the scope for increased public-sector efficiency in areas such as health and education is a good starting point, to be followed by reduced expenditure on other core public services and transfers (such as pensions and social transfers), fewer exemptions from various taxes on goods and services, and higher taxes on property.

Nevertheless, the work of consolidation will inevitably put pressures on all areas of government budgets to find cost savings and efficiencies. OECD work suggests that the adverse effects on growth of spending reductions may be smaller than those from tax increases; this puts the spotlight on government expenditure policies, including for science and research. However, cutting public spending on R&D, the development and maintenance of useful public infrastructure, education and active labour market policies may be counterproductive. These policies are expected to be growth-enhancing in the longer term – support for R&D, for example, has scope for creating new sources of growth by enhancing labour and multifactor productivity. As such, governments need to carefully consider the instruments they use for fiscal consolidation and focus on improving the long-term growth potential of their economies.

Source: OECD (2009a), OECD (2010a) and OECD (2010b).

(China) to continue to expand rapidly, with growth in excess of 10% in 2010, before easing slightly in 2011 as fiscal stimulus impacts recede (OECD, 2010a). Activity in India was projected to strengthen in 2010 and 2011 to more than 8% a year, and, after a deep recession in 2009, the Russian Federation was projected to grow at rates of more than 5% in 2010 and 2011, following the recovery of global demand and the impact of stimulus measures. Also on a positive note, the removal of industry-specific fiscal support in OECD countries may enable restructuring towards more viable and sustainable activities and create space for new innovative actors to emerge.

… but innovation can play an important role in economic recovery

While the current environment presents risks and uncertainties for R&D and innovation, science, technology and innovation can make a central contribution to a successful exit from recession and to the longer-term growth prospects of OECD and non-OECD economies. At a general level, the acquisition of knowledge, the application of discoveries to human needs and the implementation of new ideas can help to meet society's needs and wants more efficiently and effectively. For instance, empirical work has established robust relationships at the macroeconomic level between investment in innovation and productivity, and firm-level studies have also found positive and significant effects of R&D on productivity growth.[1] Recent studies using firm-level data from the innovation surveys of 18 countries found that product innovation is strongly associated with labour productivity in firms (Criscuolo, 2009). Non-technological innovation also plays a role in this process, although it is harder to measure. For instance, the implementation of new marketing or organisational methods can be a crucial complement to the commercialisation of new products or the introduction of new processes. These are particularly important dimensions of innovation in services, where measured productivity is typically lower than in manufacturing. In sum, research and innovation allow economies to do more with their resources, a point of particular relevance in a climate in which governments, firms and households are all seeking to meet their goals at lower cost. Over the longer term, too, given that low labour productivity remains the source of much of the gap in gross domestic product (GDP) per capita between most OECD countries and the United States (OECD, 2010c, p. 55), boosting countries' innovative capacities is a clear policy priority.

As well as boosting growth, research and innovation play a role in building "the world we want to see". Scientific advance and innovation have long been drivers of industrial renewal, with new ideas creating new sources of economic growth and more dynamic firms displacing less efficient ones. But innovation is increasingly viewed as a tool to take economies in new directions. The most obvious current example is "green growth": governments are encouraging research, science and technology to find new ideas and mechanisms for meeting their economies' energy and production needs in a more sustainable and environmentally sensitive way. Research and innovation may also provide new avenues for addressing several of the other major challenges facing societies, such as demographic change, security and the sustainable provision of health services (Box 1.2). Indeed, the point of conducting R&D, and exploring science and technology, is ultimately to improve the welfare of society – a consideration that should underlie any analysis of countries' R&D investments and performance.

Seen in this light, the current environment provides an opportunity to consider an appropriate future agenda for research and innovation. Government policy is challenged to provide ground rules, to set directions and strategy, and to support the activity of businesses and other institutions in their creative endeavours. Prior to the financial crisis and economic downturn, a number of countries had formulated strategies related to innovation, in recognition of its role in productivity and economic growth. As noted above, fiscal stimulus packages in many countries incorporated measures on research, science

Box 1.2. **Innovation and societal challenges**

A number of complex, intertwined challenges put pressure on policy makers and societies to change established patterns of production, consumption and interaction. For instance, climate change is expected increasingly to affect the productivity of farmland and the distribution of food production activity around the world, while population movements due to opportunities (such as easier migration paths to countries with ageing populations) and threats (such as environmental degradation) may create additional new pressures on resources. At the same time, there is optimism that advances in science and technology and new innovative approaches to products, services, processes and organisational design could help significantly to meet these challenges. For example, at a basic level, increasing the use of existing ICT tools in the health sector could improve medical decision making and patient outcomes, as well as reduce costs and errors. At a more complex level, the development of alternative energy sources could reduce carbon emissions and environmental degradation and move economic activity onto a more sustainable footing.

Future-oriented analyses highlight in some detail the multi-faceted nature of many of the issues for which governments must adopt strategic approaches and policies. For instance, the UK Government Office for Science (2010) recently drew attention to land use, to question whether it is possible to continue to deliver the many economic, social and environmental benefits of land, given the greater expectations of markets and individuals and the need to live within environmental limits. Decisions on land touch many sectors, since the productive capacity of land underpins the entire economy, not only through the provision of food, timber and other goods, but also through its use for housing, business, transport, energy, recreation and tourism. In another example, the 2030 Water Resources Group (2009) estimated that by 2030, economic and population growth would yield global water requirements that exceed the accessible reliable supply by 40%. Efficiency improvements on the scale achieved by the agriculture and industry sectors between 1990 and 2004 might close 20% of this gap, and supply augmentation via new infrastructure might close a further 20%. However, a large gap remains, and the uneven distribution of water resources across countries suggests that some areas of the world will suffer extreme water shortages.

Analyses also highlight the potential for new technology to play a role in solutions. For instance, a report from the International Service for the Acquisition of Agri-Biotech Applications (ISAAA) (James, 2009) describes how the outputs of biotechnology research are helping to meet the challenge of doubling food production sustainably by 2050 while using approximately the same area of arable land, fewer resources (particularly fossil fuel, water and nitrogen), and at the same time mitigating climate change. The contribution of biotech crops comes through increased productivity per hectare and decreased production costs (as well as lower CO_2 emissions), owing to reduced need for inputs, ploughing and pesticides. Estimates of the net economic benefits to biotech crop farmers in 2008 totalled USD 9.2 billion, evenly split between farmers in developing and industrial countries. The UK Government Office for Science (2010) suggests that new technologies have the potential to relieve some of the pressures on land use through the increased productivity of available land, reduced environmental footprints, and the possibility for people to live and work differently. For water, the 2030 Water Resources Group (2009) suggested that improving agricultural productivity would be the key for some countries, with innovative advances in seeds, crop protection and irrigation playing a central part. For other countries, industrial efficiencies could play a strong role, for example through better use of water in power generation and better reuse of wastewater. In both cases, technology providers are of central importance in closing the supply-demand gap, not only in scaling up existing products and services but in seeking new solutions. Innovative solutions in microfinance and other financial tools would also benefit end users and stakeholders in the water sector by providing the capital to improve their "water footprint".

Box 1.2. **Innovation and societal challenges** *(cont.)*

Such studies highlight, however, that innovation alone cannot successfully tackle these challenges – the underlying governance frameworks are also important. In their report on land use, the UK Government Office for Science (2010) argued that new governance arrangements would be a major part of addressing land use issues, as currently divided responsibilities create complexity and uncertainty. One important avenue will be policy integration (*e.g.* between energy and forestry); another will be ensuring that decisions are made at the right level (*e.g.* moving towards catchment-based land-use policy). In some instances, governance arrangements may need more extensive redesign, particularly for "transformative innovation", which implies far-reaching changes in technology affecting several branches of the economy and potentially giving rise to entirely new sectors (Scrase *et al.*, 2009). Such changes are considered essential for meeting some challenges, particularly those related to the environment, as incremental innovations are unable to generate change that is fast enough and deep enough. In the water arena, for example, the 2030 Water Resources Group (2009) noted that technical options for new supply or better efficiency must be compared against shifting the set of underlying economic activities, and that policy makers, the private sector and civil society must come together to put into practice a shift towards sustainability.

At a practical level, policy approaches to support innovation for societal challenges are still under consideration. Scrase *et al.* (2009) suggested that governments can support systemic change and transformation by building pathways to overcome lock-in (*e.g.* by supporting capacity building), by "enabling" markets for potentially transformative innovations (*e.g.* via procurement and regulations), and by implementing "strategic governance", which enhances capacity to make deliberate, legitimate and accountable choices about development pathways. Research into the issue of transition and innovation is ongoing; recent analysis by Smith *et al.* (2010) suggests that future work could usefully contribute to increasing understanding of niche dynamics, the way regimes are "unlocked", the way transitions work across geographic space, and the way decision making affects dynamics. In work on technology policy and climate change, Mowery *et al.* (2009) argued that the attributes of the "climate problem", particularly its cross-sector and cross-country nature and the need for widespread deployment of technologies across a heterogeneous group of actors, cautions against the use of massive, highly centralised government technology projects. Instead, altering prices to reflect environmental costs, supporting basic research and prototype testing, using procurement competition to encourage technology development and supporting demonstration projects may be better suited to the challenge.

and technology, and a focus on R&D and innovation is a continuing part of the policy efforts of most OECD economies (see Chapter 2). It will be crucial for countries to bring these various strands of action together and formulate a coherent forward-looking approach to science and innovation policy for a stronger and more sustainable future growth path.

This agenda requires maintaining productive investments in knowledge. As discussed in Box 1.1, countries face major challenges for balancing their fiscal accounts with minimal costs to their economies. With the expected contribution of science, research and innovation to the long-term growth potential of economies and to the solution of pressing societal challenges, countries should attempt as much as possible to shelter their R&D and innovation spending from cuts, while at the same time seeking to maximise the efficiency and effectiveness of this spending.

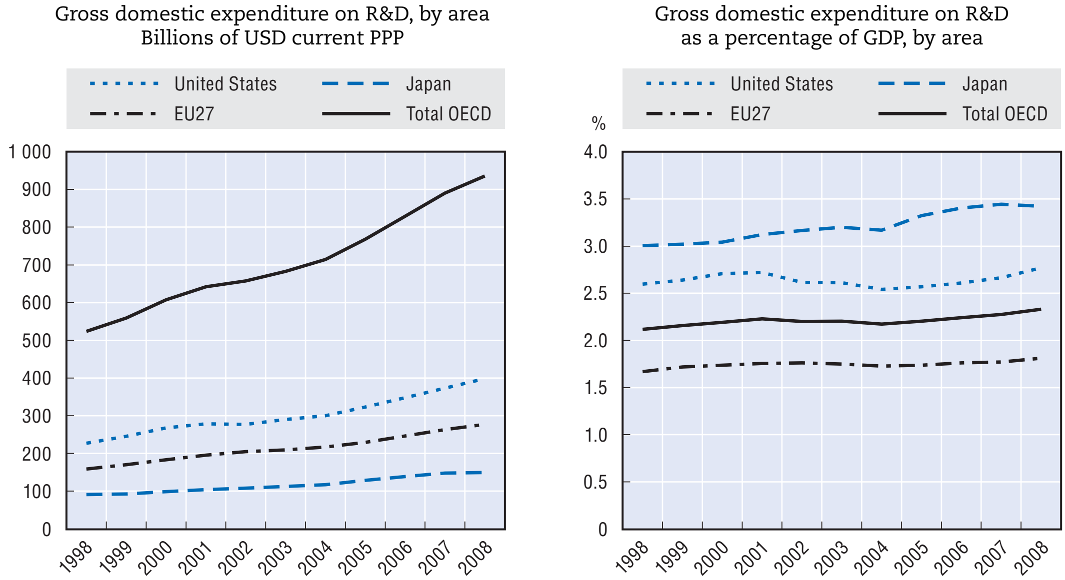
The recent expansion of R&D spending slowed through 2008

As official OECD data on R&D investment are based on retrospective surveys of performing units, the discussion of cross-country R&D spending patterns is currently limited to the end of 2008. While this makes possible an initial analysis of the impact of the financial crisis and economic downturn on R&D and innovation, attributing movements in the data to responses to the crisis and downturn call for caution. Changes in many variables will lag changes in the environment (*e.g.* private and public R&D investments tend to be planned ahead), and most countries' stimulus packages took effect from 2009 (OECD, 2009d, p. 110). Moreover, some data for 2008 for some countries are provisional. Figures for 2009, which will enable deeper analysis of the effect of the financial crisis and economic downturn, will only be available in mid-2011. Against this backdrop, this section provides an overview of expenditure patterns overall and disaggregated by performance sector and funding source, using current OECD Main Science and Technology Indicators (MSTI) data.[2] It highlights changes that can be detected for 2008, and the following section draws on additional data from various sources to help begin to analyse the effect of the economic downturn through 2009.

OECD investment in R&D, as represented by gross domestic expenditure on R&D (GERD), has steadily climbed over time, reaching over USD 935 billion in 2008 (up from USD 890 billion in 2007) (in current purchasing power parity, PPP) (Figure 1.1).[3] The United States accounted for around 42.5% of the total in 2008, slightly less than in 1998 but an increase over its share in 2007. Japan's share fell from around 17.4% to 15.9% over the period, with a notable drop between 2007 and 2008. Spending by the EU27 was equivalent to 29.5% of total OECD spending in 2008, a slight drop from 1998 but in line with its share in 2007.[4] Comparing the changes in real expenditure on R&D in 2008 with the previous decade and with recent years reveals distinct differences across these main geographic areas. In real terms, OECD expenditure on R&D grew at an average annual rate of 3.6% from 1997 to 2007, with recent annual growth rates of over 4%. However, real growth in annual spending slowed from 2007-08 to 3.1% for the OECD area. The United States experienced real growth in R&D spending of 3.4% over 1997-2007, with annual growth rates of over 4% since 2005. However, in contrast to the OECD average, growth of R&D expenditure accelerated in 2008 to 4.5%. Japan had average annual growth in real R&D expenditure of 3% from 1997 to 2007, again with faster recent growth, but saw a decline of –1.2% in expenditure in 2008. For the EU27, expenditure grew by 3.4% in 2008, in line with its average growth of 3.4% a year from 1997 to 2007, but this represented a decline from stronger growth figures in recent years.

When considered as a proportion of GDP, OECD-area R&D expenditure has risen slightly since 1998. From just over 2.1% of total OECD GDP in 1998, the figure rose to 2001, fell over the next few years and recovered to just over 2.3% in 2008 (Figure 1.1). This sustained commitment to R&D is also apparent in individual figures for Japan and the United States, whose R&D intensity rose from 3% to 3.4% and 2.6% to almost 2.8%, respectively, although intensity fell slightly in Japan from 2007 to 2008. From a lower base, the EU27 experienced a slow increase in their collective GERD-to-GDP ratio, rising 0.14 percentage points over the period to just over 1.8% in 2008.

Figure 1.1. **R&D trends in the OECD area, 1998-2008**



Note: R&D expenditure data for the United States are underestimated for several reasons, in part because capital expenditure is excluded (see MSTI for further details).

Source: OECD, *Main Science and Technology Indicators* (MSTI) (May 2010).

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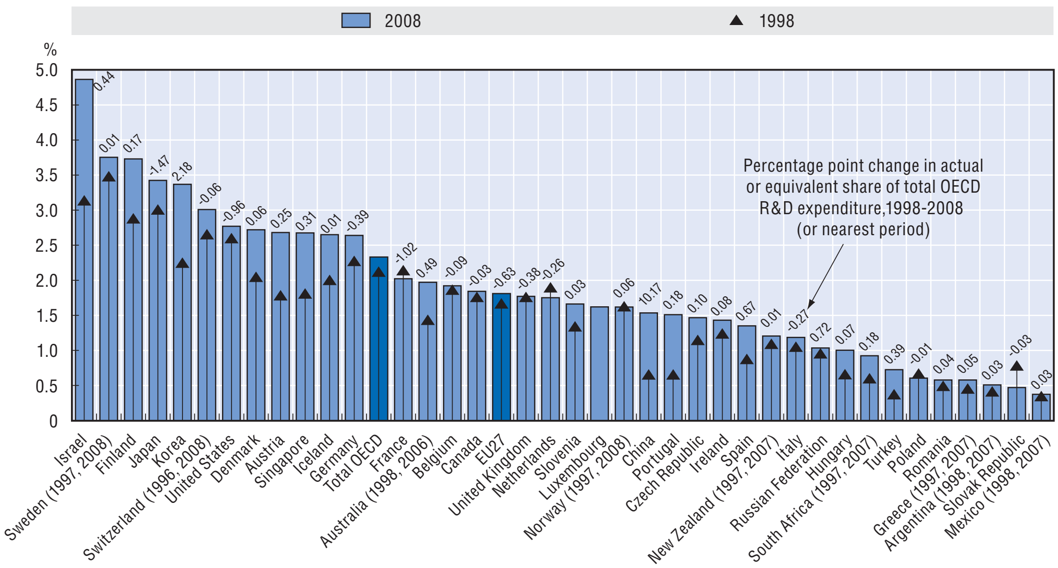
Non-OECD economies continue to expand their expenditure on R&D and are accounting for a growing share of global research. For instance, in 2008, China's real GERD was equivalent to 13.1% of the OECD total, up from around 5% in 2001.[5] In that year, the Russian Federation's spending of USD 17 billion (in constant 2000 USD PPP) was equal to 2.2% of the OECD total, close to the shares of Canada and Italy. Some of the observed growth in expenditure is due to the activities of multinational firms (MNEs) in non-member economies. In China, for instance, the share of foreign-funded enterprises in total R&D expenditure in 2008 was estimated to be around 19%; their share of R&D projects and R&D personnel was around 13% and 16%, respectively (China Statistics Press, 2009). Foreign investment is discussed again below in the context of globalisation.

Figure 1.2 reveals changes in R&D intensity across OECD member countries and selected non-member economies for the period 1998-2008. Most countries saw an increase in R&D spending as a percentage of GDP, with a sizeable upward shift in some. The biggest increases took place in China (an increase in the GERD-to-GDP ratio of 135%, or from 0.65% of GDP to 1.54% of GDP), Portugal (131%), Turkey (95%), Israel (55%) and Spain (54%). In interpreting and comparing these results, it must be remembered that the GERD-to-GDP ratio reflects changes in countries' nominal spending on R&D as well in their economic growth. For example, of the 25 OECD countries with data available for both 2007 and 2008, R&D intensity decreased in eight, but this was related to a drop in R&D spending in only two. For the other six countries, nominal GDP grew faster than R&D spending.

After Israel, whose R&D intensity (excluding defence spending) nudges 5%, the Nordic countries of Sweden and Finland have the highest R&D intensities among OECD countries (3.75% and 3.73%, respectively). The top five OECD countries have maintained their position since the last *STI Outlook*, and the United States, Denmark and Austria have moved up. The OECD average of 2.33% is pulled up by the high R&D intensities of the few top countries; a large number of countries have intensities below the OECD average. The median R&D intensity for OECD countries is approximately 1.76% of GDP (a value between that of the Netherlands and the United Kingdom). Figure 1.2 shows that among OECD countries, Korea had the largest percentage point increase in its share of total OECD R&D expenditure over the period, followed by Spain and Australia. China's R&D expenditure rose from the equivalent of nearly 3% of the OECD total in 1998 to over 13% in 2008; the shares of Japan and France, instead, fell by more than one percentage point.

Figure 1.2. **GERD as percentage of GDP, by country**

1998 and 2008, or nearest available years



Note: In Israel, defence R&D is not covered. Furthermore, humanities and law are only partially covered in the higher education sector. Due to the lack of a comprehensive business register for South Africa, R&D expenditure may be underestimated by 10% to 15%.

Source: OECD, *Main Science and Technology Indicators*, May 2010.

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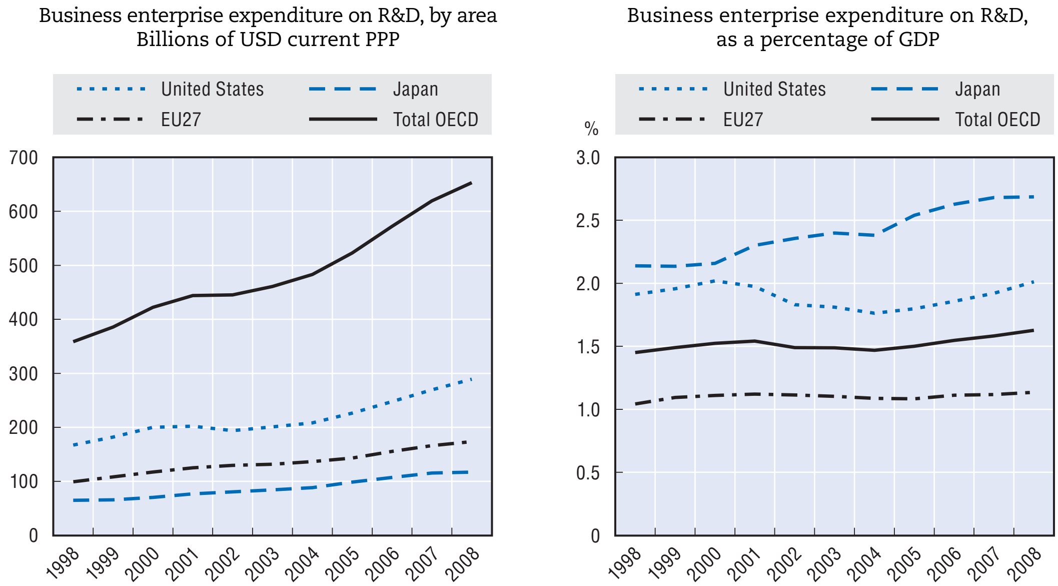
While the data on R&D intensity at the country level are informative, they must be interpreted in context. First, in general, the pattern of R&D intensity across countries displayed above follows some predictable trends. The more developed economies tend to be more R&D-intensive than catching-up economies, as they are already closer to the technological frontier and their industries are under pressure to innovate to survive. Catching-up economies can reap substantial gains from adopting and adapting technologies and may therefore feel less pressure to emphasise R&D. As such, there is a generally higher concentration of emerging economies at the lower end of the R&D-intensity spectrum. Also, as will be discussed below, countries' industrial structure has an important influence on the amount of their R&D, as some industries are more R&D-intensive than others. For example, strong natural resource bases are a feature of New Zealand's and Norway's industrial structure, and they have R&D intensities below the OECD average.

Second, rather than absolute levels of spending, the issues of ultimate relevance when analysing data on R&D are the quality and quantity of the outputs produced with investments in R&D and the resulting outcomes. Raw data on amounts spent can mask substantial differences in the efficiency and effectiveness of spending and draw attention away from other features that facilitate the creation, use and absorption of knowledge (for instance, the quality of the information technology infrastructure). Efforts to measure more meaningfully the efficiency and effectiveness of R&D spending in achieving various outputs and outcomes would be valuable. In a related issue, many firms introduce innovations without investing in R&D (for example, nearly 50% of firms in Norway; see OECD, 2010d). This shows that data on R&D expenditure tell only part of the science, technology and innovation story. Inputs such as training, knowledge management and marketing often complement R&D and may be drivers in their own right. Firms' links to the wider knowledge base are also important. Developing robust and comparable measures of these wider inputs is an ongoing activity and will contribute to a deeper understanding of the "black box" of innovation processes.

Sectoral performance of R&D

Business enterprise expenditure on R&D (BERD) covers R&D activities carried out in the business sector by firms and institutes, regardless of the origin of funding. It typically accounts for the majority of R&D activity in OECD countries and tends to be more closely linked to the creation of new products and techniques than the R&D performed in the government and higher education sectors. Figure 1.3 shows that total OECD BERD has been on a strong upward trajectory since 1998, reaching USD 653 billion in 2008, up from USD 619 billion in 2007 (in current PPP). Of this expenditure, the United States accounted for 44.3%, several percentage points less than in 1998 but more than its 2007 share of 43.5%. At 17.9%, Japan had almost the same share in 2008 as in 1998 and a fall from 18.6% in 2007. The EU27's BERD was equivalent to 26.5% of the OECD total in 2008, less than in 1998 and in 2007. Comparing the 1997-2007 decade with the most recent figures for 2008, as was done for GERD, again shows strong cross-area differences. In real terms, over 1997-2007 OECD BERD grew at an average annual rate of 3.8%. The latter years of this period saw stronger growth of over 5% a year on average, but growth slowed in 2008 to 3.4%. In the United States, average annual growth of 3.4% from 1997 to 2007 similarly reflected stronger growth in recent years, but in contrast to the OECD average, it maintained strong growth

Figure 1.3. **Business R&D, by area, 1998-2008**



Source: OECD, *Main Science and Technology Indicators*, May 2010.

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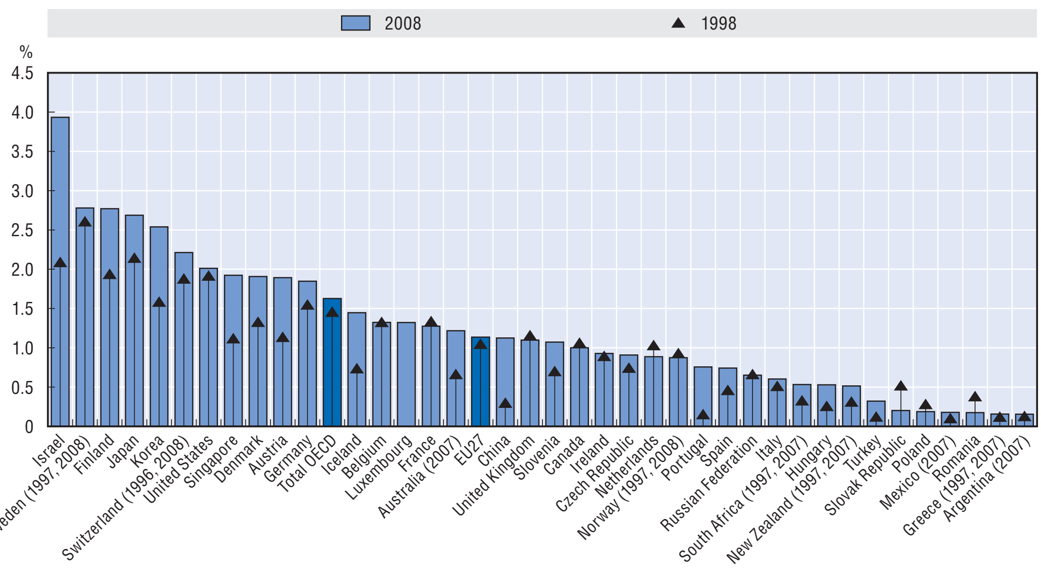
in 2008, with annual growth in real BERD of 5.1%. Japan experienced a fall in real BERD in 2008 of –0.5%, while the EU27's growth dropped to 2.8%, after an average annual growth rate of 3.5% over the previous decade. As a percentage of GDP, the OECD's BERD was around 1.6% in 2008. The figures for Japan and the United States were both higher than this average, at 2.7% and 2%, respectively. The BERD intensity for the EU27 was 1.1% in 2008, having remained essentially flat since 1999.

Looking at other economies, China stands out as experiencing extremely strong growth in BERD. Its spending of USD 74 billion (constant 2000 PPP) in 2008 was equivalent to 13.8% of total OECD BERD. China's business expenditure on R&D grew almost ten-fold from 1997 to 2007; the growth in spending from 2007 to 2008 was 17.5%. The Russian Federation's BERD of almost USD 11 billion in 2008 was equivalent to 2% of total OECD expenditure. The business R&D expenditure of new OECD member Israel grew from USD 2.4 billion in 1997 to almost USD 7.5 billion in 2008, a level not dissimilar to that of Spain and Sweden.

Figure 1.4 presents business expenditure on R&D as a percentage of GDP in 1998 and 2008 (or the most recent year for which data are available). It reveals a wide range of country experiences; after Israel, with a BERD intensity of almost 4% in 2008 (almost double its intensity in 1998), Sweden had a BERD intensity of around 2.8% of GDP, followed by Finland, Japan and Korea. At the other end of the scale, Greece's BERD intensity was 0.16% of GDP in 2007, while Mexico's reached 0.18% in 2007. The OECD average was 1.63% in 2008, and the median was around 1.05% of GDP (between the values of the United Kingdom and Canada). Alongside annual fluctuations, Canada, France, the Netherlands, Norway, Poland, the Slovak Republic and the United Kingdom experienced slight falls in their BERD intensity over the period. As with the GERD-to-GDP figures, the BERD-to-GDP ratio reflects

Figure 1.4. **BERD intensity, by country**

1998 and 2008, or nearest available years



Note: In the Russian Federation, much R&D is traditionally performed by public enterprises, which are classified in the business enterprise sector. Due to the lack of a comprehensive business register for South Africa, R&D expenditure may be underestimated by 10% to 15%.

Source: OECD, *Main Science and Technology Indicators* (May 2010).

StatLink http://dx.doi.org/10.1787/888932332664

both spending and economic growth, and countries' macroeconomic circumstances should be taken into account in analysing year-to-year changes.

As has been noted in previous Outlook publications, the size of firms and their industrial specialisation are important predictors of business expenditures on R&D, with larger firms, manufacturers, and particular sectors (such as machinery and pharmaceuticals) typically undertaking higher levels of R&D. The characteristics of each country will therefore influence their positioning within the OECD on this indicator. Recent work by Moncada-Paternò-Castello *et al.* (2010), for instance, suggested that the lower R&D intensity of EU firms compared to non-EU firms resulted in large part from sector specialisation. In particular, the EU had a stronger specialisation in automobiles and parts (regarded as medium-high R&D intensity) and a much weaker specialisation in IT hardware, software and electronics (regarded as high and medium-high R&D intensity).

Of the other economies for which data are available, Singapore was above the OECD average with an intensity of over 1.9% in 2008. China's BERD intensity falls just below that of the EU27 economies in aggregate, at 1.1% of GDP in 2008, and has grown strongly since 1998, when it was around 0.3%. Given the growth of the Chinese economy during this period, this increase further highlights the extremely strong growth of its business expenditures on R&D.

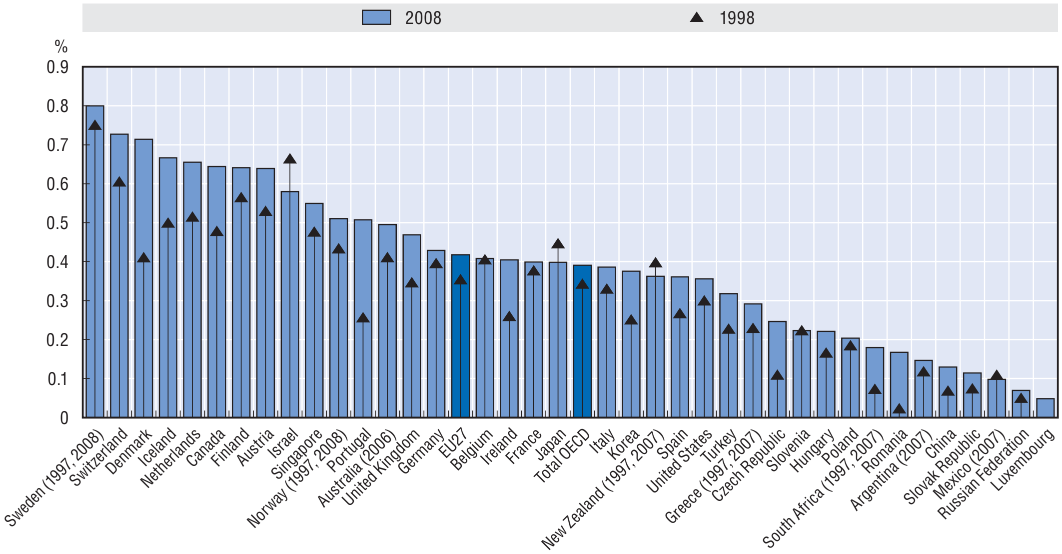
The expenditure on R&D performed by the higher education sector (HERD) forms a much smaller component of overall R&D spending across OECD countries. Total OECD spending in this area reached USD 157 billion in 2008 (current PPP), with Germany, Japan, the United Kingdom and the United States spending the largest absolute amounts. Growth was more volatile from year to year in HERD than in GERD or BERD, although it remained positive for the OECD as a whole. Average annual growth in real HERD (constant 2000 PPP dollars) for the OECD area was 5.6% over 1998-2002 and fell to 3.1% in 2002-07, and then to 1.3% in 2008. Of the 25 OECD countries for which 2007 and 2008 data were available, seven (Canada, the Czech Republic, France, Hungary, Iceland, Japan and Turkey) experienced a fall in real HERD in 2008. The strongest growth in real HERD in 2008 was in Portugal (41.1%), followed by Ireland (12.8%) and Korea (12.2%). China expanded its real HERD in 2008 by 15.7%.

As a percentage of GDP, Sweden, Switzerland and Denmark had the highest HERD intensities in the OECD in 2008, with Sweden at 0.8% of GDP (Figure 1.5).[6] The OECD average was just under 0.4%, around which OECD member countries were relatively evenly distributed. Israel and Singapore had relatively high HERD intensities in 2008, at 0.58% and 0.55%, respectively. Other non-OECD economies were clustered towards the low end of the distribution, although both China and South Africa have experienced significant growth since 1998 (for instance, South Africa more than doubled its HERD intensity, to reach 0.18% in 2007).

The expenditure on R&D performed in government research institutes (GOVERD) is a small but important part of total R&D expenditure.[7] In 2008, OECD spending totalled almost USD 103 billion (current PPP dollars), with the four largest spenders (the United States, Japan, Germany and France) accounting for over 70% of the total. In non-OECD economies, China's expenditure in 2008 of over USD 22 billion (current PPP dollars) was over half that of the United States, while Russia's was on a par with that of France. From 1998 to 2007, real annual growth of GOVERD in the OECD averaged 1.9%; growth then accelerated to 3.4% in 2008. The EU27 had a similar GOVERD pattern, with real average

Figure 1.5. **Higher education expenditure on R&D (HERD), 1998 and 2008**

As a percentage of GDP



Note: In Israel, humanities and law are only partially covered in the higher education sector.

Source: OECD, *Main Science and Technology Indicators* (May 2010).

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annual growth of 1.2% from 1998 to 2007, then growth of 4% in 2008. In China, strong growth in GOVERD has continued over the period, with an average of 10.5% a year from 1998 to 2007 and 10.3% in 2008. In Russia, however, strong average annual growth of 10.6% from 1998-2007 fell to 0.9% in 2008.

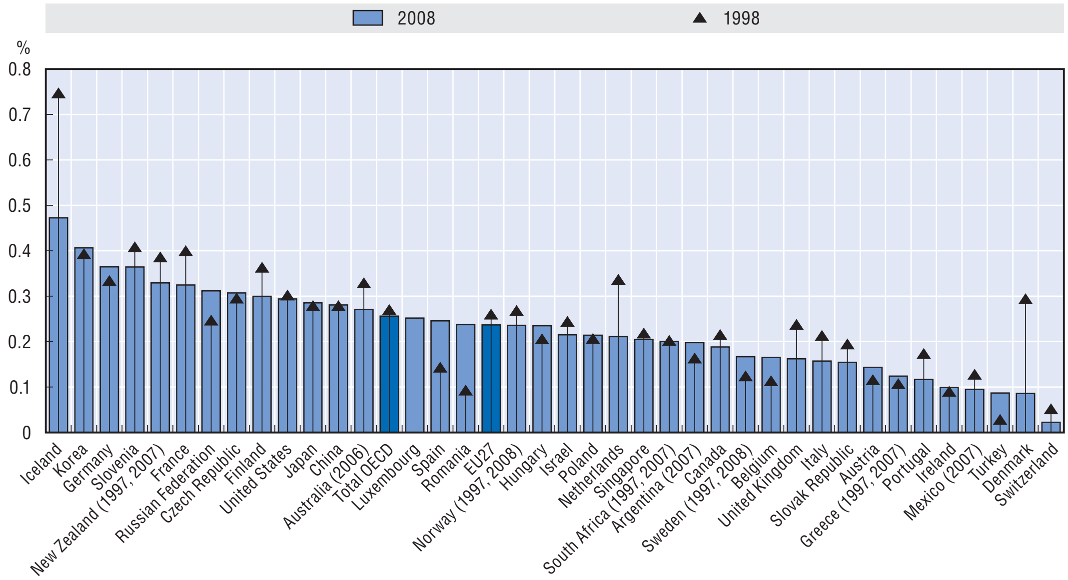
As a percentage of GDP, Iceland and Korea had the highest intensities of GOVERD in 2008, followed by Germany and New Zealand (Figure 1.6). The OECD average was 0.26%, with a median value of 0.21%. Recent OECD member Slovenia had a GOVERD intensity on a par with that of Germany, while Russia's was similar to France's, at 0.31%. China stood just below Japan on 0.28%.

Overall, the split of R&D expenditure over the three main performance sectors of business, higher education and government has remained relatively stable over time for OECD countries, with a slight shift towards business and higher education. In 1998, business expenditure accounted for 68.5% of GERD, while higher education spending and expenditure in government research institutes accounted for 16.2% and 12.7%, respectively (private, non-profit expenditures accounted for the rest). By 2008, the share of business had increased slightly to 69.8%, with higher education also increasing its share to 16.8%, while government institute spending fell to 11% of the total. Change was marginal from 2007 to 2008. However, the various country rankings along the distributions of BERD, HERD and GOVERD intensities (Figures 1.4-1.6) highlight how the environment for research differs across countries, with some more heavily involved in government-led research and others relatively more business-led.

There is some evidence from econometric analyses that R&D performed by the business sector is the strongest driver of the positive association between total R&D intensity and output growth, which might suggest that raising the share of business R&D could be desirable. However, regression analysis may not easily identify some more complex effects and such a conclusion might be overly simplistic. For instance, public-

Figure 1.6. **Research performed in government research institutes, 1998 and 2008**

As a percentage of GDP



Note: In Romania and the Russian Federation, much R&D is traditionally performed by public enterprises, which are classified in the business enterprise sector.

Source: OECD, *Main Science and Technology Indicators* (May 2010).

StatLink http://dx.doi.org/10.1787/888932332702

sector R&D in energy or health may not raise technology levels significantly in the short run but it may generate basic knowledge and technology spillovers that lead to breakthroughs and innovations further in the future (OECD, 2003). Jaumotte and Pain (2005) found that business sector R&D intensity was positively related to the level of non-business R&D intensity. This is consistent with the view that there are complementarities between the sectors. Similarly, van Pottelsberghe (2008) found that the EU countries with the highest academic R&D intensities were also those with the highest business R&D intensities, and suggested that academic research provides new ideas that stimulate further research in the business sector. In the United Kingdom, universities that carry out world-class research appear to attract research laboratories, both local and foreign, to their neighbourhood (Abramovsky *et al.*, 2007). The evidence was particularly strong for the pharmaceuticals and chemicals industries, and also for machinery and communications equipment industries.

Furthermore, as already noted, sectoral specialisation is an important driver of business R&D. In a study of 16 European countries plus Japan and the United States, Mathieu and van Pottelsberghe (2008) found that in most countries the intensity of business R&D is strongly influenced by specialisation in R&D-intensive industries and not by a country-specific environment that is particularly favourable to R&D expenditure. It is not clear that seeking to achieve a particular industrial structure in order to meet a numerical goal for business R&D intensity is useful. Rather, Moncada-Paternò-Castello *et al.* (2010) suggest that the real issue is how industrial structures affect outcomes such as macroeconomic stability, growth sustainability and productivity, and that innovation policy ought to take a wider view than just R&D inputs.

In short, each country has its own industrial and institutional environment that shapes where R&D is performed. This cautions against a "one-size-fits-all" goal for shares of business and government R&D. Indeed, the two wealthiest economies in the OECD (Luxembourg and Norway) have quite different patterns of R&D spending. Business expenditure accounted for the bulk of Luxembourg's R&D in 2008 (over 80%), while in Norway the higher education and government sectors together account for almost half.

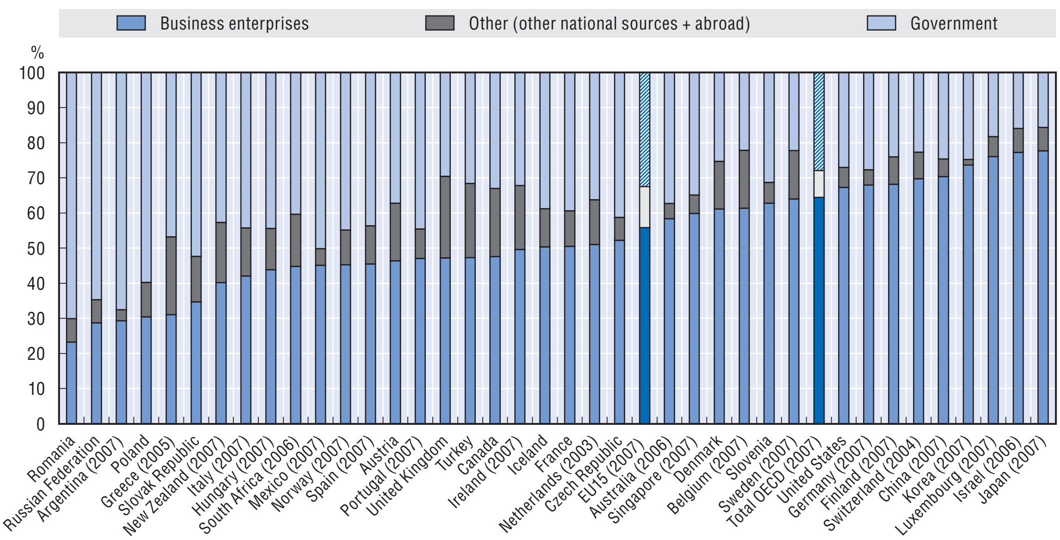
Financing of R&D

The sources of funding of R&D performed in OECD countries have also been relatively stable, with a slight shift towards business in the past few years. Financing sources are generally discussed in terms of the major performing sectors (business, government, higher education, and private non-profit) and funds from abroad. The data measure direct transfers of resources to undertake R&D and do not include provisions such as tax concessions or exemptions or R&D bonus payments. Since 2004, the percentage of R&D expenditure funded by business enterprises has risen, from 62.1% to 64.5% for the OECD area in 2008 (similar to the share in 2000). Over the same period, R&D funded by government fell from 30.3% to 27.6% of total funding, although data on government budget appropriations or outlays for R&D (GBAORD) show that most OECD governments increased their budgets for R&D and that, in many cases, R&D outlays rose faster than general government outlays.

Figure 1.7 shows the mix of funding sources in 2008 (or the latest available year) for individual OECD countries, as well as selected non-OECD economies. As with the performance data, there is clearly a wide range of financing arrangements; among OECD members, Poland had the highest share of government R&D financing at almost 60% of the total (the OECD median was 37%), while Japan had the highest share of business funding at almost 78% (the OECD median was 50%). In terms of business financing, OECD countries can be split into four groups: the first, with business enterprises financing less than one-

Figure 1.7. **R&D expenditure by source of financing, as percentage of national total**

2008 or nearest available year



Source: OECD, *Main Science and Technology Indicators* (May 2010).

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third of R&D, comprises Poland and Greece; the second, with firms financing from one-third to one-half of R&D, comprises 13, including Italy, Norway, Spain, Canada and Turkey; the third, with business spending accounting for one-half to two-thirds of R&D, includes eight countries, such as France, the Czech Republic and Sweden; and the fourth, with business enterprise spending above two-thirds of the total, comprises the United States, Germany, Finland, Switzerland, Korea, Luxembourg and Japan. China and Israel also had high levels of business financing of R&D, at 70% and 77% of the national total, respectively.

Examining the flows of R&D funding between sectors can give some insight into the interaction between them. As noted, research in the business and government sectors is complementary, and cross-sector funding may represent one way of collaborating, sharing and disseminating results across sectors. Figure 1.8 shows that, on average, OECD governments financed 7% of the R&D performed in the business sector in 2007, compared to 9.4% in 1998. For individual OECD countries, the share ranged from 1.1% in Japan to 16.3% in Spain. Thirteen OECD countries saw an increase in the share of government financing in business R&D from 1998 to 2008; in the case of the Czech Republic, Spain and Turkey, this increase was of 5 percentage points or more, but for the other countries it was small. The overall trend of decreasing government financing in the business sector is consistent with increasing use of other policies to encourage R&D, particularly those involving the tax treatment of R&D. In 2008, 21 OECD countries had R&D tax credit schemes (although New Zealand stopped its scheme in 2009) and non-OECD economies are also using such instruments to support research investment (OECD, 2009e, p. 78; see also Chapter 2 of this publication). Figure 1.8 also shows the share of business-funded R&D in the higher education and government sectors. Here, there was a small increase on average in OECD countries from 5.2% in 1998 to 5.5% in 2008. Denmark had the lowest share of business financing in these sectors, at 2% in 2008, while Turkey had the highest, at just over 15%.

There is no one "right" mix of funding sources for R&D, with the history, industrial structure and institutional frameworks in each country influencing financing arrangements. There is some suggestion that privately funded R&D yields better results than publicly funded R&D, in terms of productivity and return on investment. For instance, analysis by Guellec and van Pottelsberghe (2004) showed that business R&D with higher shares of government funding had smaller positive effects on productivity. However, disaggregating government funding according to its socioeconomic objectives showed that only defence-related funding had this effect; public funding with a civilian objective had a positive effect on the relationship between business R&D and productivity. In the case of university research, a higher share of business funding reduced the positive impact of this R&D on productivity, possibly owing to the more applied nature of business-funded university research. However, the authors warned against drawing policy conclusions from an aggregate-level study and recommended more detailed, country-level investigations and case studies. A recent review by Hall *et al.* (2009) noted that while a number of studies had found a lower rate of return to publicly funded R&D than to privately funded R&D, this could partly be explained by the difficulties of measuring returns and externalities in service sectors where public R&D money is often directed. In addition, government R&D funding tends to be spent in areas of higher risk or where there are public good issues (*e.g.* defence and health). Hall *et al.* also noted the potential for public R&D to encourage private R&D spending.

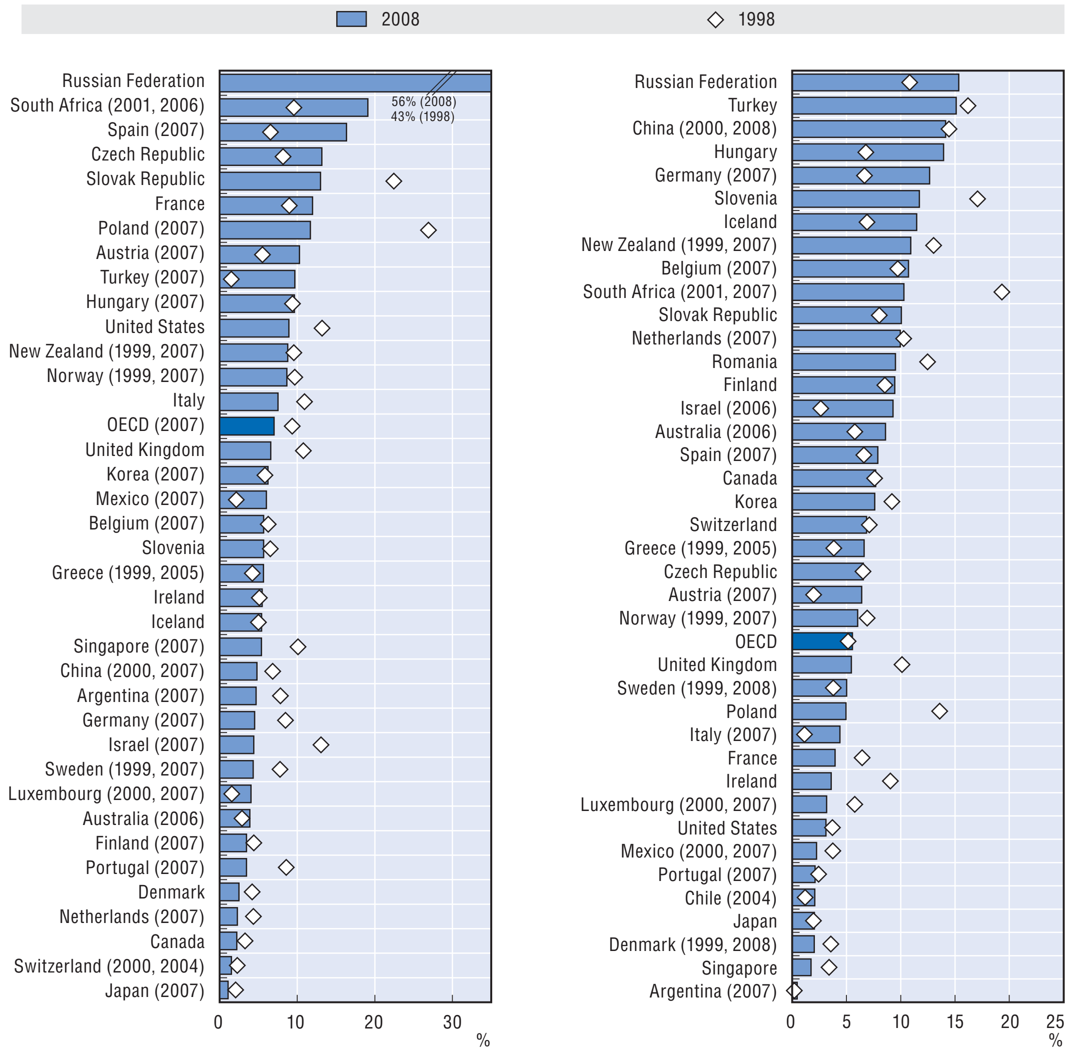
Figure 1.8. **Cross-funding of R&D**

Government-financed R&D[1] in business, 1998 and 2008

As a percentage of R&D performed in the business sector

Business-funded R&D in the higher education and government sectors, 1998 and 2008

As a percentage of R&D performed in these sectors (combined)



1. This measures direct transfers of resources to undertake R&D and does not include provisions such as tax concessions or exemptions, nor R&D bonus payments.

Source: OECD, *Main Science and Technology Indicators* (May 2010).

Note: Italy: only government sector for 1998. Luxembourg: only government sector for 2000. Switzerland: only higher education sector.

Source: OECD, *R&D Database* (June 2010).

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More recent data suggests overall R&D investment has slowed in the economic downturn

Historical data show that aggregate R&D spending moves in concert with a country's GDP. This suggests the likelihood that the economic downturn will be reflected in R&D expenditure data. OECD analysis of the period from 1982 to 2007 found that variations in GERD are generally larger than cyclical movements in GDP, and that the strength of the response to business cycles differs quite substantially across countries (OECD, 2009e, p. 26). For example, the United Kingdom's total R&D expenditure has exhibited low average responsiveness to the business cycle since the early 1980s, with a 1% change in GDP associated with a change in R&D of less than 0.5%. For the United States, Japan and Denmark, R&D expenditures moved nearly in proportion to changes in GDP, while at the top of the range, Sweden, Spain, Poland, the Slovak Republic and Hungary saw variations in GDP matched by more than twice times that variation in R&D.

The previous section found that growth in GERD for the OECD area slowed in 2008, as did growth in BERD, although with important differences across countries. For instance, consistent with the MSTI data presented earlier, Battelle noted that R&D spending in the United States in 2008 had held up despite the onset of the recession, as budgets were already established and outlooks were still optimistic. In the United Kingdom, the Department for Business, Innovation and Skills (2010) found that R&D investment by the top 1 000 UK companies increased by 9.2% in 2008, with the top 46 spenders increasing their R&D investment by over 11%; however, this contrasts with an overall drop in real business expenditure on R&D of –1.2% for the United Kingdom, as shown in MSTI data.

Initial cross-country evidence from 2009 suggests that the financial crisis and economic downturn have had an impact on firms' expenditures on innovation. A survey of European firms, conducted in April 2009, found that enterprises were two to three times more likely to have adopted a "defensive" (innovation cost-cutting) strategy over an "offensive" (innovation expenditure-increasing) strategy in response to the economic downturn, although there were important country variations (EC, 2009a). Overall, 22% of firms had decreased their innovation expenditures in the previous six months as a direct result of the economic downturn, while 9% had increased their innovation budget. Looking ahead, 28% of enterprises expected their 2009 innovation expenditures to be lower than in 2008; between 2006 and 2008 only 9% indicated a decreasing budget. Firms in countries that are considered to be "catching up" in innovative activity fared particularly badly (Box 1.3). A number of leading US companies also made substantial reductions in their R&D expenditures over the first three quarters of 2009, including: Microsoft and IBM (in the software/IT/Internet sector); Intel, Motorola and Texas Instruments (in the electronics/

Box 1.3. **Innovation and the crisis – initial firm-level analysis**

The Innobarometer 2009 survey was conducted in April 2009 in the 27 member states of the EU and in Norway and Switzerland (EC, 2009a). Its topic was "Strategic trends in innovation 2006-2008" and it included some questions aimed at understanding the initial effects of the economic downturn. Over 5 000 enterprises with 20 or more employees were surveyed, of which 92% had some innovation activity.

The survey revealed that 24% of the enterprises for which innovation was a primary source of income reported a decrease in innovation expenditures in the previous six months; 20% of firms for which innovation was a significant source of income did the same. Firms in countries considered as "catching up" were much more likely to have decreased expenditure, with 29% of firms doing so, compared to 16% of firms from countries considered "innovation leaders".* Overall, enterprises were two to three times more likely to have adopted a "defensive" (or innovation cost-cutting) strategy over an "offensive" (or innovation expenditure-increasing) strategy in response to the economic downturn, although the gap was smaller for firms in high- and medium-high technology sectors, knowledge-intensive service sectors, countries considered innovation leaders, and firms with innovation as a significant source of income.

Box 1.3. **Innovation and the crisis – initial firm-level analysis** *(cont.)*

Using the firm micro-data to analyse the 4 195 innovative firms in the survey, Kanerva and Hollanders (2009) highlighted the influence of various firm characteristics on decisions to reduce innovation expenditures. In particular, they found that firms in medium-high innovation-intensive sectors were more likely to have decreased (and to expect to decrease) their expenditures on innovation than those in other sectors. Firms with medium innovation intensities (represented by turnover spent on innovation) were also more likely to reduce expenditures. Perhaps unsurprisingly, firms that were already cutting expenditures prior to the crisis were more likely to continue this pattern. Firms in catching-up countries were more likely to have decreased expenditures in the previous six months, while firms in "follower" and "moderate innovator" countries were more likely to expect to decrease future spending. Kanerva and Hollanders suggested that these results could signal a slowdown and even a reversal of the observed convergence process in innovation performance in the EU.

Firms for which innovative products and services accounted for a larger share of sales were more likely to maintain their investments in innovation activities. Firms with broader innovation strategies, particularly those involving users, were also less likely to reduce their expenditures than other firms. The results for internationalisation were mixed; firms that viewed export markets as their greatest innovation opportunity were more likely to have cut innovation expenditures in the previous six months, but were less likely to expect to cut them in the future. Firms operating on international markets were more likely to expect to cut future expenditures than firms operating solely domestically. There was weak evidence that innovation resulting from R&D activities was less affected by the downturn than innovation from non-R&D activities. The size of firms had no notable effect on actual or expected innovation expenditures, nor did the type of innovator (product, process, etc.).

* The European Innovation Scoreboard classifies Bulgaria, Hungary, Latvia, Lithuania, Malta, Poland, Romania and Slovakia as catching-up countries and the innovation leaders as Denmark, Finland, Germany, Sweden, Switzerland and the United Kingdom.

computer hardware sector); Pfizer and Johnson&Johnson (in the biopharmaceuticals sector); and Caterpillar and DuPont (in the advanced technology/manufacturing sector) (Battelle and *R&D Magazine* 2009). Data from the US Securities and Exchange Commission also show a reduction of R&D in the first quarter of 2009, although with a small increase in the second (OECD, 2009e, p. 24).

Estimates by Battelle and *R&D Magazine* (2009) suggested that total world R&D investment for 2009 would be almost 1% lower than in 2008, measured in current USD PPP. This overall figure masks substantial differences among countries. Asia was expected to experience a 3.7% increase in R&D spending in 2009 (with India increasing by 5% and China by 20%); the United States and other Americas economies, Japan and Europe were estimated to drop by more than 2%, 5.5% and 4%, respectively. As such, the share of global R&D spending accounted for by Asia was expected to rise from 32% to 33.5%, with China increasing its share from 9.1% to 11.1% and India picking up a small increase from 2.4% to 2.5%. The drop in investment in Europe, at least, may be driven mostly by private spending, with a survey of 27 EU member states indicating that 15 countries increased their public R&D budgets from 2008 to 2009, while six reduced theirs (Mega, 2010). Several states emphasised the role of EU structural funds in maintaining public R&D during the crisis.

Financing is an important constraint on private R&D spending during economic downturns and early evidence suggests this may also be true of the current recession. A survey of innovative companies in Germany, published in September 2009, found that 16% were unable to obtain any financial support for their innovation projects and a further 14% reported worsened conditions, with small and medium-sized enterprises (SMEs) faring worse than larger firms (DIHK, 2009). However, 53% evaluated their access to external financing as unchanged, and a further 17% believed it had improved. Venture capital can be a major source of funds for new innovative firms. In 2008, firms in the United States and the United Kingdom received 58% of total venture capital investments in OECD countries, although venture capital intensities were highest in Finland (0.24% of GDP) and Sweden (0.21% of GDP).[8] Venture capital is particularly sensitive to recessions. Data from 2008 and the first half of 2009 for the United States already showed strong declines in response to the economic downturn (OECD, 2009e, p. 22). More recent data from the United States reveal that 2009 had the lowest level of dollar investment by venture capitalists since 1997, with a 37% decrease in dollars and a 30% decrease in deal volume from 2008 (PricewaterhouseCoopers and National Venture Capital Association, 2010). From a high of USD 8 billion invested in the final quarter of 2007, investment plunged to USD 3.3 billion in the first quarter of 2009. Except for the category of Networking and equipment, every industry grouping had double-digit drops for the year, and the distribution of investment changed, with biotechnology overtaking software and industrial/energy to receive the largest amount. Nevertheless, the final quarter of 2009 saw a pick-up in the number of first-time and early-stage deals completed, and 11 of 17 industry sectors had funding increases. Investment reached just over USD 5 billion in the quarter, leading the authors to suggest a potential uptick in investment for 2010.

Looking ahead

As economies begin to return to growth, R&D investment is expected to follow. The annual funding forecast of Battelle and *R&D Magazine* (2009) suggested that overall global R&D (measured in current USD PPP) would increase 4% in 2010, with China and India driving a 7.5% increase in Asian R&D, the United States experiencing a 3.2% increase, and the European economies lagging with growth of 0.5%. A survey of EU member states found that 16 planned to increase their public R&D investment over 2010, while only three foresaw decreases (Mega, 2010). However, the Battelle predictions suggested that the shares in global R&D spending of the United States and other Americas economies, Japan and Europe would fall from 2009 to 2010, with China increasing its share to 12.2% of the world total, and India reaching 2.9%. Battelle interpreted these 2010 forecasts as a continuation of a trend seen since 2005, in which both the Americas (the United States, Canada, Mexico, Brazil and Argentina) and the European economies were falling behind R&D spending in Asian countries (although it also noted that some of this was by European and American industrial firms).

At the same time, there are clear uncertainties around the size of the expected improvements. For instance, Battelle and *R&D Magazine* (2009) viewed the trade deficit, fiscal deficits and limited state revenues for state government funding of R&D as ongoing threats to R&D investment in the United States. Firms agreed: a survey conducted in mid-to-late 2009 in the United States found that the federal deficit, the global recession, corporate outsourcing to foreign firms and stock market volatility were most frequently mentioned as negatively affecting near-term R&D performance in the United States

(Battelle and *R&D Magazine*, 2009). On the positive side, renewal of the R&D tax credit, global climate change, federal science and technology (S&T) policies and American investments in STEM (science, technology, engineering and mathematics) education were viewed as strengthening potential R&D performance. Ongoing uncertainty about the future is also reflected in the rapidly changing sentiment reported in McKinsey's Global Survey results; while the percentage of respondents who said their firm would introduce new products or services in the next 12 months rose from 48% to 57% from February 2010 to April 2010, it then fell in June 2010 to 51%, reflecting heightened anxiety about consumer demand and economic volatility (McKinsey and Company, 2010a, 2010b).

To some extent, growth in future R&D will likely follow the patterns set prior to the financial crisis and recession. An analysis of the "clean-tech" sector in the United States, for example, suggested that, despite a plunge of 84% in venture capital funding at the start of 2009 (driven mainly by a collapse of funding for solar energy companies), the fundamentals behind growth in the sector remained strong (PricewaterhouseCoopers, 2009). The analysis posited that public and private initiatives to reduce energy consumption, dependence on foreign oil and greenhouse gas emissions would especially benefit companies focused on efficiency and smart grids. Analysis by the OECD (2009e, pp. 55-73) of citations of scientific articles pointed to a number of research areas that have been particularly active in recent years; given the longer-term nature of some scientific research, these areas might be expected to continue to feature prominently in the near future. In the environmental sciences, active research areas included climate change, air and chemical pollutants, and biodiversity, while in the biosciences, brain research, genomics, regenerative medicine and plant science research were strong. In nanotechnology, the research areas chemical synthesis, superconductivity and quantum computing, and nanomaterials and devices were prominent, while nanotechnology patents in nanomaterials and electronic devices and optoelectronics grew particularly strongly from 1999-2001 to 2004-06. The forecasts of Battelle and *R&D Magazine* saw strong R&D growth in the United States being driven by continued competitive pressures from globalisation and advances in a set of overlapping technologies, materials and processes including alternative energy technologies, biotechnology, infrastructure enhancements, transport, accelerating information and communication technologies (ICTs), medical devices and procedures, sustainability, agriculture and climate change implications.

Government budget allocations and recent trends in industry financing give some indication of the targets of future spending plans. For instance, the UK government announced in February 2010 that GBP 200 million of the UK Innovation Investment Fund would be used to benefit life sciences and digital and advanced manufacturing businesses, thereby adding to the GBP 125 million invested in low-carbon and clean-tech sectors. In Australia, the government is co-financing a Green Car Innovation Fund (see Chapter 2 for further examples). Battelle and *R&D Magazine* (2009) suggested that stem cells, personalised medicine and nanotechnology would continue to be supported in US research labs over the next five to seven years and would drive expanded research funding. They noted that following a lifting of restrictions, 13 human embryonic stem cell lines were approved for research studies in December 2009 and 96 more are under review and expected to be approved in 2010. Academic research involving the human genome is now being picked up by pharmaceutical and diagnostics companies, and nanotechnology research holds promise for many industries. Indeed, data on venture capital funding for the life sciences (which encompasses the biotechnology and medical devices and equipment industries) showed that it experienced a smaller fall in funding in 2009 than the average across all sectors, and commentators suggested that the sector's growth opportunities would stimulate a return of funding flows in 2010 and beyond (PricewaterhouseCoopers, 2010).

Looking further ahead, what emerging trends might governments need to consider in their R&D plans? In discussions of future orientations for STI policy, Daheim (2009) pointed to a number of "megatrends" that are likely to stimulate new markets and innovations and change the way people communicate, work and live. Unsurprisingly, the issues of climate change, resource scarcity and the search for clean and efficient energy featured prominently in the analysis. But Daheim also highlighted demographic change and urbanisation, with ageing populations in advanced economies potentially driving increased migration and the strong growth of megacities in emerging markets calling for new infrastructure solutions. Also noted was the process of globalisation at the level of socio-culture and questions about the ethical limits to innovation arising from ongoing technology convergence. These megatrends challenge policy makers to think about the desired pathway for development and to design appropriate policies. In other trends, the continuing growth in emerging-market consumers not only challenges companies to adapt products to different preferences and budget constraints; it also challenges them to develop products designed specifically for emerging-market needs and to market them in new ways (*The Economist*, 2010). The results of such "frugal innovation" may also be valuable for developed countries (better value-for-money health care was one example described by *The Economist*), and raises the importance of ensuring that policy settings allow two-way flows of knowledge across borders and enable experimentation with new ideas from emerging markets.

Information about specific emergent technologies may also be of use to governments seeking to better direct their research funding priorities. For instance, in terms of maintaining a leading edge worldwide in science and engineering (S&E) research, the National Science Board (2010a) believed that US research agencies needed to ensure adequate support for "transformative research" which yields revolutionary advances through the application of radically different approaches or interpretations and results in new paradigms or scientific fields. However, it is difficult to identify such technologies. Foresight exercises yield some suggestions on emerging fields of research and predict when certain technologies or advances may reach the marketplace (Box 1.4). Such future-oriented technology analysis (which may also encompass technology forecasting and assessment) can be a useful tool for informing policy, achieving greater participation in policy making and supporting policy definition (Haegeman *et al.*, 2010). Very broad scans (or "horizon scans"), which systematically examine potential future problems, threats,

Box 1.4. **Emerging areas of science, technology and innovation**

It is not a simple task to predict what the next big breakthrough areas of science, technology and innovation will be. Foresight exercises seek to give a flavour of the emerging environment and can give some indication of the direction of change. The following sample of ideas is drawn from a selection of future-oriented analyses, as an example of what might be "coming down the pipeline" in the science and technology arena.

Box 1.4. **Emerging areas of science, technology and innovation** *(cont.)*

Biotechnologies in agriculture and natural resources: Arundel and Sawaya (2009) predicted that several novel agronomic and product quality traits (*e.g.* stress tolerance) will come on the market for a number of crops by 2015. Almost all varieties of large market crops (*e.g.* cotton and wheat) are likely to be developed using marker-assisted selection (MAS – a non-genetic modification [GM] biotechnology), while GM varieties of barley, peanuts, peas and sugarcane will also appear. Livestock for dairy and meat will continue to be improved via non-GM techniques, in particular, by applying MAS to breeding programmes. Cloning for meat production may occur by 2015 in non-OECD countries. Public attitudes are extremely important for the future direction of biotechnology applications, and opposition could lead firms to limit investment in GM to feed and industrial feedstock crops and plants such as trees or grasses. Another study suggested that the further adoption of "biotech crops" globally will be catalysed by deployment of biotech rice as a crop, as rice is a staple food for half of the world's population, including many of the poor (James, 2009). Incorporating drought tolerance as a trait will also be a strong driver (agriculture uses over 70% of the world's fresh water). A number of rice crops are being developed, and drought-tolerant maize is expected to be deployed in the United States in 2012 and in Sub-Saharan Africa in 2017. Looking out to 2030, the OECD (2009f) foresaw a high probability of more diagnostics for genetic traits and diseases of livestock, fish and shellfish, and of more GM varieties of major crops and trees to improve industrial processing and conversion yields.

Biotechnologies in human health: Arundel *et al.* (2009) foresaw biotechnology being used in the discovery, development, manufacturing and/or prescribing of nearly all new drugs by 2015. While there is no evidence of an imminent surge in biotechnology drugs, evaluations show that biopharmaceuticals offer greater therapeutic value than other pharmaceuticals. There is a very strong biotechnology pipeline for experimental therapies (*e.g.* cell and tissue engineering), but the use of biotechnology in functional foods and nutraceuticals will remain minimal. Health-care delivery will be improved via the development of predictive and preventive medicine, drawing on the continued creation, population and maintenance of health databases. Importantly, however, tapping the full benefits of such information will require changes to health systems and policies. The OECD (2009f) considered that by 2030 there would be extensive screening for multiple genetic risk factors for common diseases in which genetics is a contributing cause, and improved drug delivery systems from convergence between biotechnology and nanotechnology.

"**General purpose**" **nanotechnology:** Nanotechnology may become the next general purpose technology, developing rapidly, offering significant scope for improvements over existing technologies, having a wide variety of uses in a wide number of application areas and industries, and both generating and depending on the development of a range of complementary technologies and innovations (Palmberg *et al.*, 2009). According to Battelle and Foresight Nanotech Institute (2007), the long-term vision of nanotechnologists is the fabrication of a wider range of materials and products with atomic precision. This could improve high-performance technologies of all kinds, and in the process could lead to new capabilities in atomically precise manufacturing. Atomically precise nano-systems and manufacturing processes have wide application potential, with products including targeted agents for cancer therapy, "smart" materials and efficient high-power-density fuel cells. Early applications are likely to come in sensors, computer devices, catalysts and therapeutic agents, but 10 to 20 years ahead, potential applications could include artificial organ systems and removal of greenhouse gases from the atmosphere.

Box 1.4. **Emerging areas of science, technology and innovation** *(cont.)*

Technologies for security: Analysis from the *SigmaScan* work-stream of the United Kingdom's Horizon Scanning Centre suggested that technologies will play a key role in the prevention, detection and response to security threats. For example, improved biometrics and new scanning technology may enable detection of potential security risks, computer forensics could help reconstruct security breaches, self-adaptive software systems may increase resilience against information technology (IT) attacks, and virtual realities can be used to train security personnel in realistic environments featuring agents who exhibit human behaviour (SigmaScan, 2009). At the same time, technology contributes to security issues; standardisation and interoperability, coupled with wireless-enabled handheld devices, can increase the reach of any security threat, and the model of "cloud computing" raises issues of control and responsibility for privacy and security. Better incorporating the "human element" is essential for security; in addition to common human factors such as carelessness, maliciousness and fatigue that can pose threats to security, increased mobility across organisations and countries creates more individuals with multiple or mixed loyalties. However, the analyses highlighted that owing to the greater use of data on human behaviour and the increased use of personal information, future technology solutions for security will tread a fine line between effective security enforcement and maintaining societal trust and privacy. While humans may draw on complex and sophisticated technology for threat prediction, detection and decision making, they will still need to take responsibility for decisions of consequence. Over the coming three to ten years, SigmaScan predicted that the use of IT-supported behavioural monitoring of employees and deployment of autonomous sensory networks with security-centric abilities would become standard. It also predicted increased use of "honey traps" in networks and "decoys" in electronic documents.

The "next next things": TechCast (2009) highlighted a sample of eight breakthrough innovations that could emerge over the next 15 years, ranging from space tourism to a cure for cancer. Its forecasts suggested that intelligent cars that drive, navigate, pay tolls and park themselves may be available by 2014, while telemedicine, incorporating features such as electronic medical records, computerised diagnoses and telesurgery, may emerge by 2015. Further into the future, TeleCast posited that by 2020 (give or take nine years) thought power could be used as a control mechanism (*e.g.* to operate devices, access bank accounts or enter buildings) and to have silent conversations. Alternative energy may provide 30% of the world's energy by 2022, and smart robots may be ubiquitous by around the same time.

opportunities and likely future developments, can complement foresight exercises by looking across policy domains and research fields and identifying relevant relationships and linkages. Van Rij (2010) noted, for instance, that such scans can play a useful role for setting research agendas and are used in some countries to push the framing of policies towards a more future-oriented mode. However, foresight and similar exercises may need further tailoring to better suit the needs of decision makers. To raise the impact of foresight exercises on government policy, they should have clear links to the current policy agenda, tap into the knowledge of senior policy makers, and connect to private-sector actors (Haegeman *et al.*, 2010; Calof and Smith, 2010).

Human resources are a central input to R&D and innovation

Almost every aspect of R&D and innovation requires the input of skilled people. Human resources in science and technology (HRST), a broadly defined group which essentially captures people with education at the university or post-secondary level and/or who work as professionals or technicians, play a central role in creating new knowledge through basic and applied research; developing, installing and improving new materials, products and devices; designing, engineering and tooling up production processes; running tests and collecting data; applying for patents and licences; adapting and adopting technologies within in the workplace; and more. The particular skills involved in these activities are many and varied, and range from in-depth academic knowledge of particular scientific fields to practical technical skills, to management and team-working skills. Given the reach of innovative activity across all sectors of the economy at both technological and non-technological levels, it is also clear that even if not directly involved in R&D and innovation, all workers require at least basic skills to be able to engage with new technologies, techniques and ways of working and to enable innovation to take place successfully in their workplace.

As for R&D investment, the currently available data on HRST does not fully cover the period of the recent financial crisis and economic downturn. This section provides an overview of available data on tertiary attainment, student mobility, researcher trends and training activities, with time coverage generally reaching to 2007 or 2008. Box 1.5 looks at recent evidence on the labour market in general, and notes some trends relevant to the impact of the downturn on HRST.

The number of individuals with tertiary education has continued to rise. In part, this is due to population growth, but it is in larger part due to increases in attainment rates, with the proportion of people completing a tertiary degree rising over time. From 1998 to 2006, the annual increase in the number of people with tertiary education averaged over 4% for the OECD as a whole, and was over 7% in Ireland, Poland, Portugal, Spain and Turkey (OECD, 2009g, p. 26). Tertiary attainment levels (for tertiary type-A degrees and advanced

Box 1.5. **Labour market implications of the downturn**

From late 2007 to the end of 2009, the unemployment rate in the OECD area rose by almost 3 percentage points, putting 17 million more people into unemployment and making the downturn comparable to the deepest recessions of the post-war period. However, analysis for the *OECD Employment Outlook* showed that the increase in unemployment varied substantially, with Denmark, Iceland, Ireland, New Zealand, the Slovak Republic, Spain and the United States experiencing much bigger increases than Belgium, Norway and Poland, for example. Certain groups also suffered more than others, with temporary workers, youth, construction, manufacturing and mining workers, and men generally all experiencing disproportionately large job losses. In contrast, highly skilled workers saw an increase in employment from 2008Q4 to 2009Q4, and in general are less sensitive to business cycles. The rise in unemployment is likely to understate the amount of labour market slack, as data indicate that many workers have withdrawn from the labour market in response to poor job prospects, while others are working shorter hours than they would like. Estimates suggest that the "jobs gap" (*i.e.* how much employment is needed to achieve pre-recession levels of employment in the working age population) was over 17 million jobs at the end of 2009.

Box 1.5. **Labour market implications of the downturn** *(cont.)*

As the output shock was relatively synchronised across economies, the variation in changes to unemployment across countries cannot be explained by the size of their recessions. Instead, it appears that differences in the way in which labour demand adjustments were made account for much of the variation. In particular, some countries adjusted employment levels (*i.e.* via hiring and firing), while others adjusted hours worked (referred to as "labour hoarding"). Overall, differences in the composition and expected duration of the shock, as well as labour market policies and institutions, play an important role in determining whether and to what extent employment levels or hours are adjusted in response to downturns. Of note for this chapter, the high-technology manufacturing and knowledge-intensive services sectors were more likely to hoard labour, as were firms making use of more skilled labour. This may be because workers in such firms are more likely to be highly qualified, with important levels of firm-specific human capital, and on permanent contracts. Nevertheless, it is not yet clear whether such labour hoarding will play a role in the recovery of the labour market and the avoidance of new structural unemployment. While labour hoarding may be associated with smaller increases in unemployment levels, it is also associated with falling labour productivity and it may perpetuate labour market segmentation.

The extent to which the surge in unemployment during the downturn translates into human capital depreciation will depend on the speed with which people find new employment and their opportunities to maintain or augment their skills through training. Past experience suggests that sharp reductions in jobs relative to output in recessionary periods are not necessarily matched by a job-rich recovery. However, Karkkainen (2010) showed that interest and participation in publicly provided education increased alongside rising unemployment and job insecurity, especially among the adult population, although some countries have seen declines in private and firm spending on education and training. The overall impact of these factors will emerge over time and, again, is likely to differ across countries.

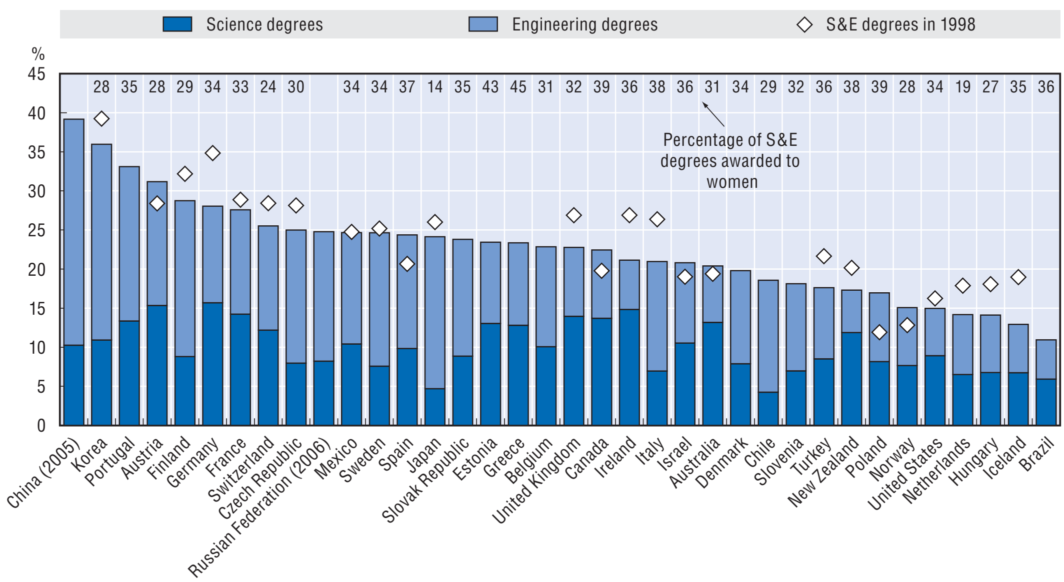
Source: Largely based on the *OECD Employment Outlook* (2010e).

research programmes[9]) among young adults aged 25-34 reached 27% on average across OECD countries in 2008, although the spread across countries was wide (OECD, 2010f). For this age group, the average attainment level for all tertiary study (type-A and type-B degrees and advanced research programmes) was 35%. Among OECD countries, Norway and the Netherlands, followed by Denmark and Korea, had the highest tertiary type-A attainment among young adults (at 35-44% of the cohort), while Austria had the lowest (at 13%). OECD partner countries displayed a similar range, with the Russian Federation exhibiting a tertiary attainment rate of 21% for this cohort, compared to 11% in Brazil. There is thus still much scope for increasing the skill base of OECD and non-member economies via increases in the supply of tertiary-qualified individuals.

A large number of students are internationally mobile and create a strong base for later flows of researchers and knowledge across countries. In 2008, over 3.3 million tertiary students were enrolled outside their country of citizenship, with France, Germany, the United Kingdom and the United States receiving the largest proportion of foreign students (43% of the total) (OECD, 2010f). Student mobility is likely to increase in future, driven by the continued worldwide expansion of higher education, the investments institutions and governments have made to encourage mobility, the increasing incorporation of "study abroad" requirements or opportunities within institutions' educational programmes (particularly those of prestigious institutions), the ongoing ease of travelling and communicating internationally, and the potential pecuniary benefits of a period of mobility (Vincent-Lancrin, 2009). The 2010 Council of Graduate Schools Admissions Survey (CGS, 2010) found that applications from prospective international students to US graduate schools continued to increase, with applications up 7% over the previous year for 2010 admissions. Using cross-country data on doctoral graduates, Auriol (2010) found that mobility is higher for this group than for other tertiary-level graduates and is higher for more recent cohorts, further indication that mobility is increasing. Data from the OECD Careers for Doctorate Holders (CDH) project showed that a large share of doctorate holders had lived abroad either prior to or during their doctoral studies, or afterwards in their professional life. For the European countries for which data are available, 15-30% of doctorate holders who were citizens of the reporting country had been abroad in the previous ten years; the figures were higher for those who had completed their studies between 1990 and 2006. Given that these data are based on the responses of returnees, they likely understate total mobility, since some mobile doctorate holders will still be abroad.

While graduates of all academic disciplines can make a contribution to innovative endeavours, particularly for non-technological innovation, people qualified in S&E fields can be a key resource for firms, public research organisations and universities that undertake R&D and technology-related innovation activities. These S&E fields cover a broad range of knowledge areas, ranging from life sciences and computing to architecture and building. Figure 1.9 shows the number of S&E degrees attained by students as a percentage of all new degrees in 2007. Among OECD countries, Korea and Portugal had the

Figure 1.9. **Science and engineering degrees as percentage of total new degrees, 2007**



Note: Data include tertiary type-A degrees and advanced research programmes (ISCED 5A and 6). A breakdown by gender is not available for China and the Russian Federation. For Brazil, ISCED 5B programmes are included.

Source: OECD *Education Database* (September 2009); UNESCO Institute for Statistics (2009); *Chinese Statistical Yearbook* (2008).

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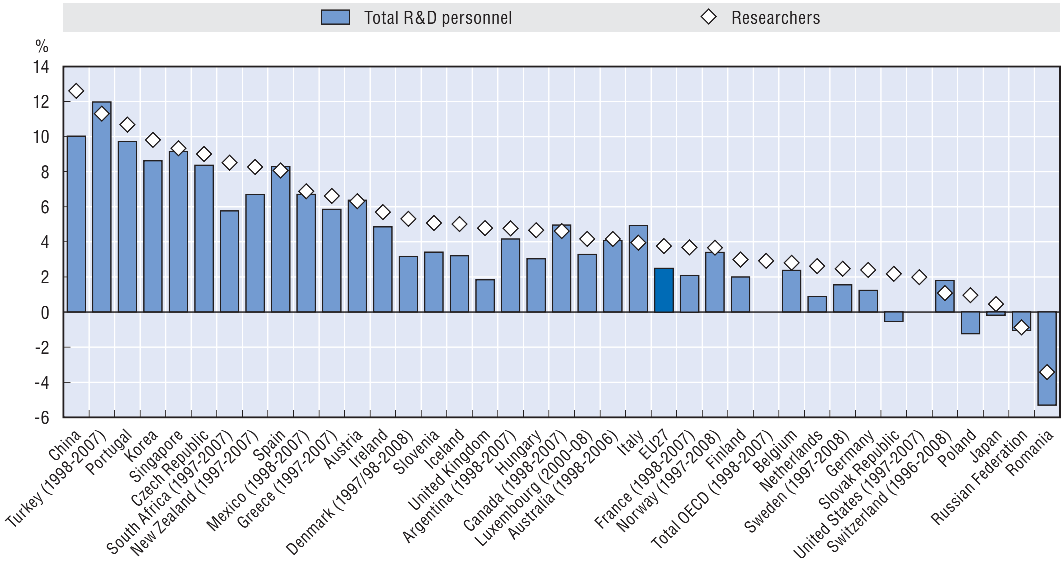
highest shares, at 36% and 33%, respectively. Among non-member economies in 2007, China stood out, with over 47% of new degrees awarded in S&E. Overall, engineering degrees appeared more popular, with a share in new degrees ranging from 5% (Brazil) to 37% (China). Science degrees accounted for shares of between 4% (Chile) and 16% (Germany). There were substantial differences among countries in the balance of the S&E degrees obtained. In Australia, Canada, Ireland, New Zealand and the United Kingdom, more than 60% of new S&E degrees were obtained in science. In contrast, in Chile, China, Japan and the Russian Federation, more than 70% were in engineering. All this suggests that the mix of skills being formed in universities differs widely across countries, perhaps because of differences in labour market demand, salaries and perceived career opportunities. In many countries the share of S&E in new degrees dropped from 1998 to 2007. There is also a wide difference in the percentage of S&E degrees awarded to women. In Japan, 14% were awarded to women in 2007, whereas in Greece, females accounted for 45%. Data show that the Czech Republic, Germany, Poland, Portugal and Sweden had the largest increases in S&E degrees awarded to women over 1998-2007.

At the doctoral level, data from the CDH project suggest that natural sciences are the first or second major field of specialisation for graduates (Auriol, 2010). They represented at least 20% of doctoral graduates for all countries in the study (except Romania), and more than 35% in Belgium, Denmark and Estonia. The relative importance of other fields differed by country; Central and Eastern European countries had large shares of doctorates in engineering and agricultural sciences, while Germany had a large share in medical sciences and Austria in the humanities and social sciences. In all countries except Austria, more than 50% of doctorate holders were employed by the public sector, predominantly the higher education sector. The public sector employed doctorate holders in all fields, while businesses tended to employ more natural scientists and engineers. Poland and Spain, in particular, had very high proportions of doctorate holders in all fields employed in the higher education and government sectors.

In the workplace, one indicator of R&D and innovation capacity is the total number of R&D personnel and researchers. Most countries have seen ongoing growth in the numbers of R&D personnel, particularly researchers (defined as professionals engaged in the conception and creation of new knowledge, products, processes, methods and systems). Over 1998-2008, researcher numbers (full-time equivalent) grew by over 4.5% a year in half of OECD countries (Figure 1.10). Portugal and Turkey had over 10% annual growth in researcher numbers, while China's researcher numbers grew at almost 13% a year. Total R&D personnel, which includes R&D managers, administrators and clerical staff, generally grew at slower rates (except in Austria, Canada, Italy, Spain, Switzerland and Turkey). Turkey had the fastest annual growth in this category (12% a year). The growth of total researcher numbers is driven significantly by business R&D expenditures, with growth in BERD more strongly associated with growth in researcher numbers than growth in HERD or overall GERD (see Annex 1.A1). The majority of researchers are not qualified at the doctorate level, although the majority of doctorate holders work as researchers (Auriol, 2010). Data from the CDH project showed that in the business enterprise sector, fewer than 20% of researchers had doctoral degrees in 2005, and fewer than 10% in Argentina, Japan, Mexico, Portugal, Singapore, Slovenia and Turkey. A higher percentage of researchers in the higher education sector were qualified to doctorate level, with the Czech Republic, Ireland, Poland, Portugal, the Slovak Republic, Slovenia and South Africa having more than 50% of higher education researchers with PhDs.

Figure 1.10. **Growth of R&D personnel and researchers, 1998-2008**

Compound annual growth rate (%)



Source: OECD, *Main Science and Technology Indicators* (May 2010).

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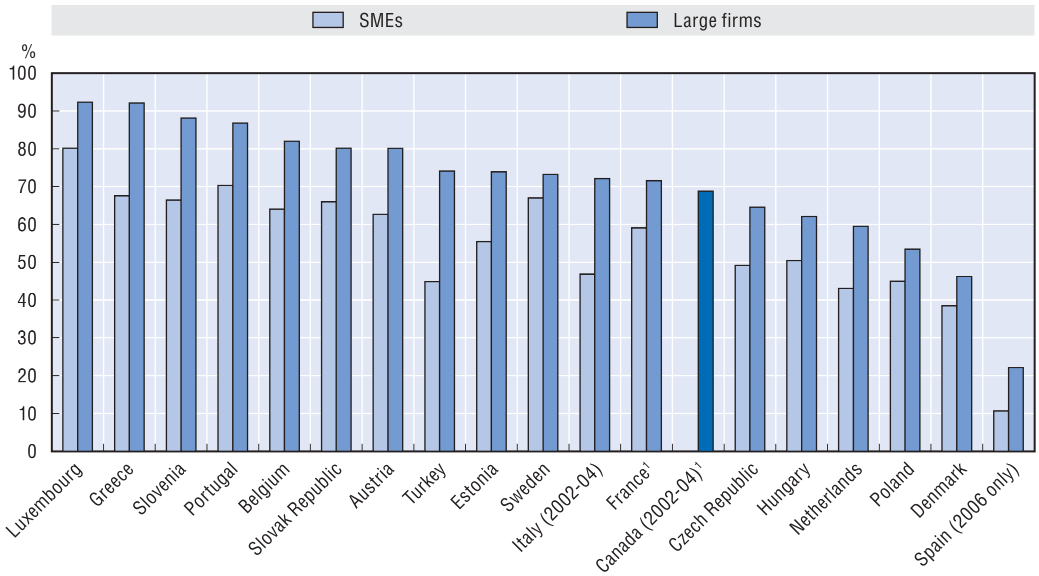
In spite of the current downturn, many countries have anticipated an ongoing increase in the demand for skilled workers. While some governments have concerns that current trends in supply will not be sufficient, the data presented earlier suggest that overall numbers of skilled people may not be the most pressing issue, given the increasing trend in tertiary attainment. Data also show that the earnings differential between workers with tertiary education and those with upper secondary and post-secondary non-tertiary education have not universally increased; in fact, the differential dropped in the last decade in Germany, Hungary, Ireland, Italy and Poland (OECD, 2009e, p. 142). Instead, the composition of skills and the matching of skilled individuals to employment opportunities may raise the greatest challenge. In addressing this challenge, it is crucial to ensure the ongoing development of human capital. Lifelong learning, whereby individuals continue to update their skills throughout their adult lives, enables the workforce to evolve to meet new skill demands. In this, the role of firms is very important, with opportunities for on-the-job training providing essential updating and extending of competences. Figure 1.11 reveals the wide variety of firms' engagement in innovation-related training activities. In Luxembourg and Portugal, more than 70% of all innovative firms provide internal or external training specifically for the development or introduction of new or significantly improved products or processes; percentages are even higher in large firms. In contrast, in Denmark, Italy, the Netherlands, Poland, Spain and Turkey, fewer than 50% of firms provided such training (if the focus is on large firms, the picture improves).

In addition to training, ongoing mobility of skilled people will provide an important means of matching the best skills to research- and innovation-related jobs. The international mobility of students and individuals trained to the doctorate level was noted above; there is also considerable mobility among skilled people in general (OECD, 2008c). Flows of people and know-how contribute strongly to sharing and augmenting the stock of global knowledge. Non-member economies will play an increasing role in this respect, with

Figure 1.11. **Firms engaged in innovation-related training activities, by size, 2004-06**

As a percentage of total innovative firms



1. Canada – data are for manufacturing only, all firms. France – data are for manufacturing only.

Source: Eurostat CIS-2006 (CIS-4 for Italy), and Statistics Canada, 2005 Survey of Innovation.

StatLink http://dx.doi.org/10.1787/888932332797

China and India already the two top exporters of students, and China devoting major resources and planning efforts to creating world-class research universities (Altbach, 2009). Globalisation is discussed further in the following section.

Both ongoing training and international mobility will help staff universities, the training ground for the next generations of researchers and other skilled individuals. The overall population of lecturers, researchers and other personnel in higher education institutions in a number of OECD countries is ageing, not because of overall ageing of the population, but because of recruitment patterns associated with the tenure system (Willekens, 2009). Training programmes may help to maintain the knowledge and skills of older staff cohorts, while personnel planning that better matches competences to jobs will be essential. Internationally mobile staff can fill gaps as well as build critical international networks that generate ongoing research collaboration. At the same time, governments must pay attention to the attractiveness of research careers. Auriol's (2010) analysis of doctorate holders found that while graduates are mostly satisfied with their situation, over 30% are unhappy about the level of salary, benefits and opportunities for advancement. Ensuring that researchers are rewarded to a level commensurate with the contribution their research and study brings to the advancement of knowledge and achievement of research goals will be an ongoing policy challenge.

Finally, making the most of all available skills for research and innovation is essential, and gender is a critical aspect of this. The concentration of men and women in certain fields of science is well documented (and demonstrated in Figure 1.9), as is the "scissor effect", which sees women's participation levels steadily drop off as the level of seniority rises. Women also tend to apply for research funding less often, for lesser amounts and to less prestigious bodies (EC, 2009b). While some of this can be attributed to personal choices, the later integration of women generally into higher education and the wider workforce, and general women's participation issues, there is also compelling evidence that barriers to female participation exist in science and technology (EC, 2008a, 2008b). In particular, persistent gender stereotypes, non-transparent nomination and appointment procedures, and use of informal processes may continue to lead to gender imbalances in science. In addition, a World Bank report (2010) which investigated aspects of the legal and regulatory environment that enables women to act as entrepreneurs and find jobs found that important gender-based distinctions still exist in OECD member countries and in the OECD's accession and enhanced engagement economies. Such differences in legal treatment, while perhaps created to protect women, should be analysed carefully to ensure that they do not limit women's opportunities or make it harder for women to contribute in the workplace.

Reaping the results

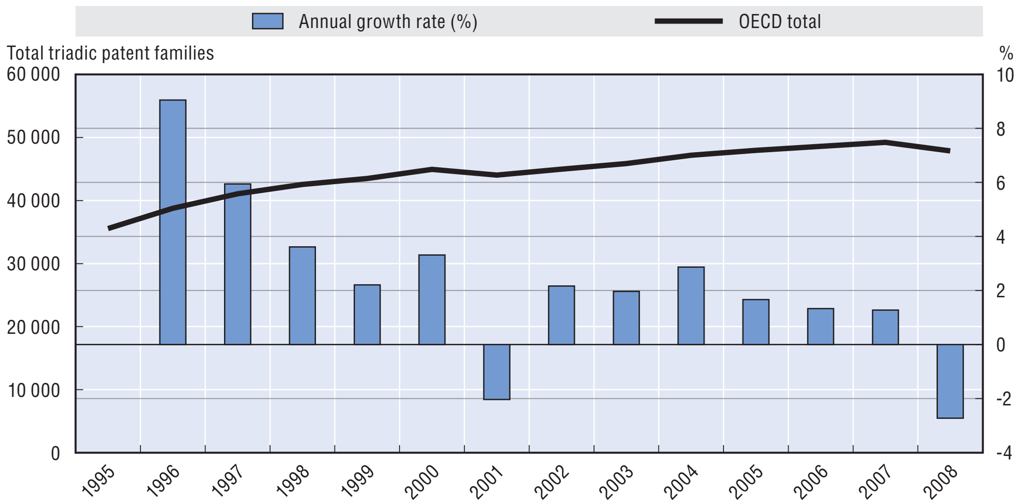
Patents and scientific articles are two measurable outputs of research which can be used to analyse the results of R&D investment. Patents can be interpreted as indicators of invention (a precursor to innovation), and there is a positive relationship between patent counts and other indicators of inventive performance such as productivity and market share (OECD, 2009h). However, it is important to note that they have certain drawbacks as indicators of technological activity, particularly in terms of coverage (not all inventions are patented or patentable), field-specificity (some technical fields have a higher propensity to file applications) and skewed value distribution (many patents have no industrial application and have low value to society, while a few patents are of extremely high value). Scientific articles are a measure of basic research and scientific discovery, and publications have traditionally been used as an indicator of the scientific productivity of universities, government research institutions and other entities. Articles are the main means of disseminating and validating research results, and their relatively open availability means that they form a key underpinning of knowledge transfer. As with patents, however, articles have some limitations as an indicator for assessing the results of research, particularly their English-language bias, differing propensities to publish across fields and quality issues.

Data on triadic patent families (*i.e.* a patent for an invention filed at the European Patent Office and the Japan Patent Office and granted at the US Patent and Trademark Office) allows for a focus on higher value patents and removes the influence of home advantage. Figure 1.12 shows that the number of triadic patents for the OECD area has grown reasonably steadily since the mid-1990s, at an average annual rate of 2.36% from 1995 to 2008. However, growth has been weaker in recent years, and OECD triadic patent applications declined in 2008. This accords with data on trademarks (another indicator of innovative activity, measuring product or marketing advances), which showed a 20% fall for 2008 (OECD, 2009e, p. 38). The most recent patent data for each country (Figure 1.12) show that Switzerland had the highest number of triadic patents relative to population, followed closely by Japan. The OECD average in 2008 was 40 triadic patent families per million population, while the OECD median was around 19. Mexico had the fewest patent families adjusted for population, below the levels of a number of non-member economies, including Argentina and Brazil. Some countries had extremely high compound annual growth of triadic patent families per million population over 1998-2008, including China (26%), Poland (17.8%), Korea (15.8%) and India (15.6%). However, when incorporating the data from 2008 a number of countries had an overall fall in population-adjusted triadic patent families from 1998-2008.

Figure 1.12. **Triadic patent families**

Trends in OECD triadic patent families[1]

Total number and growth rate

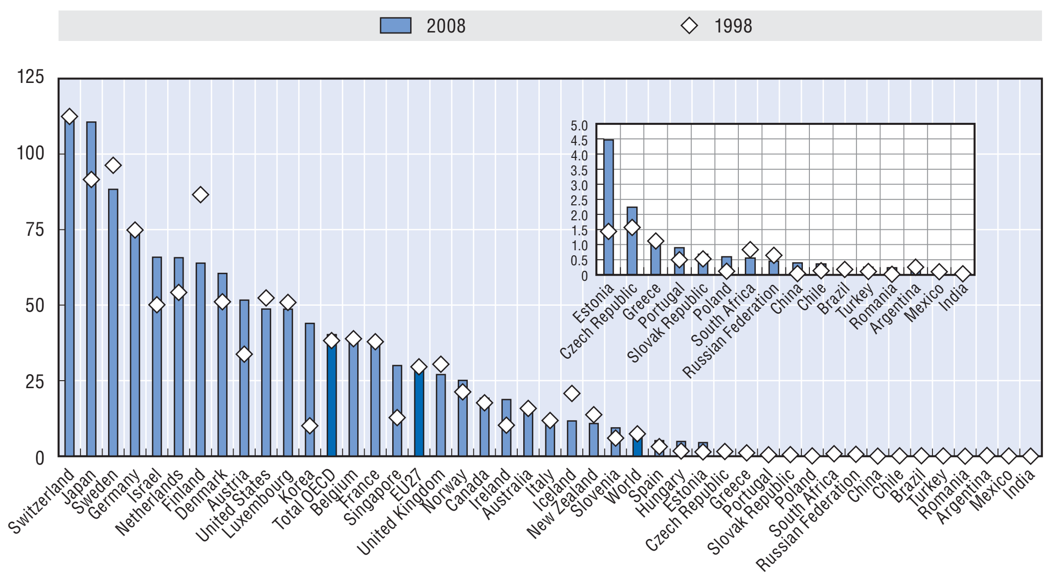


1. Patents filed at the European Patent Office (EPO), the US Patent and Trademark Office (USPTO) and the Japan Patent Office (JPO) which protect the same invention. Data from 2000 onwards are OECD estimates based on "nowcasting" (see OECD, 2009e).

Note: EPO and Patent Cooperation Treaty (PCT) patent counts are based on data received from the EPO (EPO Bibliographic Database – publications up to November 2009). Series on USPTO and triadic patent families are mainly derived from the EPO's Worldwide Statistical Patent Database (PATSTAT, September 2009).

Source: OECD, *Main Science and Technology Indicators* (May 2010).

Triadic patent families per million population, 2008



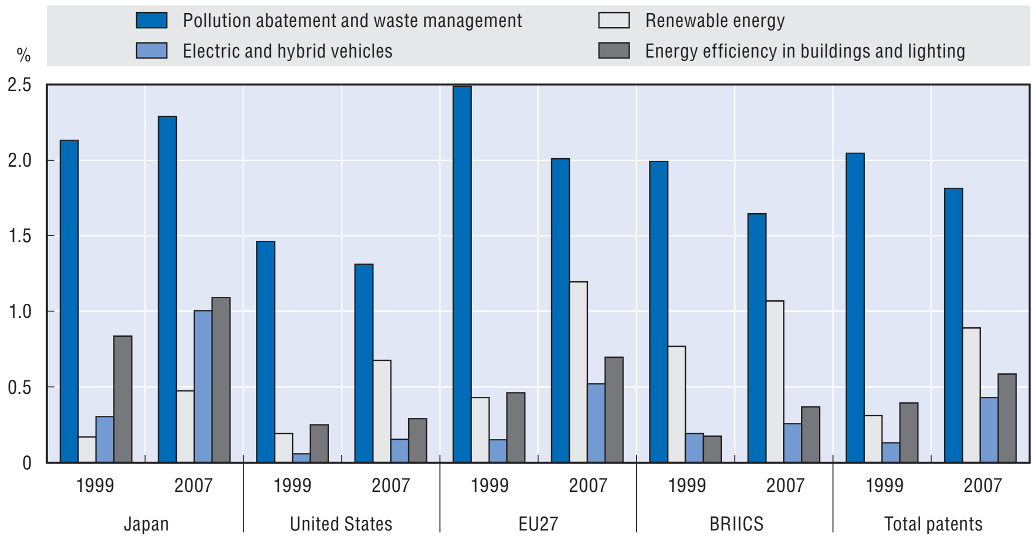
Source: OECD, *Patent Database* (June 2010); International Monetary Fund, *World Economic Outlook Database* (April 2010).

StatLink http://dx.doi.org/10.1787/888932332816

Non-member economies are making important investments in environmental technologies, a dynamic area with obvious growth potential (and clear practical relevance for the BRIICS economies – Brazil, Russia, India, Indonesia, China and South Africa) in the context of global challenges related to climate change, water and food. Figure 1.13 shows

Figure 1.13. **Patents in selected environmental technologies**

As a percentage of total PCT patent applications



Note: Data relate to patent applications filed under the PCT, at international phase, designating the European Patent Office (EPO). Patent counts are based on the priority date, the inventor's country of residence and fractional counts. BRIICS refers to Brazil, China, India, Indonesia, the Russian Federation and South Africa.

Source: OECD, *Patent Database* (July 2010).

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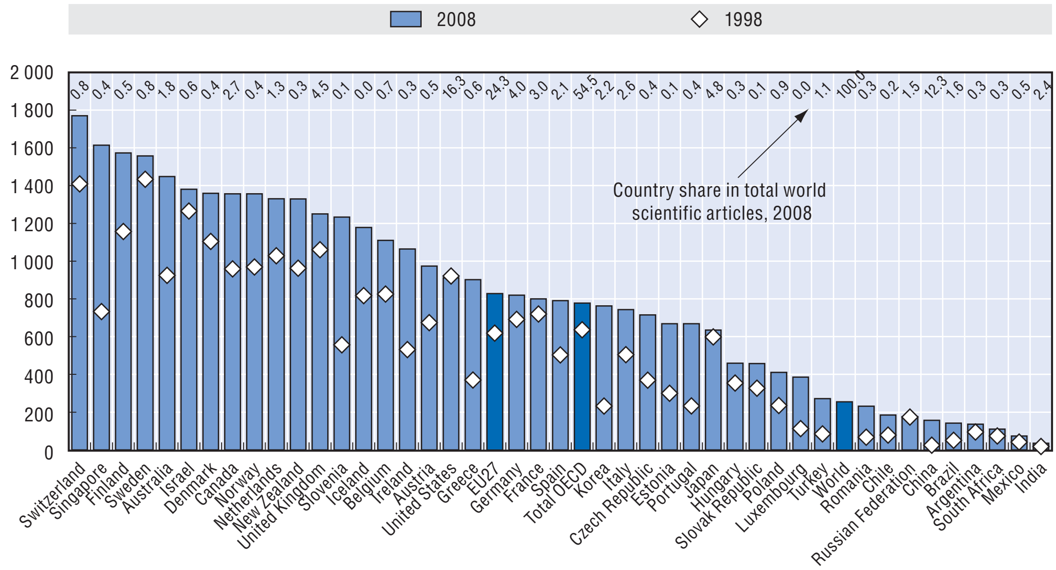
that in 2007, the BRIICS had a higher than average share of renewable energy patent applications in their submissions to the Patent Cooperation Treaty (PCT).[10] This category accounted for almost 1.1% of PCT patent applications from the BRIICS, compared to an overall share of 0.9% for this patent area in total PCT applications. Since 1999, the overall share of renewable energy patent applications to the PCT has increased, and the BRIICS have followed this trend. The BRIICS also increased their shares of electric and hybrid vehicles and energy efficiency in buildings and lighting in their PCT applications. Data on countries' shares of various environmental technology patents filed under the PCT in 2007 show that the BRIICS accounted for 1.9% of applications for pollution abatement and waste management patents (similar to the shares of Austria and Belgium) and 2.5% of renewable energy applications (similar to the shares of Austria and Switzerland). Individually, China had a share of 0.77% of the pollution abatement patent applications (similar to that of Norway); top-ranked Japan had 21.5%. In renewable energy, China's share of patents was around 1.1% (similar to Korea's); Germany's was 23.6%.

All OECD countries except the United States increased their output of scientific articles (adjusted for population size) over 1998-2008 (Figure 1.14). Among countries above the OECD average of 778 articles per million population, Greece and Ireland had relatively high growth, with compound annual growth rates of 9.3% and 7.2%, respectively. Other OECD countries with high annual growth over the period were Korea (12.6%), Luxembourg (13%), Portugal (11.1%) and Turkey (12.3%). Among non-OECD economies, Singapore had compound annual growth of more than 8% over 1998-2008, and its output of scientific articles was above the OECD average in 2008. Other non-OECD economies with fast annual growth in scientific articles were Brazil (11%), China (20%), and Estonia (8%). Switzerland replicated its overall lead in triadic patent families (Figure 1.12), with the highest number of scientific articles

Figure 1.14. **Scientific articles per million population, 1998 and 2008**



Note: Scientific articles are sourced from journals and conference proceedings and include: articles; reviews; conference papers; conference reviews; and notes. Calculations based on the address of the institution to which authors belong, and fractional counts. For Brazil, Chile, Estonia and India: population data come from the International Monetary Fund, *World Economic Outlook Database* (April 2010).

Source: OECD, *Main Science and Technology Indicators* (December 2009) and Scopus Custom Data (2009 update).

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per million population in 2008, while Mexico had the fewest on the same basis. Among OECD countries, the United States, Japan, the United Kingdom and Germany had the four highest shares of total world scientific articles (a total of 29.6%), while China accounted for 12.3% and India for 2.4% (similar to Canada, Italy and Korea).

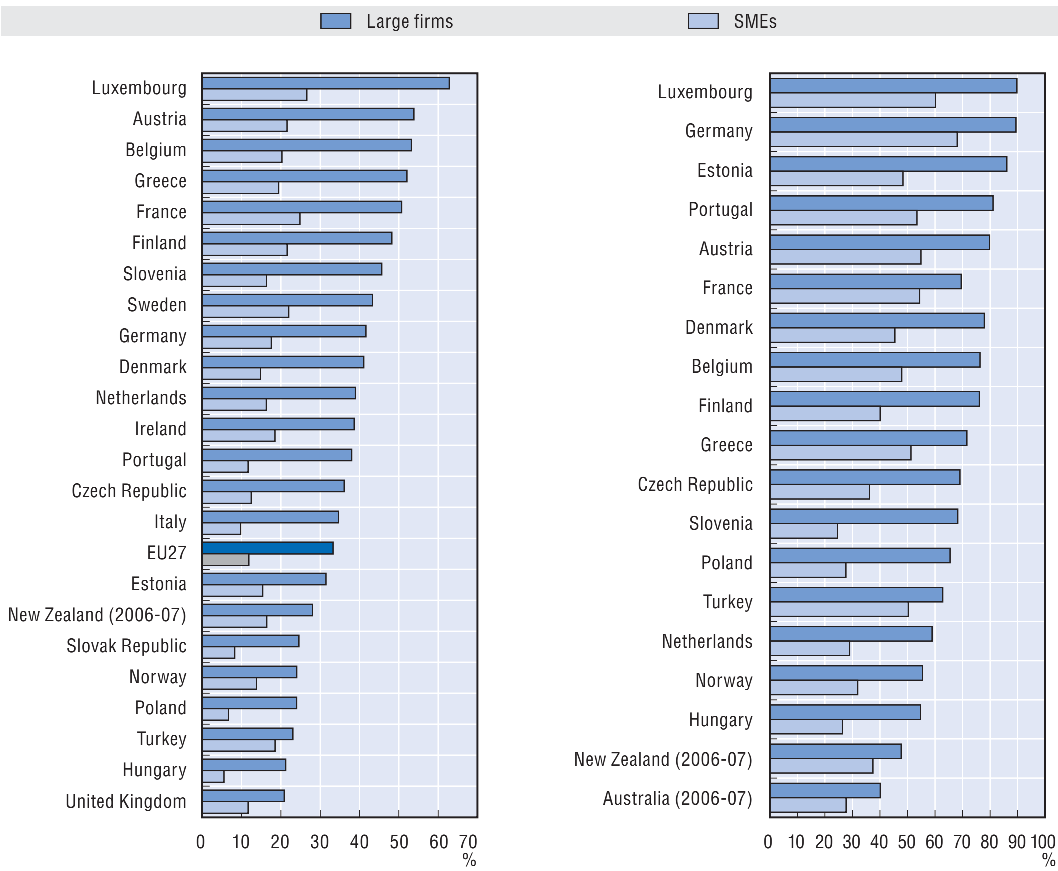
The data show a wide spread in countries' performance on patents and scientific articles. It is not necessarily the case, however, that "more is better", especially if the efficiency of production is low. Work by the National Science Board (2010b, p. 5-47) showed that from 1990 to 2001, resource inputs per publication in the top 200 academic R&D institutions in the United States increased 29% and that the pattern of increasing inputs required to produce the same quantity of publication outputs occurred across the entire US academic system. The National Science Board speculated on possible reasons, such as a rise in the complexity of research required for publication, increased communication costs for collaboration, and research costs (for faculty, postdocs, equipment, etc.) which are increasing faster than general inflation. This reinforces the point raised earlier about the importance of better measurement of the efficiency of R&D investment, particularly in an environment of tight finances. In addition, a relative lack of patents and articles does not necessarily prevent innovation. The data show that lower-income and developing countries tend to have a lower level of patent and article outputs per million population. Nevertheless, these countries can still reap innovation benefits from scientific advances through the adoption and adaptation of new ideas and technologies from elsewhere. The important issue for policy in this case is ensuring an adequate level of openness to knowledge flows and sufficient absorptive capacity to use that knowledge.

Firms may use the results of R&D as well as other inputs to develop innovative goods, services and processes (*i.e.* technological innovation), or to feed into the creation of new organisational or marketing approaches (*i.e.* non-technological innovation). Country-level innovation surveys provide information on the innovative activities of business enterprises, according to whether an innovation is new to the firm, new to the market or, at the most novel end of the scale, new to the world. Figure 1.15 shows quite a wide variation in the percentage of firms that introduced new-to-market product innovations over 2004-06. Fewer than 25% of large firms in Hungary, Norway, Poland, the Slovak Republic, Turkey and the United Kingdom introduced new-to-market product innovations over this period, while more than 50% of firms in Austria, Belgium, France, Greece and Luxembourg did so. This variation may be partly explained by industry structure, with some sectors more likely to introduce "new-to-market" products than others. A further explanation comes from the data collection process, as the definition of "market" may be interpreted differently by the firms responding to innovation surveys. In some countries, firms may regard their markets as predominantly local, while in others, they may be more active in international markets where it is harder to achieve a "new" product introduction.[11] SMEs tended to have lower levels of new-to-market product innovation; for

Figure 1.15. **Innovating firms, 2004-06**

Firms with new-to-market product innovations, by size, as a percentage of all firms

Non-technological innovators, by size, as a percentage of all firms



Note: France: manufacturing only. New Zealand: SMEs have 10-99 employees.

Source: Eurostat, CIS-2006 (May 2009).

Note: France: manufacturing only. New Zealand: SMEs have 10-99 employees. Slovenia: organisational innovations only.

Source: Eurostat, CIS-2006 (May 2009).

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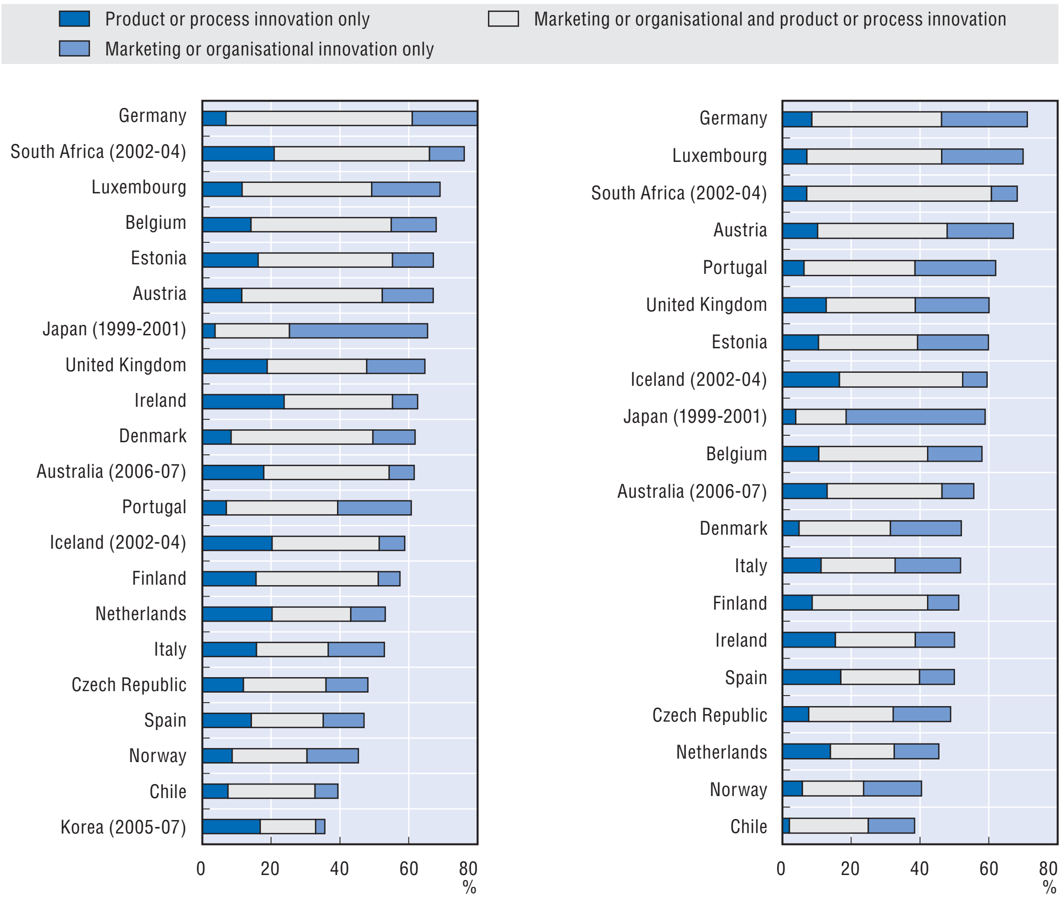
the most part, fewer than 20% of these firms had such innovations, although the level was slightly higher in Austria, Belgium, Finland, France, Luxembourg and Sweden.

Figure 1.15 also shows that a larger percentage of both small/medium and large firms introduced non-technological innovations during 2004-06; the range for SMEs was from 24.5% (Slovenia) to 68.1% (Germany), while for large firms it was from 40.1% (Australia) to 89.7% (Luxembourg). Marketing and organisational innovations are often complementary to technological innovations and are particularly important for services firms, thus widening their potential application. Indeed, the information gathered from innovation surveys indicates that non-technological innovation exists alongside technological innovation in many firms (Figure 1.16). In most countries, a sizeable percentage of both

Figure 1.16. **Complementary innovation strategies**

Manufacturing firms, 2004-06
As percentage of all manufacturing firms

Services firms, 2004-06
As percentage of all services firms



Note: For Australia (2006-07), Business Characteristics Survey 2006-07; Canada (2002-04, manufacturing), Survey of Innovation 2005; Iceland (2002-04), CIS-4; Japan (1999-2001), J-NIS 2003; Korea (2005-07, manufacturing), Korean Innovation Survey 2008; New Zealand (2006-07), Business Operations Survey 2007; South Africa (2002-04), South African Innovation Survey 2005.

Note: For Australia (2006-07), Business Characteristics Survey 2006-07; Iceland (2002-04), CIS-4; Japan (1999-2001), J-NIS 2003; New Zealand (2006-07), Business Operations Survey 2007; South Africa (2002-04), South African Innovation Survey 2005.

Source: OECD, Working Party of National Experts in Science and Technology Indicators (NESTI) Innovation Microdata Project based on CIS-2006, June 2009 and national data sources.

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manufacturing and services firms undertake product and process innovation alongside marketing and organisational innovation. There are some differences by sector, with the share of firms introducing only marketing or organisational changes higher in services than in manufacturing; even so, the share of services firms introducing both types of innovation is still higher than the share of services firms introducing only one type.

Finally, in terms of reaping the results from research, science and technology efforts, the ultimate goal is to use them to create value for society. As noted in the previous *Science, Technology and Industry Outlook* (OECD, 2008d, p. 191), the impacts of science on society and the economy range across many dimensions, and include the progress of knowledge, the introduction of innovations and the generation of new markets, through to changes in public health, the environment and organisations. Measuring impacts is difficult: the complex and multiple linkages between research and its outcomes make causality hard to establish, and time lags generate uncertainty about the full impact (both benefits and costs) of research. Ideally, one measure of the success of investments in R&D and other knowledge creation would be the extent to which the ideas found in patents, scientific articles and new innovative ideas can be used to meet challenges such as climate change and health (see Box 1.2), areas for which scientific breakthroughs and innovative solutions are keenly sought. Analysis of the economic benefits of various technologies can assist in assessments, but further work is needed to establish a coherent framework for evaluating the impacts of research on complex global challenges. Given the high level of public interest in many of these challenges and related technologies, it may be necessary to consider the standard of proof required for determining benefits and costs.

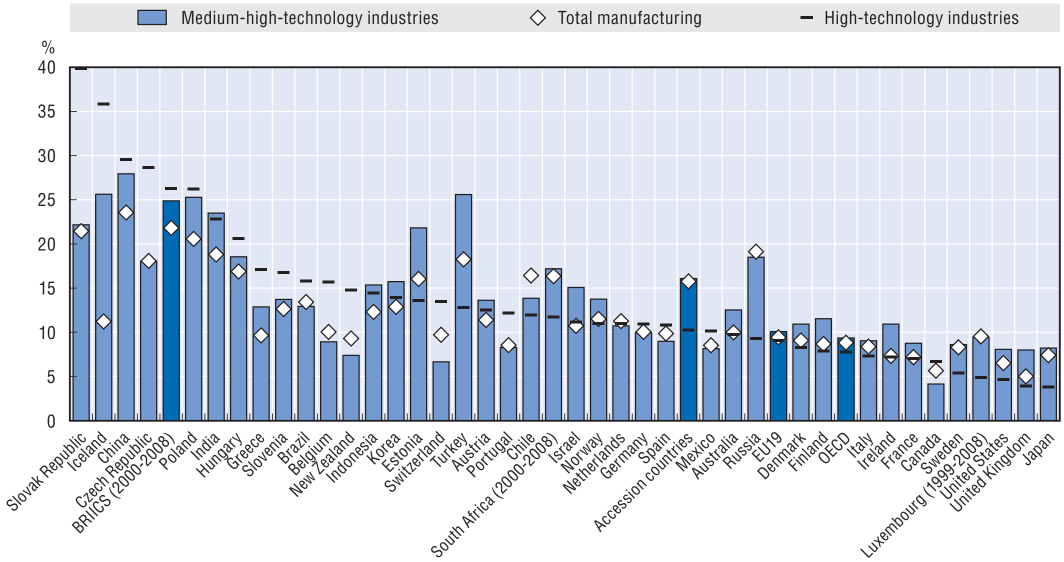
The continued importance of globalisation

In analysing the performance of research, science and technology, and the wider innovative activities of firms, it is essential to take a global view. Scientific activities are occurring and intensifying across more regions, as governments recognise that R&D leads to economic growth, employment and improved social well-being for citizens (National Science Board, 2010a). At a practical level, the conduct of research projects often requires inputs from a range of actors, and a multilateral and co-operative approach is essential to the success of many larger-scale efforts. Trade in innovative products and services, as well as foreign investment flows, are needed to tackle big issues such as climate change, and many other pressing challenges also call for multinational solutions. Firms are also recognising the benefits of collaboration and alliances and are seeking out research and innovation partners abroad. In any case, innovation is not a process easily enclosed by national boundaries. Knowledge flows across borders through the movement of people and products and through the use of increasingly sophisticated ICT tools. All this is supported by a policy environment in OECD countries that has, overall, tended towards lower barriers to trade, financial flows and movement of skilled people.

The continuing process of globalisation of science and technology is reflected in the growth of high- and medium-high-technology exports from non-OECD economies. Exports of these manufactured goods reflect the ability of countries to produce and make use of technology at a reasonably significant level, with the classification of industries into high-, medium-high-, medium-low- and low-technology based on their R&D intensities. Figure 1.17 shows that the BRIICS experienced strong growth in high- and medium-high-technology exports over 1998-2008, with average annual growth rates of around 26% and 25%, respectively. This was predominantly driven by China and India; in high-technology

Figure 1.17. **Growth of high- and medium-high-technology exports, 1998-2008**

Average annual growth rate



Note: The OECD area includes Chile but not Israel or Slovenia; the accession countries group excludes Chile and includes Israel and Slovenia. The OECD and EU aggregates exclude Luxembourg, for which data are only available from 1999. Data refer to 1999-2008 for Luxembourg, to 2000-08 for South Africa and to 2000-08 for the BRIICS group. Underlying data for China include exports to Hong Kong (China).

Source: OECD, *STAN Indicators Database*, 2010. Underlying series from the *STAN Bilateral Trade Database*.

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exports, for instance, China had average annual growth of almost 30% over the period, while India averaged 22%. In contrast, Brazil had 16% average annual growth in high-technology exports, Indonesia 14%, South Africa 12% and Russia 9% (for comparison, the OECD average was 7.8%). The annual growth rates generally slowed in 2008 for the BRIICS and OECD countries, although the reductions did not stand out from previous movements in the data over the period. The potential future rate of growth of such exports and its impact on R&D and innovation activities in non-member economies is a complex issue, and there are likely to be significant cross-country differences in accordance with sectoral specialisations and comparative advantages (Box 1.6).

Box 1.6. **Technology exports from non-OECD economies**

The extent of the expected further strong growth in high- and medium-high technology exports from non-member economies is a complex issue. With generally lower shares of high-technology exports in total manufacturing exports compared to the OECD average, there may be scope for further catch-up in high-technology manufacturing exports in some non-member economies. In 2008, all the BRIICS except China had shares of high-technology exports in total manufacturing exports below the OECD average of 22%, while the share of high- and medium-high-technology exports in the BRIICS' total manufacturing exports was 48%, compared to an OECD average of around 64% (derived from the OECD STAN Indicators Database, 2010). However, the underlying resource base and industrial structure of different economies will result in important country variations. Some countries' comparative advantage may lie in lower-technology areas and their share of high-technology exports would be unlikely to reach the OECD average in the near future.

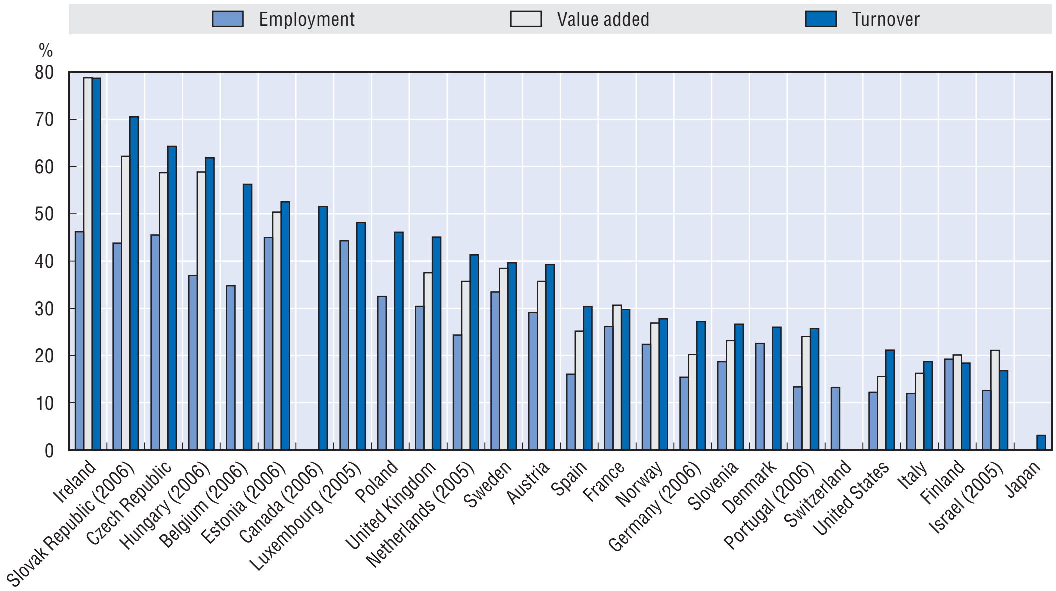
Box 1.6. **Technology exports from non-OECD economies** *(cont.)*

The impact of changing shares of high- and medium-high technology exports on R&D and innovation activities in non-member economies is also a complex issue. In China, for example, contrary to the experience of most OECD countries, R&D intensity in most high-technology industries is not substantially higher than in manufacturing on average (Schaaper, 2009). This may be because China's trade in high-technology products is still dominated by processing and assembly of imported materials, with multinational firms distributing their activities across countries in response to resource and cost considerations. Thus faster growth in high-technology manufacturing exports is not necessarily related to increased R&D activity. At the same time, lower growth in high- and medium-high manufacturing exports does not suggest that R&D and innovation are absent. Some products from low-technology industries may incorporate a high level of technological sophistication. For instance, certain food products may draw on extensive scientific research and be produced using complex manufacturing techniques. The aggregation of data into broad technology categories may mask specialisations in certain sub-sectors of high- and medium-high-technology industries in which important R&D is taking place. Finally, innovation also takes place in the services sector, where valuable advances may contribute significantly to the welfare of citizens in non-member economies.

An increasing share of foreign-controlled affiliates in manufacturing employment, turnover and value-added is another reflection of the increasingly globalised nature of economic activity. Foreign affiliates often provide access to new markets and new technologies for local operators; they also tend to invest a higher share of revenue in R&D (OECD, 2009e). During 2000-07, most countries saw an increase in the share of foreign affiliates in manufacturing turnover and employment, with the largest total increases in the Czech Republic (foreign affiliates accounted for an additional 20-25% of turnover and employment by 2007). Poland and the United Kingdom also had moderately large increases, with foreign affiliates' shares of turnover rising from 33-34% to 45-46%, and their shares of employment rising from 19-20% to 30-32%. Belgium and Italy experienced small declines in foreign affiliates' shares of turnover, while Ireland, Italy and Spain had decreases in their shares of employment. Figure 1.18 shows the most recent data on foreign-controlled affiliates in a selection of OECD countries and non-member economies. In the smaller economies of Ireland, the Czech Republic, Hungary and the Slovak Republic, over 60% of manufacturing turnover was generated by foreign-controlled firms in 2006-07, and the five highest percentages of foreign-affiliate manufacturing employment were in Ireland, the Czech Republic, Estonia, Luxembourg and the Slovak Republic.

An analysis of trends in foreign affiliates' manufacturing employment over the business cycle suggests that changes in employment in foreign affiliates resulting from the recent downturn will differ notably across countries. In some countries, affiliates follow changes in overall manufacturing employment much more closely than in others (OECD, 2009e, p. 44). In Norway and Italy, for example, over the period 2000-01 to 2006 the change in employment in foreign affiliates was 1.5-2.5 times the change in total manufacturing employment, while in the Czech Republic there was little change in foreign affiliates' employment when total manufacturing employment changed.

Figure 1.18. **Share of foreign-controlled affiliates in manufacturing employment, turnover and value-added, 2007**



Note: Production instead of turnover for Israel.

Source: OECD, *Activities of Foreign Affiliates* (AFA) *Database* and *Foreign Affiliates in Trade and Services* (FATS) *Database*, January 2010.

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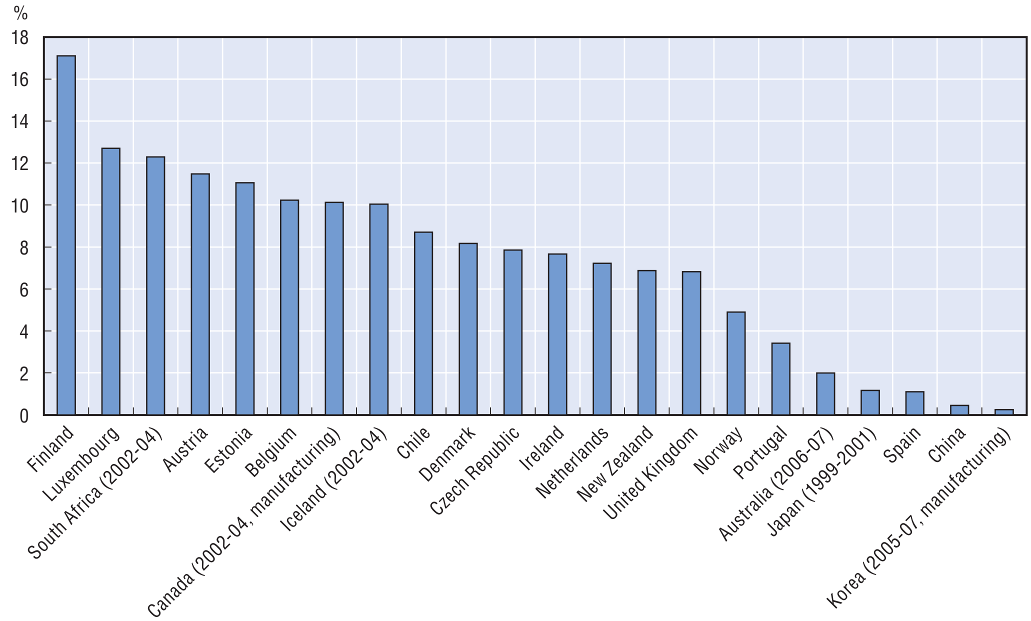
Investments in R&D activities abroad are another facet of globalisation, and one that has raised questions about the relative benefits and costs to the host and investing countries. As noted earlier, foreign-funded enterprises accounted for around 19% of R&D expenditure in China in 2008. Walsh (2007) suggested that, moving from the original rationales of establishing "listening posts" in a large market and meeting local requirements for an R&D presence, multinational enterprises (MNEs) are now establishing an R&D presence in China to complement existing production investments and to update ideas, designs and technologies to better meet local and regional demand. Walsh noted that the impact of this investment on China's technology development will depend in part on the degree to which China can effectively absorb foreign technology, research and know-how and apply these to its own scientific efforts. From the investor country point of view, the National Science Board (2010a) noted increased investments by private American firms in R&D abroad, motivated by proximity to customers, access to local expertise and educational institutions, ease of travel, location of financial assets, and lower cost structures. It commented that the worldwide restructuring of R&D, manufacturing and knowledge-intensive services challenged the United States to capitalise effectively on scientific advances, inventions and R&D work performed elsewhere. This highlights the importance for both private firms and public research bodies to build robust knowledge transfer networks through flows of people and information.

Another indicator of the globalised nature of R&D and innovation is the amount of international collaboration by firms on innovation. International collaboration allows firms to access a wider range of resources than are available in their home country and to take advantage of the different experiences and knowledge of research teams abroad. Figure 1.19 shows the percentage of firms that collaborated internationally (excluding

Figure 1.19. **Firms collaborating internationally on innovation, as a percentage of all firms**

2004-2006, or nearest available years



Note: Data exclude collaboration with other enterprises from the same group, whether national or international.

Source: OECD NESTI Innovation Microdata Project, based on CIS-2006 (June 2009) and national data sources.

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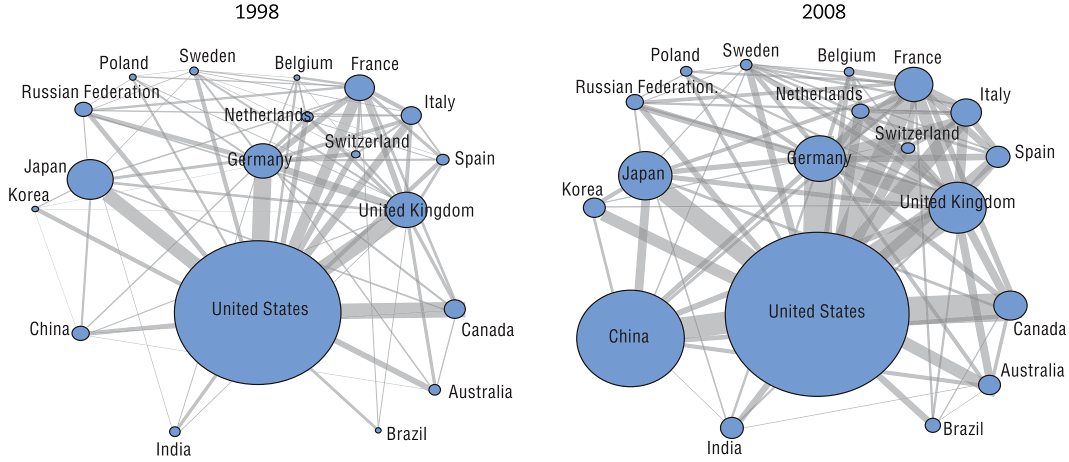
collaboration with enterprises from the same group) during 2004-06. The results range widely, and there is no strong link to country size or industrial structure. In Finland, more than 17% of firms collaborated internationally, compared to just over 1% in Spain and Japan. Estonia and South Africa had relatively high levels of collaboration, at around 11% and 12%, respectively. The absence of clear patterns and the suggestion of important country-specific factors are heightened when comparing the information in Figures 1.18 and 1.19. For example, Japan had a low share of foreign affiliates in manufacturing turnover and low levels of international collaboration on innovation, Belgium had relatively high levels of both foreign affiliates and collaboration, while Finland had low shares of foreign affiliates in manufacturing activity but high levels of collaboration.

The level of collaboration on scientific publications sheds particular light on the globalisation of academic and research institutions, since they are key sources of publication (although firms are also involved in authoring articles). Figure 1.20 displays graphically the intensity of collaboration on scientific publications (reflected by the thickness of links between countries) in 1998 and 2008. It shows that intensity has grown between a number of authoring centres, such as the United States and Germany, and that new co-authorship links have emerged, such as between Brazil and Australia. The size of the bubbles reflects the number of scientific publications, and the changes show increased activity in a number of centres, particularly China.

In addition to globalisation, however, it is important to note the regional aspect of innovation. Innovation does not necessarily take place evenly across countries; as for economic activity in general, innovation may emerge in clusters, in certain cities, or in certain regions. Patterns of patent applications, for example, show that innovative activity

Figure 1.20. **Scientific publications and co-authored articles, 1998 and 2008**



Note: Numbers based on whole counts.

Source: OECD calculations, based on Scopus Custom Data, Elsevier, December 2009.

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is quite localised – for instance, Japan's Southern-Kanto region accounted for nearly 49% of patent filings in 2005-07 (OECD, 2010d, p. 26). There are also "hot spots" of activity in fields such as renewable energy, biotechnology and nanotechnology. Altogether, the importance of globalised and regional activity points to the need for innovation policies to consider not just national factors and impacts, but also the effects of innovation actors and their activities at other geographic levels.

The future potential of non-member economies in science and technology

The figures presented in the chapter so far have shown that non-member economies have been increasing their weight and involvement in R&D systems and that some are making steady progress towards being engines of science and innovation. In terms of R&D spending, output of patents and scientific articles, and contribution to the global stock of skilled research personnel, economies such as Brazil, China, India, Russia and Singapore are playing a greater role, and the dampening impact of the financial crisis may not have moderated their research efforts as much as in some OECD countries.

Research, science and technology are critically related to the longer-term economic prospects of many non-member economies. Looking ahead, the OECD's *Going for Growth* work on the BIICS (BRIICS less Russia) economies suggested that the large income gaps between these economies and the OECD pointed to the continuing scope for catch-up as a driver of growth (OECD, 2010c, p. 210). Currently, Brazil and South Africa have GDP per capita of around 25% of that of the top 15 OECD countries, while the figures for China, Indonesia and India are around 14%, 9% and 6%, respectively. For the most part, this gap is due to lower labour productivity, although South Africa also has a relatively large gap in labour utilisation. While differences in physical and human capital are a significant source of the gap in productivity, lower total factor productivity (which is strongly related to technology) is probably the biggest driver. Adoption and adaptation of new techniques and processes, use of innovative products, and access to sources of knowledge will thus be key factors in the future trajectory of these economies, a clear indication of the importance of R&D and innovation activities.

However, a number of policy challenges must be addressed if the BIICS are to benefit from the potential of research, science and technology. Several policy areas highlighted by the OECD's *Going for Growth* analysis for their importance in economic growth also stand out for their relevance to science and technology in these economies. First, while secondary attainment among younger cohorts has increased strongly (particularly in China), tertiary attainment remains significantly below the level in OECD countries. There are also indications that the quality of education lags that in OECD countries and that there is room for efficiency gains in the administration of publicly provided education. Given that skilled human capital is vital for developing more skill-intensive industries and new technologies, as well as diffusing technology and ideas among firms (including between multinationals and local firms), ongoing improvements in education are fundamental if the BIICS are to succeed in the global R&D landscape. Second, there remain important barriers to entrepreneurship, trade and investment that discourage investment and are likely inhibiting the diffusion of new technologies and production techniques from abroad. Administrative burdens on entrepreneurs are high and discourage entry, while tariffs and restrictions on foreign ownership mean that knowledge transfer via more modern intermediate inputs and capital goods and via diffusion of better (or best) practice is constrained. Third, relatively low levels of private R&D in the BIICS reinforce the impact of low levels of human capital and barriers to trade and foreign investment that reduce the absorption of new ideas. Combined with issues of protection of property rights, and the need for ongoing financial market deepening that would free up capital for entrepreneurial endeavours, it is clear that while the BIICS have massive potential in research, science, technology and innovation, they also have to meet substantial policy challenges.

Alongside these common policy challenges, however, a large variety of country circumstances will also influence the speed and direction of progress in science, technology and innovation. First, the outlook for non-member economies obviously differs substantially according to their level of development. Foray (2009) noted that lower-income countries are less exposed to external technologies and have weaker absorptive capacities. In this case, the path to increased involvement in global science and innovation systems will be longer than for economies with more established trade and investment links and a larger base of knowledge institutions and actors. For lower-income countries, Foray suggested that policy needed to aim at supporting entrepreneurs in their discovery of promising country-specific areas for science and innovation, as well as at developing research capabilities, investing in human capital and removing barriers to interaction between knowledge producers and users.

Second, the focus of science, technology and innovation for emerging economies will differ according to country-specific circumstances, and may be (and in some cases needs to be) different from that of OECD countries, at least in the near future. For instance, work by the World Bank on India's innovation potential highlighted the necessity of spreading the gains from innovation across the wider population (World Bank, 2007). It noted the dual nature of India's economy, with world-class players in biotechnology and ICTs existing alongside a subsistence economy in which almost 50% of women and 25% of men are illiterate. As well as reforms to education and competition, and policies to better diffuse existing knowledge across enterprises, the World Bank called for the promotion of "inclusive innovation", which would seek innovations of value for the poorer segments of society (*e.g.* solar power for poor rural households), support the innovation efforts of "grassroots" innovators (*e.g.* IPR for traditional knowledge) and help the informal sector absorb knowledge and upgrade technology. With around two-thirds of India's population relying on rural employment for a living, innovations relating to this sector will be particularly relevant. Some efforts are under way, such as the World Bank's *India National Agricultural Innovation Project*, introduced in 2006, which aims to accelerate collaboration among public research organisations, farmers, the private sector and stakeholders in the use of agricultural innovations.[12] Battelle and *R&D Magazine* (2009) noted that the Indian government plans to increase R&D spending as a percentage of GDP to 2% by 2012, with a particular focus on the agri-biotechnology sector. (Currently, the pharmaceutical industry is a key player in the Indian innovation system, accounting for 20% of total R&D expenditures, and the automotive industry is also a leading player.)

Third, the political environment that provides a backdrop to decisions on science and technology in emerging economies will have an important effect on the shape of their future R&D and innovation activity. With respect to China, for instance, Battelle and *R&D Magazine* (2009) noted that the key policy difference with OECD countries is that political goals dominate in China. The top-down elaboration of Chinese S&T and innovation policies has focused on achieving specific objectives, including promoting basic research in selected scientific fields and R&D on new technologies in selected high-technology areas of national priority, such as biotechnology and energy technology (OECD 2008e, p. 78). However, looking ahead, the OECD's review of China's innovation policy recommended that R&D efforts be widened and provide support to industries that are not considered high-technology (such as traditional industries and the services sector). It also recommended that a greater role be given to market forces, competition and the private sector. In this context, Roach (2010) considered that China's current export- and investment-driven development model is not sustainable in the face of post-crisis reductions in demand and that the forthcoming 12th Five-Year Plan should concentrate on moving China towards a new growth model, with policies promoting a transition to an internally driven consumption model. Roach suggested that by unlocking the income-generating potential of rural citizens, enabling the development of service industries and expanding the social safety net, China could increase employment growth, reduce environmental degradation, and temper the risk of global trade frictions. It is not clear what such a policy would mean for R&D priorities in China, although one corollary of an increased focus on the services sector could be an increased demand for innovative solutions in sectors such as retail, health and business services.

For OECD countries, the rise of non-member economies in research, science and technology creates both opportunities and challenges. Non-members offer large consumer markets, new sources of skilled people and ideas, and new collaborative networks. At the same time, the resulting re-organisation of production and research activity pushes OECD governments to adopt policy frameworks that support the reallocation of resources to new activities and help people adjust. Importantly, the increasing participation of non-OECD economies in R&D and technology is not a zero-sum game. As the improved performance of individual OECD countries can be viewed as a source of combined strength and an opportunity to expand the global stock of knowledge that can be drawn on to solve societal challenges, so too the increased activity and proficiency of non-member economies can be viewed as ultimately benefiting all countries.

Summary

Since the 2008 *Science, Technology and Industry Outlook*, the global economy has experienced a financial crisis and an economic downturn that has affected most countries across the world. Growth has resumed in the OECD area but the economic outlook is weak and government budgets are under extreme pressure in a number of countries. Although fiscal packages introduced in the wake of the downturn included a number of supports for businesses, these should soon be withdrawn and the need for fiscal consolidation may constrain some OECD governments that seek to maintain their investment in R&D and innovation. At the same time, science, technology and innovation will play a key role in emerging from the downturn and in building "the world we want to see" in terms of new regimes of production and consumption that support sustainability and other societal goals. In this respect, governments should make efforts to protect their R&D and innovation investments from cuts and aim to improve the efficiency and effectiveness of their R&D budgets.

Real growth in investment in gross domestic and business R&D, while still positive, slowed in 2008 in the OECD area. However, behind this lay much cross-country heterogeneity, with some countries experiencing falls in R&D intensities in 2008, some experiencing reductions in absolute spending levels, and other maintaining strong expenditure growth. Given lags between changes in the macro-environment and changes in R&D investments, as well as the timing of fiscal stimulus packages (generally starting from 2009), attributing movements in the recent data to firm and government responses to the crisis calls for caution. Cross-country data for 2009 will enable a deeper analysis of the impact of the economic downturn on R&D; early indications point to a slowing of investment.

Differences across countries in terms of industrial and institutional structure caution against too strict a comparison of levels of business and government spending. In fact, the central question is what value this investment has yielded. Patents steadily increased over the last decade, although growth was slower in recent years, and there was a fall in applications in 2008. Scientific publishing increased for almost all countries, and innovation survey data show activity across the spectrum of product, process, organisational and marketing innovation. The contribution to societal outcomes is difficult to determine, and further work is needed to establish a coherent framework for evaluating the impacts of research on complex global challenges.

Most countries have experienced increases in their human capital for research, science and technology, and the ongoing mobility of students creates a strong base for later flows of researchers and knowledge across countries. With concerns about meeting future demand for skilled workers, governments and firms will be challenged to ensure the ongoing development of human capital, and lifelong learning and on-the-job training will be important. It is noteworthy that many innovative firms provide innovation-related training to their staff. Making the most of all available skills will be essential, and continued efforts to optimise female participation in science and technology will reap rewards.

Scientific activities are intensifying and occurring across more regions and a global view is essential. An increasing share of foreign-controlled affiliates in manufacturing employment, turnover and value added is one indicator of this; others are the rise of international collaboration and co-authoring. Non-member economies are playing a

greater role and are making important investments in dynamic areas with growth potential, such as environmental technologies. Research, science and technology will be critical to the longer-term economic prospects of these economies, and catch-up will be a continuing source of growth for them. Nevertheless, some policy challenges must be addressed if these countries are to meet their innovative potential, especially in terms of improvements in tertiary education attainment, barriers to entrepreneurship, trade and investment, and levels of private R&D.

Notes

1. See, for example, OECD (2003), Guellec and van Pottelsberghe de la Potterie (2004), and Khan and Luintel (2006).
2. The OECD *Main Science and Technology Indicators (MSTI) Database* includes data for 32 OECD member countries (Chile is not included), an OECD aggregate (not including Chile or, at this time, Israel or Slovenia), an EU27 aggregate, the OECD accession economy of Russia, the OECD enhanced engagement economies of China and South Africa, and several other non-member economies such as Argentina, Romania and Singapore. Where possible, data on all members and all accession and enhanced engagement economies are given; however, this depends on data availability within the datasets used. Note that data are not available for all countries for all of the figures presented in this chapter. The MSTI documentation contains a full account of country-specific data issues in this database.
3. Note on recent OECD membership changes and data:

   Chile: Chile became a member of the OECD on 7 May 2010. Chilean data on science and technology are not yet part of the OECD *Main Science and Technology Indicators (MSTI) Database*. References to OECD historical averages in the following sections do not include Chile unless explicitly noted.

   Estonia: On 10 May 2010, the OECD's governing Council invited Estonia to join the Organisation. Estonia will formally become a member of the OECD when it has deposited an instrument of accession to the OECD Convention with the depositary (the French Government). Estonian data on science and technology are not yet part of the OECD *MSTI Database*.

   Israel: On 7 September 2010, Israel became a member of the OECD. Israeli data on science and technology are available in the OECD *MSTI Database*; however, references to OECD historical averages in the following sections do not include Israel unless explicitly noted. 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.

   Slovenia: Slovenia became a member of the OECD on 21 July 2010. Slovenian data on science and technology are available in the OECD *MSTI Database*; however, references to OECD historical averages in the following sections do not include Slovenia unless explicitly noted.
4. The EU27 includes: Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, the Slovak Republic, Slovenia, Spain, Sweden and the United Kingdom.

   Data note concerning Cyprus in this document:

   The following note is included at the request of 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 the United Nations, Turkey shall preserve its position concerning the 'Cyprus issue'." *The following note is included at the request of 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."
5. For most of the non-OECD economies featured in MSTI, PPP rates provided by the World Bank are used to convert data from national currencies into PPPs. If R&D is relatively expensive in some groups of countries compared to others, the use of PPP data may distort the comparison of real expenditures on R&D. However, alternative methods of producing comparable data across

countries are not yet available. A discussion of methods for deflating and converting data on R&D expenditures expressed in national currencies is contained in Annex 9 of the *Frascati Manual* (OECD, 2002).

6. The high intensity in Sweden may be partly a result of the particular structure of public R&D in Sweden, and partly due to accounting practices (*e.g.* PhD students in Sweden are employed full time by their university). For further information, see Granberg and Jacobsson (2006).
7. In assessing the data, it is important to be aware of changes in methods, breaks in series and national practices (for example, reforms to governance and ownership arrangements that have the effect of changing the sectoral attribution of institutions). The documentation for the *MSTI Database* has further information.
8. Data drawn from the OECD *Entrepreneurship Financing Database* (April 2010).
9. Tertiary type-A qualifications equate to the International Standard Classification of Education (ISCED) level 5A, which are largely theory-based tertiary programmes that are intended to provide sufficient qualifications for gaining entry into advanced research programmes and professions with high skills requirements. Tertiary type-B qualifications equate to ISCED 5B; they are typically shorter qualifications and focus on occupationally specific skills geared for entry into the labour market. Advanced research programmes equate to ISCED level 6 and are devoted to advanced study and original research.
10. The PCT (Patent Co-operation Treaty) allows countries to seek patent rights in a large number of countries by filing a single international application (PCT application) with a single patent office. Over 130 countries are party to the treaty. The decision on whether to grant or reject patent rights rests with national or regional patent offices. See OECD (2009e) for further details.
11. The *Oslo Manual* (OECD and Eurostat, 2005) notes that an additional option for innovation surveys is to ask whether innovations are new to the world. Some countries, such as Australia, use this category in their innovation survey to further distinguish the degree of novelty (ABS, 2006).
12. See World Bank, India National Agricultural Innovation Project, Project ID P092735.

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ANNEX 1.A1

Relationship of R&D expenditure growth to growth in researcher numbers

OECD countries have experienced ongoing growth in the number of researchers, with half of all countries seeing growth in full-time-equivalent researchers of more than 4.5% a year over 1998-2008. To begin to investigate whether this growth is driven by the business sector or other sectors, the figures below plot the compound annual growth rate (CAGR) of gross domestic expenditure on R&D (GERD), business enterprise expenditure on R&D (BERD) and higher education expenditure on R&D (HERD) against the compound annual growth rate of total researchers, business enterprise researchers and higher education researchers (all expressed in full-time-equivalent terms), respectively, for OECD countries over 1998-2008 (or the nearest similar period; see Box for details). The figures include a simple linear trend line and associated regression results.

The figures show a relatively strong relationship between GERD growth and total researcher growth, with a 1 percentage point increase in the compound annual growth rate in a country's gross R&D expenditure associated with a 0.81 percentage point increase in the compound annual growth in total researcher numbers. However, the relationship is stronger for BERD, with a 1 percentage point increase in the growth of BERD associated with a 1.07 percentage point increase in growth of business enterprise researchers. For HERD, the relationship between spending and researcher numbers is similar to that for GERD. The figure for OECD countries (excluding Luxembourg) shows that a 1 percentage point increase in the compound annual growth rate in a country's HERD is associated with a 0.76 percentage point increase in the compound annual growth in higher education researcher numbers. One explanation of these observations may be the more applied nature of business R&D activities, which may be more labour-intensive, but further analysis is required to fully explore the issue.

Data notes

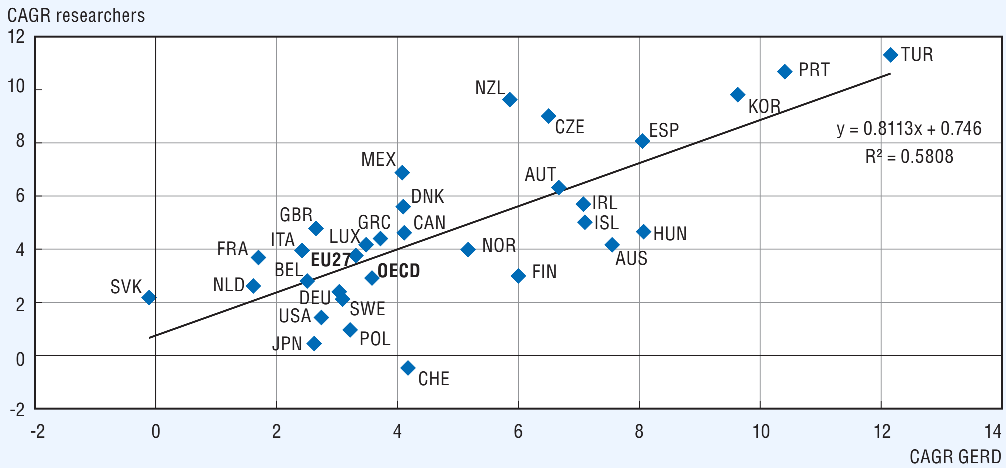
The data on R&D expenditure and researchers are drawn from the OECD's MSTI Database, for the period 1998 to 2008. In some cases, data were not available for this time period, in which case the following data points were used:

GERD and researcher data: Australia 2006; Canada 2007; France 2007; Greece 1999-2007; Luxembourg 2000; Mexico 2007; New Zealand 1999-2007; Norway 1999; Sweden 1999; Switzerland 2000; Turkey 2007; United States 1999-2007. Total OECD 2007.

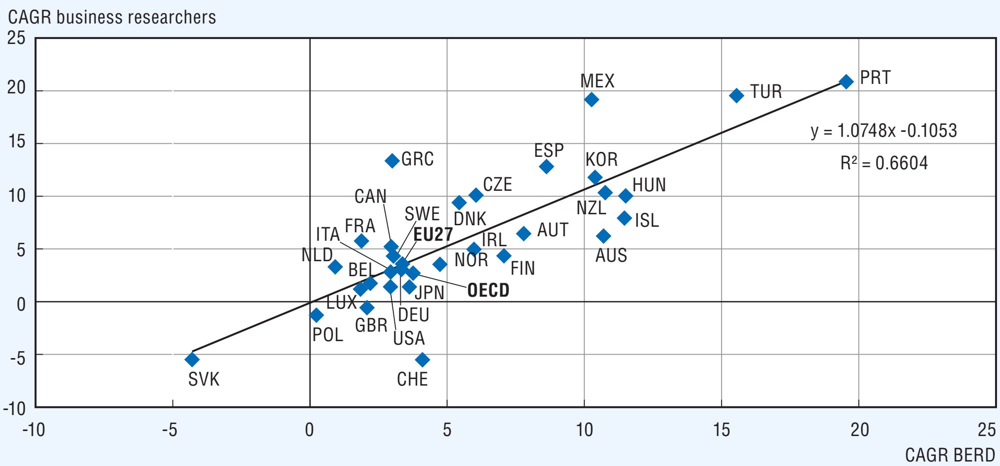
BERD and business enterprise researcher data: Australia 2007; Canada 2007; France 2007; Greece 1999-2007; Luxembourg 2000; Mexico 2007; New Zealand 1999-2007; Norway 1999; Sweden 1999; Switzerland 2000; Turkey 2007; United States 2007. Total OECD 2007.

HERD and higher education researcher data: Australia 2006; Canada 2007; Denmark 1999; France 2007; Greece 1999-2007; Mexico 2007; New Zealand 1999-2007; Norway 1999; Sweden 1999; Turkey 2007. No recent data available for United States or OECD aggregate. Luxembourg not included due to extreme outlier status.

Relationship between GERD and total researchers, 1998-2008 (or nearest similar period)

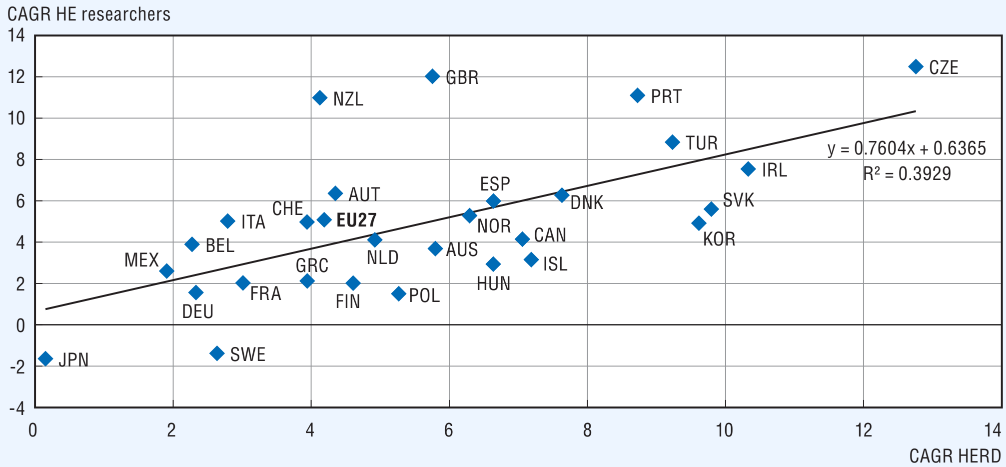


Relationship between BERD and business enterprise researchers, 1998-2008 (or nearest similar period)



Data notes *(cont.)*

Relationship between HERD and higher education researchers, 1998-2008 (or nearest similar period)



Source: OECD *MSTI* (May 2010) and OECD calculations.

StatLink http://dx.doi.org/10.1787/888932332987

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Chapter 2

Main Trends in Science, Technology and Innovation Policy

This chapter presents the main trends in national science, technology and innovation policies, with a particular focus on policies and programmes introduced between 2008 and 2010. It discusses developments relating to public-sector research, government support for business R&D and innovation, collaboration and networking among innovating organisations, globalisation of R&D and open innovation, human resources for S&T, and the evaluation of research and innovation policies.

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.

Introduction

Since the 2008 edition of the *OECD Science, Technology and Industry Outlook,* science, technology and innovation policies have continued to evolve in terms of strategic orientation and related governance structures and with respect to the "policy mix" of instruments.[1] A key message is that despite the recent economic crisis, OECD governments so far have maintained – and in some cases expanded – support for research and development (R&D) and innovation as a means to foster longer-term economic growth, especially in the face of growing competition from emerging economies. In particular, strengthening the science base and the business sector's capacity to innovate and generate new sources of economic growth, especially in "green" areas, remains a key focus of public policy. At the same time, policies for supporting science, technology and innovation are becoming more broad-based and interdependent. On the one hand, there is awareness in policy circles that non-technological innovation and the diffusion and application of new and existing knowledge in both the private and public sectors can help foster productivity and generate growth. On the other hand, there is growing recognition that horizontal policies to support business innovation – from R&D tax credits to innovation voucher schemes for small and medium-sized enterprises (SMEs) – must consider the broader local and global technological and economic context. This is illustrated by a growing effort in some OECD countries to better align supply and demand-side public support for innovation. Indeed, and despite the counter-cyclical boost to public and private R&D in response to the recent economic crisis, policy reform remains on the agenda as OECD countries seek to improve the outcomes and impacts of public support to research and innovation.

A broad set of policy trends has thus emerged or been reinforced since the last edition of the *STI Outlook*:

- *Across many OECD countries,* recent policy trends point to a "greening" of national research and innovation strategies as most countries continue to place environmental issues, climate change and energy high on the agenda of their national science, technology and innovation (STI) strategies. Health and quality of life also remain important priorities in the strategies of OECD countries. In addition, national STI strategies are being complemented by national educational initiatives or strategies as well as regional innovation plans.
- *As global growth shifts to areas outside the OECD, emerging economies – from China, Brazil, Russia and South Africa – increasingly focus on innovation as a means to move up the value chain.* The policy focus is not just on developing technological innovations for export competitiveness, but also on using existing technologies and non-technological innovations to address infrastructure and social needs such as water, health, education, transport and energy.
- *The "governance" of STI remains a key issue on national agendas but also with regard to international collaboration to address global challenges.* Some countries have reorganised

ministerial or departmental functions to strengthen the links between R&D and higher education or between industry and research. Others have enhanced structures to involve societal stakeholders. Germany and the Nordic countries have also launched internationalisation strategies for their public research sector in order to facilitate, and to build capacity for, multilateral collaboration in STI.

- *Re-investing in the science base.* Another development in national strategies concerns the re-emergence of the science base as essential to future innovation, especially as concerns the technologies that will be needed to achieve environmental sustainability. Hungary, Japan, Norway and Sweden give the highest priority to strengthening the science base in order to drive future innovation.
- *Countries are focusing support on key research areas and enabling technologies* such as biotechnology, nanotechnology, information and communication technology (ICT), new materials and advanced manufacturing. While most countries support research in such technologies, there is a growing effort to better target policy support at different stages of the innovation value chain (*i.e.* providing incentives for R&D via grants or tax credits, or fostering specific technology clusters or venture funds) in order to enhance the ability of firms to capitalise on public and private investments and specialise in emerging technologies and industries.
- *Reform of funding mechanisms for research institutions continues* to link budget allocations to performance in order to enhance excellence.
- *Full-cost economic recovery for public research funding is gaining ground in OECD countries.* This allows research institutions to amortise assets and overheads and invest in infrastructure at an adequate rate to maintain future capability.
- *Direct and indirect support to business R&D and innovation continues to increase*, but as in previous years it is characterised by streamlining programmes and improving ease of access and use, especially for SMEs. There is also growing interest in assessing the interaction of various policy instruments used in the "policy mix".
- *Countries continue to adjust R&D tax credits* either by reviewing eligible R&D expenditures or reformulating levels of support in order to increase impact and effectiveness in light of their specific industrial structure and context.
- *Demand-side innovation policies such as innovation-friendly procurement and standards,* are receiving growing attention both in OECD and emerging economies although evaluating impacts and aligning demand with supply-side policies remain a challenge.
- *The recent focus on innovation in the public sector*, for example in the United Kingdom and the United States, has received an impetus as fiscal consolidation in OECD countries creates pressure to generate efficiency gains in the delivery of public goods and services, but also presents new opportunities for innovation.
- *Fostering industry-science relations is an area of continuing reform and policy experimentation.* Countries continue to reform their universities to allow for greater collaboration and public-private partnerships. New initiatives include programmes to speed up commercialisation and promote academic entrepreneurship and spin-offs.
- *Policies to support knowledge networks and markets are emerging.* Key instruments include measures to upgrade ICT infrastructure, improved access to public research data and IPR training on and support for intellectual property rights (IPR) in academia.

- *Support for non-technological and user-driven innovation, including in services, is increasing in some countries*. Recognising that non-technological and other forms of innovation (*e.g.* design, branding) are important for competitiveness, especially in services firms, member countries such as Chile, Denmark, Finland and the United Kingdom, as well as non-members such as Brazil, are trying to raise awareness and encourage non-technological innovation alongside technological innovation.
- *Human resource development and capacity building remain important for innovation*. Policies to improve the development of human resources in science and technology (HRST) range from initiatives to raise interest in and awareness of science among youth, reduce gender gaps in science and technology education, and improve funding opportunities for PhD study and postdoctoral training.
- *The international mobility of students and young researchers and other highly skilled expatriates also remains a high priority in OECD countries that compete for foreign talent*. However, as patterns of world trade, foreign direct investment (FDI) and R&D evolve to include more south-south flows and north-south flows, the international mobility of the highly skilled may also evolve, making it more challenging for some OECD countries to attract foreign talent.
- *A broad-based approach to evaluation is developing that takes into account the qualitative impacts on the economy* as well as the impacts on the missions and development of research institutions themselves. There is also increasing interest in using evaluation findings for policy design.

National strategies for science, technology and innovation

At first glance, the national innovation strategies of OECD countries appear broadly similar. Indeed, strengthening business innovation to improve industrial competitiveness remains a common goal of national plans or strategies for science, technology and innovation in OECD countries especially in terms of raising productivity growth, jobs and living standards. Non-member and emerging economies also view innovation as a means to modernise economic structures and achieve sustainable growth. However, even among OECD countries there are differences in emphasis. For countries that already rank high in terms of business R&D and innovation, such as Korea, Japan and the United States, there is renewed focus on investing in the science base, both public research and human resources, to strengthen the base for future innovation. These countries are also prioritising their research and innovation support to gain competitive advantage for future growth areas such as green technologies and health and at the same time helping to address global challenges. In Germany, for example, successive governments decided to continue the High-Tech Strategy beyond its first phase (2006-09) until 2013, and then 2020, but with a focus on priorities: health, nutrition, climate protection, energy, mobility, security and communication. These are areas in which Germany has the potential to develop lead markets and which contribute to addressing social and global challenges. In addition, in 2009, the federal government and the *Länder* decided to continue three major German policy initiatives that complement the High-Tech Strategy: the Higher Education Pact, the Initiative for Excellence and the Joint Initiative for Research and Innovation. The total funding volume amounts to EUR 18 billion.

For OECD countries in which innovation performance lags, there is a focus on building the institutional capacity to steer or "govern" STI policies, to strengthen the links between public research and industry and to improve the quality of higher education and research. For their part, catching-up and emerging economies are seeking to integrate STI strategies as part of their national economic development strategies. A summary of major developments is presented in Table 2.1.

Table 2.1. **Revised or new national plans for science, technology and innovation policy in OECD countries and selected non-member economies, 2010**

Country	National plan	Period covered	Main objectives
Australia	Powering Ideas: An Innovation Agenda for the 21st Century	2009-20	Integration of innovation across the economy, supported by a substantial boost in funding to: improve high-quality research; reinforce the base of skilled researchers; foster industries of the future and secure value from R&D commercialisation; improve dissemination of new technologies, processes, and ideas; encourage a culture of research; increase sectoral and international collaborations on R&D; and improve policy development and service delivery.
Austria	National STI Strategy 2020	2010-20	Improve networking and co-operation between science and industry; strengthen framework conditions; public infrastructure; financing innovation and foster human resources for innovation.
Belgium	Federal Government Agreement	Since 2008	Federal Belgian policy focuses on reducing costs of researcher employment, stimulating the creation and development of SMEs and supporting R&D efforts towards the 3% of GDP Lisbon target.
	Flanders in Action and Pact 2020	2009-20	Flemish policy focuses on the 3% targets boosting investments in higher education institutions (up to 2% of GDP), boosting creativity and innovative capacity, giving more attention to research outputs, encouraging students to study sciences and giving researchers better prospects. Flanders also foresees a simplification of the set of innovation policy instruments.
	Marshall Plan 2.0 Vert	Since 2009	Wallonia's strategy focuses on boosting business R&D and linking universities to industry, consolidating clusters, especially in environmental technologies, strengthening human capital and vocational training, and putting a stronger focus on sustainable development.
	2006 Regional Innovation Plan	2007-13	Brussels Capital Region focuses on regional clusters and plans to increase regional R&D capacities up to the 3% target by focusing on three areas (ICT, health, environment).
Brazil	Action Plan in Science, Technology and Innovation for National Development	2007-10	Leverage STI for Brazil's sustainable development: boost innovation in the business sector, *inter alia*, by increasing the share of researchers in firms to 33.5% and the share of innovative firms receiving government support to 24% by 2010 and consolidate the national innovation system (the Brazilian Technological system, SIBRATEC).
	Productive Development Programme	Since 2008	Raise private R&D expenditures to 0.65% of GDP. Increase innovation resources; strengthen IPR system (double patent deposits by national firms in Brazil and triple patent deposits abroad).
Canada	Mobilizing Science and Technology to Canada's Advantage	2007 onwards	The strategy is based on four guiding principles: promoting world-class excellence; focusing on priorities; fostering partnerships; and enhancing accountability. In June 2009, the government released a progress report on the implementation of the strategy, and expressed its commitment to bring forward investments to make Canada a world leader in science and technology.
Chile	National Innovation Strategy for Competitiveness	From 2006	Build the institutional framework for the national innovation strategy in order to improve medium-term competitiveness and, in the longer term, double GDP per capita; improve technology absorption; increase critical mass in scientific capacity; build human resources in S&T.

Table 2.1. **Revised or new national plans for science, technology and innovation policy in OECD countries and selected non-member economies, 2010** *(cont.)*

Country	National plan	Period covered	Main objectives
China	Medium- and Long-term Programme for Science and Technology Development	2006-20	Enhance China's S&T and innovation capabilities; use innovation as a tool for restructuring Chinese industry; shift growth modes from investment-driven to innovation-driven; build a conservation-minded and environmentally friendly society; and enhance independent innovation capabilities as a national priority. Raise R&D investment to 2.5% of GDP by 2020; rank in the world top five in patenting and international citations.
Czech Republic	National Policy for Research Development and Innovation	2009-15	Improve efficiency of and simplify R&D support, support excellence in R&D and facilitate application of R&D results in innovation, strengthen co-operation with users of R&D results, improve organisational flexibility of public research institutes, ensure HRST supply, increase involvement in international co-operation. Four thematic areas have been prioritised: sustainable energy and competitive industry, molecular biology for health and prosperity, information society, society and environment.
Denmark	Denmark 2020 – Knowledge > growth > prosperity > welfare	2010-20	Increase public investment in research and innovation, strengthen fundamental research and develop world-class universities (at least one Danish university to be in Europe's top ten by 2020), improve co-ordination in the national innovation system, focus on green research and innovation, increase internationalisation of universities (all Danish universities should maintain or improve their international rankings).
Estonia	Knowledge-Based Estonia. Estonian Research and Development and Innovation Strategy	2007-13	Increase value added in manufacturing and services and enhance export capability: increase intensity and quality of R&D (increase R&D expenditures, HRST supply, patenting, publications, develop a digital research system and new research, development and innovation infrastructures); foster innovative entrepreneurship (increase business investment in R&D and innovation, employment, productivity and commercialisation); create an innovation-friendly society aimed at long-term development (attract foreign investments and foreign talents, increase international co-operation, develop national brands and trademarks internationally).
Finland	National Innovation Strategy	2007-11	Make Finland's innovation environment one of the best in the world by 2015. Raise R&D to 4% of GDP by 2010, develop demand- and user-driven innovation policy.
	Internationalisation of education, research and innovation (ERI)	2010-15	Secure financing and human resources, create and maintain infrastructures, speed up the internationalisation of enterprises, promote networking and risk-taking.
France	National Strategy for Research and Innovation	From 2009	Strengthen incentives for the private sector to invest in R&D (increase in the Research Tax Credit, CIR), develop synergies between key innovation actors and improve transfer from public research to innovation (competitiveness cluster policy), support SME competitiveness and growth through better funding. Three priorities over the next four years: health, well being, food and biotechnologies; environment, emergency and eco-technologies; and information, communication and nanotechnologies.
Germany	High-Tech Strategy 2020	2020	Following a review, the strategy now focuses on priorities which have been defined in accordance with lead-market-oriented topic areas in which the state has special responsibilities and which are of special societal and global relevance: health, nutrition, climate protection, energy, mobility, security and communication.

Table 2.1. **Revised or new national plans for science, technology and innovation policy in OECD countries and selected non-member economies, 2010** *(cont.)*

Country	National plan	Period covered	Main objectives
Greece	Strategic Plan for the Development of Research, Technology and Innovation	2007-13	The priority areas of the "Strategic Plan" are: • Increase and improve investments in knowledge and excellence with a view to sustainable development. • Promote innovation, the dissemination of new technologies and entrepreneurship to generate economic and social "value". A New Action Plan for Research and Technology is under preparation aimed at linking R&D policy with the country's growth model, promoting "green" activities, enhancing human S&T resources, promoting excellence and quality in research, and making Greek innovation more outward-oriented. Finally the recent transfer of the General Secretariat for Research and Technology to the Ministry of Education, Lifelong Learning and Religious Affairs underlines efforts to build a unified area for Education and Research.
Hungary	S&T Innovation Policy Strategy	2007–13	Increase total R&D expenditure to 1.8% of GDP by 2013 with half the R&D performed by the business sector. Strong focus on "key technology areas" (incl. ICT, biotech, nanotech, renewable energy resources tech., environmental technologies), commercialisation (translation into knowledge-based industries) and regional innovation systems.
Iceland	Policy Statement of the Science and Technology Policy Council	2009-12	Revise support system for R&D and innovation (including competitive funding, real cost model for R&D, quality assessment and performance-based funding, tax incentives), greater focus on design and creative industry, consolidate R&D infrastructure, improve access to and utilisation of research results.
India	Science and Technology for the XIth Five Year Plan and other policy documents	2007-12	Increase R&D spending to 2% of GDP with the business sector doubling its contribution; give top priority to primary education and higher education (increase spending by 6% of GDP by 2015) as well as vocational training; better link public research to business needs; strengthen IPR; promote international co-operation; foster research and innovation in agricultural sector (*i.e.* the Second Green Revolution) to address climate change.
Ireland	Strategy for Science, Technology and Innovation	2006-13	Promote R&D to become an innovation-driven economy; improve competitiveness; remain attractive for FDI; and maximise social cohesion. Increase R&D expenditures to 2.5% of GNP by 2013.
Israel	Series of national reports and STI related policy documents		Increased investments and greater policy focus on biotechnology, nanotechnology and low-tech industries. Growing interest in cleantech sectors (renewable energies, water and oil substitutes). Establish and develop an information system on innovation (*i.e.* innovation survey and database).

Table 2.1. **Revised or new national plans for science, technology and innovation policy in OECD countries and selected non-member economies, 2010** *(cont.)*

Country	National plan	Period covered	Main objectives
Italy	National Research Plan	2010-12	Promote knowledge-driven research, strengthen the involvement of business sector and co-operation with the public sector, support the internationalisation of research. Promote centres of excellence in the national/international context, concentrate efforts on large projects and research infrastructure (*www.istruzione.it/web/ricerca/pnr_2010-2012*).
	Industry 2015	2006-15	Enhance competitiveness of the productive system through the implementation of industrial innovation projects; promote public-private partnerships.
	Strategy for the Internationalisation of the Italian Research	2010-15	Renew the vision of Italian research in the European/ international context for implementing the EU2020 strategy, adapting the national context to the present global situation, in a prospective of a sustainable society. (Ministerial act of address 2010)
	Research Infrastructures of Excellence for Italy – The Italian Roadmap 2010	2010-12	Identify research infrastructures of excellence in all areas demanded by Italian scientific communities and recognised by all stakeholders, taking into account the international and European context and expressed priorities for the next 5-10 years.
Japan	New Growth Strategy	2009-20	Lead the world in green innovation and life innovation; increase the number of world-leading universities and research institutions and reform public research institutes; ensure full employment of S&T doctorate holders and provide young researchers with career prospects; foster innovation; encourage utilisation of intellectual property by SMEs; improve ICT use; increase public and private investment in R&D (4% of GDP); improve government services delivery.
Korea	2nd S&T Basic Plan – "577 Initiative"	2008-12	Become one of top five countries in terms of S&T competitiveness by 2012 with highly advanced S&T; increase total R&D investments up to 5% of GDP in 2012; set 7 strategic areas and systems; become the 7th S&T power in the world. Increase the ratio of basic research up to 50% of public R&D investments (focusing especially on basic sciences and big science).
	National Strategy and Five Year Plan for Green Growth	2009-13	The National Strategy fixes a long-term agenda and objectives to mitigate climate change, enhance energy independence and create new economic growth engines (green technologies, green industries, advancing industrial structure, and engineering a structural basis for the green economy) and to improve quality of life and enhance international standing (greening the land, water, building, transport infrastructure, daily life, and becoming a role-model for the international community). The first Five-Year Plan for Green Growth, as a mid-term plan, sets specific budget earmarks and detailed tasks (*e.g.* invest about 2% of annual GDP on green growth programmes and projects).
	International Science-Business Belt Plan		Strengthen basic science and links to business opportunities.
Luxembourg	National Plan for Innovation and Full Employment	2009-14	Increase and improve R&D investments notably by firms, increase R&D activities and increase supply of human resources through better employment conditions. Support innovation in all its forms in encouraging new business creation, promoting intellectual property and norms, accelerate the transition towards an information society by generalising ICT use, developing ICT infrastructures and ensuring quality and security.

Table 2.1. **Revised or new national plans for science, technology and innovation policy in OECD countries and selected non-member economies, 2010** *(cont.)*

Country	National plan	Period covered	Main objectives
Mexico	Programa Especial en Ciencia, Tecnología e Innovación (PECiTI)	2007-12	Apply short-, medium- and long-term state policy to strengthen education, basic and applied science, technology and innovation; decentralise scientific, technological and innovation activities; promote greater funding of basic and applied science, technology and innovation; increase investment in infrastructure for science, technology and innovation; evaluate public investment in development of human resources in S&T and scientific research, innovation and technology.
Netherlands	Innovative, Competitive and Enterprising	2007-11	Strengthen the innovativeness of the Dutch business sector: stimulate innovation in SMEs and promote environmental innovation in industry; foster the development of strong internationally prominent clusters; pursue social innovation (health, safety and security, water, energy); support eco-efficient innovation; strengthen workforce through education and research and strengthen higher education system.
New Zealand	Picking up the Pace – Economic Transformation Agenda	From 2006	Plan for the Ministry of Research, Science and Technology to set clearer directions for research, create a more stable funding environment, accelerate commercialisation of research; support long-term sustainable investment in research, science and technology; support high performers; support engagement of New Zealanders in research, science and technology; and skills for the future. New statement in 2010 to commit to high-quality innovation in traditional resource sectors and to boost support to innovation in new knowledge-intensive activities.
Norway	White Paper on Climate for Research	2009-onwards	The major shift in research policy introduced with the White Paper in 2009 consists of a stronger focus on impacts and results. The White Paper on research defines the nine goals and output areas. These output goals are meant to complement the long-term ambition that total R&D expenditure will reach 3% of GDP. The new goals imply a new direction in research policy with a stronger emphasis on global challenges, welfare issues in research, and on impacts and results. One goal is to introduce a systematic approach to indicators, evaluations and other types of assessments of research.
	White Paper on "An Innovative and Sustainable Norway"		Increase innovation by advancing: a creative society with a sound framework and a favourable climate for innovation.; creative human beings who develop their resources and competences, while grasping the possibility to apply them; and creative undertakings that develop profitable innovations. Improve the knowledge base and establish strategy councils in specific areas (for SMEs and environmental technology further to those for tourism and the maritime industry).
Poland	Strategy for increasing the innovativeness of the Polish Economy	2007–13	Develop human resources to build the knowledge-based economy; link public R&D activities to the needs of the enterprise sector; improve IPRs; mobilise private capital to create and develop innovative companies; build the infrastructure for innovation.
	National Foresight Programme – Poland 2020	2020	Four development scenarios for Poland to 2020. Based on a special report, *Poland 2030. Development Challenges*, that outlines potential routes for Poland's development during the next 20 years and will serve as the basis for the Long-term Strategy of Developing Poland.
Portugal	Technological Plan of the New Government Programme	2006-10	Raise the number of researchers and new PhDs; increase investment in R&D in the public (x 2) and private (x 3) sectors, increase patenting and citations; promote industry-science co-operation, develop partnerships for innovation and employment and activate clusters.

Table 2.1. **Revised or new national plans for science, technology and innovation policy in OECD countries and selected non-member economies, 2010** *(cont.)*

Country	National plan	Period covered	Main objectives
Russian Federation	Strategy for Developing Science and Innovation	To 2015	Raise domestic R&D spending to 2% of GDP by 2010 and to 2.5% by 2015; enhance the prestige of Russian science; increase level of patent activity and capitalisation of R&D; raise the number of small innovative enterprises; and increase innovation activity.
Slovak Republic	Long term Objective of the State S&T Policy of the Slovak Republic to 2015	2008–15	Higher involvement of science and technology (S&T) in development and more intensive use of S&T in solving economic and social problems. Better conditions for developing S&T in the Slovak Republic and through participation in the European Research Area. Setting targets for S&T development in ten focus areas.
	Innovation Strategy	2007-13	Building high-quality infrastructure and an efficient system for the development of innovation; developing high-quality human resources; developing efficient innovation policy tools including support to entrepreneurs, technology transfers and business innovation.
Slovenia	Slovenian Development Strategy	2006-13	Better link science to business needs and capabilities; increase R&D expenditures and promote business R&D investment; raise business absorption capacity and encourage commercialisation of research results; reform the organisational structure of public R&D; increase the number of researchers and sectoral mobility; shift public research towards applied and targeted research; encourage international co-operation; stimulate patenting and high-tech exports.
	National Research and Development Programme	2006-10	The programme has six main goals: *i)* increase the impact of R&D and technology transfer to the business sector, *ii)* increase investment in R&D to 3% of GDP by 2010 and double private sector investments in R&D, *iii)* increase the quality of R&D by redefining the mission of higher education institutions and public research institutes, introduce overall supervision of public R&D activities, reform the evaluation system and strengthen international co-operation in R&D, *iv)* strengthen human resources in R&D, *v)* develop a supportive environment for R&D, *vi)* increase the number of high-tech and innovative companies.
South Africa	Ten Year Innovation Plan (TYIP)	2008-18	The TYIP is aimed at underpinning the country's transformation to a knowledge economy and will be driven by four elements: human capital development (HCD); knowledge generation and exploitation (R&D); knowledge infrastructure development; and policy and institutional enablers to address the "innovation chasm" between research results and socioeconomic outcomes.
Spain	State Innovation Strategy E2I:	2010 onwards	The aim of the strategy is to increase the number of innovative businesses. It is based on five core areas of action: *i)* the modernisation, adaptation and creation of a financial environment conducive to entrepreneurial innovation; *ii)* backing innovative and socially oriented markets through regulation and public procurement; *iii)* internationalisation of innovation activities; *iv)* co-ordination of public policies by means of territorial integration with particular emphasis on the production sector and SMEs; and *v)* human capital.
	The National R&D&I Plan 2008-11		Includes specific public funding instruments to support strategic research in health, biotechnology, energy and climate change, telecommunication and information societies, nanotechnology, new materials and new industrial processes.

Table 2.1. **Revised or new national plans for science, technology and innovation policy in OECD countries and selected non-member economies, 2010** *(cont.)*

Country	National plan	Period covered	Main objectives
Sweden	Sweden Research and Innovation Bill	2009-12	Successive increases in central government support during 2009-12, to reach a permanent increase of SEK 5 billion in 2012 (EUR 500 million) – total addition of SEK 15 billion. The bill implements the largest reform of the funding system for basic research in over 60 years (introduction of appropriations by strategic areas). Strengthen quality relevance and competitiveness with a view to maintaining Sweden's place in the international research arena.
Switzerland	Education, Research and Innovation (ERI) Dispatch	2008–11	The goal of all planned measures is to enable the players and institutions of the ERI sector to extend Switzerland's capacities as a location for thought and work. Education is guided by the principle of securing and improving quality, and the goal in research and innovation is increased competitiveness and growth.
Turkey	National Science and Technology Policies Implementation Plan (BTP-UP) for 2005-2010	2005-10	Seven core strategic objectives: *i)* increase S&T awareness in society and improve STI culture; *ii)* advance the quality and quantity of human resources for S&T; *iii)* support high-quality, results-oriented research; *iv*) enhance the effectiveness of STI governance; *v)* boost S&T performance of the private sector; *vi)* improve the research climate and research infrastructure; *vii)* further the effectiveness of national and international networks.
	International STI Strategy	2008-10	Encourage entrepreneurship, innovation and productivity; use S&T capacity; support the development of sustainable strong competitive markets; develop appropriate infrastructure and environment; international co-operation and co-ordination of the innovation system.
United Kingdom	Science and Innovation Investment Framework	2004-14	Retain and build world-class centres of excellence; improve the responsiveness of publicly funded research; increase business investment in R&D; strengthen supplies of scientists, engineers and technologists; ensure sustainable and financially robust universities and public laboratories; boost public confidence in and awareness of scientific research.
	Innovation Nation White Paper	2008	Promote innovation in business and make the public sector and public services more innovative; strengthen use of procurement and regulation.
United States	A Strategy for American Innovation: Driving Towards Sustainable Growth and Quality	From 2009	The US Innovation Strategy is organised around three pillars: invest in the building blocks of American innovation, including R&D and human, physical and technological capital; promote competitive markets that spur productive entrepreneurship; and catalyse breakthroughs for national priorities such as developing alternative energy sources and improving health outcomes.
	American Recovery and Reinvestment Act (ARR)	2009-2013	Out of the USD 787 billion allocated under the AAR, USD 100 billion will be used to support investment in innovative and transformative programmes. In this context, four areas are targeted: modernisation of transport, including advanced vehicle technology and high-speed rail; renewable energies (wind and solar); broadband, Smart Grid, and health IT; and groundbreaking medical research.

Source: Responses to the STI Outlook 2010 Policy Questionnaire; OECD (2008), *OECD Science, Technology and Industry Outlook*, OECD, Paris; European Commission, ProInno Europe country reports and national sources.

Selecting and focusing S&T policies on priority areas

National plans serve to articulate priorities for research and innovation and to set out policies and instruments. Table 2.2 highlights the continued shift towards environmental sustainability in the strategic orientation of national priorities across OECD countries. In addition to environment and energy, new and emerging technologies as well as food security issues remain high on the STI policy agenda. Social issues such as health-related sciences, transport, ageing and urbanisation also rank high in national STI strategies.

Table 2.2. **Main national priorities in research and innovation policy, 2010**

	Strategic STI policy priority areas											
	National security	Environment, climate change and oceans	Natural resources and energy	Food security	Health and related life sciences (incl. biotech.)	Social challenges (incl. pension, transport, urbanisation, housing)	Engineering and advanced manufacturing	New materials/ technologies (incl. nanotech.)	ICT	Children, education and creativity	Regional influence, tourism and culture	Others[1]
Austria	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Belgium (Flanders)		✓			✓	✓		✓	✓			✓
Belgium (Wallonia)				✓	✓	✓	✓					✓
Canada		✓	✓		✓			✓	✓			
Czech Republic		✓	✓		✓	✓			✓		✓	
Denmark		✓	✓	✓	✓	✓		✓	✓	✓		
Finland	✓	✓	✓			✓						
France		✓	✓		✓	✓		✓	✓			
Germany	✓	✓	✓		✓	✓	✓	✓	✓			✓
Hungary		✓	✓		✓			✓	✓			
Israel		✓	✓		✓			✓	✓			✓
Italy	✓	✓	✓	✓	✓		✓	✓	✓		✓	
Japan		✓	✓	✓	✓	✓			✓	✓	✓	
Korea	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Netherlands	✓	✓	✓	✓	✓	✓		✓		✓		✓
New Zealand		✓	✓	✓	✓	✓						
Norway		✓	✓	✓	✓			✓	✓	✓	✓	
Slovenia		✓	✓	✓	✓	✓		✓	✓			
Spain		✓	✓		✓			✓	✓			
South Africa		✓	✓		✓	✓						✓
Sweden	✓	✓	✓		✓	✓	✓	✓			✓	
Turkey	✓	✓	✓	✓	✓		✓	✓	✓			
United Kingdom		✓			✓			✓	✓			
United States	✓	✓	✓		✓							

1. Others policy priority areas include: space in Belgium, Korea and South Africa; mobility in Germany and the Netherlands; and low-technology industries in Israel.

Source: Responses to the STI Outlook 2010 Policy Questionnaire.

High-quality S&T governance and reform

A key element of national STI strategies is the governance structure for STI policy making. In most OECD countries, but also in non-members, the governance of STI is organised as a multi-layered matrix in which ministerial bodies, advisory bodies and a range of different actors are involved in the making and steering of policy and its implementation. This matrix has bottom-up and top-down flows in the advisory and decision-making processes. As in previous years, some countries have created new interministerial committees or co-ordinating councils which often operate at the top levels of government. Some countries are also making changes at the operational level, such as merging the functions of various agencies, in order to improve co-ordination and implementation.

Advisory councils, co-ordination and implementation

The creation of interministerial councils at the highest levels of government to develop national strategies for science, technology and innovation has become more widespread in the past decade. Many of these councils are assisted by high-level expert or advisory councils with links to research funding agencies and non-governmental stakeholders. Overall, many countries have seen increased participation by various actors in the STI system and governments have responded by developing or strengthening co-ordinating structures.

New institutions and institutional structures

Changes in institutional structures for STI policy have sometimes resulted from efforts to consolidate responsibility for related policy areas under a single institutional umbrella in order to improve co-ordination or to reflect the higher priority of these fields. In other cases, they reflect changes in government and a reshuffling of responsibilities. Some countries have reorganised ministerial or departmental functions to strengthen the links between R&D and higher education. The following are some of the recent changes:

- In Austria, following a recent review of research and innovation policy, the government is reassessing the role and organisation of its two advisory councils (the Research, Technology and Innovation Council and the Science Council) in order to improve STI governance.
- In Belgium, the roles of the advisory bodies of Flanders and Wallonia have been broadened. The Flemish advisory board now advises on innovation policies in general, while the Walloon body takes care of specific policies for the French speaking community (*e.g.* education policies).
- The Canadian federal government took steps to enhance accountability and value for money from the Granting Councils. The Natural Sciences and Engineering Research Council (NSERC) and the Social Sciences and Humanities Research Council (SSHRC) have separated the roles of President and Chair of the Granting Councils and increased membership in the councils from the research user community. Other initiatives are under way to better co-ordinate programmes, facilitate interdisciplinary and international collaboration, and improve client service. Efforts are being made to collect and report standardised data on the results and impacts of investments made by the three Granting Councils and the Canada Foundation for Innovation (CFI). The Government of Canada has also taken significant steps to realise gains in S&T management – moving forward with activities aimed at strengthening Canada's domestic and international science and technology (S&T) partnerships and seeking a fresh approach to accessing external S&T advice.
- In the Czech Republic, the government has reduced the number of funding bodies from 22 to less than ten, simplified administrative procedures and introduced a Technology Agency for applied R&D.

- The Danish advisory and funding system for research was evaluated in 2009. Based on this evaluation, the legislation was revised in 2010, with changed requirements for peer reviews of applications, a stronger international orientation, closing down of the co-ordinating body of the system, and strengthening of the independent policy advisory body.
- The Finnish Advisory Board for Sectoral Research, whose goal is to improve the commissioning of sectoral research by government ministries and enhance the targeting of sectoral research across administrative boundaries, has been strengthened and instructed to co-ordinate the overall steering of sectoral research funded by the government.
- In 2010, in line with government decree [198/2005(IX.22)], Hungary launched an evaluation of the Operation of the Research and Technology Innovation Fund over 2004-09 to consider the system and context requirements for the evaluation of publicly financed STI programmes.
- Since 2009, the Israeli government has shifted from an annual to a biennial budget which allows for better planning and execution of STI policies and budgets.
- Since it reorganised its Ministry for Education, University and Research in 2009, Italy promotes a new approach to STI policies at national and international level, with the establishment of a General Directorate for Internationalisation of Research. During 2009 and 2010 several interministerial groups involving different national STI stakeholders were established to broaden the national debate and improve decision processes in key sectors (*www.istruzione.it/web/ministero/organizzazione/dg_uni_internazionalizzazione*).
- In 2008, the new Korean administration merged a number of STI agencies into two ministries: the Ministry of Education, Science and Technology (MEST), which mainly focuses on basic R&D, and the Ministry of Knowledge Economy (MKE), which mainly focuses on industrial applied R&D.
- In New Zealand, the government has made changes to institutional arrangements for the publicly owned Crown Research Institutes and in March 2010 merged the Ministry for Research, Science and Technology with the main funding agency, the Foundation for Research, Science and Technology. This merger led to strategic priorities and operational decisions about funding allocations made by the same department.
- South Africa is introducing a new Technology Innovation Agency (TIA) to stimulate and intensify technological innovation. The TIA will be fully operational in 2013 with the establishment of national and provincial TIA offices, the implementation of a framework for Centres of Competences and the creation of a National Intellectual Property Management Office (NIPMO). The TIA will head and consolidate existing funding programmes including the Innovation Fund (IF), the Support Programme for Industrial Innovation (SPII), and the Technology for Human Resources in Industry Programme (THRIP). In parallel the government has enacted the establishment of a National Space Agency.
- The Spanish government is working on a new Science and Technology Act that will create a new framework for research funding. The State Research Agency will be the funding body for basic research in Spain. The act will improve co-ordination between the General State Administration and regional administrations in order to develop national plans for R&D and innovation and to improve STI governance.
- Switzerland's innovation promotion agency (CTI) has become an independent authoritative government commission. Beginning in 2011, CTI is taking up business activities in its new form. The promotion activities of CTI are not affected by this organisational change.

- The United Kingdom's White Paper, *Innovation Nation*, mentions that regional development agencies (RDAs) and devolved administrations will work with the Technology Strategy Board (TSB) in developing strategies and programmes for translational research, infrastructure and demonstration together with the Research Councils. RDAs and the TSB have also put in place new arrangements to align their funding and activities to implement the recommendation in the Sainsbury Review to enable a collective RDA network investment of at least GBP 180 million over three years (2008-11) in activities to support the Technology Strategy. Further, the Science and Innovation Investment Framework (SIIF) aims to develop closer working relationships between regions and central government departments in order to ensure the best use of resources at national and regional level. Consequently, certain elements of government funding are now being managed at the regional level.

Box 2.1. **Russian initiatives in green technologies**

Among the latest Russian initiatives in the area of green technologies are the following:

- The Water Strategy of the Russian Federation for 2020 (adopted in 2009), envisages the development of mechanisms to implement technologies for improving the use of water resources. A special section is devoted to S&T issues, including the introduction of the best available technologies for supplying water to industrial enterprises, agriculture and households, purification and the efficient use of water, monitoring and forecasting water resources, etc.
- The Russian Priority Areas for S&T Development approved by the President in 2006 include the area of "Rational Use of Natural Resources" which includes five critical technologies for environmental protection. The priorities are implemented via funding relevant projects in the framework of the Federal Targeted R&D Programme managed by the Russian Ministry of Education and Science.
- President Medvedev initiated a technology modernisation programme for Russian industry with a focus on the energy sector and the introduction of green technologies.
- The Russian Ministry of Natural Resources and Environment recently declared it would introduce stronger penalties for harmful impacts on the environment by industry and that it would decrease those penalties (up to 70%) for the enterprises that introduced green technologies.
- The development of the Environmental Strategy of the Russian Federation for 2030 is currently one of the key tasks for the Ministry of Natural Resources and Environment. The introduction of the best available technologies is the key instrument to achieve the goals of the Strategy.
- The Center of Ecological Certification – "Green Standards", operating under support of the Russian Ministry of Natural Resources and Environment, is involved in developing regulations to ensure the functioning of the systems of ecological certification. The non-profit partnership Center of Ecological Certification – "Green Standards" has developed two systems of voluntary certification for the building sector: "Green standards" and "Ecological passport".
- The Federal Targeted "National Technological Base" Programme (2007-11), co-ordinated the Russian Ministry of Industry and Trade, aims to, *inter alia*, improve the ecological situation of the country.
- The Russian Ministry of Natural Resources and Environment has presented to the conclusion of the Ministry of Justice of the Russian Federation legislative amendments aimed at enhancing environmental protection. The amendments envisage the possibility of an unequivocal definition of environmental harm and increasing penal sanctions for ecological infringements.
- The "RosNano" State Corporation is elaborating a system of standards for nano-products that would allow the identification of, *inter alia*, materials and technologies potentially harmful for the environment.

Source: OECD, based on national sources.

Evaluation

The demand for effective evaluation tools to inform decisions on research funding and impacts has increased in line with public investments in R&D and innovation as countries try to enhance competitiveness and improve innovation capacity. The increased interest in evaluation also reflects societal demands for greater accountability. While much of the policy discussion on evaluation has focused on applying quantitative methods and tools to assess impacts, increasing attention is being paid to developing a broad-based approach that takes into account the qualitative development of research institutions with regard to their changing missions and ability to adapt. Of course, evaluation concerns not only discrete policy interventions or instruments but also entire research portfolios or the overall research and innovation system. International peer review of institutions or entire systems are increasingly used for this purpose. Finally, there is increasing public demand for extending evaluation processes to enhance the understanding of possible scientific and technological developments and their impacts on the wider economy and society.

Among the recent initiatives reported to the STI Outlook Policy Questionnaire are the following:

- In Belgium the Federal Science Policy Office has launched an international network financed by the European Commission on "impact assessment". The Walloon Council for Science Policy has carried out several broad evaluations, benchmarking Wallonia and comparing its recovery with European regions presenting similar industrial traditions. Following these evaluations, many recommendations were made to the Walloon government. Flemish research institutes have been evaluated by looking at their broader socioeconomic impact and efforts have been made to use an evaluation toolbox to determine a balance between research funding instruments.
- In 2008 The Danish Ministry of Science, Technology and Innovation drew up a framework for its research evaluation practices which deals with a number of questions concerning research evaluations such as their organisation and the principles on which they rely. The purpose of the evaluations is to document the quality of Danish research, create a basis for qualifying future prioritisations, and assess the results of research investments. The framework covers four areas: funding instruments, areas of research, research programmes and research systems. To create the highest possible degree of transparency, guidelines have also been drawn up. They contain a detailed description of the evaluation process, including when different stakeholders are involved.
- Finland's Science and Technology Policy Council has initiated an effort, spearheaded by Tekes and the Academy of Finland, to develop a commonly accepted Impact Framework and Indicators for Science, Technology and Innovation (VINDI). Within the framework, the impacts of science, technology and innovation are examined in relation to four key societal and economic areas: *i)* The economy and renewal. This impact area addresses the economic impacts of science, technology and innovation; *ii)* Learning and skills. The impact area of learning and skills includes the impacts of R&D and innovation activities on the accumulation of knowledge, a skilled labour force and networks of experts; *iii)* Well-being of Finns: This impact area consists of impacts of science, technology and innovation on the objective and subjective factors of well-being, such as health and social relations; *iv)* Environment. The impact area of environment addresses the impacts expected from science, technology and innovative activities in the face of environmental challenges such as climate change.

- From 2008, responsibility for the evaluation of Germany's technological performance and innovation system was transferred to the Expert Commission for Research and Innovation (EFI), established in 2007, which now publishes an annual expert opinion on federal policies for research, innovation and technological productivity.
- In Italy, a new Agency for Assessment of the University and Research Institutions (ANVUR) was established in February 2010 under the supervision of the Ministry for Education, University and Research and based on the positive evaluation experience previously developed in CIVR (*www.civr.miur.it*). It represents a completely new approach for the evaluation of national research quality (*http://anvur.miur.it/index.php/*). Part of the central institutional budget for ordinary financing is assigned to universities based upon the results of the evaluation. At local level, universities and research institutions have already adopted the ANVUR criteria and excellence indicators to distribute human and limited financial resources to research groups. The national large-scale facilities, which grant open access to research groups on the basis of excellence, have developed evaluation procedures close to those typically applied at international research infrastructures.
- In New Zealand, the government increased its emphasis on evaluation at the programme level to measure the benefits of investment in R&D and assess the value for money from such investments. In the specific case of research targeted to industry needs, the government has used several methods in parallel to identify economic impacts. These include microeconomic case studies showing qualitative and quantitative impacts, general equilibrium modelling of diffuse economy-wide impacts and counterfactual microdata analysis. Agencies have sought to collaborate to achieve better vertical integration of evaluation outcomes so as to link evaluations of strategic policy and operational policy agencies. At the institution level, the government is developing new arrangements for the Crown Research Institutes to address the recommendations of the independent CRI Taskforce to set new performance indicators for financial and non-financial performance of institutional behaviour and financial and non-financial outcomes from investment of public funds.
- The Norwegian Ministry of Education and Research has begun the process of developing a set of indicators for each of Norway's national goals. As a part of this process an independent expert committee – *Fagerbergutvalget* – was set up. The committee has been given the task of assessing goal achievement for publicly funded research, and as part of this, the indicators to be employed in evaluating progress. The committee is one of several efforts announced in a new White Paper on research in order to facilitate more efficient use of resources and results in the Norwegian system. The committee´s final report is expected in May 2011.
- The Swiss government published in 2009 its overall strategic assessment of education, research and innovation during the funding period 2004-07, concentrating on the impact of measures. Currently, the assessment framework is being redesigned in light of the findings.
- NESTA in the United Kingdom is developing an Innovation Index to improve the way the UK government measures investment in innovation and its impacts. The pilot index was launched in November 2009 and is expected to be ready in final form in autumn 2010. The Pilot Index has three components: *i)* a measure of the amount of investment in intangible assets in the United Kingdom and its contribution to economic growth and

productivity; *ii)* a tool to understand innovation at firm level that captures "hidden innovation" and reflects the different ways in which innovation occurs in different sectors; and *iii)* a set of metrics that can be tracked to assess how favourable is the UK climate for innovation. A parallel work stream to measure innovation in the public sector is also under way. This is an area in which metrics are not as well developed, but where innovation is nonetheless essential.

- The US National Science Foundation created a new research programme on the "science of science policy" that aims to set a scientifically rigorous and quantitative basis for science policy. In 2009 a joint Office of Management and Budget (OMB) and Office of Science and Technology Policy (OSTP) memo outlined federal priorities for FY 2011 and emphasised that agencies should develop science of science policy tools that can improve management of their research and development portfolios and better assess the impact of their science and technology investments (*www.scienceofsciencepolicy.net/*).

Improving actors' competences and enhancing incentives for innovation

Business, public research institutes and the higher education sector are key actors in the innovation process. However they are not the only ones; the public sector itself, users-consumers and non-government institutional actors, such as private non-profit foundations, play a role in translating knowledge into innovation. While policy has long supported strengthening capacity and incentives for innovation among the former set of actors (business, public research institutes and higher education), there is now a trend for policy to encourage capacity building in the latter group.

Increasing public support to R&D

Despite the slowdown in economic growth and the resulting fall in tax revenue, government investments in R&D have outpaced outlays in other areas. Government investments or spending and tax cuts, taken together, have represented on average more than 3% of GDP in the OECD area and up to 5% of GDP in the United States and Korea. Recognising that innovation is a source of long-term growth, many governments have policies to improve infrastructure, support basic science, R&D and innovation, strengthen human capital, promote green technology and innovation, and foster entrepreneurship. Recent stimulus packages have also provided additional support to science, R&D and innovation ranging from 0.01% (Finland and Norway) to 0.29% of GDP (Sweden) in 2009 (OECD, 2009a).

One of the drivers for the increase in R&D outlays has been the setting of R&D spending targets in most OECD countries (Table 2.3). In line with the Lisbon Agenda, many EU countries had set R&D targets of 3% of GDP by 2010. However, most have fallen short of that target, although countries such as Austria and Portugal have made significant progress in closing the gap. Austria expects to reach its target of 2.8% of GDP by 2010. It is noteworthy that countries with significant R&D and technological capacity have set targets beyond the 3% target: Korea (5% by 2012); Finland (4% by 2010); Sweden (4% by 2010); and Japan (4% by 2020).

A number of specific measures have been taken to stimulate the recovery from the recent economic crisis. The European Union has urged member states to increase planned investments in R&D and consider ways to increase private-sector R&D investments (Box 2.2). Luxembourg increased its R&D support by EUR 30 million in 2009. Norway has

Table 2.3. **R&D spending: targets and achievements, 2010**

	R&D spending targets		R&D expenditures GERD (% of GDP)	
	Target	Target date	2006	2008 or latest
Austria	3.0% of GDP	2010	2.47	2.73
Belgium	3.0% of GDP	2010	1.86	1.92
Brazil[1]	0.65% of GDP (business sector)	2010	1.02	1.09
China	2.5% of GDP	2020	1.42	1.54
Czech Republic	2.06% of GDP	2010	1.55	1.47
Denmark	3.0% of GDP	2010	2.48	2.72
Estonia[2]	3.0% of GDP	2014	1.14	1.29
Finland	4.0% of GDP	2011	3.48	4.01
France	3.0% of GDP	2012	2.10	2.02
Germany	3.0% of GDP	2010	2.53	2.64
Greece	2.0% of GDP	2020	0.58	0.58
Hungary	1.8% of GDP	2013	1.00	1.00
India[1, 3]	2.0% of GDP		0.71	
Ireland	2.5% of GNP	2013	1.25	1.43
Italy	2.4% of GDP	2010	1.13	1.19
Japan	4.0% of GDP	2020	3.40	3.42
Korea	5.0% of GDP	2012	3.01	3.37
Netherlands	3.0% of GDP	2010	1.78	1.75
Norway	3.0% of GDP	Indefinite	1.52	1.62
Poland	2.2-3.0% of GDP	2010	0.56	0.61
Portugal	1.8% of GDP	2010	1.02	1.51
Russian Federation	2.5% of GDP	2015	1.07	1.03
Slovenia[2]	3.0% of GDP	2013	1.56	1.66
Spain	2.2% of GDP	2011	1.20	1.35
Sweden	4.0% of GDP	2010	3.74	3.75
Turkey	2.0% of GDP	2013	0.58	0.73
United Kingdom	2.5% of GDP	2014	1.75	1.77
United States	3.0% of GDP	Indefinite	2.61	2.77
European Union	3.0% of GDP	2010	1.76	1.81

Note: The last year available for GERD data is 2007 for Greece, 2009 for Austria and Finland.
1. Data for R&D expenditures come from national sources and may not be fully comparable with others countries.
2. Data from Eurostat.
3. Data for R&D expenditures are for 2004.
Source: OECD (2008), *OECD Science, Technology and Industry Outlook 2008*, OECD, Paris; and OECD (2010a), *Main Science and Technology Indicators 2010/1.*

allocated more than NOK 1.8 billion in direct grants for R&D and innovation and radically expanded its fiscal support to R&D through tax relief. Despite fiscal pressures, Spain is aiming to strengthen public investment in R&D through tax credits and public procurement. Estonia has pledged to maintain its focus on increasing R&D spending and plans to increase levels by 44% in 2009 and by 25% in 2010 (OECD, 2009a). As part of the American Reinvestment and Recovery Act of 2009, the United States government has increased its spending on R&D related to climate change by USD 26.1 billion, and to energy by USD 6.36 billion. An additional USD 10 billion was allocated for biomedical research funded by the US National Institutes of Health and an additional USD 2.3 billion was allocated to research funded by the National Science Foundation. The response to the crisis has also given a boost to efforts.

Box 2.2. **European Union "Innovation Union" initiative**

In June 2010 the European Union agreed on a new "Europe 2020" strategy, which succeeded the previous Lisbon Strategy, with the priorities of smart, sustainable and inclusive growth. The strategy includes a number of headline targets, including the aim to invest 3% of GDP in R&D by 2020 and proposed the development of a new indicator on innovation. To implement the strategy, seven flagship initiatives were announced.

One of the flagship initiatives is entitled "Innovation Union" and proposals were presented by the European Commission in October 2010. The "Innovation Union" is intended to provide an integrated strategy across research and innovation with over 30 measures to be implemented across the EU and by EU member states. These cover:

- Improvements to the knowledge base, in particular to complete the "European Research Area" which is now an explicit commitment in the EU Lisbon Treaty, including the removal of barriers to the movement of researchers and funding between EU countries. The Innovation Union also points the direction for future EU research and innovation funding programmes, towards a reduction in complexity, simpler access, a broadening to non-technological areas such as design and creativity, and more emphasis on the take up of results through open access and innovation.
- Enabling entrepreneurs to get good ideas to market more quickly. Specific measures include further support to venture capital, loans and guarantees; a rapid agreement on the EU patent; and a strengthening of demand side policies for innovation, notably public procurement and standard setting.
- Social and regional impacts of innovation, including using the EU Structural Funds to support smart specialisation strategies in the eligible regions of the EU member states, and launching pilot activities in social innovation and public sector innovation.
- A new approach, labelled "European Innovation Partnerships" with the aim of bringing together both supply and demand side policies to focus on specific societal challenges. A first pilot Partnerships is proposed to address the challenge of active and healthy ageing with a specific target to increase by 2 years the average number of healthy life years of EU citizens.
- Concerning international co-operation, the Innovaton Union proposal suggests a closer collaboration between EU member states in their co-operations with non-EU countries around some commonly agreed priorities.
- Building on the policy principles set out in the OECD innovation strategy, the European Commission proposes a policy diagnostic tool to support EU member states to conduct self assessments of the research and innovation policies.
- Finally, the European Commission proposes the development of a new indicator to measure the share of fast growing, innovative companies in national economies. This was the outcome of discussions by a High Level Panel that was established to consider a headline innovation indicator for the Europe 2020 strategy. As pointed out by the Panel, such an indicator requires development work to access the necessary data sources and define the indicator in a way that allows international comparisons.

Source: Response to the STI Outlook 2010 Policy Questionnaire.

Building critical mass in public research

Reinforcing the science base remains an important element of national STI strategies and is among the highest priorities for Hungary, Japan, Norway and Sweden (Table 2.4). In addition, Canada, Germany, Norway, Spain and Sweden have reported additional increases to public funding for R&D. The German federal government and the *Länder*, for example, have expanded

Table 2.4. **Strengthening public research: performance, priority level and measures taken between 2008 and 2010**

	Performance 2008 or nearest			Priority level	Increase financing of public R&D				Reforms of public research institutions							
	GOVERD + HERD intensity[1] 2008	Basic research performed by the public sector[1, 2] 2008	Scientific publications[3] 2008	Strengthen the science base	Additional funding	New targets	Quality assessment	Full economic cost recovery	Autonomy of universities	Accountability of universities	New structures	Research priorities setting	Ownership and licensing	Improve rankings of HEIs	Internatio-nalisation	Quality of infrastrucures
	Index 100 = Highest OECD value			Self-reported (1-8)[4]	Measures/initatives taken between 2008 and 2010			Principle applied	Measures/ initatives taken between 2008 and 2010							
Austria	69	62	50	7					✓	✓				✓	✓	✓
Canada	73		61	7	✓			✓	✓			✓				✓
Czech Republic	49	64	33	7		✓		✓		✓	✓		✓	✓	✓	✓
Denmark	70	46	71	6			✓	✓	✓	✓		✓			✓	✓
Finland	83		72	7				✓	✓	✓	✓	✓	✓	✓	✓	✓
France	64	79	39	7		✓			✓	✓		✓			✓	✓
Germany	70		38	6	✓				✓	✓	✓	✓	✓		✓	✓
Hungary	40	35	22	8							✓				✓	✓
Israel	70	83		7							✓				✓	✓
Italy	48	51	32	7			✓		✓	✓	✓	✓			✓	✓
Japan	60	41	25	8					✓						✓	✓
Korea	69	45	29	7		✓		✓	✓	✓	✓		✓	✓	✓	
Netherlands	76		64	6					✓							
New Zealand	61	61	62	7												
Norway	66	46	68	8	✓	✓	✓				✓					✓
Poland	37	30	18	7					✓				✓	✓		✓
Slovenia	52	25		7												✓
South Africa	33	24		7							✓		✓			
Spain	53	35	35	7	✓						✓		✓		✓	✓
Sweden	85		76	8	✓	✓	✓	✓	✓	✓						✓
Switzerland	66	100	100	n.a.	✓							✓			✓	✓
Turkey	36		10	n.a.												
United Kingdom	55		57	n.a.						✓	✓	✓	✓			
United States	57	63	39	6				✓								

Note: The table only includes countries that provided responses to the STI Outlook 2010 Policy Questionnaire as of 31 August 2010. However, indicators of performance are calculated for all OECD countries for which data are available. Therefore, the highest OECD value may not appear in the table and the ranking takes into account a larger number of countries than those presented here.

n.a.: Response not available.

1. As a percentage of GDP.
2. The public sector includes the government and higher-education sectors.
3. Per capita.
4. Self-reported ranking of national STI priorities based on scale whereby 1 = least important and 8 = most important.

Source: OECD (2010a), *Main Science and Technology Indicators*, 2010/1; OECD, *Research and Development Statistics*, 2010; OECD (2010b), *Measuring Innovation: A New Perspective*, OECD, Paris; responses to the STI Outlook 2010 Policy Questionnaire.

public R&D funding to major public research institutes by 3% annually between 2005 and 2010 and plan to further increase their contribution by 5% annually between 2011 and 2015. Sweden has assigned an additional SEK 5 billion to the initial SEK 25.6 billion allocated by the central government in 2008. This increase represents about 20% additional resources over 2009-12 and accompanies the largest reform of the funding system for basic research in over 60 years.

In Portugal, a national contract for the development of higher education has been collectively signed between the government and all public universities and polytechnics. This contract entails an increase of public investment in higher education to show the commitment of the Portuguese government and higher education institutions to increase the qualifications of the Portuguese population by setting a goal of graduating a further 100 000 adults annually to current graduation levels by 2013.

Strengthening public research entails more than increases in expenditures on public R&D however. Policy reforms of funding mechanisms, university governance and autonomy as well as evaluation all aim to enhance efficiency, research quality and impact.

Box 2.3. **Recent developments in China's STI policies**

In January 2006, the Chinese government adopted the Medium- and Long-term National Strategic Plan for Science and Technology Development (2006-20) (MLSTSP). The aim is to make China an innovation-oriented society by 2020 and eventually a leading science and technology power and innovation economy. One of the main targets is to increase R&D intensity from 1.23% of GDP in 2004 to 2% in 2010 and to 2.5% by 2020. The plan has been implemented through the 11th Five-year National S&T Plan (2006-10), to be followed by the 12th Five-year S&T Plan (2011-15). The State Council document, Implementing Policies for the Medium- and Long-term National Plans for S&T Development, aims to raise the innovative capacity of firms in China via a combination of supply and demand-side policies (*e.g.* R&D tax incentives) and demand-side policies (*e.g.* innovation-friendly public procurement policy, IPRs).

Key priorities. The 11th five-year plan consists of two main parts: major national S&T projects (the so-called megaprojects) and the basic R&D programmes. It identifies 11 priority research fields: energy, water and mineral resources, environment, agriculture, manufacturing technologies, transport, information technology, population and health, urbanisation, public security and national defence. In addition, eight frontier technologies are priorities for funding; biotechnology, information technology, new materials and nanotechnology, advanced manufacturing technologies, advanced energy technologies, ocean technology, laser technology and aeronautics and astronautics. The 16 "megaprojects" address specific objectives defined in the Medium and Long-term National Strategic Plan in the engineering and science fields. They have been conceived, directed and funded by the government with a view to achieving R&D breakthroughs in key platform, general purpose, technologies needed for national strategic products, important S&T projects and large-scale S&T infrastructure projects.

Support to business R&D and innovation. Many measures encourage innovative activities on the supply side; they include technology and R&D tax incentives (Table 2.7), the national high and new technology zones, and national science and technology incubators. Furthermore, in response to the global financial crisis, the State Council on 19 September 2009 issued "several opinions on further development of SMEs" and the central government released RMB 10.9 billion in 2009 (roughly EUR 1.1 billion) to support technological innovation by SMEs, upgrading of the industry structure, and development of international markets.

Box 2.3. **Recent developments in STI policies in China** *(cont.)*

Public procurement and innovation. On the demand side, the Chinese government has tried to use government procurement policy to encourage Chinese enterprises to develop their own core technologies, products and brands, hence the term "indigenous innovation", in order to increase their longer-term competitiveness. According to China's Ministry of Finance (MOF), government procurement reached RMB 599.1 billion in 2008, a 28.5% increase from 2007. This represented 2% of GDP and 9.6% of total fiscal expenditure. In 2009, government procurement represented RMB 741.3 billion, a further 23.7% increase from the previous year. The initial implementing policies proposed that indigenous innovative products should have priority in public procurement and that accredited companies competing in public tenders with innovative products will benefit from a discrete price advantage. Furthermore, no less than 60% of the cost of purchasing technology and equipment should go to domestic firms. In response to foreign concerns about market access, the Ministry of Science and Technology (MOST), MOF, and National Development and Reform Commission (NDRC) jointly issued a draft notice in April 2010 that made some changes to the criteria for defining such products. Under Circular 618 of 2009, they had to have a trademark owned by a Chinese company and registered in China; the company also had to have full ownership of the product's intellectual property (IP) in China. Under the 2010 draft notice, a product is eligible if the applying party has exclusive rights to the product's trademark in China and is licensed to use the IP in China. These policies to promote innovation through public procurement in China continue to be high on the agenda in discussions with foreign governments and business representatives.

Support for IPRs and innovation. On 5 June 2008, the State Council of the People's Republic of China issued the "Outline of the National Intellectual Property Strategy", which reiterated China's determination to "create, utilise, protect and manage IPRs at a relatively high level by 2020". The strategy gives particular attention to the role of firms in the creation and use of IPRs. On 15 September 2009, the Ministry of Finance released the Interim Measures for the Administration of Special Funds for Subsidising Foreign (or International) Patent Applications, which encourage Chinese applicants to participate in the international patent system and to protect their innovations. On 26 May 2010, the Ministry of Finance and the SIPO (State Intellectual Property Office) jointly formulated the Circular on Organising Funding for Patenting Overseas. The MOF has laid aside RMB 100 million to subsidise Chinese international patent applications. SMEs, public institutions and research institutions are eligible for the subsidy, which can partly cover the fees incurred during the patent application phase, the annuity fees for the first three years after grant, and fees paid to related agencies. Each Patent Cooperation Treaty (PCT) filing should be granted a minimum of RMB 100 000 per country for a maximum of five countries, with the exception of big innovation projects. In 2009, the central government granted RMB 52.85 million to 1 146 PCT applicants. These subsidies have helped SMEs to meet the high cost of filing abroad, which is often a barrier for small companies seeking to expand in international markets.

Human resources in S&T. On 6 June 2010, the Communist Party of China and the State Council issued the first Medium and Long-term Talent Development Plan 2010-20. Under the plan, by 2020, the number of researchers should increase to 3.8 million, with 40 000 top scientists in leading innovation fields. Researchers should reach 43 per 10 000 population in 2020, up from 25 in 2008. The share of the labour force with higher education should reach 20% by 2020, up from 9.2% in 2008. Furthermore, 300 innovation "talent bases" have been set up, along with "elite scientific studios", in order to foster joint research

Box 2.3. **Recent developments in STI policies in China** *(cont.)*

projects and scientific co-operation. College graduates are encouraged to work in rural areas and contribute to local scientific development. In order to promote mobility of researchers to firms, a number of schemes have been launched to link academic S&T personnel with industry and to promote the return of overseas Chinese scholars and graduates.

Source: OECD Secretariat based on national sources and "Policy Updates on Selected Key Issues in China's S&T and Innovation Policies", OECD, 2010, forthcoming.

Revising funding mechanisms for public research institutes and universities

Public research organisations have always been important actors in country innovation systems and they contribute to major technological breakthroughs and innovations. However, since the early 1980s, the share of R&D performed in the government sector has declined and recent years have seen a number of challenges facing public research institutes, including their relationships with other actors, the renewal of their infrastructure, and the commercialisation of public research results. In response, governments have introduced a number of changes to priority-setting processes, governance structures and mechanisms for allocating funding for public research (Basri and Box, 2009).

One of the key issues with regard to funding is to balance competitive funding mechanisms with longer-term non-competitive funding. Competitively awarded funding, either for projects or block grants, allows research systems to encourage competition among researchers and research institutions and encourages institutions to attract external funding, in particular from industry. Non-competitive, institutional block funding ensures financial stability and long-term outlooks which may be more favourable to fundamental research or projects that require more time to reach maturity. Such institutional funding also helps prevent the fragmentation of research and allows more time for research as opposed to fund-raising activities.

Although institutional funding remains important, a shift towards project funding has been observed for some years. Many countries have introduced or strengthened mechanisms for competitively awarded project funding:

- Belgium. Flanders research programmes receive funds according to the ratio of research funds per university based on output criteria (bibliometric and other) and responses from individual researchers to open calls and the evaluation of proposals by independent experts.
- Czech Republic. In the context of the reform of its R&D and innovation system, the Czech Republic has increased the use of project-based funding.
- Germany. Procedures for funding higher education institutions have been increasingly oriented towards a performance-based approach based on indicators. Today, the majority of German federal states have such procedures in place. In many cases current models have been adapted and modified in accordance with new demands, *e.g.* by modifying the set of indicators or expanding the share of budget allocated according to performance.

- France has increased significantly its support to public research through project funding with the creation of the National Research Agency (ANR) while institutional grants have remained stable. In addition, the pooling of education and research grants and university autonomy in allocating funds represent significant changes in national funding mechanisms.
- Netherlands. Recently the Netherlands has increased the share of public funding allocated through competitive grants (from 27% to 33% of total public funding between 2008 and 2010), but a large part of this increase is due to temporary measures taken in response to the financial crisis.
- Norway. Effective 1 January 2009, there is a new core funding system for the research institute sector.[2] It has two parts: performance-based basic funding and strategic institute programmes. Basic funding is comprised of a permanent allocation and a fluctuating allocation of about 10% which is distributed on the basis of institutes' performance on the following indicators: scientific publications, co-operation with the higher education sector, income from the Research Council of Norway, income from abroad, and income from national research commissions. The institutes' scores are adjusted using a relevance component, calculated according to the percentage of the institute's R&D income that is subject to competition. The institutes are divided into four groups to ensure that relatively similar research institutes compete for core funding on similar terms. The four groups are environment and development research institutes, primary industry research institutes, social science research institutes, and technical and industrial research institutes. The government has also stipulated how much of the core funding framework may be allocated to strategic institute programmes for each of the institute groups. The Research Council of Norway is responsible for administering the new funding scheme which will be evaluated after an initial three-year period.

Countries are also incorporating elements of competition or performance-based allocation into their institutional or block funding. Denmark has introduced a new competitive block funding instrument for world-class research. The Investment Capital for University Research (UNIK) is granted to universities that compete for large grants which can be used as block funding. Sweden has put more emphasis on long-term support based on institutions' research profiles to develop new research areas. The funders of national research will be provided with an additional SEK 670 million a year for strategic investments.

In line with increased use of competitive funding, block funding is also increasingly linked to *ex post* performance evaluation in many countries:

- Belgium (Flanders). One important feature of university research in Belgium is a gradual shift towards output-based financing based on criteria such as PhDs awarded, citations, publications, etc.
- Denmark has implemented a bibliometric model based on scientific publications to introduce a performance-based measure into the distribution of general university funds (GUF). The model was introduced in 2009 and covers all fields of science but currently only concerns a limited proportion of the total funds allocated to the universities.
- Finland. The Ministry of Education and the Higher Education Institutions set specific quantitative goals and new indicators.
- France. The development of international partnerships and co-publications are systematically used as performance indicators for public research institutes.

- Norway funds part of its total public general university fund on the basis of several performance indicators, including bibliometric results and third-party research funds.
- Slovenia. The Slovenian Research Agency has set up a system for monitoring the transfer of knowledge from public research institutes to potential users which is used to increase budgetary funds for R&D.
- Sweden. Quality is measured in terms of institutions' capacity to attract external funding and number of publications, combined with a citations analysis.

There is increasing evidence of countries seeking to recover the full economic cost of research activities so as to allow research institutions to amortise assets and overhead and invest in infrastructure at an adequate rate to maintain future capability. Full economic costing means that capital, infrastructure, maintenance and functioning costs associated with each piece of research are included in the final price. This requires sponsor departments or bodies to contribute to the building and sustaining of the necessary infrastructure within the science base. Recovering the full economic costs of research activities helps guarantee universities' and public research institutes' financial sustainability. This approach represents a step towards establishing internal and external market pricing.

- Canada has implemented the federal Indirect Cost of Research Programme. Grants are awarded annually (for a total budget of CAD 325 million in 2009-10) and institutions must re-apply every year to continue receiving funds. Indirect costs grants are inversely based on the amount of money received so as to help in priority smaller universities and institutions to strengthen their research capacity.
- From 2008/09 Finnish universities have been developing full costing models. Along with the 2010 reform of universities, the government is raising awareness of cost accounting and is stressing the importance of applying a full cost model in all university operations, not just for research funding. Full costing has become a strategic institutional management tool. Similarly, as of 2009, the Finnish Funding Agency for Technology and Innovation (Tekes) has implemented a full economic cost recovery model in its funding decisions and the Academy of Finland has already adopted a partial economic cost recovery model (80%).
- In Sweden the common rule to withdraw 35% for university overhead from public grants has been reformed and Swedish universities receive compensation for the full costs of their projects based on their own evaluation.
- In the United States, the Office of Management and Budget has established guidelines that are periodically updated for direct and indirect cost recovery by higher education institutions.

Although Germany and Norway do not apply the full economic cost recovery principle at central level, the new German Higher Education Pact 2020 foresees funding of programme overhead of higher education institutions by the German Research Foundation, and the Research Council of Norway provides specific funding instruments that take into account cost elements such as maintenance costs and the day–to-day running of scientific equipment.

Strengthening research infrastructure for universities and public research institutes

Maintaining high-quality research infrastructure is crucial to the improvement of the quality of public research and to the provision of the best research conditions to attract national and world-class researchers. Many governments have increased the resources allocated to universities and public research institutes to modernise old infrastructure or to build new capabilities (Table 2.5).

Belgium (Flanders) has set up several new public research institutes in recent years, in the field of medical (pharmaceutical) research and materials. Improvements in public research funding has led to more investment in infrastructure and new investments in research laboratories.

Table 2.5. **Country initiatives to improve research infrastructure, 2008-2010**

Country	Programme/ Funding agency	Budget	Timeline	Objective
Austria	Federal Government	EUR 34 M	2009-10	Competitive funding for the modernisation of university infrastructure.
Belgium (Flanders)	"Herculus" fund	EUR 15 M (2010)	Since 2007	Created in 2007 to allow HEIs to acquire heavy infrastructure (cost above EUR 1.5 million) or mid-heavy research lab infrastructure (between EUR 150 000 and EUR 1.5 million).
Canada	Canada Foundation for Innovation	CAD 750 M	2009-17	Renew the infrastructure that support world-class research and training (accelerate repairs, maintenance and construction of universities, funding leverage to advance frontiers of knowledge and ensure skills training).
Denmark	Programme for Research Infrastructures	DKK 6 billion	2010-11	Support investments of strategic and scientific importance and improve quality of university research labs.
France	"Plan Campus"	EUR 5 billion	2008-2015	Renovation of universities' buildings and support to excellence in teaching and research. Reinforce the international attractiveness and influence of French universities.
Germany	Intiative for Excellence	EUR 1.9 billion + EUR 2.7 billion	2007-12 and 2013-17	Promote cutting-edge research at universities.
Hungary		EUR 209.4 M		Develop educational, research and IT infrastructure of national HEIs.
Italy	Research Infrastructures of Excellence for Italy – The Italian Roadmap 2010	EUR 100 M annually	2010-15 and 2015-20	Promote, coordinate and support the Italian participation to the European Programme for Research Infrastructures (ESFRI Roadmap). Improve the facilities at the National excellence centers to strengthen their role as sites of European size infrastructures.
Norway	National Research Fund	NOK 208 M	Each year	Research infrastructure.
	Centres for Excellence		2009	
Slovenia	Centres of Excellence	EUR 77.4 M	2009-13	Creation of 8 new Centres of Excellence
				Acquisition of new research equipment by universities and institutes.
Spain	International Excellence Campus Programme	EUR 203 M		Improve the research infrastructure of national universities.
	Map of Singular Scientific and Technological Infrastructures			Increase the availability of S&T infrastructures; improve the existing S&T capacity; foster the internationalisation of the Spanish facilities.

Source: OECD (2009a), *Policy Responses to the Economic Crisis: Investing in Innovation for Long-Term Growth*, OECD, Paris, and responses to the 2010 STI Outlook Policy Questionnaire.

In 2009 Canada invested CAD 50 million to support the construction and cost of a new research facility at the Institute for Quantum Computing at the University of Waterloo. This investment followed a previous CAD 50 million outlay provided in 2007 to the Perimeter Institute for Theoretical Physics and aims to position Canadian researchers at the forefront of quantum computing. In parallel, the federal government provided additional new funding for the Canadian High Arctic Research Station and TRIUMF (Canada's premier national laboratory for nuclear and particle physics). The government has also established the Canada Excellence Research Chairs (CERC) programme under which universities receive up to CAD 10 million over seven years to support each of the 20 CERC holders and their research teams in establishing ambitious research programmes at Canadian universities.

In 2010 Denmark launched a forward-looking digital work programme. Universities as digital spearheads are particularly targeted. An international conference in 2010 focused on how universities can use ICT to create innovative learning environments. In addition an increased focus will be put on ICT research at Danish universities.

Israel has set up a programme for the promotion of converging technologies, which includes investment in equipment and research infrastructure. The TELEM Forum decided in 2006 to finance the creation of R&D infrastructures in the field of nanotechnology over the years 2006-2011 for a total budget of ISL 220.5 million. Six new nanotech laboratories have been spread across national academic institutions. Israel has also supported the establishment of a Biotechnology Institute in the Ben Gurion University and the establishment of two technological centres dedicated to renewable energies and water that will conduct market-oriented public R&D. In addition the Planning and Budgeting Committee (PBC) and a philanthropic association, Yad HaNadiv, created in 2009 a joint ISL 30 million fund to encourage research in the humanities.

In Italy, the "Research Infrastructures of Excellence for Italy – The Italian Roadmap 2010" sets up a national plan for research infrastructures, including participation in European and global facilities, as well as upgrading national centres of excellence.

The establishment of the European Spallation Source (ESS) in Lund and Copenhagen will lead to the first large-scale research facility north of Hamburg. The facility will boost European leading-edge research in scientific fields such as material science and life sciences. When the facility is completed, up to 5 000 researchers may work there annually.

South Africa has implemented the South African Research Chairs Initiative (SARChI) designed to significantly expand the scientific research base and support the making of an internationally competitive global knowledge economy. In 2009, 15 new research chairs were created.

The United States has established the ARPA-E (Advanced Research Projects Agency-Energy) with initial funding of USD 400 million to develop innovative and transformational clean energy technologies. An additional USD 1.3 billion was provided to the US National Institutes of Health in 2009 to fund the construction, renovation and repair of existing non-federal biomedical research facilities and to pay for shared instrumentation and other capital research equipment.

Fostering the autonomy of universities and public research institutes

In addition to changes in the level and mechanisms of funding, many countries have reformed the governance of universities and public research institutes to increase their efficiency and responsiveness to societal needs.

Finland has introduced reforms in state universities with the adoption of a new Universities Act that bestowed economic and administrative autonomy on the universities. The universities will be given the status of independent legal person under public law. Their assigned tasks of research, teaching and societal interaction remain unchanged. The state ensures the institutions' core funding but the criteria used for funding and university steering have been modified to take into account the diversity of the institutions and are applied to the same extent to all institutions. In particular quality criteria have been markedly enforced to account for a third of funding.

In Sweden, higher education institutions can now propose representatives when appointing board members. Furthermore, the Commission on University Autonomy has investigated the future organisation of the higher education sector in Sweden and submitted proposals to the government to promote greater autonomy.

Since the 2007 Law on freedom and responsibilities of the universities (LRU), two-thirds of French universities have benefited from greater autonomy in terms of funds and human resource management. In particular, the functions of the universities' scientific and technological councils have been broadened to include taking responsibility for the distribution of funds among research labs. Since 2009, the "*crédits écoles doctorales*" that were allocated to institutions for organising seminars for PhD students and preparing them for postdoctoral life have been integrated with the funding of the universities.

Japan plans to speed up reforms of universities and public research institutes and provide an environment for autonomous research, and the Russian Federation has authorised educational and research institutions to establish spin-out companies, thus promoting postgraduate training and employment and stimulating R&D investments (OECD, 2009a).

Fostering business R&D and innovation

Business enterprises are the main source of innovation. They play a primary role in funding and performing R&D in most countries and, more than ever, governments seek to increase business investment in R&D and innovation. Global competition and the emergence of new players, such as China and India, have led countries to seek to boost the innovative capacity of the business sector. In the EU, another catalyst has been the EU's 3% R&D spending target, which is to be achieved primarily by increasing business investments in R&D to 2% of GDP.

Table 2.6 provides an overview of country performance in business R&D investment based on four indicators: *i)* the intensity of business expenditures on R&D (BERD) as a percentage of GDP; *ii)* the share of BERD performed by SMEs (as percentage of total BERD); *iii)* the share of BERD performed in the services sector (as percentage of total BERD); and *iv)* triadic patents per million population.

The intensity of BERD indicates the financial effort devoted by the business sector to advance research. Japan and Sweden, for example, have high BERD and patenting intensities. Smaller firms and non-traditional actors play a greater role in R&D in small countries (New Zealand) or catching-up innovation systems (Greece, Portugal and Spain). The shares of the services sector and SMEs in BERD tend to mirror the structure of business R&D systems and the relative contribution of non-manufacturing and SMEs to R&D performance. Triadic patenting is an indicator of the ability of innovation systems to generate new inventions that may be exploited globally.

In addition to framework conditions such as competition policy and access to capital markets, a broad range of direct policy instruments, such as block grants or competition-based schemes, are used to stimulate business R&D and innovation. Increasingly, many direct support R&D schemes are being oriented or targeted to strategic sectors/technologies in order to foster competitiveness but also to help firms in their specialisation strategies. Soft support, such as assistance in firm creation, counselling and entrepreneurship measures, is also being used to complement direct R&D support and to encourage risk-taking attitudes. While the general tax system is used to foster investment in innovation by firms, specific R&D tax incentives remain important in many OECD and emerging economies, even if their design and scope continues to evolve. Finally, OECD governments increasingly look to use public procurement as a way to accelerate the diffusion of innovative products or services in the business sector while meeting public demand for goods and services.

Responses to the STI Outlook Policy Questionnaire 2010 (Table 2.6) make it clear that direct support to business innovation, in the form of competitive grants or subsidised and guaranteed loans, remains important and has increased in some countries, especially for key industrial sectors such as renewable energy, advanced manufacturing, ICTs and health. However, the balance between merit-based and block instruments varies considerably according to factors such as industrial structure, existence of large R&D-intensive firms, R&D intensity and specialisation (Figure 2.1). For example, Canada provides most of its direct support to business R&D through credit loans and guarantees as well as through competitive grants, although most support to business R&D is indirect in the form of tax credits. In the Czech Republic, and despite recent emphasis on indirect funding, direct support (partly through EU structural funds) remains the main policy tool to foster R&D spending; the Czech Technology Agency allocates extra funds to applied research.

Spain offers a combination of subsidies, loans, venture capital and tax relief, depending on the company and the project. In recent years, there has been an increase in the use of government loans to companies, above all in the industrial sector.

Since 2008, Denmark has increased national support to R&D and innovation by 40% via the National Council for Technology and Innovation. This covers the establishment of a new national infrastructure of competence, of innovation networks and of an innovation voucher scheme. Moreover, a new fund for green growth was set up in 2009 to support green transformation and development in SMEs (EUR 100 million from 2010 to 2012).

The United Kingdom has put forward plans for a new fund to financially support low carbon investments (GBP 250 million, USD 364 million), GBP 50 million (USD 72.85 million) for the Technology Strategy Board to support innovation and research in advanced manufacturing, low carbon tech and life sciences; and GBP 10 million (USD 14.6 million) for UK Trade and Investment to help promote UK expertise at home and abroad (OECD, 2009a).The United States is providing USD 26 billion of loan guarantees as part of the American Reinvestment and Recovery Act of 2009 to improve energy efficiency and spur development of clean energy technologies.

Meanwhile, the Netherlands launched in mid-2008 a new innovation credit scheme that aims to meet companies' needs for a credit facility for high-risk innovation projects. The EUR 50 million structural budget starting in 2009 supports 10-20 development projects a year. In addition, local and regional Dutch authorities have created several loan and credit schemes (*e.g.* the Acceleration Agenda for the Innovation Fund in Limburg).

Table 2.6. **Foster business R&D and innovation: performance, priority level and measures taken between 2008 and 2010**

	Performances				Priority level			Stimulate private investments in R&D and innovation							Targeted public support									
								Direct public funding						Indirect support	Support to SMEs and new-technology based firms							Support to services and specific industries		
	BERD intensity[1] 2008	BERD performed by SMEs[2, 3] 2008	BERD performed in the services[3] 2007	Triadic patent families[4] Average 2005-07	Strengthen business R&D and innovation capacity	Improving framework conditions for STI	Demand-side STI policy	Credit loans and guarantees	Repayable advances (sales contingent claims, etc.)	Compe-titive grants	R&D subsidies	Technology consulting services, extension programs	Other	Tax incentives	Angel investor incentives	Venture capital (funds of funds)	SBIR	Innovation vouchers	Public procu-rement	IPR support	Other	Non-techno-logical innovation	Services	Industries/ techno-logies
	Index 100 = Highest OECD value				Country self-reported note (1-8)[5]			Principal instruments used							Measures/initatives taken between 2008 and 2010									
Australia	41	44	68	14	n.a.	n.a.	n.a.							✓										✓
Austria	64	38	47	40	6	4	4	✓		✓	✓	✓		✓				✓					✓	
Belgium	45	50	27	33	n.a.	n.a.	n.a.							✓										
Canada	37	50	60	19	8	6	4	✓		✓						✓					✓			✓
Czech Republic	31	50	61	1	6	5	4			✓				✓				✓		✓		✓	✓	✓
Denmark	65	43	56	48	5	5	2			✓	✓	✓				✓		✓				✓	✓	
Finland	100	27	23	52	5	6	8	✓		✓		✓	✓			✓	✓					✓	✓	
France	43	25	16	33	7	3	1		✓	✓	✓			✓					✓	✓		✓		✓
Germany	63	15	16	63	8	6	4	✓		✓	✓	✓				✓				✓		✓	✓	✓
Greece	5	82	75	1	n.a.	n.a.	n.a.							✓										
Hungary	18	40	36	4	8	7	5			✓	✓						✓	✓		✓				
Ireland	32	63	55	14	n.a.	n.a.	n.a.							✓										
Israel	134		106		8	6	1	✓	✓	✓	✓		✓							✓		✓		✓
Italy	22	23	44	11	7	5	6				✓	✓		✓	✓					✓	✓	✓	✓	✓
Japan	91	9	14	94	8	7	7				✓			✓		✓				✓			✓	✓
Korea	86	31	12	41	6	5	7	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓			✓	✓
Mexico	6		55		n.a.	n.a.	n.a.							✓										
Netherlands	30	30	37	53	7	3	4	✓			✓	✓	✓	✓			✓	✓	✓	✓				
New Zealand	18	100	69	11	7	3	3			✓		✓	✓	✓										
Norway	30	68	67	23	8	7	7			✓	✓			✓			✓		✓	✓		✓		
Poland	6	45	50		7	6	4	✓		✓	✓	✓	✓	✓		✓		✓		✓	✓	✓	✓	✓
Portugal	26	53	74	1	n.a.	n.a.	n.a.							✓										
Russian Federation	22		121		n.a.	n.a.	n.a.							✓										
Slovenia	37	36	22		8	7	5	✓		✓				✓		✓		✓		✓				

Table 2.6. **Foster business R&D and innovation: performance, priority level and measures taken between 2008 and 2010** *(cont.)*

	Performances				Priority level			Stimulate private investments in R&D and innovation							Targeted public support									
								Direct public funding						Indirect support	Support to SMEs and new-technology based firms							Support to services and specific industries		
	BERD intensity[1] 2008	BERD performed by SMEs[2, 3] 2008	BERD performed in the services[3] 2007	Triadic patent families[4] Average 2005-07	Strengthen business R&D and innovation capacity	Improving framework conditions for STI	Demand-side STI policy	Credit loans and guarantees	Repayable advances (sales contingent claims, etc.)	Competitive grants	R&D subsidies	Technology consulting services, extension programs	Other	Tax incentives	Angel investor incentives	Venture capital (funds of funds)	SBIR	Innovation vouchers	Public procurement	IPR support	Other	Non-technological innovation	Services	Industries/ technologies
	Index 100 = Highest OECD value				Country self-reported note (1-8)[5]			Principal instruments used							Measures/initatives taken between 2008 and 2010									
South Africa	18		61	1	7	8	5			✓	✓													✓
Spain	25	74	56	4	6	5	5	✓			✓					✓			✓				✓	
Sweden	95	25	26	73	6	1	5			✓	✓		✓				✓	✓		✓	✓	✓	✓	✓
Turkey	11		52		n.a.	n.a.	n.a.	✓		✓	✓	✓		✓			✓			✓	✓			✓
United Kingdom	37	25	39	23	n.a.	n.a.	n.a.	✓		✓	✓			✓	✓	✓	✓	✓		✓				
United States	68	12	50	45	6	3	3			✓			✓											✓

Note: The table only includes countries that provided responses to the STI Outlook 2010 Policy Questionnaire as of 31 August 2010 and countries that provided responses to the NESTI questionnaire on R&D tax incentives. However, indicators of performance are calculated for all OECD countries for which data are available. Therefore the highest OECD value may not appear in the table and the ranking takes into account a larger number of countries than those presented here.

n.a.: Response not available.

1. Value equal to 1 to 100 based on data expressed as a percentage of GDP.
2. Fewer than 250 employees.
3. As a percentage of BERD.
4. Per million population.
5. Self-reported ranking of national STI priorities based on a scale whereby 1 = least important and 8 = most important.

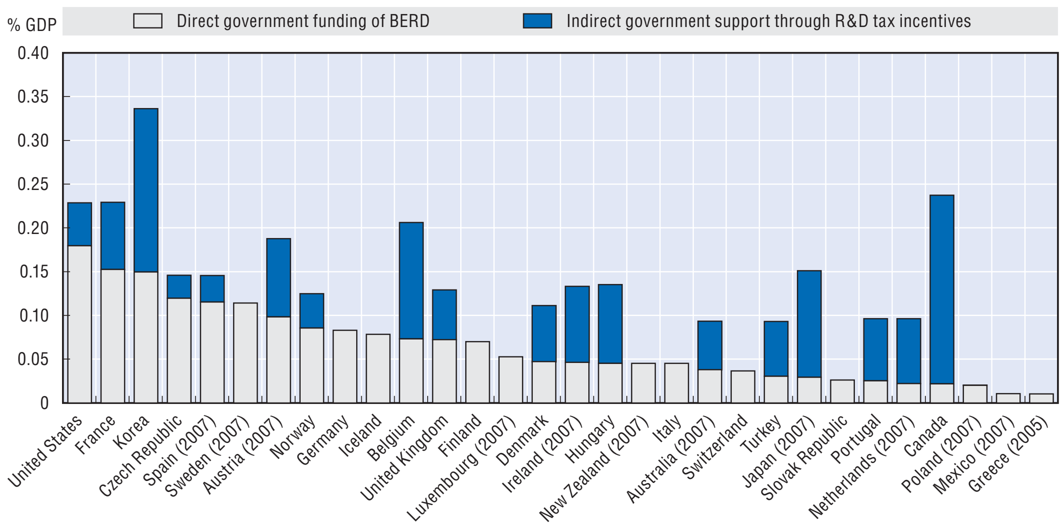
Source: OECD (2010a), *Main Science and Technology Indicators 2010-1*; OECD (2010b), "*Measuring Innovation: A New Perspective*", OECD, Paris; responses to the STI Outlook 2010 Policy Questionnaire.

Stimulate private investments in R&D and innovation

As mentioned above, direct public funding through grants, subsidies and loans remains the most frequent form of support to business R&D, with competitive and merit-based grant programmes having gained ground. However tax relief for R&D continues to complement more direct measures in many countries. Tax credits on social charges for researchers engaged in R&D have recently been introduced as a subsidy for highly skilled human capital, especially in small research intensive firms.

Figure 2.1. **Direct and indirect government funding of business R&D and tax incentives for R&D, 2008**

As a percentage of GDP



Note: The estimates of R&D tax expenditures do not cover sub-national R&D tax incentives. The Austrian estimate covers only the refundable research premium. The estimate for the United States covers the research tax credit but excludes the expensing of R&D. Italy, Greece and Turkey offered R&D tax incentives in 2008, but estimates of the foregone tax revenues are not yet available. Claims under the French R&D tax scheme totalled EUR 4.2 billion in 2008 (or 0.21 per cent of GDP), but France's scheme allows carry-forwards and a 3-year lag before total refunds of unused credits, and because the tax credit was much lower until 2007, only EUR 1.5 billion (or 0.08 per cent of GDP) are registered as government forgone tax revenue in the above figure.

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

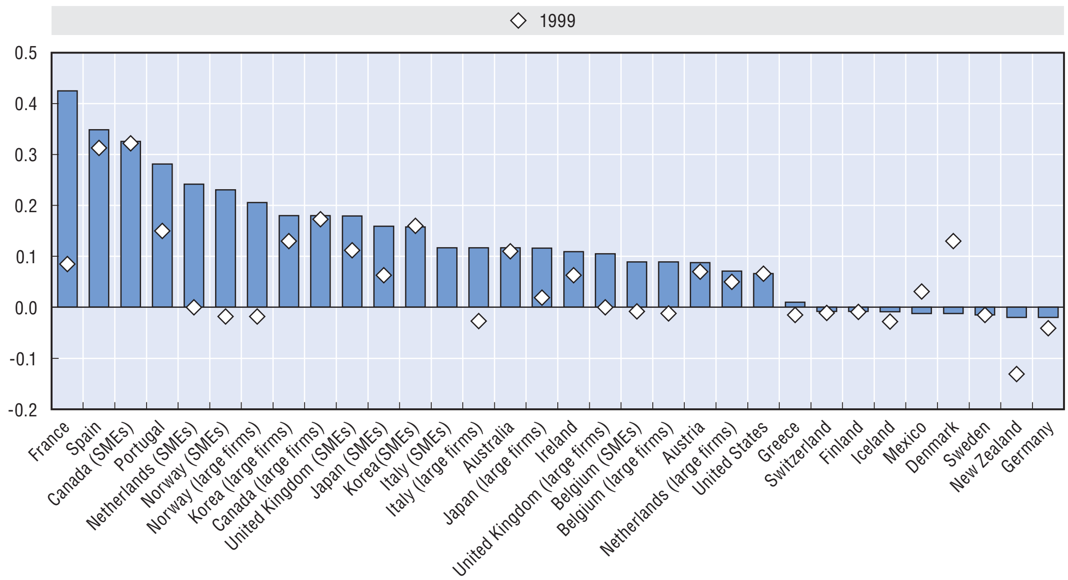
StatLink http://dx.doi.org/10.1787/888932333006

There are broadly speaking three major forms of R&D tax incentives: *i)* R&D tax credits that allow a deduction from the tax payable; *ii)* R&D allowances that represent an additional deduction from taxable income; and *iii)* depreciation allowances. Depending on the country, tax concessions are calculated either on a volume share of R&D expenditure, an incremental share (marginal R&D performed above a certain threshold of qualified expenditures), or a mix of both. Moreover, differences in country practices (*e.g.* eligible R&D activities, expenses base, rolling base *versus* fixed base for incremental credits, carry-forward of unused R&D tax credits, tax credit refund mechanisms) add to the great variety of fiscal schemes (Colecchia, 2007). In addition to the three major types of schemes, the Belgian and Dutch systems represent a fourth category, as tax incentives in those countries aim at lowering the cost of researchers either by diminishing wage tax and social contributions (*i.e.* the Netherlands WSBO scheme) or just the taxes on wages (as in Belgium) (Table 2.7).

To date, 22 OECD governments provide fiscal incentives to sustain business R&D, up from 12 in 1995 and 18 in 2004 (OECD, 2008, 2010b) (Figure 2.2). Tax credits for R&D are particularly widespread in Canada and Japan, where over 80% of public support to business R&D is provided in the form of fiscal incentives. In countries like the United States (through competitive R&D contracts) or Spain (through grants, subsidies or loans), direct support remains the main vehicle for public funding of business R&D. The wider issue of how many firms take part in public support schemes for innovation (as opposed to R&D) is not well documented. It is estimated that between one-tenth and one-third of innovating firms participate in public support programmes for innovation, with large firms receiving support more frequently than SMEs (OECD, 2010b).

Figure 2.2. **Change in tax treatment of R&D, 1999 and 2008**[1]

Tax subsidy to R&D (calculated as 1 minus B-index)[2]



1. 2009 for Mexico.
2. For example, in France, 1 unit of R&D expenditure results in 0.425 unit of tax relief.

Source: Warda, J. (2009), "An Update of R&D Tax Treatment in OECD Countries and Selected Emerging Economies, 2008-2009", mimeo.

StatLink http://dx.doi.org/10.1787/888932333025

Although some countries do not offer any tax incentives for R&D or innovation, R&D tax subsidies have become more generous over the decade to 2008 in all countries that offer them except Italy (for SMEs) and Denmark (Figure 2.2). However, France, Norway and the Netherlands (for SMEs) are the countries which have enlarged their indirect support to R&D most significantly. In 2008, France and Spain provided the most generous schemes with respectively 0.425 and 0.349 units of tax relief per US dollar of R&D expenditure. These instruments are also being developed in non-member countries. Brazil, China, India, Singapore and South Africa provide a generous and competitive tax environment for R&D investments (OECD, 2009b).

Several countries also have adopted special provisions for smaller firms and in 2008 granted larger subsidies for SMEs than for large firms. Korea stands out as an exception since tax credits for large firms have increased faster than for SMEs. Greece, Italy and the

Slovak Republic have recently introduced R&D tax incentives. Germany has plans to do so within the current legislation.

Contrary to the general trend, Mexico and New Zealand have repealed their R&D tax credit since 2008. Mexico converted its R&D tax credit to direct assistance in 2009. New Zealand had introduced a R&D tax credit of 15% in 2008 but has since repealed it with effect from the 2009-10 fiscal year and introduced new schemes (Table 2.7). Finally, it is worth noting that in Belgium, tax relief on social charges allows lowering the wages of the researchers in both the private and public sectors. This extra funding to universities and public research institutes is estimated at EUR 200 million; the government funds directly EUR 844 million of the EUR 1.2 billion higher education R&D expenditures.

Many countries have changed their R&D tax credit schemes in order to expand the number of beneficiaries and increase the amount of business R&D spending. Some have modified the criteria of eligibility, extended the coverage of R&D activities or the coverage of firms eligible for tax relief. Table 2.7 provides an overview of recent trends in R&D tax credits.

Table 2.7. **Recent and proposed changes in R&D tax incentives in OECD and selected non-member countries**

Australia	Australia has announced its intention to replace its R&D tax concession with an R&D tax credit. The new scheme will provide 45% on volume refundable for small firms (aggregate turnover of less than AUD 20 million) and 40% of volume non-refundable for large firms (aggregate turnover of greater than AUD 20 million). Eligibility for the scheme has been expanded in line with OECD non-discrimination articles to include all Australian resident companies and foreign companies, subject to certain requirements. The new R&D tax incentive redirects assistance to activities most likely to generate spillovers. It tilts assistance in favour of smaller innovative firms, as they are more likely to respond to fiscal incentives. The new incentive also removes the requirement that intellectual property (IP) be held in Australia, encouraging investment by the growing number of multinational enterprises in Australia that hold their IP overseas.
Belgium	A partial exemption of payment to the tax administration of withholding tax on earned income has been gradually introduced (since October 2003) with respect to remunerations paid to research workers. The exempted part that is deducted but not paid to the tax administration stays at the disposal of the employer. Research workers are allowed to set off the part not paid to the tax administration against their income tax liability on their tax return. The payment to the tax administration of withholding tax on earned income is exempted to 75% (new percentage since January 2009) and is valid for the following research workers: • European universities and *hautes écoles*, as well as for one of the Belgian research institutes; • scientific institutions approved by royal decree; • private companies employing research workers collaborating with the above-mentioned institutions; • companies employing research workers having either a PhD in applied sciences, exact sciences, medicine, veterinary medicine or pharmaceutical sciences or civil engineering, or a Master or equivalent in fields of sciences. These persons must be working on R&D programmes.
Canada	On the basis of consultations with stakeholders, the Government of Canada introduced several changes in 2008 to enhance the availability and accessibility of financial support for R&D for Canadian SMEs. It also allocated additional funding to improve the administration of the Scientific Research and Experimental Development (SR&ED) investment tax credit programme. In particular: • Budget 2008 improved the availability and accessibility of financial support for small and medium-sized R&D performers by increasing the expenditure limit for the enhanced refundable SR&ED investment tax credit available to small Canadian-controlled private corporations (CCPCs) from CAD 2 million to CAD 3 million and increased the upper limit for the taxable capital phase-out range from CAD 15 million to CAD 50 million. Budget 2008 also extended the SR&ED tax credit to certain activities carried out outside of Canada. • Budget 2008 also announced some improvements to the administration of the SR&ED programme that will facilitate access to the programme, improve its consistency and predictability, and enhance the quality of the claims process. Changes to SR&ED as a result of the 2008 federal budget are explained at *www.cra-arc.gc.ca/txcrdt/sred-rsde/whtsnw/bdgtch-eng.html*.

Table 2.7. **Recent and proposed changes in R&D tax incentives in OECD and selected non-member countries** *(cont.)*

China	The 2008 Corporate Income Tax Law (CIT) allows an enterprise to claim an additional deduction of 50% of R&D expenses incurred for the development of new technologies, new products and new craftsmanship. If the R&D expenses result in an intangible asset, then the enterprise is allowed to amortise the intangible asset based on 150% of the capitalised R&D costs. In addition, since October 2009, qualified foreign-funded research and development centres ("FIE R&D centres") are eligible for the import tax exemption treatment. Moreover, qualified R&D centres regardless of whether they are domestic-funded or foreign-funded can obtain the VAT refund treatment for the purchase of domestic-manufactured equipment ("DME VAT Refund"). The *Caishui* Circular 115 of 2009 stipulates the minimum threshold of R&D expenditure, the number of R&D personnel and accumulated costs of equipment purchased since the establishment of the R&D entity. In order to encourage the establishments of FIE R&D centres as well as effectively implementing the above-mentioned circulars, on 22 March 2010, the Ministry of Finance (MOF), the General Administration of Customs (GAC) and the Ministry of Commerce (MOC) jointly issued circular *Shangzifa* [2010] No. 93 concerning measures for verifying tax exemption/refund eligibility related to the purchase of equipment by FIE R&D centres.
Denmark	Denmark provides tax incentives for experimental research conducted by the private sector. Foreign researchers and key staff are also taxed at a lower income tax rate than the normal income tax. Foreign researchers and key staff can choose between a 25% tax rate in 36 months or a 33% tax rate in 60 months. A number of limitations and conditions apply. The system was introduced in 1991 and was modified in 2008 with the opportunity to choose between the 25% or 33% tax rate (including labour market contribution the tax rates are 31% and 38.4%). From 2010, individuals will get a deduction for gifts to charities, etc., which use their resources for research to the benefit of the public. The purpose is to make an opportunity for more resources to flow research that benefits the public.
France	The reform of the national tax credit, the *Crédit d'impôt recherche* (CIR), in effect since 2008, has seen no major changes. As part of the stimulus package the French government has agreed to temporarily modify the statutes of the CIR in order to provide temporary tax relief to companies that carried out R&D activities between 2005 and 2008 (OECD, 2009b). From 2011 the R&D tax credit for SMEs will systematically be reimbursed immediately.
Germany	The new German federal government has agreed to introduce R&D tax incentives during the current legislative period 2009-12.
Hungary	Since 1 January 2005, a tax credit on wage costs related to R&D activity and software developers has been applicable, and as of 1 January 2006, a specific tax credit on wage costs incurred in connection with software developers was introduced for SMEs. As of 1 January 2008, the limit of the development reserve was increased from 25% to 50% of the pre-tax profit. The VAT regulation for enterprises changed on 1 January 2006 to make purchases under funded projects eligible for refund of VAT.
Ireland	In 2009 (accounting periods commencing on or after 1 January 2009), the tax credit for incremental R&D spending has been increased from 20% to 25% with the base year fixed at 2003-13. Such expenditure can be taken against corporate tax. Companies may claim cash payments over three years in the event of insufficient or no corporation tax. The tax credit on buildings/structures can be fully claimed (25%) in the period when the expenditure is incurred. The requirement that building/structure be used wholly and exclusively for R&D has been removed. Credit is now due if at least 35% of all activities carried on in the initial four-year period are R&D activities. Companies may claim cash payments over three years in the event of insufficient or no corporation tax.
Israel	Israel has adopted a slightly different tax scheme to support R&D. Tax benefits are calculated on annual turnover but eligible firms are intensive R&D performers. Since September 2007 the Law for the Encouragement of Capital Investment allows companies that are considered to have a high rate of R&D expenditures (at least 7% of annual turnover and 20% of employees devoted to R&D activities) to reduce their turnover base annually by 10% and benefit from a tax credit. Additional benefits that a company could receive after capital investment is approved by the authorities will enjoy tax relief and deductions.
Italy	In Italy, the budget law of 2006-07 established a volume-based R&D tax credit of 10% for business R&D expenditures and a rate of 15% for eligible business R&D carried out in collaboration with universities and public research institutions. The budget law of 2007-08 raised the rate of 15% to 40% as well as the limit on eligible expenditures from EUR 15 million to EUR 50 million.
Japan	In FY 2003, the government established a permanent volume-based credit of 8-10% (12% for SMEs) for total R&D expenditures within 20% of corporate income tax. In this system, firms are allowed to carry forward the unused portion of their R&D tax credit only if they increase the amount of R&D expenditures during the next fiscal year. In FY 2006, the government abolished a special depreciation of equipment for "developmental research". In FY 2008, the government modified its tax incentive system to allow firms to claim an additional credit for 5% for the increase in R&D expenditures or an additional credit for 0.2% multiplied by the amount of R&D expenditures exceeding the equivalent of 10% of average sales, both within an additional 10% of corporate income tax. In FY 2009, the government, as a measure of addressing the economic crisis, temporarily increased the limitation of total tax credits up to 30% of corporate income tax for FY 2009 and 2010; and allowed firms to carry forward the exceeded tax credits in those fiscal years to 2012.
Korea	In 2008, the tax credit rate for research and human resource development was raised to 10% (it was previously 7%). In 2009, this tax credit became permanent and the preferential tax credit rate for SMEs was raised to 25% (previously at 15%). In 2010, a 20% preferential tax credit rate is expected for new-growth-engine R&D (30% for SMEs), and a 25% preferential tax credit rate is expected for original-sourcing-technology R&D (35% for SMEs).
Mexico	In 2009, the government converted its R&D tax credit to direct assistance.

Table 2.7. **Recent and proposed changes in R&D tax incentives in OECD and selected non-member countries** *(cont.)*

Netherlands	The budget for the WBSO tax scheme (reduction of wage tax and social security contributions for companies with R&D personnel) was increased to EUR 115 million by 2011. In addition, an extra deduction will be created for existing companies (not start-ups) embarking on R&D for the first time. Finally, consideration is being given to raising the limit up to which companies may profit from the high rate. As of 2009 the definition of R&D has been extended to the development of services based on software.
New Zealand	A R&D tax credit was introduced on 1 April 2008 and was stopped after a year. However, the government has recently launched two new business R&D schemes. A technology development grant is available from 1 July 2010 to firms with a strong R&D record that spend 5% revenue or more on research. A technology transfer voucher is available from 1 November 2010 to firms with limited R&D capability so that they may commission research from accredited research organisations.
Norway	In 2002, the Ministry of Finance launched a tax incentives scheme (*Skattefunn*) as a broad instrument that covers every sector and all companies. The scheme gives enterprises with business activity in Norway a tax credit on their R&D projects. The R&D content must be approved by the Research Council of Norway *ex ante*. The scheme offers a rebate of 20% of expenses for SMEs and 18% for large enterprises. In 2009, the cap on expenses per enterprise for intramural R&D projects increased to NOK 5.5 million (previously it was NOK 4 million), and NOK 11 million (previously it was NOK 8 million) for projects conducted at an R&D institution. If the calculated rebate exceeds the assessed taxes of the enterprise, the difference is refunded as part of the assessment. About three-quarters of the total tax expenditure under the *Skattefunn* scheme has been such cash refunds. The total R&D tax rebate for 2008 is approximately NOK 1.0 billion.
Poland	The act on some forms of support for innovation activity was modified as of 1 January 2006 to enable all enterprises to deduct from their tax base no more than 50% of their expenditures for the purchase of new technologies (including patents and intangible assets). In 2009 the government introduced a deduction from the tax base for development costs in the month during which the expenditure was made. In 2010 the government is working on R&D tax credits for entrepreneurs granted the status of R&D centre.
Portugal	Portugal has an established policy of tax credits granted to companies that perform or contract R&D activities, called SIFIDE. This tax measure was created in 1997, suspended in 2004 and 2005, re-established in 2006 (under severe public budget constraints imposed by the European Union) and reinforced in 2009. Following SIFIDE's reinforcement, companies can now reduce their tax debts by a percentage double the amount invested in R&D activities (*e.g.* the basic rate that corresponds to 32.5% of expenses, and an incremental rate of 50% of the increase of expenses in regard to the average of the two previous years but up to the new limit of EUR 1.5 million). The institution responsible for this measure is the Ministry of Science, Technology and Higher Education and the Innovation Agency (AdI) is responsible for managing it.
Russian Federation	The Russian Federation now allows full deduction of current R&D expenditures for tax purposes. Previously only 50% of such expenditures were taken into account.
Slovenia	In 2010 general tax allowances on business R&D expenditure were increased from 20% to 40%, thus enabling total (general + regional) allowances on business R&D expenditures of a maximum 60%.
South Africa	The enhanced R&D tax incentive introduced in November 2006 offers a 150% tax deduction on current expenditure, and a three-year accelerated depreciation on R&D capital investment of 50:30:20. Before 2006, the tax deduction was 100% and depreciation was 40:20:20:20.
Spain	To compensate for the general decrease in corporate taxes (as of 2007), R&D and innovation corporate tax credits were gradually reduced and were to be phased out completely by 2011. However, the Royal Decree-law 3/2009 suppressed the temporary limit on the deductibility of R&D investments from tax income, and the R&D tax remains in force.
Turkey	Issued in 2008, the Law on Promoting Research and Development Activities (No. 5746) is a policy tool primarily aimed at addressing the need to create R&D centres with critical mass. It aims to increase the scale of R&D carried out even in large firms so that it is at a favourable level with the top global competitors. It is thus an additional incentive to promote large R&D centres in Turkey. In particular, under this law, several incentives are provided, without any sectoral or regional distinction, including: R&D allowances (100% on volume; and for large R&D centres with at least 500 FTE researchers, 50% on incremental R&D from the previous year); incentives on income tax withholding (90% of FTE PhD researchers and 80% of other R&D workers), insurance premiums, stamp duties; and 100% depreciation of the capitalised R&D expenditures for R&D centres with at least 50 FTE researchers. These incentives are provided until the end of 2023.
United Kingdom	The Pre-Budget Report of December 2009 announced the government's commitment to promoting innovation through the R&D tax credit scheme. At the time of publication, over 36 000 claims had been made, with over GBP 3 billion of relief claimed, supporting over GBP 32 billion of R&D activities by companies. To enable companies to access the scheme more easily, the government announced the dropping of the condition that any IP deriving from the R&D must be owned by the company making the claim. This will allow companies to benefit from the scheme without distorting their commercial arrangements in relation to IP. In 2008, the R&D tax credit scheme for SMEs was extended to mid-size companies and the enhanced relief was increased to 175% (for SMEs) and 130% (for large companies) of eligible expenditure.
United States	The Federal Research and Experimentation (R&E) tax credit was established by the *Economic Recovery Tax Act of 1981*. Given its temporary status it is subject to periodic extensions and it was last renewed by the *Emergency Economic Stabilization Act of 2008* through 31 December 2009. The *AmericanRecovery and Reinvestment Tax Actof 2009* (P.L. 111-5; February 2009) increased the research credit for energy research and allowed for claiming a refundable credit for certain unused research credits in lieu of depreciation allowance for eligible qualified property. Legislation to extend the R&D tax credit continues to be considered in both chambers of the US Congress.

Source: OECD responses to the STI Outlook 2010 Policy Questionnaire and OECD, responses to the 2009 NESTI R&D tax incentives questionnaire.

Support for R&D and innovation in SMEs and start-ups

Although large firms tend to introduce more "novel" innovations than SMEs, which tend instead to be adopters (OECD, 2009b), SMEs form the bulk of businesses and play a key role in knowledge diffusion. Their contribution is more significant in marketing or organisational innovation than in technological innovation.

SMEs typically have more limited access to finance than large firms and fewer resources for generating and stocking knowledge. The credit crunch caused by the crisis has raised serious concerns about their capacity to remain innovative. Consequently, many countries have developed specific policy instruments to foster innovation among SMEs.

Direct financial support to small firms is used to subsidise R&D, finance technology investments, and help them develop human capital or access knowledge-intensive services.

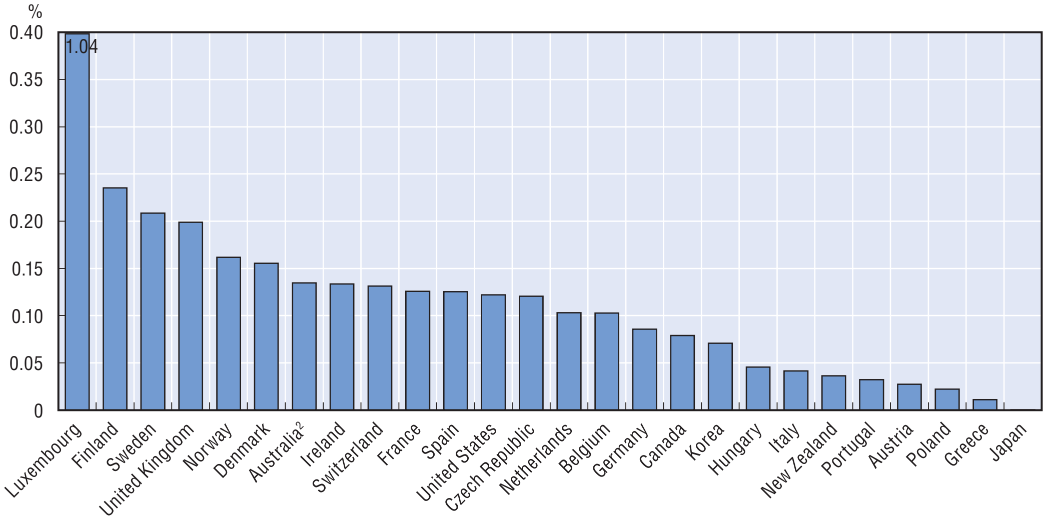
- In the context of their second stimulus package (*Konjunkturpaket II*), Germany pledged EUR 900 million for R&D in SMEs in 2009 and 2010 and the programme is being expanded to include larger companies with up to 1 000 employees. In addition more than EUR 950 million were earmarked in 2009 for technology funding for SMEs.
- In 2009 Canada also temporarily expanded its funding to initiatives for technology-based SMEs (CAD 200 million over two years) during the economic downturn. Canada introduced the Innovation Commercialization Program, a two-year-pilot initiative (CAD 40 million over two years) through which federal departments and agencies will adopt and demonstrate the use of innovation prototype products and technologies developed by SMEs.
- One of the most important tasks of the Danish Competence and Innovation Networks is to ensure that smaller companies participate in network projects and that this target group makes use of innovation policy initiatives.
- Finland provides SMEs funding for the procurement of innovation services. Eligible targets include consultation related to the development of a company's business model and strategy, market and customer needs surveys, and studies on rights to a product or service. The funding for SMEs consists of either a financial grant of 35% or 50%, or of a loan of a maximum of 70% of the total costs, depending on the nature of the project.
- In 2008, France replaced the previous AII scheme by the *Innovation Stratégique Industrielle* (ISI) programme to help SMEs and medium-sized firms (up to 5 000 employees) with high-growth potential to develop breakthrough innovations in the framework of collaborative projects involving firms and centres of competences (annual budget of EUR 150 million). In addition, EUR 1.5 billion have been allocated to the national agency for innovation and SMEs (OSEO) for grants, advances, guarantees and loans to innovative SMEs and medium-sized firms and to allow the OSEO to take higher risks.
- In Sweden, the SME lending facility (*Almi*) was substantially increased. At the same time a new governmental evergreen fund, *Almi Invest*, was introduced, investing at the level of SEK 1-10 million in SMEs.
- Turkey has developed new support systems (KOSGEB) to provide innovative SMEs with R&D facilities and to support their technology development (OECD, 2009a).

Innovation vouchers aim to encourage and help SMEs to access and use knowledge from the higher education and research sectors. At the same time, innovation vouchers help firms to formalise their knowledge needs and allow knowledge institutions to identify business demand and make public research more relevant. Innovation vouchers have already been implemented in many countries and policy makers have tended to simplify their use and to extend their scope.

- Belgium (Wallonia) has introduced technological vouchers (*chèques technologiques*) as a 75% subsidy, granted within three business days and available to all SMEs in Wallonia interested in using the services of a research centre.
- In 2008 Denmark established a new Innovation Voucher Scheme. The scheme is open to projects in all scientific fields and has been designed to reduce bureaucratic measures as much as possible. There are two vouchers: *i)* a "basic" voucher for research-based business development projects to ensure transfer of knowledge from research to SMEs (state co-funding level of 40% with a maximum of DKK 100 000); *ii)* an "extended" voucher with similar characteristics for a larger-scale R&D collaboration project to find new solutions to current problems (state co-funding level of 25% with a maximum of DKK 500 000).
- In 2009, Greece introduced innovation vouchers for SMEs (EUR 8.4 million). The new scheme grants innovative consulting and support services from public research institutes (universities, technical institutes, research centres, industry companies) to SMEs with up to 20 employees (mainly in the manufacturing sector). Each grant or voucher is issued in amounts up to EUR 7 000 and allows SMEs to get specialised services and expertise in order to address a problem, a query or improve a production process.
- In Italy, several regional governments granted vouchers to SMEs for R&D services and the development of human capital in 2009 and 2010 (*e.g.* the region and chamber system of Lombardy has provided around EUR 6 million).
- The Netherlands has renewed its commitment to intensify its innovation voucher scheme. Since it was launched in 2008, over 20 000 innovation vouchers have been provided to entrepreneurs. In addition, in 2009 another 8 000 vouchers were issued to entrepreneurs in the SME sector. The success of the instrument relies on low-threshold access which allows broad coverage among SMEs and a digital format that reduces the administrative burden and makes it easy to apply for (the application process can take as little as eight minutes). To expand the potential of the innovation voucher scheme, a pilot project has been carried out with 1 000 innovation vouchers that can be cashed in with private knowledge suppliers. Syntens, an executive body of the Ministry of Economic Affairs, was involved in helping entrepreneurs find the appropriate knowledge institute.
- Slovenia has implemented innovation vouchers through the Agency for Entrepreneurship and Foreign Investments.
- The Swedish Agency for Innovation Systems (VINNOVA)'s VINNOVA Research & Grow programme was modified in 2008 to allow continuous application handling for small projects (grants up to SEK 100 000). This reshaped the programme to create a more voucher-like instrument and make the process more open and faster, especially for SMEs.
- In 2009, the Swiss innovation promotion agency CTI launched Innovation Voucher for SMEs with a value of CHF 7 500 per voucher. Given the positive reaction, CTI launched in 2010 a further series of innovation vouchers, again with a value of CHF 7 500 per voucher. This second series is open exclusively to projects in the field of "cleantech".

Venture capital (VC) plays a crucial role in promoting innovation and is a key determinant of entrepreneurship (OECD, 2009b). But venture capital is highly sensitive to economic downturns and the appetite in markets for new technology-based firms (Figure 2.3). Most private venture capital funding concerns expansionary capital in

Figure 2.3. **Venture capital, as a percentage of GDP, 2008**[1]



Note: The OECD defines venture capital here as the sum of "seed/start-up stages" and "early development and expansion stages". The coverage of VC stages within these two broad groups differs across countries and the data may therefore not be fully comparable. See notes at the end of Chapter 3 for further details.

1. 2006 instead of 2008 for Japan.
2. Venture capital in Australia includes seed, start-up, early and late expansion, and turnaround investment. Australian data are overestimated.

Source: OECD, *Entrepreneurship Financing Database,* July 2010.

StatLink http://dx.doi.org/10.1787/888932333044

higher-technology industries. Consequently, governments have tended to provide funds for early-stage and seed financing, often along a "fund of funds" model in which government invests along with private actors and the fund is privately managed.

In 2008, Luxembourg led, with venture capital investments of 1.04% of GDP. Venture capital investments were also substantial in Finland, Sweden and the United Kingdom (around or slightly above 0.20% of GDP) but very limited in Japan and Greece (around or below 0.01% of GDP) (Figure 2.3).

In Canada and Germany, where venture capital markets are relatively limited, new measures in favour of risk capital have been introduced. In 2008 Germany approved the Act on the Modernisation of Framework Conditions for Venture Capital and Equity Investments. The federal government's High-Tech Start-ups Fund, with a volume of some EUR 272 million, invests venture capital in young, promising technology companies making entrepreneurial use of promising research findings.

The government of Canada provided CAD 350 million to expand venture capital activities, of which CAD 260 million will be directly invested in Canadian firms and another CAD 90 million in Canadian venture capital funds. In addition CAD 75 million have been earmarked to create a new privately run venture capital fund aimed at later-stage Canadian technology firms. To further improve access to financing for Canadian businesses, the federal government launched the Business Credit Availability Program (BCAP) in 2009 to deliver at least CAD 5 billion in incremental financing to businesses, largely SMEs.

In the framework of *Investissements d'avenir*, France has allocated EUR 400 million to a fund managed by the Strategic Fund of Investment (FSI) to reinforce start-up capacities.

Support for R&D and innovation in specific industries and technological areas

Government has a key role to play in sustaining industrial competitiveness and promoting cutting-edge research in advanced technology areas. Canada has maintained individual programmes, such as the Strategic Aerospace and Defence Initiative (SADI), which offers repayable investments for industrial research and pre-competitive development in aerospace, defence, security and space industries (up to CAD 225 million a year). In 2009, France implemented the *Pacte Automobile*, a national plan for the automobile industry which involves EUR 6.5 billion in participative loans for car manufacturers, an up-to-90% guarantee fund managed by OSEO, a EUR 600 million sectoral fund, higher partial unemployment compensation, and support schemes to innovation.

To address its lag in expanding fields, such as nanotechnology and biotechnology, France has boosted funding for nanotechnology research by EUR 70 million. Japan has allocated funds to research on advanced and innovative technologies such as regenerative biology. More broadly, the Japanese New Growth Strategy aims to address the issues of an ageing society and long life expectancy by promoting innovative pharmaceuticals and medical and nursing care technologies and fostering drug development ventures. Korea announced a Green New Deal and government investment in green technology R&D for a total of USD 4.7 billion over four years (OECD, 2009a).

Box 2.4. **Greening the automotive industry**

As a response to the global crisis that hit the automobile industry, many OECD governments have deployed rescue plans aiming to sustain the vehicle cluster during the economic downturn and ensure the foundations of future international competitiveness.

Governments have implemented financial compensation schemes to renovate the automobile park and prompt businesses and households to replace their old cars for newer and more energy-efficient ones. France, Germany, Italy, Japan, Portugal, Spain and the United States all have such incentives, with differences in the criteria of eligibility (age of the car) and the amount of the allocation (OECD, 2009a).

In addition many governments have developed incentives to better link automobile production to clean technologies (OECD, 2009a). Green R&D and the development of non-polluting energy sources are at the core of national strategies. Australia has invested in a New Car Plan for a Greener Future to improve environmental outcomes of the national automobile sector. In Belgium, both the Walloon and the Flemish governments have launched cluster policies in the automotive sector and the greening of the car industry has been high on the policy agenda. The Flemish research institute VITO in particular has invested in research on green cars. Germany has pledged EUR 500 million to foster the development of hybrid and other clean car technologies. Korea has increased its R&D spending for the development of technology in green cars. The US government awarded USD 2 billion in grants to spur private sector investment in battery and electric drive components; another USD 25 billion in loans was made available to accelerate the production of more fuel efficient vehicles. The European Green Cars Initiative covers a broad range of technologies and research on smart energy infrastructures to achieve a breakthrough in this direction.

Box 2.4. **Greening the automotive industry** *(cont.)*

Canada has launched major initiatives to advance automotive research: *i)* the Automotive Partnership Canada (APC), with CAD 145 million over five years (2009-14) to support collaborative industry-driven R&D; *ii)* the Automotive Innovation Fund (AIF), a CAD 250 million fund created in 2008–09 to support large-scale R&D projects that may help increase competitiveness and environmental performances of the Canadian automobile industry. A CAD 80 million repayable contribution has already been allocated to the Ford Motor Company of Canada's Renaissance Project to establish a flexible engine assembly plant (Ontario), and to create a new North American Centre for Diesel and Advanced Powertrain Research in order to advance research on powertrains (CAD 730 million by 2012).

The Swedish government created in late 2009 a venture capital firm, *Fouriertransform AB*, to finance commercially viable investment and R&D projects in the vehicle cluster. The firm has been allocated capital of EUR 300 million to be invested in operations that aim to strengthen the Swedish automotive industry's international competitiveness especially in terms of safety and respect of environment.

Source: OECD (2009a).

R&D and innovation in services and non-technological innovation

While OECD economies are clearly serviced-based, services still contribute a much smaller share of R&D activity (OECD, 2007). Iceland (60%) and Luxembourg (55%) are the rare OECD countries in which most business R&D is performed in the services sector.[3] In smaller OECD economies such as Chile, Greece, Portugal or the Slovak Republic, the services sector accounts for 43-45% of total business R&D expenditures. It represents less than 10% of total business R&D expenditures in France, Germany, Japan or Korea.

Services firms contribute substantially to non-technological innovation. In Austria, Greece, Portugal and Luxembourg, more than half of the firms in the services sector introduced organisational or marketing innovations between 2004 and 2006. In these countries, as in Finland, New Zealand as well as in the Czech Republic, Hungary and Poland, the services sector appears to be even more innovative than the manufacturing sector; more services than manufacturing firms have introduced non-technological innovation (OECD, 2009b).

Policy makers have paid increasing attention to promoting innovation in the services sector. Health services have particularly benefited from the increased policy focus.

Austria initiated in 2010 a Service Initiative for technological and non-technological services and provided funding with an emphasis on projects for innovative services. The initiative is at the moment limited to 2010.

Finland has launched two support programmes. Innovation in Social and Healthcare Services (2008-15) aims to renew social and health-care production processes, improve the availability of services and their quality and effectiveness, and promote new business opportunities. Serve – Pioneers of Service Business (2009-13) aims to broaden services development of Finnish industry and to promote academic research in service-related areas.

Germany has devoted EUR 17.5 million annually to the programme Innovation with Services (2006-11) to realign services research, create conditions for attractive jobs and improve market position. In addition a Service Task Force has been established to help link services research and technological research. Health and energy efficiency are the first areas in which pilot projects have been launched.

Korea formulated five "growth engines" with support for research in high-value-added services including health care, education and tourism (OECD, 2009a).

Greece launched in 2009 a new scheme to support new innovative companies (spin-offs, spin-outs) to promote both technological and non technological innovation.

In addition to efforts to stimulate health and care services, Japan plans to develop its tourism potential with an objective of 25 million foreign visitors annually by the beginning of 2020 and 30 million in the future. Japan has announced its intention to ease tourist visa requirements for citizens of Asian countries and study "local holiday systems" and other ways of staggering vacation times.

Sweden is working on the formulation of a strategy for promoting innovation in services and non-technological innovation. A debate is also under way concerning the establishment of a national research institute in services, possibly within the existing Research Institutes of Sweden Holding (RISE) infrastructure. Some services have already been identified as strategic research areas and benefited from the additional public funding provided in the framework of the 2008 Research and Innovation Bill. Health and IT services will receive particular support. Finally, Sweden launched in 2009 a VINNOVA research programme to increase knowledge about leadership in and organisation of service-oriented domains. Thematically, the largest number of service-oriented projects financed is in transport, followed by life sciences, and then production and product development.

Other examples of initiatives around services, non-technological and user-driven innovation include:

- Denmark has implemented a programme backed with a yearly budget of DKK 100 million (2007-10) to strengthen the diffusion of methods for user-driven innovation in the private as well as the public sector. Moreover the Danish Council for Technology and Innovation has an Open Pool for new types of collaboration.
- Canada has implemented a network of over 240 industrial technology advisors located in technology communities, local associations, universities and colleges across the country which provide support to SMEs on technological and non-technological matters. They assist firms from concept to product, give technical and business advice, referrals and other innovation services.
- Finland has significantly increased public allocations for non-technological development, which accounted in 2009 for 41% of the total financing of its main Funding Agency for Technology and Innovation (Tekes). Tekes' Workplace Development Programme (2004-09) aims to improve the modes of operation of Finnish companies and other work organisations, and enhance productivity and the quality of working life.
- In 2008 France implemented the *Plan Qualité et Performance 2010* to improve the diffusion and appropriation of best practices by SMEs through the organisation and funding of collective actions (diagnostics, awareness campaigns, and implementation of operational tools). In addition, a policy action was implemented late in 2009 to foster education on these best practices. At local level, higher education institutions of the *Rhône-Alpes* region are developing a pilot *atelier-école* project to implement these best practices and measure their impact on the production line.

- Germany is providing EUR 22.5 million a year to develop innovations in the workplace and an additional EUR 10 million annually to improve the employability of individuals by introducing training and new concepts for personal development. In addition, Germany is funding an international monitoring project to study the development of working skills.
- Sweden is developing its R&D activities to advance current knowledge on how to achieve and maintain organisational and managerial conditions for innovation and to promote learning, creativity and innovation at work.

Several countries have also emphasised fostering creative industries and sectors.

- Denmark has focused public efforts on improving market conditions for the design sector, increasing the visibility of Danish design, and strengthening research as well as education and training in the areas of design.
- France has reinforced general tax incentives for the textile, craft and art industries. The French government has also commissioned a comparative survey of creativity schools in France and abroad, and an international survey of design policy in order to implement new policy actions and increase the influence of French design internationally.
- Israel has adopted two special programmes to support innovation in industrial design and to encourage companies going through the creativity process.
- Spain has implemented the ADÑ programme to help establish a culture that promotes innovation and design through the diffusion of good practices and advanced knowledge.
- Sweden has allocated EUR 7 million over three years to stimulate the creative and cultural sector.

Demand-side innovation policies

Demand-oriented innovation policies have recently attracted much attention from policy makers, partly in response to interest in increasing market demand and uptake of innovation that can address certain societal needs while improving economic performance. The existence of market or system failures which stunt market demand for innovation (*e.g.* information asymmetries, spillovers, externalities or appropriability of public goods) may justify policy action, especially in areas for which the public sector is a provider of goods and services. Targeted demand-oriented innovation policies include public procurement, lead markets, regulations and standards, pricing schemes and consumer policies.

Box 2.5. **Examples of demand-side innovation policies**

Australia: The Australian Industry Participation (AIP) National Framework (2001) aims at supporting Australian industry to innovate, develop and enhance competitive capabilities and take advantage of investment opportunities. In its 2009 Procurement Statement, the Australian government announced a series of measures to extend and strengthen the Australian Industry Participation framework, notably to apply the AIP framework to large Commonwealth tenders (above AUD 20 million) and Commonwealth infrastructure projects; and to emphasise the connection of Australian suppliers to Commonwealth-funded infrastructure (AUD 8.5 million will be provided to the Industry Capability Network).

Austria: Austria will launch an Action Programme on Innovation – Promoting Public Procurement in 2010 to deal with major issues related to public procurement for innovation such as co-ordination of stakeholders, SMEs and acceleration of the process.

Box 2.5. **Examples of demand-side innovation policies** *(cont.)*

Denmark: The Danish programme for user-driven innovation aims to strengthen the development of products, services, concepts and processes in companies as well as public institutions through increased focus on innovation from the perspective of the user. The programme funds projects that develop and test methods of user-driven 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 competitiveness 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.

Germany: Via its Innovation with Norms and Standards, the BMWi is supporting the German Institute for Standardisation (DIN) in early, systematic identification of standardisation requirements in high-technology fields covered by the High-Tech Strategy (such as aero-space technology, micro-system technology, nanotechnology, medical technology and biotechnology). The aim of the (partially demand-side) effort is to provide an optimal framework for future innovation and thereby to promote the marketability of such innovations.

Italy: The government has recently re-oriented its innovation strategy towards societal challenges, notably the transition to a low-carbon economy. The government aims to achieve this by linking supply- and demand-side policies in the area of green technologies, especially in energy co-generation, photovoltaic plants, solar thermic plants and new high-tech long-distance power lines.

Japan: In a new innovation strategy, Japan shifts from scientific innovation in four strategic fields (biotechnology, ICT, nanotechnology, environment) to demand-pull innovation (low carbon society, ageing).

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 and Medium Business Administration finances the technological development of SMEs, and public institutions purchase the products for a certain period.

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

South Africa: To ensure that local companies participate in the major infrastructure built by state-owned enterprises (SOE) the Competitive Supplier Development Programme (CSDP) requires foreign-based original equipment manufacturers (OEMs) to subcontract local companies as Tier 2 and 3 suppliers.

Box 2.5. **Examples of demand-side innovation policies** *(cont.)*

Spain: The Spanish State Innovation Strategy is developing measures for an innovation policy based on specific markets: health and welfare, green economy, e-government, science, defence, tourism and ICT. For these markets, public procurement policies encourage innovation through public sector demand, under the legal framework recently endorsed by the new laws on public contracts and on the project of sustainable economy.

Sweden: VINNOVA, the Swedish innovation agency, started a pilot programme of Innovation procurement in late 2009. The programme aims to stimulate the development of new products/processes in the public sector.

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. In addition, the government is using standards to support demand for biometrics by supporting the development of technical standards that support interchangeability and interoperability. The idea is that standards can help reduce risk for the procurer, system integrator and end user, because they simplify integration and enable vendor substitution, technology enhancement and development.

United States: To stimulate demand for advanced health information technology systems, the United States has established a system of incentive payments under two large, public health programs (Medicaid and Medicare) for physicians and hospitals that demonstrate "meaningful use" of electronic health records (EHRs). As complementary measures, the United States established standards for certifying that qualified EHRs meet specified "meaningful use" criteria, and has funded regional extension centres to assist users in selecting and implementing qualified EHR systems.

Enhancing networking among actors

Countries' innovation performance depends increasingly on their ability to catch and make the most of globalised knowledge flows. Co-operation across sectors, fields and borders has become indispensable. Firms collaborate more with customers, providers or competitors on innovation processes. The production of scientific knowledge is shifting from individuals to groups, from single to multiple institutions and from national to international (OECD, 2010b). Not surprisingly, policies to support networking and collaboration among innovation actors are intensifying throughout the OECD area.

Encourage the development of STI platforms and open infrastructures

It is widely recognised that the effectiveness and efficiency of innovation systems are determined to a considerable extent by the degree and quality of linkages and interactions among various actors, including firms, universities, research institutes and government agencies. Four indicators can be used to measure the connectivity of innovation infrastructures: *i)* the regional concentration of patenting as a percentage of Patent Cooperation Treaty (PCT) patent applications; *ii)* the number of broadband subscribers per 100 inhabitants; *iii)* the share of innovative firms engaged in collaboration on innovation and *iv)* the degree of collaboration on scientific publications (per capita). The regional concentration of patents indicates the presence of research hubs that host public labs, leading research universities and innovative firms. The broadband penetration rate reflects how widespread are high-speed networks that serve as a platform supporting innovation.

Broadband has become the leading delivery system for a wide range of content and has dramatically changed personal and business practices. The share of innovative firms engaged in collaboration and the degree of collaboration on research publications provide direct measures of collaboration in industry and in science (OECD, 2010b).

Virtually all countries give high priority to policies aiming to improve the physical STI infrastructure and to link public research to industry and society (Table 2.8). In fact, the development of STI platforms and infrastructures ranks as a top priority for Canada and Japan, where collaboration in industry for the former and in both industry and science for the latter, are weaker than in many other OECD countries. Finland and Sweden seem to show the best performance in terms of STI infrastructure.

Table 2.8. **Innovation infrastructure: performance, policy priority level and measures taken between 2008 and 2010**

	Performances in 2008 or nearest				Priority level		Develop STI platforms and open infrastructures			
	Regional concentration of patenting,[1] 2004-06	Broadband penetration rate,[2] June 2009	Share of innovative firms engaged in collaboration 2004-06	Scientific publications[3] in collaboration, 2007	Improve the physical infrastructure for STI	Link public research to industry and society	Improve ICT network	Foster clusters	Develop PPPs	Encourage public research diffusion
	Index 100 = Highest OECD value				Country self-reported[4] (1-8)		Measures/initatives taken between 2008 and 2010			
Austria	58	57	64	49	5	7			✓	
Canada	100	78	37	60	8	8		✓		✓
Czech Republic	36	48	67	32	6	8	✓	✓	✓	✓
Denmark	56	97	55	70	6	6		✓		
Finland	70	78	100	72	7	6		✓		✓
France	62	76		38	3	7	✓	✓	✓	
Germany	53	77	25	38	6	7	✓	✓	✓	✓
Hungary	67	44		20	7	8	✓			
Israel					6	6		✓	✓	✓
Italy	58	52	22	33	8	8	✓		✓	✓
Japan	75	64	41	26	8	8	✓		✓	
Korea	77	86	36	30	5	7	✓		✓	✓
Netherlands	49	100	65	64	6	6		✓	✓	✓
New Zealand	55	60	52	59	7	7				
Norway	65	91	59	66	7	7			✓	✓
Poland	75	30		17	7	6				
Slovenia					7	8				
South Africa			61		6	8				
Spain	65	55	26	36	6	8	✓		✓	
Sweden	71	83	68	75	6	8		✓	✓	
Switzerland	30	89		100	n.a.	n.a.				
Turkey	93	23		9	n.a.	n.a.				
United Kingdom	62	76	45	53	n.a.	n.a.				
United States	70	70		37	2	5		✓		✓

Note: The table only includes countries that provided responses to the STI Outlook 2010 Policy Questionnaire as of 31 August 2010. However, indicators of performance are calculated for all OECD countries for which data are available. Therefore the highest OECD value may not appear in the table and the ranking takes into account a larger number of countries than those presented here.
n.a.: Response not available.
1. PCT patent applications.
2. Number of subscribers per 100 inhabitants.
3. Per capita.
4. Self-reported ranking of national STI priorities based on a scale whereby 1 = least important and 8 = most important.
Source: OECD, *REGPAT Database*, June 2009; OECD, *Broadband Statistics, June 2009*; OECD, Innovation Microdata Project based on CIS-2006, June 2009 and national data sources; OECD (2010b), "*Measuring Innovation: A New Perspective*", OECD, Paris; responses to the STI Outlook 2010 Policy Questionnaire.

Nurture world-class nodes and bridge industry and science

Reinforcing industry-science linkages continues to be a major thrust of innovation policies. Linkages between public research institutes and industry occur in many ways, from the most direct – joint research projects or joint ventures (spin-offs) – to the more indirect – training, consultancy, staff mobility – to informal co-operation.

Public-private partnerships have been encouraged at different levels and by different levers. Reforms in general policy, regulation or changes in organisational structures have created new areas of co-operation.

- Sweden has amended its Higher Education Act so as to introduce the building of external partnerships into the mission of higher education institutions, together with education and research, and to encourage them to actively exploit research outcomes. In this context, a model agreement has been developed to regulate responsibilities and rights in collaborative research.
- Similarly the Netherlands has adopted changes in regulations governing the types of agreements negotiated between public research institutes and businesses and their implications for access to and exploitation of research results.
- Since 2008 Austria has allowed the temporary research studios that were mainly based within the Austrian Research Council to be based at universities or non-university institutes.
- Israel has planned to implement 30 new centres of excellence for research, development and innovation (ICORE – Israeli Centers of Research Excellence) within the new national plan (2011-15) for a total budget of about USD 350 million (ILS 1.35 billion). A third of this programme will be financed by the government, while the rest will derive from universities' own funds and assigned donations. The first four centres of excellence will be established during the academic year 2010-11.
- Slovenia has established eight new centres of excellence for a four-year budget of EUR 77 million in priority areas including materials and nanotechnologies, complex systems and innovative technologies, health and life sciences, and technologies for a sustainable economy. In the near future seven more centres of excellence will complement the system.
- South Africa is developing a framework for its centres of competences (CoC) to provide them with guidelines for their establishment and management. These physical and virtual platforms serve to establish collaborative technology development partnerships between government, industry, higher education institutions and public research institutes. Public-private partnership arrangements are also encouraged through regulations administrated by the Department of National Treasury.

Governments have increased financial support to collaborative schemes and research projects involving public and private partners. This is the case for Spain but also for Norway where requirements of industry-science collaboration have been included into all major and minor funding schemes.

- One of the main tasks of the new Czech Technology Agency has been to strengthen industry-science co-operation. The Czech government supports collaboration platforms that provide infrastructure for business R&D, training and training of human resources to enhance the development of start-ups and academic spin-offs.
- In France, EUR 400 million have been allocated over four years (2009-12) to a new ADEME *démonstrateur* fund to facilitate the testing of new technologies at industrial scale and

help validate technological choices. New alliances have been created to co-ordinate main actors in an area and to design thematic R&D programmes that are consistent with the national strategy. These partnerships will provide the National Research Agency with S&T roadmaps and assist it in setting the national R&D agenda. In the near future they will also develop public-private partnerships.

- Israel has created a joint public-private sector fund to support investments in biotechnology and has announced the establishment of two technological centres dedicated to water and renewable energies that will promote the transfer of know-how from academia to industry. In addition the Magnet Programme funds industrial and academic partners involved in pre-competitive R&D on new generic technologies with the aim of creating a new generation of advanced products. The Users Association in Advanced Technologies also gives users from the private sector the opportunity to better exploit advanced technologies.
- In Japan, the Innovation Network Corporation of Japan provides capital and managerial support to public-private partnerships to next-generation businesses in promising new technologies.
- In Sweden the additional funding to be allocated by the central government to strategic research areas will indirectly support partnership programmes with industry since these areas have been specifically defined in fields in which government R&D funding strengthens the competitiveness of Swedish industry. The Swedish government has also allocated extra funding to bridge academic research, needs-based research, and company-related R&D (*Innovationsbron AB* for SEK 200 million).

Public schemes to strengthen public-private partnerships often include commercialisation partnerships. In 2008 Canada took a series of commitments in this direction and granted substantial investments to further develop the Networks of Centres of Excellence (NCE),[4] in particular with the creation of Business-Led NCEs (CAD 46 million in investments over four years), the Centres of Excellence for Commercialization and Research (CAD 350 million in investments over five years) and the College and Community Innovation Program (CAD 18 million over five years and will continue at CAD 30 million, as of 2011-12).

Clusters

Strengthening existing or developing clusters has become a pillar of national innovation policy. Clusters group together enterprises, higher education institutions and public research institutes that collaborate in a certain area. In all OECD countries, innovation is geographically concentrated owing to the existence of local clusters and the dynamics of regional economies (OECD, 2007).

Since the early 1990s many OECD countries have promoted a cluster-based approach to innovation in parallel with traditional sectoral R&D programmes policy. More recently health, energy, natural resources and food production have been particularly targeted.

- The Swedish programme Innovation Channels within the Health Service aims to support the development of ideas from the health service into needs-driven innovations within county councils and municipalities. These innovation channels should act as a contact node for companies and facilitate the introduction of innovations in the health service sector.
- The United States has announced a multi-agency funding opportunity to support an Energy Regional Innovation Cluster (E-RIC). This pilot initiative will spur regional economic growth while developing innovative energy-efficient building technologies, designs and systems.

- Canada has funded collaborative research in automotive, manufacturing, forestry and fishing industries as well as in health. The Canadian government has also enabled researchers to collaborate on large research projects related to nanoscience and nanotechnology. Regional economic development agencies have been provided new resources too. The Atlantic Canada Opportunities Agency receives CAD 19 million a year; Canada Economic Development for Quebec Regions CAD 14.6 million a year; and Western Economic Diversification Canada CAD 14.7 million a year.
- In 2010 Denmark established strategic platforms for innovation and research (SPIR) to pool the funds of the Danish Council for Strategic Research and the Danish Council for Technology and Innovation to encourage large industry-science collaborations within thematic areas. The initiative first addressed energy and food production issues.
- Finland set up new strategic centres for science technology and innovation (SHOK) to speed up innovation processes, renew industry clusters and create radical innovations. These multidisciplinary centres (EUR 40-60 million annually each) provide a permanent forum for companies and research organisations to orient innovation processes, open avenues for training and recruitment, and act as gateways to international co-operation. Six centres are in operation in forestry (Forestcluster Ltd), ICT industries and services (TIVIT Ltd), metal products and mechanical engineering (FIMECC Ltd), energy and the environment (CLEEN Ltd), environment innovations (RYM Ltd), health and well-being (SalWe Ltd). In addition Finland has reformed the organisation of the Centre of Expertise Programme (OSKE) on a cluster-based model to increase regional specialisation and to strengthen co-operation between centres of expertise.
- Japan has begun a reform to foster regional activities and revitalise urban areas, in particular by supporting regional autonomy through the autonomous settlement regions and by expanding the physical infrastructure. Japan promotes the development of regional networks for business creation, co-operation for commercialisation and business matching with clusters in others countries.
- In the framework of its High-tech Strategy, Germany has launched the Leading Edge Clusters Competition which supports the formation of strategic partnerships between business and science. In 2008 and 2010 ten clusters were selected, each of which receives a maximum of EU 40 million over five years. A third round is planned for the end of 2010. In the framework of its Excellence Initiative, university-centred excellence clusters have also been built up. The objective was to establish internationally visible and competitive research beacons at universities which can co-operate with non-university research establishments, universities of applied sciences and the private sector. Each of the 37 clusters selected during the two current funding rounds receive on average EUR 31.8 million over a five-year period.
- Greece established in 2006 its first innovation cluster the mi-Cluster (Nano/Microelectronics and Embedded Systems). It members have increased to include over 100 organisations from all over the country. The Corallia Clusters Initiative aims at boosting competitiveness, entrepreneurship and innovation in knowledge-intensive and exports-oriented technology segments in which Greece has the capacity to build a sustainable innovation ecosystem and can attain a worldwide competitive advantage.
- Switzerland has launched a research initiative, SystemsX.ch, to promote systems biology. SystemsX.ch is a network and partnership of nine universities and three research institutions and benefits from a CHF 100 million federal budget (2008-11) and an equivalent investment from industry and other funding agencies. Switzerland has also launched the

Nano-Tera.ch initiative which aims to put Switzerland at the forefront of a new technological revolution based on engineering and information technology for the health and security of humans and the environment in the 21st century. Several Swiss universities as well as private research institutions and companies are involved in Nano-Tera.ch for a total budget of CHF 120 million, of which 50% is funded by Nano-Tera and 50% by participants.

- In Belgium, the Walloon authorities have invested during the last decade in the development of 14 business clusters and six innovative partnerships (in the so-called Marshall plan.2 green). Since 2005, competitiveness poles have been a major plank of Walloon STI policy with a budget of EUR 280 million (2006-10). In Flanders the Flemish Science and Innovation Policy Council identified six strategic clusters: *i)* transport – logistics – services – supply chain management; *ii)* ICT and services in health care (e-health); *iii)* healthcare; *iv)* new materials – nanotechnology – manufacturing industry; *v)* ICT for socioeconomic innovation (e-health, e-government, e-learning; *vi*) energy and environment (smart grids and intelligent energy networks Voka).
- In 2007 the Netherlands launched a four-year regional policy programme, Peaks in the Delta, to foster excellence in key areas and enhance the growth and innovativeness of strong economic clusters of national importance in six Dutch regions. The programme includes a subsidy scheme, supports R&D co-operation among key regional players, provides incubator facilities, accommodates cluster needs for skilled workers via specific educational tracks, develops innovation campuses, and fosters organisational capacity. In 2011, when the current programme comes to an end, a new four-year programme will begin.
- France has entered the second phase of its cluster programme *Pôles de compétitivité* (2009-12) with EUR 1.5 billion allocated to support R&D, reinforce the governance of the poles of excellence, introduce new funding mechanisms and develop an innovation and growth ecosystem. In addition several technological research institutes (*instituts de recherche technologique – IRT*) have been created. These pool public and private labs from the same geographical area and same technological field and integrate education, training, research and innovation.

Strengthen physical infrastructures for STI

Sound physical infrastructure, especially high-speed broadband access and powerful IT equipment, are essential to support knowledge advancement, communication and co-operation.

As part of their stimulus packages many OECD and non-OECD countries have made large investments in ICT infrastructure and applications (OECD, 2009a). These investments will have lasting effects on STI infrastructures by closing the broadband gap and extending access to remote areas without connectivity, on the one hand, and by upgrading the existing network and accelerating the adoption of high-speed technologies, on the other.

Several countries are reinforcing their IT systems to permit faster communication and wider information dissemination among public and private agents.

- Denmark has set the goal that all citizens and businesses in Denmark should have access to high-speed broadband (at least 100 Mbit/s) by 2020 (the previous objective was 512 kbit/s by 2010). This new broadband objective will ensure that Denmark has an infrastructure ranking among the best in the world. In addition, as one of the country's largest owners of buildings, the Danish Science Ministry will focus on integrating ICT in its building processes.

- Spain is funding new ICT-based services through the RedIris optical fibre network that provides advanced communication services to the scientific community and national universities.
- Finland has set up the Funet network service, a superfast data communication network at the disposal of research and education. Funet services are the backbone network of academia and include high-speed national and international data communication connections to other research networks, access to the Internet, data security services, modern communications services (*e.g.* video conferences, media services, wireless network roaming) and consultancy and specialist services. In addition the IT Center for Science Ltd (CSC), a non-profit company, provides IT support and resources for academia, research institutes and companies. CSC offers a powerful supercomputing environment with access to supercomputers and IT consulting services, an internationally competitive set of services for computational science, and a wide collection of scientific software, training, in-depth support, software development and grid computing infrastructures. CSC provides solutions for data storage, management and analysis as well.
- Belgium has implemented the BELNET network based on over 1 650 km of fibre, covering the entire country, which provides high-speed access to the Internet and the global research network to about 200 institutions of research and education, research centres, governments and public services, representing more than 650 000 users.
- The Czech Republic has stimulated the implementation of information systems in SMEs in order to increase organisational innovation.
- Japan plans to encourage further utilisation of ICT, through improved training, better protection of personal information and increased security. Systems and regulations will be revised to this purpose. Furthermore, Japan has announced increased efforts to build infrastructure in areas such as rail transport, water supply and energy, to develop cities in harmony with the environment, and to consolidate physical infrastructure between regions.
- France has implemented the ICT&SME 2010 programme (TIC&PME 2010) to reinforce SMEs' competitiveness through better use of ICT. This programme aims to group the efforts of SMEs from the same business sector and to develop common tools based on international standards. The *PMI-Diag* guide has also been developed as a diagnostic guide to help SMEs to evaluate their IT system, organisation and strategy. In addition, the government proposes to small firms with fewer than 20 employees a new free awareness and initiation programme ("*Entrepreneurs, faites le choix de l'économie numérique*") on ICT use.

Encouraging innovation diffusion and enhancing access to scientific information

Governments foster diffusion of public research results to enhance firms' productivity. In the Netherlands, the *Act of Higher Education* entrusts Dutch universities with the task of ensuring the transfer of knowledge transfer, in addition to their mission of research and education.

Many countries have promoted wider dissemination of public data in centralising public research output and developing ICT-based information systems that enhance access to information.

- Norway is implementing a new information system that will bring together all relevant research-related information. A key aspect and main priority of this new information system is the creation of a bibliographic database, the Norwegian Scientific Index, to cover all scientific publications in the public research sector.

- Similarly Finland has developed a national resource centre, the Social Science Data Archive (FSD), which archives, promotes and disseminates digital social science research data for research, teaching and learning purposes.
- The United States government has established a centralised Data.gov website from which datasets generated and held by the US federal government can be easily found and downloaded. The purpose is not only to improve access to federal data but also to expand their creative use beyond the walls of government and drive innovation.
- Although access to data and results from publicly funded research is left to the discretion of public research institutes in Germany, the Alliance of German Science Organisations is working to establish structures for the collection, archiving and re-use of primary research data in all applicable disciplines. This open access programme includes the formulation of a common data policy, close co-operation between scientists and information providers (possibly through the funding of pilot projects) and the establishment of a system of internationally networked discipline-specific repositories for primary research data.
- Canada has developed new infrastructure as well as new services (*e.g.* IT and cloud computing services) to enable greater public access to public research results and to accelerate the translation of knowledge into more effective health products and services.

Some countries also report initiatives at institutional level. In April 2008, the US National Institutes of Health (NIH) made its public access policy mandatory, requiring all funded investigators to submit an electronic version of their final, peer-reviewed manuscripts to PubMed Central, the agency's free digital archive of biomedical and life sciences journal literature. Manuscripts must be submitted upon acceptance for publication, but public access may be delayed for up to 12 months following the official date of publication. Furthermore the NIH and some of its individual institutes have established policies that expect funded investigators conducting specific types of research (*e.g.* genome-wide association studies, autism research) to submit data to repositories for long-term storage and sharing with other investigators according to specified timelines and procedures.

Finland has launched the National Digital Library project which puts the achievements of culture and science at everyone's fingertips and aims to improve the long-term preservation of the electronic materials of libraries, archives and museums. The public interface is a website that will give universal access to the electronic information resources and services of libraries, archives and museums from 2011. Finland has also launched a competition, Apps4Finland – doing good with open data, to find new ways to use public sector data. Developers and designers compete by creating ideas, functional web applications and digital utilities that make use of public data and facilitate collaboration between citizens and public organisations.

Improving the access to public information ensures that public research has a broader impact in the economy. Additional initiatives along these lines include:

- Denmark has centralised R&D statistics at Statistics Denmark in order to move the production of the national statistics to a central agent. In the framework of its digital work programme, the Danish government recently introduced an improved digital signature, NemID (EasyID), which makes it easy and secure to be a citizen in digital Denmark. Denmark is also promoting the use of open standards in the public sector, including standards for document formats. The intention is to strengthen competition and freedom of choice between IT suppliers through the greater interoperability of IT systems that open standards make possible.

- The United States issued in 2009 a Memorandum on Transparency and Open Government in order to establish the principles of transparency, participation and collaboration across the whole of government and bridge the gap between citizens and the government. The US National Science Foundation has implemented the Research.gov website to enable organisations and researchers to access streamlined research grants management services and other resources for multiple federal agencies in one single location.
- Similarly Norway plans from 2011 to lay the foundations of a common information system for all Norwegian research to bring together relevant information on most important research output (*e.g.* publications, citations, innovations), ongoing research activities (*e.g.* researcher projects), available research infrastructure and human resource competences. The Current Research Information System (Cristin) will be designed in co-operation with universities, research institutes and research hospitals; industry is expected to be invited to take part later.
- Canada is aligning the programmes and activities of the federal research funding agencies. Efforts to better serve clients include the harmonisation of diligence processes and the co-location of some services delivered by the Canadian research funding agencies. For instance, in April 2008, the two Canadian research funding agencies NRC (National Research Council) and NSERC (Natural Sciences and Engineering Research Council) launched a joint call for technology-driven research proposals in nanotechnology.
- Japan will promote the computerisation of various types of administrative procedures and provide "one-stop" government services. In addition Japan wishes to speed up investigations in linking various types of identification numbers to resident code numbers. ICT will be used to improve the quality of medical, education and other services, such as by facilitating collaborative education, in which children teach and learn from each other.
- Australia announced as part of its stimulus package the development of standard procurement documents and the introduction of a guarantee of payment for new small businesses' contracts with Commonwealth government departments (OECD, 2009a).

IPRs and knowledge diffusion

Appropriate IPR regimes and practices are necessary to secure returns on investments in innovation and to encourage knowledge sharing. A key issue for policy is finding a balance between rights to control use of an invention via IPR and the diffusion of knowledge about the invention (through licensing, publication, open networks, etc.). Getting the balance "right" is the key goal of the knowledge networks and markets that are emerging as a means to trade and exchange knowledge within more open networked systems of innovation.

Although few internationally comparable data are available at this stage, three indicators may reflect the emergence and spread of knowledge networks and markets, or at least the parts of these that focus on patent development and exchange: *i)* the average share of patents filed by public research institutes between 2000 and 2007; *ii)* the country share in total OECD exports of royalties and licence fees, compared to the country share in total OECD services exports; and *iii)* the growth index of triadic patent families over the last decade, between 1995-97 and 2005-07. The share of patents filed by public research institutes shows the degree to which inventions resulting from public research are marketable. A country's relative share in OECD exports of royalties and licence fees highlights its capacity to market internationally inventions developed locally (inventions as codified in patents). The rise in patenting is a direct measure of the expansion of patenting activities. Table 2.9 presents evidence on patenting and policy measures to foster the commercialisation of public research and, more broadly, knowledge networks and markets.

Table 2.9. **Fostering IPRs, licensing and commercialisation: performance and measures taken between 2008 and 2010**

	Performances			Foster IPR licensing and commercialisation				
	Patents[1] filed by PROs, 2000-07	Relative share[2] in OECD royalties and license fees exports, 2008	Growth[3] in patenting between 1995-97 and 2005-07	Encourage commercialisation of public research results	Reform rules governing ownership and licensing of publicly-funded research results	Reform IPR legislation	IPR support towards SMEs	IPR courses
	Index 100 = Highest OECD value			Measures/initatives introduced between 2008 and 2010				
Austria	25	9	25	✓				
Canada	92	30	24	✓				
Czech Republic	42	1	31		✓		✓	
Denmark	41	21	22					
Finland	3	27	13	✓	✓			
France	89	36	17	✓	✓	✓		
Germany	15	21	17		✓	✓	✓	
Hungary	14	23	24				✓	
Israel	92	22	31	✓		✓	✓	
Italy	41	4	17					
Japan	39	100	20			✓	✓	
Korea	42	18	100					
Netherlands	16	90	19			✓	✓	
New Zealand	19	11	26					
Norway	11	9	21				✓	✓
Poland		4	33					
Slovenia		3	45	✓				
South Africa	35	2	16	✓				
Spain	100	3	35		✓	✓		
Sweden	1	39	13	✓			✓	
Switzerland	21	91	16					
Turkey			90					
United Kingdom	95	27	15		✓		✓	
United States	83	97	18					

Note: The table only includes countries that provided responses to the STI Outlook 2010 Policy Questionnaire as of 31 August 2010. However, indicators of performance are calculated for all OECD countries for which data are available. Therefore the highest OECD value may not appear in the table and the ranking takes into account a larger number of countries than those presented here.

1. Average percentage of PCT patent applications.
2. Compared to the country share in total OECD services exports.
3. Growth index in triadic patent families, 1995/97 = 100.

Source: OECD, *Patent Database*, January 2010; OECD (2010a), "*Main Science and Technology Indicators: 2010-1*", OECD, Paris; Responses to the STI Outlook Policy Questionnaire 2010.

Reforms to IPR

In the Netherlands, reforms of patent legislation came into force in 2009 with a change in the fee structure that means lower entrance costs, the abolition of the so-called six-year (non-examined) patent and the introduction of the possibility of filing (national) patent applications in English. In line with the EU London protocol, the translation requirement is limited to the conclusions of the patent.

France adopted in 2009 a new decree relative to IPRs and implemented the specialisation of IP jurisdictions that would enforce guarantees offered to claimants.

In Germany, since 2008 SIGNO has been supporting higher education institutions, SMEs, start-up entrepreneurs and inventors for legally protecting and commercialising their innovative ideas. In addition IPRs have been enforced by law with the *Act on Better Enforcement of Intellectual Property Rights* that came into force in 2008.

Israel has recently undertaken to enhance and strengthen its IPR mechanisms. Steps were taken to streamline the patent registration process and shorten the examination period. A new Exposure Bill requires the publication of patent applications promptly after the expiration of an 18-month period from the filing date at Israel's Patents Authority (or earlier if a Paris Convention priority right has been claimed). Furthermore a draft is under preparation to amend the Patent Law to reduce the number of reference countries (from 21 to the five major EU countries and the United States). Israel is also about to extend the term of protection of pharmaceuticals tests after marketing approval.

In the context of the economic crisis, the European Union urged its member states to reduce fees for patent applications and maintenance by up to 75% (OECD, 2009a). Furthermore the European Commission adopted in 2009 a recommendation to the Council that would provide the Commission with negotiating directives for the conclusion of an agreement creating a Unified Patent Litigation System (UPLS). This European and EU Patents Court (EEUPC) would lead to significant savings compared to the costs of piecemeal litigation. Such reductions in legal costs could permit many SMEs to enforce their patent rights in all EU and European Patent Convention (EPC) countries.

Japan has tested the Super Accelerated Examination System on a pilot basis since 2008. Green-technology-related patent applications have been eligible for treatment under the conventional accelerated examination system on a pilot basis since 2009. In addition, examination guidelines have been revised in order to expand the patentable subject in advanced medical technologies and the Patent Law was amended in spring 2009 to revise the registration system for non-exclusive licences and to expand the claim period during which one may request an appeal against a refusal.

Encouraging SMEs to patent innovations and build IP capacity is another goal of policies. In the Czech Republic, SMEs can apply for support on IPRs through the Innovation Patent programme. The Japan Patent Office (JPO) provides aid to SMEs for overseas development through the SME support centres of prefectural governments. Sweden has implemented a pilot action to fund SMEs for professional IP consultancy. As the cost of this programme was relatively low and the impact comparably high, the Swedish government is considering the extension of the programme in 2010/11. The Netherlands allows the use of innovation vouchers to cover (part of) the costs involved in an SME's first patent application. The measure, introduced in 2008, involves both direct application costs and the costs of patent attorneys, both domestically and abroad.

Facilitating the commercialisation of public research

The commercialisation of the results of public R&D through patenting or spin-offs is an important channel for transferring knowledge. Recent initiatives in this area include:

- In the framework of the performance agreements concluded with the Austrian government for 2010-12, Austrian universities are obliged to develop IP strategies and improve IP management. Regular meetings involving ministries, public research institutes and the private sector take place as well in order to exchange information and discuss ways to improve knowledge transfer.
- In Finland the new *Act on University Inventions* would improve the environment for innovation at the universities by simplifying questions of ownership. In contract research, the universities are now entitled to get the rights. The concentration of rights makes transfer more efficient and simpler than before. In addition labour contracts in universities include several forms of agreement, such as non-disclosure agreements or agreements on assignment of rights to the university.
- France introduced in 2009 the principle of a unique mandate for IPR management that will be granted to public research institutes that hosted research activities conducive to the invention, in most cases the university. The new decree would allow co-inventors to reduce transaction costs and facilitate technology transfer.
- The adoption of the European Charter for the management of IP in 2008 provides a framework for the treatment and negotiations of IP between public research institutes and companies.
- In 2008 South Africa enacted new legislation on IPRs from publicly financed research. In addition the *IPR-PFR Act* established the National Intellectual Property Management Office (NIPMO) which will facilitate the creation of offices of technology transfer (OTTs) at higher education institutions and public research institutes in order to support them in the identification and management of IP, oversight of IP legislation and negotiation of benefit-sharing agreements.

Some countries have added funding schemes to support technology transfer and commercialisation in academia:

- Sweden is offering universities and university colleges specialised in technology, medicine or science funding to carry out strategies for knowledge transfer and commercialisation. More broadly, the VINNOVA Key Actors programme aims to develop expertise, methods, processes and structures for utilising knowledge and commercialising research results.
- Finland is offering researchers and students funding capacities to access business expertise (*e.g.* purchasing surveys to evaluate the business potential) through the Tuli programme (EUR 50 million for 2008-14).

Countries have also provided public research institutes with infrastructure and non-financial support. Sweden is building up special innovation services offices at universities for researchers whose research may be commercialised. Slovenia has supported the implementation of technology transfer offices at major universities and public research institutes. Austria has implemented an IP National Contact Point in the Ministry for Science and Research to help public research institutes to establish IP policies and IP management procedures. Norway provides grants to academic institutions that incorporate courses on IPRs in their curriculum.

Adjusting to the globalisation of R&D and innovation

The globalisation of R&D and innovation also affects the scope for national policy intervention. Consequently, more OECD and emerging economies increasingly take into account recent trends in the globalisation of R&D when formulating their national strategies. Levels of policy priority given to the internationalisation of national STI vary markedly from one country to another (Tables 2.10 and 2.11). In Finland, Japan and Norway, this ranks high among STI policy priorities; it ranks lower in Austria, the Netherlands and the United States, countries that at the same time are open and internationalised.

Three indicators reflect the internationalisation of STI and the extent to which a country may access international knowledge: *i)* foreign direct investment as a percentage of GDP, *ii)* the share of international students in tertiary enrolment; and *iii)* the percentage of patent applications filed under the Patent Cooperation Treaty (PCT) with co-inventors located abroad. The intensity of FDI inflows reflects the degree to which a country may benefit from knowledge spillovers and additional R&D investment from multinationals. The presence of many international students suggests the contribution of foreign talent to research and the building of connections with international university networks. The share of PCT patents with foreign co-inventors is a direct measure of international co-operation in research.

Linking domestic firms to foreign sources of knowledge, attracting knowledge-intensive businesses and foreign highly skilled workers, providing opportunities for inward and outward international mobility are key aims of policies to adjust to and benefit from globalisation.

Encouraging the internationalisation of innovation actors

With the continuing internationalisation of science and innovation, tapping into foreign sources of knowledge becomes more important. This has led to a range of policy initiatives in various countries and at EU level.

Regional, cultural and historical dynamics are efficient drivers of R&D internationalisation and international co-operation. The European Research Area (ERA) plays a key role in helping EU member countries and associated states to link domestic firms with foreign sources of research and innovation. Many EU members report participation in the EU 7th Framework Programme for Research and their involvement in ERA initiatives to access foreign knowledge and contribute to international research. This is also the case for countries such as Norway and Israel. Similarly, Nordic co-operation provides Nordic countries with the opportunity to collaborate through Nordic centres of excellence and researcher networks, and to create regional synergies.

The Iberoeka projects are instruments which support technological business co-operation in Latin America. This initiative is part of the Latin American Programme of Science and Technology for Development (CYTED) in which 19 Latin American countries, Portugal and Spain participate. CDTI, the Spanish management organisation of Iberoeka projects, promotes the participation of Spanish companies in this initiative by advising on the presentation of new proposals, on the search for partners and on access to sources of financing.

Enhancing the internationalisation of the national innovation system requires governments to reinforce their own capacities. Sweden has implemented a Global Links for Strong Research and Innovation Milieus (*starka FoI-miljöers globala länkar*) programme to

Table 2.10. **Internationalisation of knowledge: performance, priority level and measures taken between 2008 and 2010**

	Performances		Priority level	Link domestic firms to foreign sources of research and innovation							Attract foreign firms and FDI										Support the internationalisation of domestic PRIs			
	FDI inflows,[1] average 2003-08	Share[2] of PCT patents with co-inventors located abroad 2004-06	Internationalisation of STI	Additional or preferential funding	Co-funding	Support to find international partners	R&D tax incentives	Provision of infrastructures and support	Cluster initiatives	Other	Direct financial support	General fiscal incentives	R&D tax incentives	Taxation of intellectual assets and revenues	Administrative support	Provision of infrastructure	Public procurement	Active recruitment of foreign firms	Advertising and international campaigns	Other	Additional funding	Co-funding	Support for the establishment of affiliates abroad	Other
	Index 100 = Highest OECD value		Country self-reported[3] (1-8)	Measures/ initatives in place in 2010																	Measures/initiatives taken between 2005 and 2010			
Australia	12	34	n.a.		✓				✓				✓	✓	✓	✓			✓					
Austria	37	59	4			✓			✓		✓	✓	✓			✓		✓						
Canada	16	63	6	✓		✓		✓			✓	✓	✓			✓		✓	✓	✓				✓
Czech Republic	27	71	6			✓			✓			✓	✓		✓	✓		✓			✓	✓	✓	
Denmark	9	45	6	✓	✓	✓			✓						✓						✓	✓		
Finland		35	8	✓		✓			✓		✓				✓	✓	✓	✓	✓		✓			✓
France	19	48	3	✓		✓							✓			✓		✓						
Germany	6	36	7	✓		✓		✓	✓		✓				✓	✓		✓	✓		✓		✓	
Hungary	100	68	7	✓		✓					✓		✓		✓				✓		✓			
Israel		35	7	✓	✓	✓			✓			✓			✓			✓	✓		✓	✓		
Italy	7	31	7			✓	✓	✓		✓		✓	✓						✓					✓
Japan	1	7	8										✓											
Korea	3	11	7	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓						✓
Netherlands	25	42	6	✓		✓			✓			✓	✓	✓		✓		✓			✓			
New Zealand	16	42	7										✓											
Norway	6	43	8	✓		✓							✓								✓	✓		
Poland	22	78	5								✓	✓	✓		✓	✓		✓	✓		✓			✓
Slovenia		43	5	✓							✓		✓						✓					
South Africa		25	7			✓	✓				✓	✓	✓						✓					
Spain	17	44	7	✓		✓					✓		✓											
Sweden	24	42	n.a.			✓			✓							✓	✓							
Turkey	11	28	n.a.										✓											
United Kingdom	25	55	n.a.			✓							✓					✓						
United States	8	24	4																	✓				

Note: The table only includes countries that provided responses to the STI Outlook 2010 Policy Questionnaire as of 31 August 2010 and those that answered the TIP policy questionnaire on adjusting policy to the globalisation of R&D and innovation. However, indicators of performance are calculated for all OECD countries for which data are available. Therefore the highest OECD value may not appear in the table and the ranking takes into account a larger number of countries than those presented here.

n.a.: Response not available.

1. As a percentage of GDP.
2. Percentage of PCT patent applications.
3. Self-reported ranking of national STI priorities based on a scale whereby 1 = least important and 8 = most important.

Source: IMF, *Balance of Payments Statistics*, July 2009; OECD, *Patent Database*, June 2009; responses to the STI Outlook Policy Questionnaire 2010.

Table 2.11. **Internationalisation of human resources: performance, priority level and measures taken between 2008 and 2010**

	Performances	Priority level	Increase international mobility						
	Share[1] of international tertiary students 2008	Internationalisation of STI	Changes in immigration legislation	Changes in employment law, University Act, etc.	Funding (scholarships, grants, etc.)	Creation of special positions in academia	Fiscal incentives	Return migration programmes (incl. funding)	Other
	Index 100 = Highest OECD value	Country self-reported[2] (1-8)	Measures / initiatives taken between 2008 and 2010						
Australia	100	n.a.	✓		✓			✓	
Austria	75	4	✓	✓	✓			✓	✓
Canada	32	6	✓		✓		✓	✓	
Czech Republic		6	✓		✓	✓			
Denmark	13	6			✓		✓		
Finland	15	8	✓	✓	✓	✓		✓	
France		3	✓		✓	✓		✓	
Germany	45	7	✓	✓	✓			✓	
Hungary	16	7	✓		✓			✓	
Israel		7			✓			✓	
Italy		7		✓	✓	✓	✓	✓	
Japan	14	8			✓			✓	
Korea		7			✓	✓			
Netherlands	24	4							
New Zealand	63	7							
Norway	10	8	✓		✓				
Poland		5							
Slovenia	6	5	✓		✓		✓	✓	✓
South Africa		7							
Spain	10	7			✓	✓		✓	
Sweden	27	n.a.			✓				
Turkey		n.a.							
United Kingdom	71	n.a.							
United States	17	4							

Note: The table only includes countries that provided responses to the STI Outlook 2010 Policy Questionnaire as of 31 August 2010 and those that answered the TIP policy questionnaire on adjusting policy to the globalisation of R&D and innovation. However, indicators of performance are calculated for all OECD countries for which data are available. Therefore the highest OECD value may not appear in the table and the ranking takes into account a larger number of countries than those presented here.
n.a.: Response not available.
1. As a percentage of all tertiary enrolment. Except for Germany where the index is based on the share of international students enrolled at tertiary-A level. Year of reference 2007 for Canada. Data are underestimated for the Netherlands and Switzerland.
2. Self-reported ranking of national STI priorities based on a scale whereby 1 = least important and 8 = most important.
Source: OECD (2010), *Education at a Glance 2010: OECD Indicators*, OECD, Paris; responses to the STI Outlook Policy Questionnaire 2010.

increase the international attractiveness and competitiveness of strong R&D milieus in Sweden. Switzerland approved in 2010 its international strategy for education, research and innovation to strengthen the definition of goals and priorities where Switzerland demonstrates excellence; its aim is to further develop Switzerland as a competitive international hub for education, research and innovation.

Germany has accelerated the internationalisation of its public research institutes. Universities have been encouraged to develop their own internationalisation strategies and been provided support and advice by the German Rector's Conference. In 2008, the German federal government launched an internationalisation strategy: *i*) to strengthen research co-operation with global leaders; *ii*) to improve international exploitation of innovation potential; *iii*) to intensify co-operation with developing countries in education, research and development on a long-term basis; and *iv*) to use German research and innovation potential to meet global challenges in the areas of climate, resources, health, security and migration.

The German federal government is also strengthening the international profile of national networks and clusters, for instance by initiating contacts with relevant technological or scientific clusters worldwide. Twelve projects have been already selected in environmental technologies, medical technology, life sciences, transport and ICT. In addition the federal government supports international higher education marketing and since 2001 helps universities to develop their own study programmes abroad. The Max Planck Society established in 2008 a Max Planck Florida Institute in the new biosciences cluster in South Florida.

The German Academic Exchange Service (DAAD) adopted in 2008 "Quality through internationality" guidelines for academic exchange as well as plans to encourage support for international students and developing countries. The German universities have also adopted a National Code of Conduct through the Rector's Conference which ensures that foreign students receive support and advice when studying in Germany.

Denmark is strengthening its co-operation with China on research and university education by establishing a Danish University Centre in Beijing at one of China's most prestigious universities, the Graduate University of the Chinese Academy of Sciences (GUCAS). This new structure is expected to accommodate 300 master's degree students, 75 PhD students and 100 researchers evenly divided between both countries. It will cost about EUR 13 million (DKK 100 million) a year and will be financed jointly by the Chinese University, the Danish universities and the Danish state.

Direct funding, fiscal incentives and provision of infrastructures are also used to promote the involvement of national firms in international co-operation.

- The Czech Republic has implemented a complex support system to encourage research organisations and SMEs to participate in the European Research Area. This includes organising large-scale awareness and training events on the EU 7th Framework Programme, providing professional consultation, offering financing support for the preparation of large projects, and building relationships with entities in ERA countries. The government also manages an Internet portal to inform foreigners about local R&D structures and enable Czech teams to publish their proposals on European co-operation.
- The Finnish Funding Agency for Technology and Innovation (Tekes) has integrated conditions of international co-operation into criteria of eligibility for almost all of its funding schemes.
- Greece also includes criteria on international co-operation for all new funding schemes introduced since 2009.
- Israel maintains a Global Enterprise R&D Cooperation Framework to facilitate co-operation with Israeli SMEs.
- Spain is granting funding under preferential conditions (soft loans of up to 75% of the budget of Spanish participation and possibility of a non-refundable part of 33% of the loan granted) to Spanish companies that are involved in the Bilateral Programme for Technological Co-operation with foreign entities in Canada, China, India, Japan or Korea. This programme supports the execution of joint technological projects oriented towards

the development and/or adaptation of new products, processes or services intended for international markets.

- Within the Central Innovation Programme for SMEs (ZIM), Germany provides 20% additional funding for personnel costs to projects with foreign partners outside Europe. The International Bureau of the Federal Ministry of Education and Research (BMBF) assists public research institutes and SMEs in international networking. In addition to providing financial support on behalf of BMBF, the Bureau arranges networking opportunities, provides advice and runs a web portal "Kooperation International" which is considered a gateway to extensive information on international co-operation opportunities.
- Israel has four bi-national R&D funds with Canada, Korea, Singapore and the United States to support collaboration between Israeli and foreign companies.

Countries are also seeking to improve their attractiveness to foreign firms. In Finland, registered foreign-owned companies are also eligible for public funding, and foreign entities, firms or research institutions are treated on equal terms with Finnish ones. Finland has also created the FinNode Innovation Centre Network as a gateway for international enterprises looking for business contacts, cutting-edge research or R&D resources to link with partners in Finland. FinNode is already operating in China, Japan, Russia and the United States. Germany has implemented international advertising campaigns (*e.g.* South Korea Pilot Measure) under the umbrella campaign "Research in Germany" to facilitate the initiation of R&D co-operation with new partners abroad. Canada is reforming its system of international taxation to facilitate investment, cut red tape and streamline the compliance process associated with the taxation of cross-border activity.

Support for the internationalisation of SMEs is also emphasised in strategies to improve attractiveness. Sweden has set up at public cost support offices to help SMEs in strategic sectors, such as biotechnology, forestry and transport. The Swedish government also launched in 2009 a pilot programme, VINN EXPORT, to support SMEs financially to develop their innovation capacity with partners or customers on export markets. The Netherlands launched in 2009 a "prepare2start" scheme (2009-10) to help 600 SMEs to enter international markets by subsidising feasibility studies for investments in emerging markets. Germany supports SMEs in building international technology collaborations with partners from non-EU countries. Israel has signed a framework agreement to facilitate international co-operation involving SMEs.

To address global challenges, Canada has fostered international collaboration with developing countries. In 2008 the Canadian government initiated a CAD 6.2 million programme to link research teams at home and in the developing world in S&T priority areas including the environment and natural resource management and ICT for development.

International mobility of highly skilled researchers and students

The migration of people across national borders is part of the globalisation process. However, competition for talent has intensified worldwide and the highly skilled are more internationally mobile than medium- or low-skilled workers. The mobility of the highly skilled is now a concern for a broader range of ministries, beyond the immigration ministry, these include higher education, research and economic ministries.

Not surprisingly, most OECD and non-OECD countries consider international mobility fundamental and have implemented policies both to retain and attract HRST and to accompany national talent out and back.

In 2009, Austria amended its *University Act 2002* to require Austrian universities to post research job vacancies internationally, at least EU-wide (EURAXESS Jobs are mentioned in the legal commentary as a possible cost-free tool to do so). In addition, according to the Programme of the Austrian Federal Government 2008-13, by 2020, every two graduates from higher education should be able to demonstrate at least one period of residence abroad. Special fast-track immigration procedures have traditionally been introduced to ease foreign students' and researchers' entry and to facilitate their access to the labour market.

- The Czech Immigration Act was amended in 2008 to introduce a specific admissions procedure for third-country nationals for the purposes of scientific research.
- Denmark has several schemes to make it easier for highly qualified foreigners to work and live in Denmark. International students are granted a green card which enables them to stay and look for a job for six months after graduation. Other initiatives aim to improve the opportunities for researchers coming to Denmark by developing fast-track procedures for residence permits.
- Norway has introduced an early employment scheme that entitles employers to recruit directly and let employees start working before their immigration application has been processed. The scheme applies to skilled workers, defined by expertise, and specialists, defined by pay. It is left to the employer to ensure that the employee meets the conditions for being granted a permit as a skilled worker or specialist.
- France has softened the requirements and the *habilitation* process for foreign scholars and researchers who apply to national universities for positions similar to those they hold in their country of origin. Furthermore, employees and representatives of resident firms who have entered the country through internal mobility or have been directly recruited from abroad benefit from an additional income tax credit since 2009.
- Germany has lowered from EUR 86 400 to EUR 64 800 the income threshold for an open-ended residence permit. Such residence permits include work permits. Furthermore the federal government laid the foundations of a legislative process to improve recognition procedures for vocational qualifications, diplomas and skills earned in foreign countries.
- Canada has introduced several measures to make the Canadian immigration system more competitive, in particular recognition of foreign credentials for trained individuals to help them better use their skills in the local labour market. The Canadian government is also allocating CAD 50 million to develop a common approach across provinces and territories to assess foreign credentials and ensure better integration of immigrants.

Box 2.6. **The Dutch analysis of highly skilled immigrant behaviour**

The Netherlands has conducted an analysis of the behaviour of highly skilled migrants, defined as every migrant with an educational level up to ISCED 5 or ISCED 6 (International Standard Classification of Education 1997).

Box 2.6. **The Dutch analysis of highly skilled immigrant behaviour** *(cont.)*

The analysis involved an overview of theoretical and empirical research into motives of migration, a double survey among the highly skilled currently living in the Netherlands and among Dutch highly skilled emigrants, the construction of an index measuring the competitive strength of countries in attracting highly skilled migrants, and finally an exploration of possibilities for calculating reliable, recent and internationally comparable statistics of migration flows.

It appeared that national admissions policies have little impact on the choices of highly skilled migrants and thus on the recruitment of highly skilled. Indeed salary and career motives appeared to be the main drivers of migration, as well as an appealing living environment.

Similarly researchers, in the framework of this survey, valued the quality of the knowledge infrastructure and the knowledge intensity of the economy, the reputation of the academic climate and the high quality of the scientific output.

Direct funding and fiscal incentives remain the most frequent policy instruments to support international mobility of HRST:

- Austria has reformed its usual funding programmes for international mobility to attract a larger number of postgraduates, postdocs or lecturers from abroad (enlarged eligibility of the Ernst Mach Programme) and to incite young Austrian scientists previously encouraged to work abroad to return to Austria to pursue an academic career (return phase of the Erwin Schrödinger fellowships). New schemes have also been introduced to support highly qualified young researchers who pursue doctoral studies at an Austrian university to carry out 6-12 months of their research work abroad (Marietta Blau Scholarship Programme).
- Belgium offers return schemes set up by all of the different regions.
- In 2010 the Canadian government allocated CAD 45 million over five years to establish a new internationally competitive postdoctoral fellowship programme to attract top-level talent to Canada. These fellowships will be valued at CAD 70 000 a year for two years. The first fellowships will be awarded in 2010-11. At maturity, the new programme will fund 140 fellowships annually.
- As part of its China strategy, Denmark has allocated 13 industrial PhD projects to students with a master's degree from a Chinese university. The company has to be a private company with divisions or subsidiaries located in Denmark and China. The student is employed in a Danish division and receives a salary (minimum pay rate of the collective agreement for PhD students employed in the Danish state).
- Finland has implemented competitive grants through the Finland Distinguished Professor Programme (FiDiPro) to attract both international and expatriate researchers who are able to commit to long-term co-operation with a Finnish university or research institute.
- In 2009 France adopted a return postdoc programme managed by the National Research Agency (ANR) to encourage young researchers abroad to return and develop a research project in France. This programme has EUR 11.5 million to be distributed in the form of

individual financial aids which can cover labour, equipment and overhead costs during project initiation. Grants are up to EUR 700 000 over three years.

- In 2009, Denmark, Norway and Finland introduced the Nordic Research Opportunity. This new mobility measure addresses US graduate research fellows from the US National Science Foundation and offer them the opportunity to do part of their research at a Nordic research institution. The research fellows may stay from two to 12 months during which they keep their NSF fellowships and receive additional funding from the Research Council of Norway, the Academy of Finland and the Finnish Funding Agency for Technology and Innovation (Tekes), or the Danish National Research Foundation (DNRF).
- Israel plans a new Fulbright Scholarships programme for 2011, geared to encourage American postdoctoral students to perform research in Israel. This programme will also promote student and researcher exchange between Israel and the United States. The creation of new centres of excellence would also encourage the return of national researchers back to Israel.
- In addition to the many scholarships Japanese government grants for international students or scholars, Japan launched in 2009 the JSPS BRIDGE Fellowship which provides the opportunity for former JSPS fellows to maintain and strengthen collaborative ties and networks with their Japanese colleagues by re-visiting Japan to attend meetings or seminars, plan or arrange joint research projects, give lectures or train young researchers.
- Slovenia, under the requirements of the European Framework Programmes, introduced in 2009 fiscal incentives for foreign researchers working in the country. In addition several programmes have been established by the National Bureau for Slovenes living abroad and by the Slovene Science Foundation to stimulate the return of expatriate researchers.
- Sweden finances postdoctoral researcher qualification opportunities for women in fields of strategic importance (VINNMER) and promotes collaboration between Sweden's centres of excellence in research and innovation (R&I environments) and prominent international environments abroad (such as the EU, North America, China, Japan and India).
- Italy introduced income tax incentives to scientific researchers residing abroad who return to Italy. These consist of a flat income tax rate of 10% for researchers and the exclusion of their income from certain regional taxes (OECD, 2009a).
- Germany provides expatriate researchers with travelling grants for job interviews and conferences as well as reintegration grants of up to six months. The federal government has also sponsored the Green Talents competition, inviting 15 outstanding young scientists from around the world to visit research facilities throughout Germany and learn about opportunities for co-operation with German partners.
- In the framework of the National R&D&I Plan 2008-11 Spain has created special positions at universities or public research centres for expatriate and foreign researchers (Programme I3). Spain grants postdoctoral junior and senior grants to promote the return of expatriate students, scientists and engineers (National Programme for Recruitment and Incorporation of Human Resources).
- Some countries are reinforcing communication efforts and non-financial support for foreign highly skilled workers. The Austrian government provides foreign researchers

with a guide to residence and employment available in English and plans to complete the English translation of its website (*www.help.gv.at/*) with information on living and working in Austria.

- In 2008-09 Denmark developed a national brand – Study in Denmark – based on the pay-offs: Think, Play, Participate. The process included a national survey of international students and resulted in a strong framework for the recruitment and retention of international talent by Danish higher education institutions. In addition Denmark established in 2010 a global network of international students who were awarded the title of youth goodwill ambassador. The network represents a diversity of nationalities and reflects relevant target markets for Danish institutions of higher education, Danish companies and other relevant stakeholders. The goal is to brand Denmark, Danish business, culture and academic programmes worldwide. A joint effort by the Danish government and higher education institutions has also led to national guidelines for the recruitment of international students into higher education programmes. The so-called Code of Conduct aims to provide an ethical approach to marketing and sets high standards for how international students are recruited.

Developing and strengthening human capital

Human resources in science and technology are essential for advancing science and innovation and generating productivity growth. In most OECD countries they represented in 2008 more than a quarter of total employment and over a third in northern Europe (Sweden, Denmark, Norway), Australia, Canada and the United States (OECD, 2009b).

Over the past decade, employment in HRST occupations has grown faster than total employment, owing to the increasing participation of women and the fast-growing demand for professionals and technicians in the services sector. Some countries with low HRST shares have been catching up too (*e.g.* Greece, Hungary, Ireland and Spain).

At the same time several OECD countries have expressed concerns that the supply of highly skilled workers is diminishing and will not be able to meet demand. With an ageing population, the current supply of new graduates may not be sufficient to replace outgoing cohorts. Many OECD and non-member countries have therefore sought to increase the supply and quality of HRST. Policy actions take place at various levels during general education, scientific university studies, advanced research programmes and postdoc training or after workers have entered the labour market. Policy actions target pupils, students, households, employees and employers.

In general OECD countries give a high level of priority to developing HRST in their national STI strategy (Table 2.12). Consequently, many have policies to increase HRST. Governments' intervention aim broadly to: *i)* raise interest in science among youth and wider civil society and create a culture of innovation; *ii)* improve formal education at all levels and beyond S&T fields; *iii)* improve employment conditions, especially in researcher careers, and lifelong learning opportunities.

Innovation for all: creating an innovation culture

A culture of innovation is a common feature of any innovation system. It supposes a positive attitude towards novelty and change and requires a general acknowledgement by society of the beneficial effects of science for social progress and well-being.

Table 2.12. **Innovation for all: performance, priority level and measures taken between 2008 and 2010**

	Performances			Priority level	Raising interest of science among youth					Steering households' demand for innovative products/ services
						of which				
	Educational attainment at secondary level,[1] 2008	Prevalence of science proficiency[2] at 15, 2006	Share[3] of households consumption on health, communication and education 2008	Developing HR for STI	All kinds	National communication campaigns	Mentorship	Exemplify S&T achievements (awards and prizes…)	Hand-on learning (direct participation to research projects, contests…)	
	Index 100 = Highest OECD value			Country self-reported[4] (1-8)	Measures/initatives taken between 2008 and 2010					
Austria	89	48	29	7	✓				✓	✓
Canada	96	69	36	7	✓	✓	✓	✓		
Czech Republic	100	55	30	7	✓	✓				
Denmark	82	32	23	6	✓					
Finland	89	100	32	7	✓				✓	
France	77	38	31	5	✓	✓		✓	✓	
Germany	94	57	37	6	✓					
Hungary	88	33	37	6	✓					
Israel	89	25	50	5						
Italy	59	22	28	n.a.	✓					
Japan		72	41	8	✓	✓	✓			
Korea	87	49	78	6	✓					
Netherlands	81	63	32	5	✓	✓				✓
New Zealand	79	84		7	✓			✓		
Norway	89	29	28	7	✓			✓		
Poland	96	32	36	8	✓					
Slovenia	90	62	34	8	✓					
South Africa				8	✓					
Spain	56	23	32	6	✓	✓		✓		
Sweden	94	38	29	6						
United Kingdom	77	66	23	n.a.	✓		✓			
United States	98	43	100	6	✓	✓	✓		✓	✓

Note: The table only includes countries that provided responses to the STI Outlook 2010 Policy Questionnaire as of 31 August 2010. However, indicators of performance are calculated for all OECD countries for which data are available. Therefore the highest OECD value may not appear in the table and the ranking takes into account a larger number of countries than those presented here.
n.a.: Response not available.
1. As a percentage of the population aged 25-64. Year of reference 2002 for the Russian Federation.
2. Percentage of top performers in science based on PISA score.
3. Share in total households' final consumption.
4. Self-reported ranking of national STI priorities based on a scale whereby 1 = least important and 8 = most important.
Source: OECD, *Education at a Glance 2010*, OECD, Paris; OECD, *PISA Database* 2006; OECD, *National Accounts Database*, February 2010; OECD, *OECD Science, Technology and Industry Outlook 2008*, OECD, Paris; responses to the STI Outlook Policy Questionnaire 2010.

Three indicators may reflect the presence of an S&T and innovation culture among OECD countries: *i)* the percentage of the population aged 25-64 with at least a secondary level degree; *ii)* The percentage of top performers in science among 15-year-old students (PISA); and *iii)* the percentage of households' total consumption spent on health, communication and education. Educational attainment shows the extent to which a population is equipped with the minimum knowledge required to operate and perform well in a knowledge-based society. The prevalence of top science performers at 15 mirrors youth's attitudes and motivations regarding science and to some extent their enjoyment and active engagement in science learning (OECD, 2009d). Household consumption of health, education and communication is an indicator of consumer demand in three areas in which technological and organisational innovation is important and in which users and consumers can play an active role by orienting innovation efforts (OECD, 2010b).

Norway and the Netherlands have taken a global approach in addressing the issue of HRST. In February 2010 the Norwegian government launched a new strategy plan, "Science for the future – strategy for promotion of mathematics, science and technology 2010-2014" which takes into consideration the entire education and research system, from kindergarten to high-level research, and involves stakeholders from various sectors including the business sector (Confederation of Norwegian Enterprise [NHO] and the Federation of Norwegian Industries). The integration of the entire education system from primary education up to the labour market is an approach in force in the Netherlands since 2004. The Dutch Delta Plan for science and engineering and technology supports initiatives in both educational and research institutions.

Raising interest in science among youth

OECD countries continue to place particular emphasis on raising interest in science among youth. Measures range from large public communication campaigns to the organisation of joint research projects involving youth and senior scientists. Spain has created, in the framework of the National R&D&I Plan 2008-2011, the National Programme for Scientific Culture to promote the interest in and awareness of science among youth and the society. South Africa adopted in 2007 the Youth into Science Strategy (YISS) targeting school-going youth and undergraduates in science, engineering, technology and mathematics. The YISS is currently implemented through different national plans: the National Educator Support Programme; the National Plan for Camps, Competitions, Olympiads; the National Rollout Plan for the Establishment of a Network of Science Centres; and the National Plan to Place and Support Successful Graduates in the National Youth Service Programme.

Many countries also intend to communicate more effectively regarding the general benefits of science. National events such as Science Weeks or Science Days bring together partners from across government, industry and academia and offer young people but also to a wider public a variety of events (workshops, visits, talks, exhibitions, games, contests, etc.). Such initiatives are also arising in emerging economies (South Africa, India).

At European level the EUREKA network has implemented the I AM EUREKA advertising campaign to appeal to the public and to increase recognition of the EUREKA brand. The publication of six advertisements in the Brussels Airlines in-flight magazine from November 2008 to April 2009 was a pilot project and a cost-effective and efficient way of launching a pilot campaign and reaching a large number of influential people flying in and out of Brussels.

In its national R&D and Innovation Policy (2009-15), the Czech Republic has emphasised increasing publicity and promotion of research, development and innovation in media.

Some governments attempt to personalise communication to young people through either a mentorship approach or the use of entertaining digital tools.

- Canada has recently created Synapse Youth Connection, through which some 4 000 researchers, graduate students and postdoctoral fellows voluntarily mentor youth to expose them to their passion about careers in health. In its first year, the programme reached more than 20 000 students directly and more than another 26 000 indirectly.

- The United Kingdom has introduced a new scheme, Researchers in Residence, which plans the placement of researchers in schools. A STEMNET network has also been developed to inform young people about science, technology, engineering and mathematics (STEM), enable them to engage in debate and make decision about related issues.
- In the framework of its new Educate to Innovate programme, the United States harnesses the power of media, interactive games and hands-on learning to inspire the next generation of inventors and innovators. Japan encourages junior high school girls to choose science courses by providing them with opportunities for exchanges with women researchers and engineers, during experiment lessons, visiting lectures or summer camps.

Japan also promotes dialogue between scientists and citizens and intends to increase opportunities for experiencing science and technology in familiar settings.

Italy has recently launched a call for proposals for the yearly week of "scientific and technological culture" with a budget of EUR 10 million (*http://attiministeriali.miur.it/anno-2010/luglio/dd-19072010.aspx*). The programme is financed by the Ministry for Education, University and Research.

Finally a few countries have encouraged the involvement of young people in science through participation in research projects or science contests. These initiatives essentially take a hands-on learning approach. Austria's Sparkling Science Programme involves students up to the age of 18 as junior scientists. They work side by side with senior scientists on over 100 interdisciplinary projects in which they actively take part (carrying out surveys, interpreting data, developing new products, publishing results). The programme's strategic plan is set for ten years (2007-17) with annual funding intended to be about EUR 3 million. The Academy of Finland arranges annually the science competition Viksu for upper secondary students who are invited to submit essays in all scientific disciplines. The best essays are awarded scholarships worth EUR 30 000. The United States has introduced programmes to engage young people in scientific inquiry and challenging designs (competitions to develop game options). Japan holds national student S&T contests and the best Japanese students are invited to compete with their peers from other countries in international contests.

Promoting science through recognition of STI achievements

Recognising STI achievements, creating role models and rewarding the best initiatives are also ways to raise interest in science among youth and to promote a broader culture of innovation.

Canada exemplifies this with outreach initiatives through its website *www.science.gc.ca*. For example, the Great Canadian Science Race reaches over 325 000 children and 14 000 teachers across the country. The website continues to grow in popularity and had a 32% rise in unique visitors in 2008.

New Zealand introduced in 2009 a series of five Prime Minister's Science Prizes. These are awarded to: a researcher or a team of researchers; a young scientist (within five years of completing a PhD); a science teacher; a secondary school student; a researcher on science media communication (the last of these prizes underlines New Zealand's interest in widespread communication on S&T issues).

First introduced in 2008, Norway's biannual Kavli Prize (*www.kavliprize.no*) recognises outstanding scientific research, honours highly creative scientists, promotes public understanding of scientists and their work, and fosters international co-operation among scientists.

Similarly EUREKA launched in 2008-09 a new EUREKA Innovation award to reward an R&D-performing SME for a project chosen on the basis of outstanding technological and commercial achievement and societal impact. This annual award comprises a range of EUREKA products (individual projects, Eurostars, Clusters and Umbrellas). It aims to ensure long-lasting visibility and has a clear and strong impact on the EUREKA image.

Improving the supply of skills for innovation

Higher education systems are the main source of HRST, together with immigration and job-to-job mobility (OECD, 2009b). Accordingly, OECD countries give a high or medium-high priority to improving education for innovation.

Four indicators can reflect the capacity of national education systems to supply skills for innovation: *i)* total public and private expenditures on education, as a percentage of GDP; *ii)* the percentage of new university graduates in science and engineering; *iii)* the graduation rate at doctoral level and *iv)* female participation in doctoral studies. The intensity of education expenditures measures the proportion of a nation's wealth that is invested in educational institutions and shows the priority a country gives to education in terms of its overall resource allocation[5] (OECD, 2009d). The percentage of university graduates in science and engineering indicates the country's potential to absorb, develop and diffuse knowledge, on the one hand, and to supply the labour market with scientists and engineers, on the other (OECD, 2009b). The graduation rate at doctoral level shows the country's capacity to provide students with the highest education level and train them specifically to conduct research and contribute to knowledge diffusion (OECD, 2009b). Finally the female participation rate in doctoral studies reflects the gender balance in doctoral programmes and early research career paths.

Finland, Sweden, the United States and Israel are among the highest OECD performers, with a large amount of GDP spent on education, numerous new S&E graduates, higher graduation rates at doctoral level and stronger participation of women in advanced research programmes. In addition Portugal has in recent years strongly reinforced its capacities for human capital formation and Switzerland benefits from a strong vocational education training and education system (OECD, 2008). Conversely Japan, Spain and the Netherlands lagged slightly behind others OECD countries in terms of HRST development.

Strengthening higher education

Improving education facilities for the 21th century is a key goal of many economic recovery plans. Germany and the United Kingdom have put support for education at the heart of policy action. Spain or Portugal took the crisis as a starting point for triggering reforms of their higher education institutions. Australia, Austria, Canada, Germany, New Zealand, Norway and Spain invested to renovate and build new schools and universities. Italy fostered digital innovation in schools. Next to the renovation and refurbishment of

Table 2.13. **Improve education for innovation: performance, priority level and measures taken between 2008 and 2010**

	Performances in 2008 or nearest				Priority level	Improve education for innovation						
	Expenditures on education,[1] 2006	% of university degrees in science and engineering, 2008	Graduation rate[2] at doctoral level, 2008	Female participation in doctoral studies,[3] 2008	Developing HR for STI	Revising academic curricula	Improving teaching in mathematics and science	Developing entrepreneurial and soft skills	Reducing gaps in S&T education (gender, minority)	Financing for PhD study and post-doc. training	Industry involvment in PhD training	Others
	Index 100 = Highest OECD value				Country self-reported note (1-8)[4]	Measures/initatives taken between 2008 and 2010						
	2006	2007										
Austria	69	82	59	71	7			✓	✓	✓	✓	
Canada	81	65	33	75	7					✓		
Czech Republic	60	89	43	62	7	✓	✓		✓	✓	✓	
Denmark	91	60	46	72	6		✓	✓		✓	✓	
Finland	73	85	72	91	7			✓		✓		
France	74	81	43	70	5				✓	✓	✓	
Germany	60	88	76	70	6	✓	✓	✓	✓	✓	✓	
Hungary	71	47	22	72	6					✓		
Israel	97	61	44	86	5		✓			✓		
Japan	63	79	33	46	8		✓	✓	✓	✓		
Korea	92	100	34	50	6			✓	✓			
Netherlands	70	44	50	70	5		✓	✓	✓			✓
New Zealand	78	56	42	84	7							✓
Norway	68	48	55	75	7		✓		✓	✓	✓	
Slovenia	76	58	41	80	8	✓			✓	✓	✓	
South Africa					8							
Spain	58	77	29	82	6					✓	✓	
Sweden	79	69	93	75	6							✓
United Kingdom	74	68	61	75	n.a.				✓	✓	✓	
United States	92	46	45	86	6	✓	✓		✓	✓	✓	

Note: The table only includes countries that provided responses to the STI Outlook 2010 Policy Questionnaire as of 31 August 2010. However, indicators of performance are calculated for all OECD countries for which data are available. Therefore the highest OECD value may not appear in the table and the ranking takes into account a larger number of countries than those presented here.
n.a.: Response not available.
1. The value is from 1 to 100 based on data expressed as a percentage of GDP.
2. New doctorate graduates as a percentage of relevant age cohort. Year of reference 2007 for Australia, Canada, China and the Russian Federation.
3. Percentage of doctorates awarded to women. Year of reference 2007 for Australia and Canada.
4. Self-reported ranking of national STI priorities based on a scale whereby 1 = least important and 8 = most important.

Source: OECD, *Education at a Glance 2010*, OECD, Paris; OECD, *OECD Science, Technology and Industry Scoreboard 2009*, OECD, Paris; OECD, *OECD Science, Technology and Industry Outlook 2008*, OECD, Paris; responses to the STI Outlook 2010 Policy Questionnaire.

schools and universities, large investments in childcare facilities have highlighted the importance given to early childhood education for the future (OECD, 2009a).

To ensure that national education systems reach high standards, countries are reinforcing their education system, the budget allocated to education, their institutions and teachers' competences.

In response to the crisis, Australia allocated up to 1.4% of GDP for education, Germany spent a further 0.6% of GDP, the United States 0.58% of GDP and Portugal 0.41% of GDP (*ibid.*). In 2008-09, the federal government of Canada provided through its 2007 budget CAD 3.2 billion in support for post-secondary education and federal investments are planned to grow in the future at a 3% annual rate.

Hungary has launched new training programmes for teachers with a budget of EUR 70 million (*ibid.*) Denmark, which has a high dropout rate in secondary studies and has demonstrated low PISA performance in science (OECD, 2008), established in autumn of 2009 a new national centre for education in science, technology and health which will cover and focus on improving the quality of the education and on interest and recruitment in these areas in the educational system. Japan plans to improve the quality of teachers and develop local systems for supporting education, including through the participation of private citizens.

A reform of the national university system is underway in Italy, and is currently evaluated by Parliament. The reform aims at strengthening higher education and reinforcing the quality of teaching (*www.senato.it/service/PDF/PDFServer/BGT/00446650.pdf*) through a stronger and more internationally recognised system of evaluation of professors, on the one hand, and clusters of universities and scientific institutions that will improve the quality of the educational offer, on the other. The law also foresees greater use of fellowships and other student incentives.

Governments have also increased the financial resources allocated to universities and higher education institutions. Germany has created new capacities at university level with additional funding (Higher Education Pact 2020). This has already stopped the downward trend in numbers of new university entrants. The second phase (2011-15) would enable universities to accept 275 000 additional new entrants with a contribution from the federal government of more than EUR 5 billion.

In addition to the financial resources newly allocated to schools, universities and higher education institutions, some countries enlarged public support to students to pursue tertiary studies (grants, subsidies, loans, reduced tuition fees, etc.).

- Canada has modernised the system of financial support for nationals who pursue a college or university education. The new consolidated Canada Student Grant programme channels about CAD 350 million and will receive additional funding to reach CAD 430 million by 2012-13. Since 2009, some 245 000 students have benefited from this programme. Canada also plans to reform the Canada Student Loans programme to make it easier for students to access financial assistance and to manage their loans. CAD 123 million will be invested for four years starting in 2009-10.
- In December 2009, Denmark hosted the United Nations Climate Change Summit. To emphasise the importance of sustainable climate solutions, the Danish government decided not to give any gifts or conference kits to COP15 participants and the resources saved were put into eleven COP15 Climate Scholarships for highly qualified students. The scholarships, which cover both tuition fees and living expenses, were made available for a range of excellent two-year master's programmes, including MSc programmes in wind energy, environmental engineering or sustainable energy planning.
- Russia plans to help students with low interest rate loans, state scholarships, free student accommodation and a potential freeze on tuition fees. Some students have also been transferred to government-paid programmes (OECD, 2009a).
- The United States' stimulus package includes new programmes of student aid and higher education tax cuts to allow certain students to enter higher education.

Ensuring that education delivers the right mix of skills

Mathematics and science proficiency used to be considered the foundation of a knowledge-based and innovation-driven society. However recent developments and the growing importance given to non-technological innovation have stressed the need for complementary skills, including entrepreneurial capacities and "soft" skills.

Some countries have emphasised reinforcing mathematics and science education. Improving teaching has been a first axis of policy action. Norway has significantly increased the number of teachers in mathematics and natural sciences (at least 1 000 more by 2014). The United States has introduced various programmes to improve teaching in mathematics (*e.g.* Race to the Top), to build local communities of support around teachers and develop civic participation in bringing discovery-based science experiences to students in grades K-12 (*e.g.* National Lab Day), and to foster private and philanthropic involvement in support of STEM teaching and learning. Japan has developed initiatives to enhance teachers' educational activities in science, mathematics and technology. Israel is offering the three-year Guastella Fellowship to outstanding doctoral students to promote research and development in the field of science teaching.

Revising the curriculum is another way to improve students' participation and literacy in mathematics and science. The United States has announced a comprehensive federal education initiative with an initial federal investment of US 74 million to develop courses on clean energy at universities, community and technical colleges, and K-12 schools (Regaining our Energy Science and Engineering Edge). The Netherlands are thinking about integrating science and technology in primary education and involving organisations that operate at the cutting edge of these disciplines. In contrast, Austria, for example, has specifically targeted higher-level students or researchers, while Finland and Germany have adopted a system-wide approach to skills and education.

Entrepreneurship education is also part of the focus on innovation skills. In 2010, Denmark launched a new Strategy for Education and Training in Entrepreneurship, including education in management, start-up and interdisciplinary co-operative skills. The idea is to develop pupils' and students' knowledge about entrepreneurship, as well as their ability to act entrepreneurially, by stimulating their ability to think innovatively, to see opportunities and to turn ideas into value. A new fund, the Foundation for entrepreneurship, has been established to pool efforts in this area (*http://en.fi.dk/publications/2010/strategy-for-education-and-training-in-entrepreneurship/*). The Netherlands also supports entrepreneurial education and introduced entrepreneurship education from primary school up to university to help students acquire knowledge, competences and positive attitudes to entrepreneurship. Germany's EXIST start-up programme provides special training and support for future entrepreneurs. Japan is also promoting vocational education to cultivate students' entrepreneurial abilities. Meanwhile, South Africa, as part of the 2008 IPRs Act, is supporting entrepreneurial skills together with IP management skills and industry training.

Widening access to scientific studies and promoting equity

The low level of female participation in scientific studies and doctoral programmes is a long-standing concern in OECD countries. On average 45% of women at the relevant age graduate at university level compared to less than 30% of men. And yet they are much less represented in science and engineering fields, notably in OECD countries such as Japan or

Korea (OECD, 2009b). Some countries have implemented specific measures to reduce gender gaps in S&T education and researcher employment. While women outnumber men among graduates from tertiary education, they account for less than half of doctoral students and are underrepresented in the research workforce. Furthermore they are less likely than their male colleagues to advance, as they obtain fewer research grants or subsidies and publish less. Some countries have provided women with preferential access to research funding and better opportunity to make cutting-edge advances. The Austrian Federal Ministry of Science and Research (BMWF) proposes a two-semester course to help women put together successful grant proposals. This programme also provides information on various sources of funding, personality development, etc. (the Forte Coaching programme).

For its part, the Netherlands has adopted targets for women in academia. In 2010, it adopted a target of 15% of female professors, still far beneath the European target of 25%. The Dutch Aspasia programme, initiated in 1999, was a scheme to increase the number of female senior lecturers. The programme is set to be extended with a larger budget of EUR 4 million a year. Norway also announced an incentive for the recruitment of women to senior positions in higher education institutions within S&T disciplines, with financial effect from 2011. Institutions recruiting women for senior positions will receive an amount which depends on the number of women recruited. EUR 1.2 million (NOK 10 million) will be allocated to follow up this incentive.

Other recent initiatives to broaden access to scientific studies to underrepresented populations include:

- The United States launched a Broadening Participation programme managed by the National Science Foundation (NSF) in the framework of the "Educate to Innovate" initiative in order to reduce gender and ethnic minority gaps.
- Norway has identified the issue of gender equity in mathematics, science and technology in its main STI strategy goals and initiated both a statistical survey aiming to see if more females select the natural sciences as part of their higher secondary education and a two-year project aiming to stimulate more women to study the natural sciences (Action Plan for Gender Equality in Kindergarten and Basic Education 2008-10).
- The Netherlands has developed a Mozaïek programme focused on immigrant research talent. Based on the results of a national survey which showed that graduates from ethnic minorities were not moving on to doctoral research because of a lack of information, a lack of personal networks and the deficiency of academic institutions in identifying their potential, the Netherlands deployed in 2004 a funding scheme that awards personal grants for a four-year period of doctoral research. A total subsidy of EUR 4 million was allocated in 2010 to 20 Mozaïek grants.
- Sweden helps disadvantaged populations to access S&T education by offering science classes to people with grades that are too low to enter university. After completing one year (and passing the exams) they are guaranteed a place at university in natural science or engineering. The number of graduates has increased by more than 60% during the past ten years.

Doctoral and postdoc training

Fostering advanced research programmes and postdoc training requires both financial resources and regular evaluations. Governments have increased support for this purpose.

- Canada has established the Vanier Canada Graduate Scholarships programme to support 500 Canadian and international doctoral students each year with three-year scholarships valued at up to CAD 50 000 per year. The government has also increased the funding of Canada Graduate Scholarships for an additional 500 doctoral scholarships valued at CAD 35 000 per year.
- France introduced in autumn 2009 the *contrat doctoral*, a three-year labour contract that offers social benefits to doctoral students equal to those afforded under public law. This contract is identical across public research institutes and higher education institutions. The minimum wage is fixed at the national minimum level but the remuneration can be freely negotiated (there is no upper limit) between doctoral students and research institutions.
- Germany has reinforced its doctoral programmes and financial support.
- Japan has kept increasing the number of JSPS Research Fellowships for Young Scientists granted to young Japanese postdoctoral researchers and graduate students who conduct research activities at Japanese universities or research institutions. In 2010 5 944 fellowships were awarded (5 428 in 2008 and 5 648 in 2009). Japan also plans to further expand its scholarship system in higher education. Spain has offered financing opportunities for PhD study and postdoctoral training through the National Programme for Training Human Resources and the National Programme for Recruitment and Incorporation of Human Resources.
- Switzerland has strengthened and complemented its support for different phases of scientific careers. It has expanded its doctoral programmes and will continue to do so in the years to come, with a new division of labour between the funding agency and the Rector's Conference. It has also introduced a new funding scheme to support highly qualified postdocs.
- The US Administration has announced its intention to triple the number of National Science Foundation Graduate Research Fellowships over four years. The United States had already granted new fellowships for science as part of its stimulus package (OECD, 2009a).
- In the framework of the general reform of universities, the Academy of Finland has paid more attention to supporting young doctorates to become independent researchers. Young PhDs are receiving a three-year postdoctoral post including funding for research cost.

Evaluations of national doctoral programmes will be undertaken in Norway in 2010/11. Norway has however announced that it is maintaining its current policy towards PhDs (the PhD position is salaried in Norway, PhD candidates are categorised as scientific staff rather than as graduate students, and resources for PhD positions are allocated to higher education institutions with a priority for positions in S&T and medicine).

Industry post-docs

Industry involvement in the funding, design and steering of PhD and postdoc training continues to be used to ensure that public academic research better responds to business and societal needs. The industry PhD programmes allow for instance a PhD student to carry on an industry-oriented research project and share time between a university lab and a firm. Such programmes bring together academic research projects and the business world and give PhD students the opportunity to experience both working environments. The industry PhD programmes are also effective ways to build organisational and personal networks that bridge the gap between academia and the private sector.

- Canada invested over CAD 25.5 million in new Industrial Research and Development Internships (IRDI) launched in 2008-09 for graduate students and postdoctoral fellows.
- In 2010, Denmark has allocated DKK 135 million (DKK 104 million in 2009) for new industrial PhD projects. This is equivalent to 100-120 new PhD projects. Accordingly, it is assumed that all qualified applications from the private sector will receive funding; more than half were approved in 2009.
- In France doctoral patronage by firms (*Mécénat de doctorat*) has been in place since 2008. The scheme grants a 60% tax credit on funds used for the remuneration of PhD students.
- In Norway the training scheme for industrial PhDs was established in 2008. The students are employed by the firms, and the costs (salary and other expenses) are shared between the firms and the Research Council of Norway. The growing number of participants shows the success of the programme.

Employment conditions for researchers and opportunities for lifelong learning

HRST are major actors in innovation but many university graduates drop out of the labour market or are employed in occupations below their educational level. Differences by gender at lower levels of education persist among the highly skilled. Women with university degrees are more likely to remain unemployed and obtain lower wages than their male counterparts (OECD, 2009b). The place of women in science has already been largely documented.

Four indicators can illustrate employment conditions for highly skilled: *i)* HRST occupations as a percentage of employment; *ii)* researchers per thousand employment; *iii)* unemployment rate of university graduates and *iv)* gender differentials in earnings for 30-44 year-old university graduates. The share of HRST occupations reflects the structural demand for workers in S&T occupations with a high innovation potential. The density of researchers indicates the relative size of human resources engaged in R&D. Unemployment rates mirror labour market failures to allocate human capital to the production process. Gender differentials in earnings show unequal working conditions in early career paths between women and men (OECD, 2009b).

The Nordic countries (Sweden, Denmark, Norway and Finland) and Luxembourg have the highest OECD performance. The labour market for the highly skilled is broader and the human capital devoted to R&D is relatively larger. Furthermore university graduates are less likely to be unemployed and, although women still earn less than men, earnings differentials by gender are less than in other OECD countries. Portugal, Spain, Turkey and Greece have among the weakest OECD performances.

Attractiveness of careers in research and innovation

Changes in the international labour market for researchers have deeply affected employment conditions and the career paths of researchers, even in the public sector. The polarisation of legal status and the growing number of temporary contracts in universities

Table 2.14. **Improve employment conditions and opportunities of life-long learning: performance, priority level and measures taken between 2008 and 2010**

	Performances				Priority level	Improve employment conditions and opportunities of life-long learning					
	Share of HRST ocupations in total employment, 2008	Researchers per 1 000 employment, 2008	Unemploy-ment rate of university graduates[1] 2008	Gender equity in earnings[2] for 30-44-year-old university graduates, 2007	Developing HR for STI	Improving women's access to research and academia	Make research and innovation careers more attractive	Quality of university labs and infra-structure	Improving sectoral mobility	Favorising recruitment of HRST in enterprises and or public organisations	Enforcing life-long learning
	Index 100 = Highest OECD value				Country self-reported note (1-8)[3]	Measures taken between 2008 and 2010					
Austria	72	52	29	78	7	✓	✓	✓	✓		✓
Canada	85	51	55	86	7	✓		✓		✓	✓
Czech Republic	81	35	21	85	7						
Denmark	94	66	32	84	6	✓		✓		✓	
Finland	82	100	44	81	7		✓		✓	✓	
France	78	52	60	88	5	✓	✓	✓			
Germany	87	45	46	84	6	✓					✓
Hungary	67	26	31	82	6	✓		✓		✓	
Israel			45	77	5					✓	
Japan	36	68	36		8		✓			✓	✓
Korea	45	59	33	98	6		✓	✓			
Netherlands	90	36	21	82	5	✓			✓	✓	✓
New Zealand	69	67	29	81	7						
Norway	91	62	19	83	7	✓	✓	✓	✓		
Slovenia		44	43	99	8			✓			
South Africa		9			8						
Spain	60	40	74	98	6		✓	✓		✓	
Sweden	95	66	42	85	6						
United Kingdom	65	51	26	90	n.a.	✓					
United States	78	60	28	80	6			✓			

Note: The table only includes countries that provided responses to the STI Outlook 2010 Policy Questionnaire as of 31 August 2010. However, indicators of performance are calculated for all OECD countries for which data are available. Therefore the highest OECD value may not appear in the table and the ranking takes into account a larger number of countries than those presented here.

n.a.: Response not available.

1. As a percentage of the labour force aged 25-64 at this level of education.
2. Annual average female earnings as a percentage of male earnings.
3. Self-reported ranking of national STI priorities based on scale whereby 1 = least important and 8 = most important.

Source: OECD, *Education at a Glance 2009*, OECD, Paris; OECD, *OECD Science, Technology and Industry Scoreboard 2009*, OECD, Paris; OECD, *OECD Science, Technology and Industry Outlook 2008*, OECD, Paris; responses to the STI Outlook 2010 Policy Questionnaire.

and public research institutes have led to the emergence of a "secondary" labour market where lack of clear rules on recruitment, employment and promotion may lead to job insecurity and inequity. Consequently, OECD countries are addressing issues of career development in research more broadly.

- Austria has initiated a broad reform of career prospects and working conditions in universities. Collective agreements between university representatives and the union of public employees which came into force in October 2009 foresee a standard career model which offers more flexibility, regular evaluation and higher minimum wages for researchers. They prolong the duration of short-/fixed-term contracts by the length of maternity leave and offer the possibility of leave for study, training or research purposes. Universities can act flexibly in the framework of the performance agreements they have with the ministry for the period 2010-12. In return the Ministry of Science and Research supports the implementation with additional funds.

- France adopted in 2010 a decree introducing profit-sharing with public research institute personnel involved in scientific research or services. In addition the government has invested EUR 252 million in the *Plan carrières* (2009-11) to support the career development of researchers. This programme plans an upward revision of salaries, mobility allowances, pedagogical responsibility allowances, and scientific excellence bonuses. It offers greater career opportunities and faster career tracks, work flexibility according to education *versus* research priorities and the acknowledgement of practical training activities. Another policy initiative in favour of researchers' careers is the creation of mixed chairs between universities and public research institutes.
- Germany has addressed the question of equal opportunities and work-family balance in its Initiative for Excellence for young scientists.
- Japan has announced its intention to diversify career paths for young researchers and to prepare an appealing environment for research, including funding and support systems, as well as desirable living conditions, to attract superior researchers from around the world. In particular, Japan is undertaking new initiatives to improve work-family balance, extending childcare leave and offering preferential consideration to businesses that take the lead in developing working arrangements for parents with small children. The government also plans to provide enhanced support for resumption of employment and reemployment following the birth of a child and infant care.
- Norway has pledged in its White Paper on Research in spring 2009 to increase the ability of the higher education institutions to create good career paths and particularly better conditions for qualifying to professor positions.
- South Africa launched in 2009 the National Postdoctoral Research Forum and its website to facilitate interaction among postdoctoral students and provide them and recruiters the platform for posting job opportunities. In addition the South Africa PhD Project, a non-funding programme of the National Research Foundation, encourages master's graduates to register for doctoral studies and serves as a market place for PhD students, supervisors and funders to look for and give information on job and funding opportunities.
- Slovenia is undertaking an evaluation of its higher education and research programme.

Mobility of human resources is a key component of knowledge diffusion among firms and from academia to industry. Governments can encourage the employment and mobility of the highly skilled, first as employers themselves, then by providing incentives to firms. Several countries are addressing the issue of researcher mobility.

- Austria has implemented a new programme on human resources for the economy that, among others things, provides an incentive for higher sectoral mobility.
- In Finland's reform of the universities at least 40% of the members of the new university Board of Directors must come from outside the university.
- In 2010 the Swedish Foundation for Strategic Research (SSF), an independent research foundation, allocated around SEK 15 million for a strategic mobility programme covering a period of two years. The purpose of the programme is to increase personal mobility and cross-fertilisation between academia and industry and thereby increase knowledge of the different conditions under which people work in academia and industry.

Outlook: future challenges

The contribution of innovation to productivity growth and competitiveness remains a key issue for OECD countries but also for emerging economies. As this chapter shows, OECD countries continue to reform their science, technology and innovation policies to improve the efficiency of their national innovation systems. The increasing focus on STI to address environmental sustainability, energy security and at the same time to foster new growth industries and services illustrates the convergence of competitiveness goals with efforts to mobilise STI to address social challenges. Indeed, these challenges are increasingly driving countries' research and innovation agendas.

Public support to the "supply side" of research and innovation remains a key area for STI policies although attention to the "demand side" of innovation, such as public procurement, standards and involvement of users to "pull" innovation, continues to gain ground. Changes in innovation processes, not least those driven by the broadening of innovation, the rise of new global players and global value chains, and technological convergence also affect how governments design, develop and implement policies to support scientific and innovative performance. This places pressures on governments to monitor and adjust the effectiveness of national STI governance structures and policies to ensure co-ordination and coherence at the regional, national and, increasingly, international level.

The near-term outlook for public and private investment in research and innovation remains positive as governments continue to support investments in STI to foster longer-term growth. But fiscal pressures and continued slow growth in OECD countries will affect business investment decisions as well as the scope for public support. One implication is that there will arguably be greater pressure on governments to set strategic as well as thematic priorities for research and to improve effectiveness of innovation policies and instruments, given limits to public investments in research and innovation.

In the longer term, the participation of emerging and developing economies in global R&D and innovation networks will re-draw the global map for STI, even if OECD countries will continue to predominate in R&D. Increasingly, countries as diverse as China, South Africa, Indonesia or Vietnam are developing broad-based innovation strategies that encompass existing and new technologies as well as social innovations. This reflects a change in the understanding of the role of and interplay between the creation and diffusion of technology. The notion in developmental theories that countries need to "exhaust" their potential for catching up before embarking on their "own" innovation and R&D activities is being challenged. This opens up avenues for mutual learning and multilateral collaboration on science, technology and innovation between OECD and developing countries.

Notes

1. This chapter is based mainly on the responses from countries to the STI Outlook 2010 Policy Questionnaire received as of 5 August 2010. It also draws on responses to related questionnaires or requests for policy information (*e.g.* on R&D tax credits) in other OECD working parties and committees.
2. Institutes that mainly perform public administration-related tasks are not included under this scheme, which therefore encompasses 51 research institutes.
3. The most recent data are for 2005.

4. The core NCE programme consists of 15 networks working in the four national strategic areas and partnering close to 2 000 organisations (companies, government departments/agencies, hospitals, universities) in Canada and around the world. The NCE employed in 2006-07 more than 6 000 researchers and highly qualified personnel. The NCE supported its scientists in filing 110 patents and publishing 4 309 papers in referred journals, obtained or launched negotiations on 20 licences and generated four spin-off companies.
5. The proportion of total financial resources devoted to education in a country results from choices made by government, enterprises and individual students and their families, and is partially driven by the size of the country's school-age population and enrolments in education. Moreover, if the social and private returns to investment in education are sufficiently large, there is an incentive to expand enrolment and increase total investment (OECD, 2009d).

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OECD Science, Technology and Industry
Outlook 2010

Chapter 3

Science and Innovation: Country Notes

This chapter complements Chapters 1 and 2 of this publication by providing an individual profile of the science and innovation performance of each OECD country in relation to their national context and current policy issues. Overviews of OECD accession countries (Estonia and the Russian Federation) and other BRIICS countries (Brazil, China, India, Indonesia and South Africa) are also included in the chapter. The graphs enable countries to see some of their relative strengths and weaknesses compared to the performance of other countries.

The common indicators in the first (radar) graphs were selected on the basis of current policy issues. They focus on research and innovation inputs, scientific and innovation outputs/outcomes, linkages and networks – including international linkages – and investment in human resources. A standard set of indicators is used; however, when data are not available, alternative indicators are applied. Indonesia's overview does not include a radar graph owing to insufficient data. Annex 3.A1 provides a full list and description of the indicators, methodological notes and data sources.

For each indicator in the radar graph, the OECD country with the maximum value is set at 100 (with a position on the outer ring of the radar). The average is calculated by taking into account all OECD countries with available data (non-OECD countries are excluded from the average). Annex 3.A1 provides further details.

The radar graphs are accompanied by country-specific figures that further illustrate national characteristics and underpin policy-specific discussions. The selection of comparator countries in these graphs aims to highlight the general position of the focal country; in some instances data on other countries may also be presented.

Note on new member countries

Chile: Chile became a member of the OECD on 7 May 2010. Chilean data on science and technology are not yet part of the OECD Main Science and Technology Indicators (MSTI) Database. *References in this chapter to OECD averages, maximum values and rankings do not include Chile unless explicitly noted.*

Israel: On 7 September 2010, Israel became a member of the OECD. Israeli data on science and technology are available in the OECD MSTI Database*; however, references in this chapter to OECD averages, maximum values and rankings do not include Israel unless explicitly noted. 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.*

Slovenia: Slovenia became a member of the OECD on 21 July 2010. Slovenian data on science and technology are available in the OECD MSTI Database*; however, references in this chapter to OECD averages, maximum values and rankings do not include Slovenia unless explicitly noted.*

AUSTRALIA

Australia's innovation landscape is dynamic and displays a number of strengths. Gross expenditure on R&D (GERD) has grown since 2000 to a record 1.97% of GDP in 2006. Business expenditure on R&D (BERD) was 1.2% of GDP in 2007, below the OECD average that year of 1.6%. The share of GERD financed by industry increased from 54.3% to 58.3% from 2004 to 2006, while the share financed by government fell from 40.3% to 37.3%. Industry financed 96% of BERD in 2007, up from 89% in 2001. In 2006, the services sector performed 40% of BERD. Based on a broad definition of venture capital, venture capital intensity (0.13% of GDP) exceeded the average in 2008. Based on a narrower definition (excluding private equity), however, this ratio has fallen in recent years.

The number of triadic patents increased by almost 6% between 1998 and 2008, to 14.6 per million population. However, at 0.6% of the world share of triadic patent families, this is below the OECD average. This result can be ascribed to the nature of the resource and agricultural sectors, combined with a decline in the high-technology manufacturing sector due to global competition. Scientific publications were well above the OECD average in 2008, with 1 448 scientific articles per million population, or nearly 2% of world output.

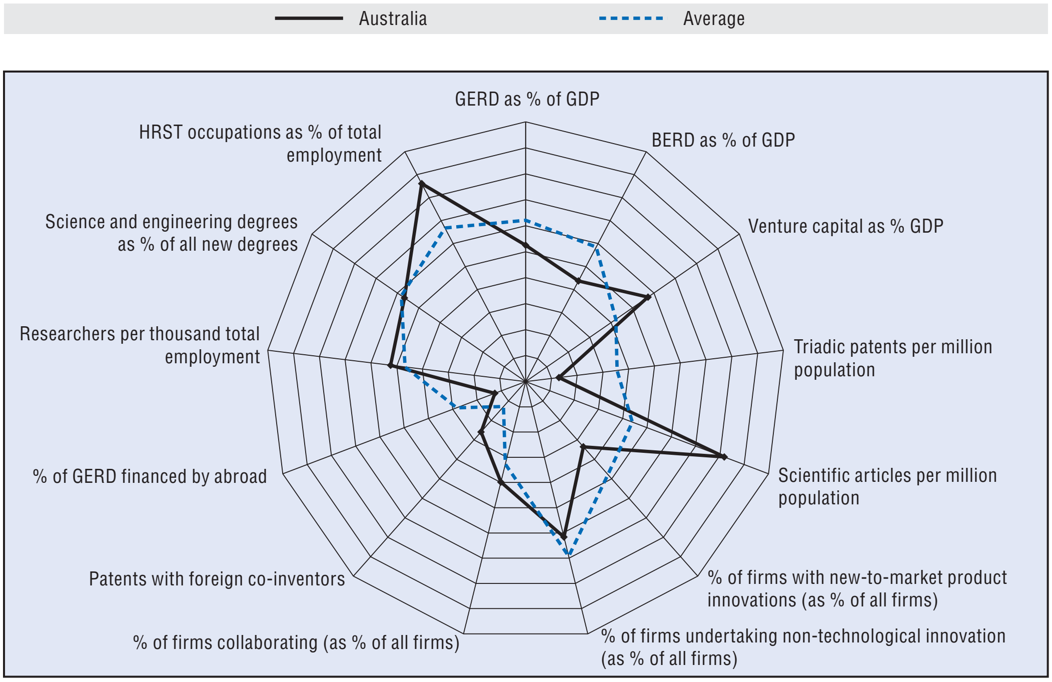
Innovation linkages indicators vary. Around 12% of firms collaborated with an external partner during 2006-07 and a comparatively high 15.6% of patents were developed with foreign co-inventors during 2005-07. Australian firms rank comparatively low on in-house product innovation and non-technological innovation, but comparatively better on in-house process innovation. By firm size, a relatively low 28% of SMEs and 40% of large firms undertook non-technological innovation in 2006-07. In 2006, a relatively low 2.4% of GERD was financed by abroad.

Science and engineering graduates in total university degrees (20.4%) are close to the OECD average. Human resources in science and technology (HRST) occupations as a share of total employment declined from 38% in 2004 to 36% in 2008 but remain above average and are distributed equally between men and women. Researchers per thousand total employment edged up to 8.5 in 2006.

Australia's economy averted a technical recession in 2008 and 2009. Real GDP increased by 1.4% in 2009, and the unemployment rate was a comparatively low 5.6%. Relative to the United States, GDP per capita was above average (82%) in 2008, while GDP per hour worked exceeded the OECD average by 4 percentage points.

The government's innovation agency, the Department of Innovation, Industry, Science and Research, published its *Powering Ideas* in mid-2009, outlining a ten-year reform agenda to make Australia more productive and competitive, supported by a substantial boost in funding. Looking forward, the key policy issues include developing an integrated approach to science and innovation and improving links with global research and innovation systems.

Science and innovation profile of Australia



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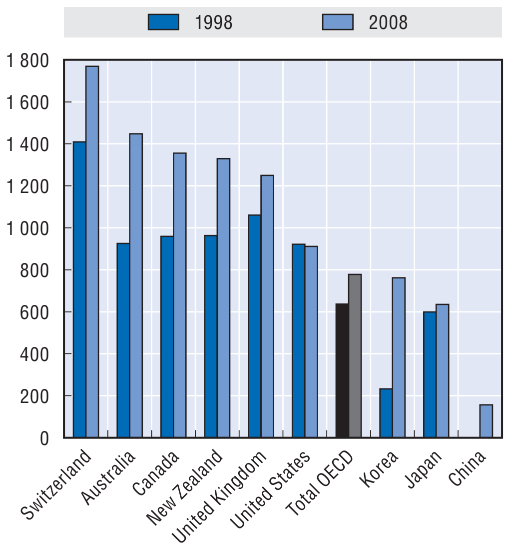
Scientific articles published

Per million population, 1998 and 2008



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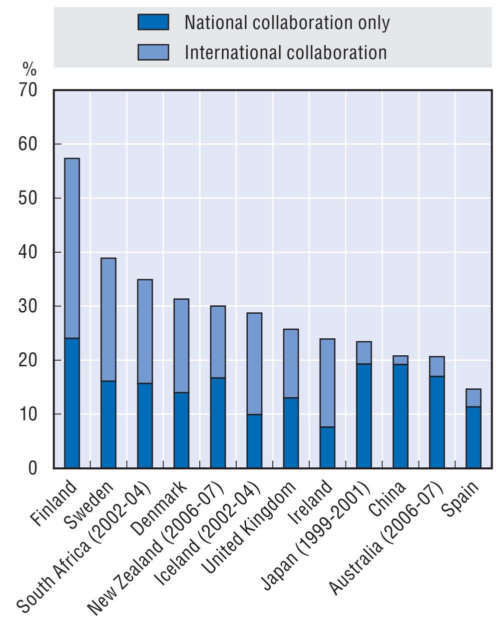
Firms with collaboration on innovation

As a percentage of innovative firms, 2004-06



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AUSTRIA

Austria performs well on a number of science and innovation indicators. Since 1998 gross expenditure on R&D (GERD) has increased consistently as a share of GDP to 2.7% in 2008, mainly owing to higher business expenditure on R&D (BERD) (1.9% of GDP). The 23.8% of GERD performed by the higher education sector was slightly lower than in preceding years; that of government (5.3%) increased slightly.

BERD growth has been particularly strong in the office machinery, computer and pharmaceutical industries. The share performed in service industries also increased slightly to 2006. The 23.3% funded from abroad in 2007 was the OECD leader, owing to the strong presence of foreign multinationals. Industry financed 66.3% of BERD in 2007, and the government-funded share increased sharply from 5.5% in 1998 to 10.3%. In 2008, venture capital investment was 0.03% of GDP, well below the average (0.1%).

Triadic patents increased by 53% in the decade to 2008 to 52 per million population. At 973 scientific articles per million population in 2008, Austria was above the OECD average and accounted for 0.5% of world output. Almost a quarter of all firms introduced new-to-market product innovations during 2004-06, and 56% of firms undertook non-technological innovation.

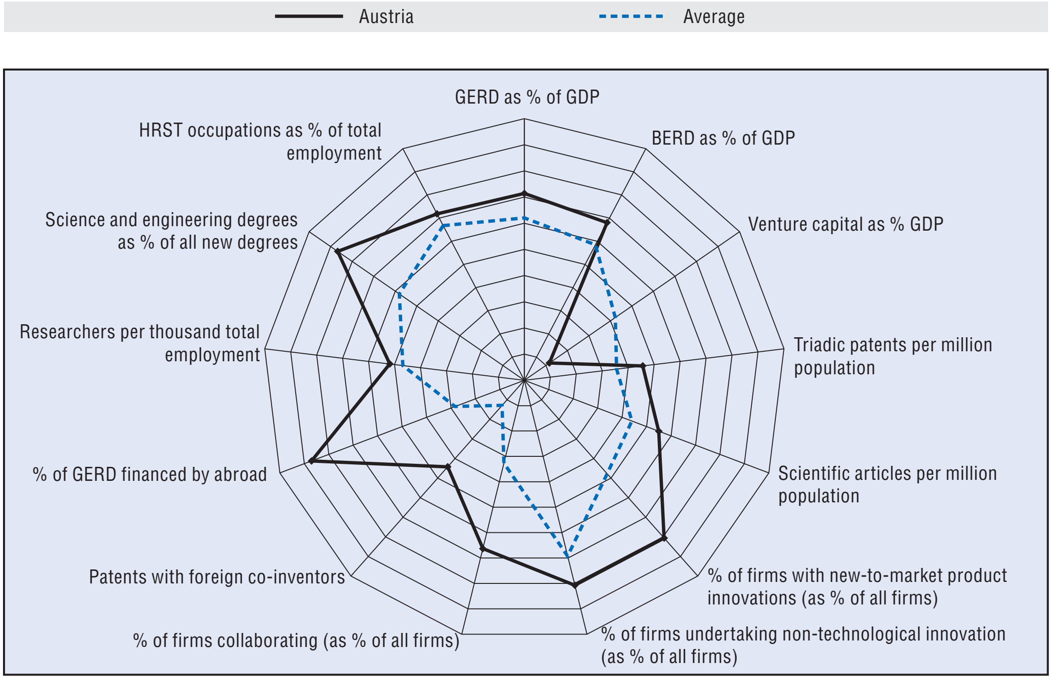
Innovation links are strong. The percentage of firms collaborating on innovation activities was a relatively high 20% in 2004-06. During 2005-07, Austria lodged 27% of Patent Cooperation Treaty (PCT) patent applications with foreign co-inventors, three times the OECD average. In 2008, 16.5% of GERD was financed from abroad.

Austria's human resources in science and technology (HRST) indicators firmed over the past two years. Science and engineering degrees represent 31% of all new degrees, well above the OECD average. HRST occupations represented almost 30% of total employment in 2008. The number of researchers increased to 8 per thousand total employment, slightly above average.

GDP grew by a strong average 2.4% a year between 2001 and 2008, but contracted by 3.6% in 2009. Unemployment increased to a modest 4.8%. GDP per capita was 80% relative to the United States in 2008, and remained above the OECD average. Labour productivity growth slowed to 0.8%.

The Austrian federal government is to launch its *Research Strategy 2020* in the second half of 2010; it will outline the government's science, technology and innovation activities for the next decade. Despite the recent economic crisis, Austria aims to be among the top three European innovation leaders by 2020, and to become a country with production structures at the "technological frontier" with substantially higher productivity.

Science and innovation profile of Austria



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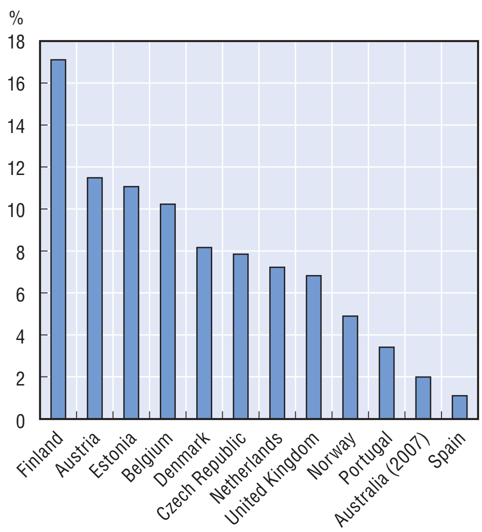
Firms collaborating internationally on innovation

As a percentage of all firms, 2004-06



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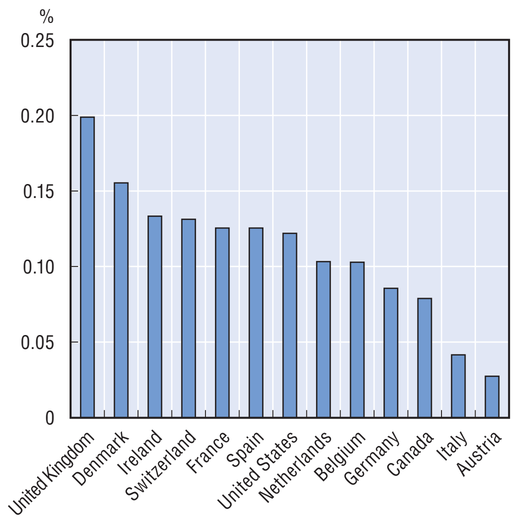
Venture capital investment

As a percentage of GDP, 2008



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BELGIUM

The shape of Belgium's science and innovation profile reveals a number of strong features. Investment in human resources in science and technology (HRST) is a policy priority. Belgium has 8 researchers per thousand employment, slightly above the OECD average. Science and engineering degrees represented 23% of new degrees in 2007, marginally above the OECD average, and in 2008 HRST occupations accounted for 32.5% of total employment.

Belgium's profile also reveals areas for improvement. In 2008, gross expenditure on R&D (GERD) was a relatively low 1.9% of GDP, although it has grown in constant terms in recent years. In that year, business expenditure on R&D (BERD) was a steady 1.3%, while venture capital was on the average at 0.10% of GDP. R&D expenditure in the pharmaceutical industry exceeds the OECD average as a percentage of both BERD and GDP.

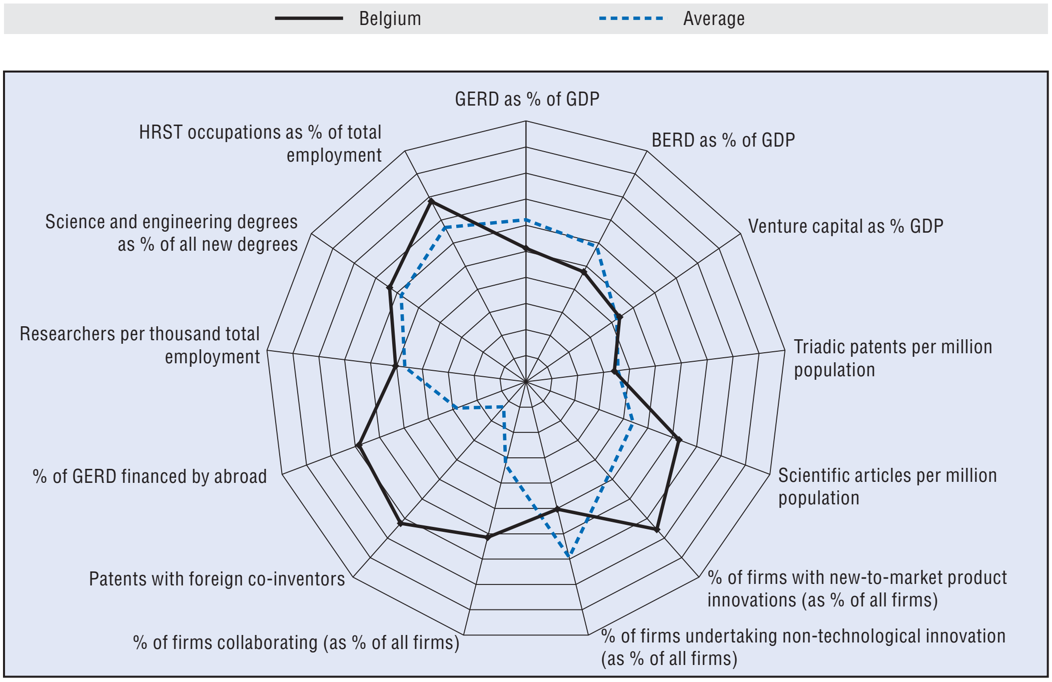
Belgium accounted for a relatively low 0.8% of total triadic patent families in 2008. With 39 triadic patents per million population, it stands marginally below the OECD average, and lower than a decade earlier. Its 1 110 scientific articles per million population are above the average and account for 1% of the world total. More than one in five Belgian firms introduced new-to-market product innovations in 2004-06, and 48% of SMEs and 76% of large firms undertook non-technological innovation, predominantly in the manufacturing sector.

Innovation linkages in Belgium are strong. A relatively high 18% of firms collaborated on innovation activities during 2004-06, and a high 44% of Patent Cooperation Treaty (PCT) patent applications were with foreign co-inventors. In 2007, 13% of GERD was financed from abroad, a further sign of strong international integration. Another indication of Belgium's openness is the 59% of R&D expenditure by foreign affiliates as a percentage of total R&D, the third highest in the OECD area.

Belgium's GDP grew at a compound annual rate of 2% between 2001 and 2008, but in 2009 the economy contracted by 3.1%, with the unemployment rate increasing to 7.9%. Belgium's GDP per capita relative to the United States was 75% in 2008, while GDP per hour worked relative to the United States was 98%.

Innovation in Belgium is guided by policies in the three regional governments: Flanders, Wallonia and Brussels Capital. In 2005, Wallonia adopted a number of documents that remain the baseline for policy in the period to 2010. The Marshall Plan2.Green was recently updated to reflect the integration of sustainable development as a priority. Flanders in Action (FIA) is the action plan meant to lead Flanders to the top five regions in Europe, and the main document governing innovation policy in the Brussels Capital region is the 2006 Regional Innovation Plan for 2007-13. The federal finance agency (FPS Finance) has recently increased R&D tax credits to EUR 470 million, nearly doubling the share of the federal government in public R&D funding.

Science and innovation profile of Belgium



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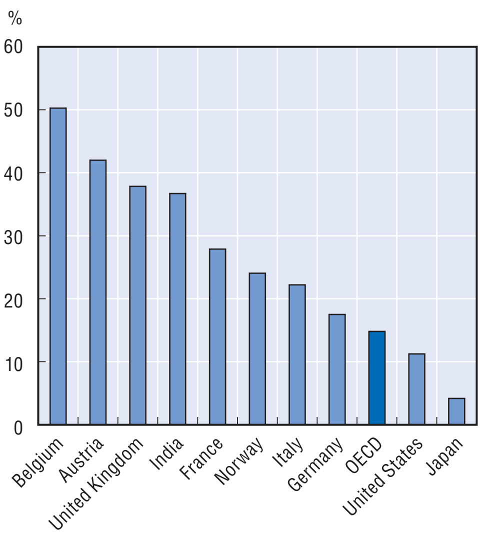
Foreign ownership of domestic inventions

Percentage share, 2004-06



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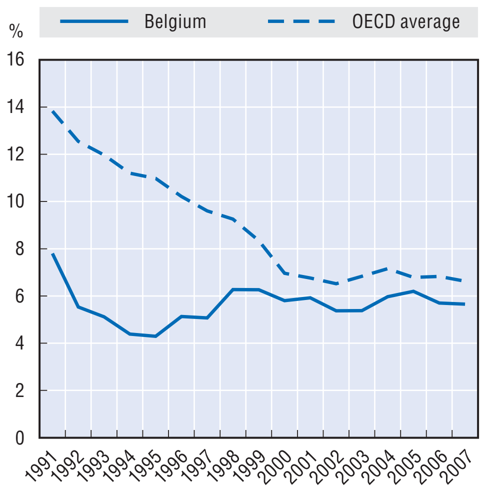
BERD financed by government

Percentage share of total BERD, 1991-2008



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BRAZIL

Brazil's economy is characterised by large and well-developed agricultural, mining, manufacturing and services sectors. Its USD 2 trillion economy is expanding rapidly into world markets, and is also changing structurally. Over the decade to 2008, high-technology manufacturing exports increased at an average annual 16%, faster than total manufacturing exports (13%), a sign of higher competitiveness.

Brazil's science and technology profile shows weaknesses, but some areas have improved over the past two years. In 2008, gross expenditure on R&D (GERD) was 1.1% of GDP. While this is below the OECD average, it is higher than in India, Russia and South Africa. Business expenditure on R&D (BERD) was 0.5% of GDP in 2008. To raise this, Brazil has a generous 25.5% tax subsidy rate for every US dollar of R&D.

Emerging economies produce few patents relative to R&D, as illustrated by Brazil's 0.3 triadic patents per million population in 2008. However, Brazil is increasingly involved in patent development in waste management, water pollution control and renewable energy. In 2008 it published 26 806 scientific articles; at 141 per million population, this indicator is well below the OECD average but has increased sharply over the past two years. In 2008, it had 1.6% of world scientific articles, more than the Netherlands, for example. Between 1998 and 2008, publications increased by 12.2% on an average annual basis. Only 3.6% of Brazil's firms introduced new-to-market product innovations during 2003-05, and a below average 36% of firms undertook non-technological innovation.

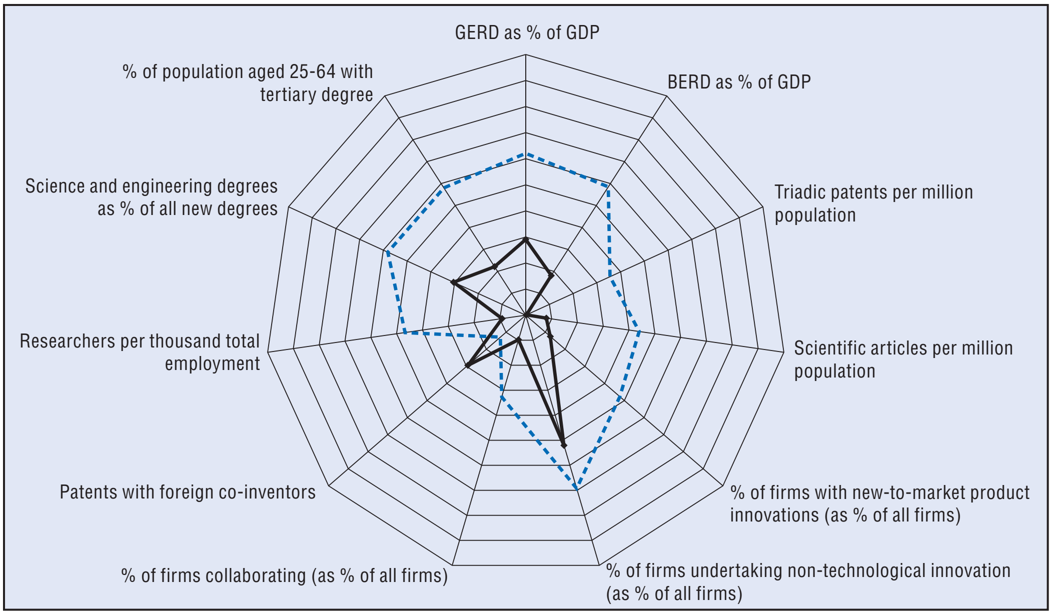
International integration appears weak. While the average ratio of exports and imports to GDP increased in all OECD countries between 1997 and 2007, it was less than 20% in Brazil. A small 3% of firms collaborated on innovation activities in 2003-05, but the percentage of Patent Cooperation Treaty (PCT) applications in 2005-07 with foreign co-inventors (18%) was above the OECD average of 7.7%.

Brazil's indicators for human resources in science and technology (HRST) remain weak. In 2006, there were only 1.5 researchers per thousand total employment. Science and engineering degrees increased to 11% of all new degrees in 2007, around half the OECD average. A comparatively low 11% of the population aged 25-64 is qualified at the tertiary level. However, there is a rising trend in doctorates awarded. In spite of low graduation rates, Brazil, like Russia, awards more doctorates per capita than the OECD average.

Brazil's GDP grew by 6.1% in 2007 and 5.1% in 2008 but contracted by 0.2% in 2009. However, it was one of the first emerging economies to begin to recover. The labour market remained resilient, and unemployment fell from 7.9% in 2008 to 7.4% in 2009. GDP per capita was 22% relative to the United States in 2009.

To complement the government's Growth Acceleration Plan, the Ministry of Science and Technology has launched its own Action Plan for Science, Technology and Innovation – *Plano de Ação para Ciência, Tecnologia e Inovação 2007-2010 (PACTI)* – with initiatives and programmes to enhance the role of science, technology and innovation in Brazil.

Science and innovation profile of Brazil



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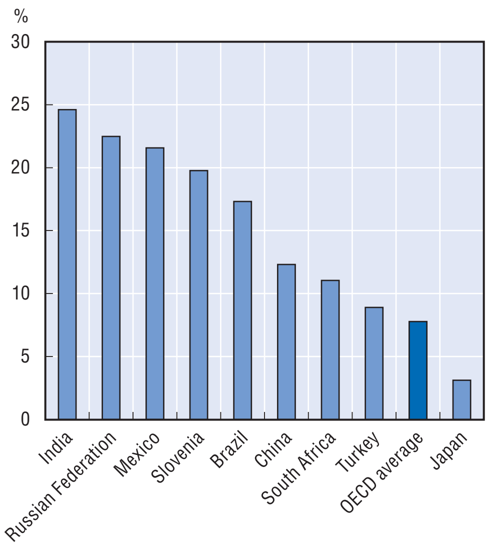
Patents with foreign co-inventors

Percentage of PCT applications, 2005-07



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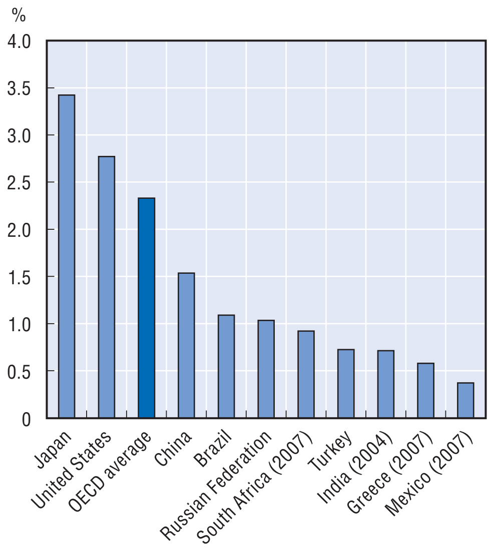
Gross expenditure on R&D

As a percentage of GDP, 2008



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CANADA

Canada has a unique innovation landscape and its science and innovation profile displays notable strengths. It has strong human resources in science and technology (HRST) and HRST occupations are well represented in total employment. It counts 22.4% of science and engineering graduates in total university graduates, slightly above the OECD average. Canada has a high share of tertiary-level graduates in total employment, 58% of whom are women. Researcher numbers increased more slowly in 2007 to 8.3 per thousand total employment, but remained above average.

However, gross expenditure on R&D (GERD) has declined as a share of GDP since 2005. After reaching around 2.1% of GDP between 2001 and 2005, it fell to 1.8% in 2008. GERD per capita is also relatively low. GERD financed by industry fell from 50% in 2004 to 48% in 2008, while government financing increased from 31% to 32%. Business expenditure on R&D (BERD) fell to 1% of GDP in 2008, below the OECD average of 1.6%. Defined broadly, venture capital represented 0.08% of GDP in 2008.

In 2008, triadic patents were 19 per million population, about half the OECD average, and accounted for 1.4% of total triadic patent families. Scientific publication output was above average in 2008 with 1 356 scientific articles per million population, for 2.7% of the world's scientific publications, the sixth highest in the OECD. Canadian manufacturing firms performed well in terms of new-to-market product innovations during 2002-04. Around 36% of BERD was performed in service industries in 2006.

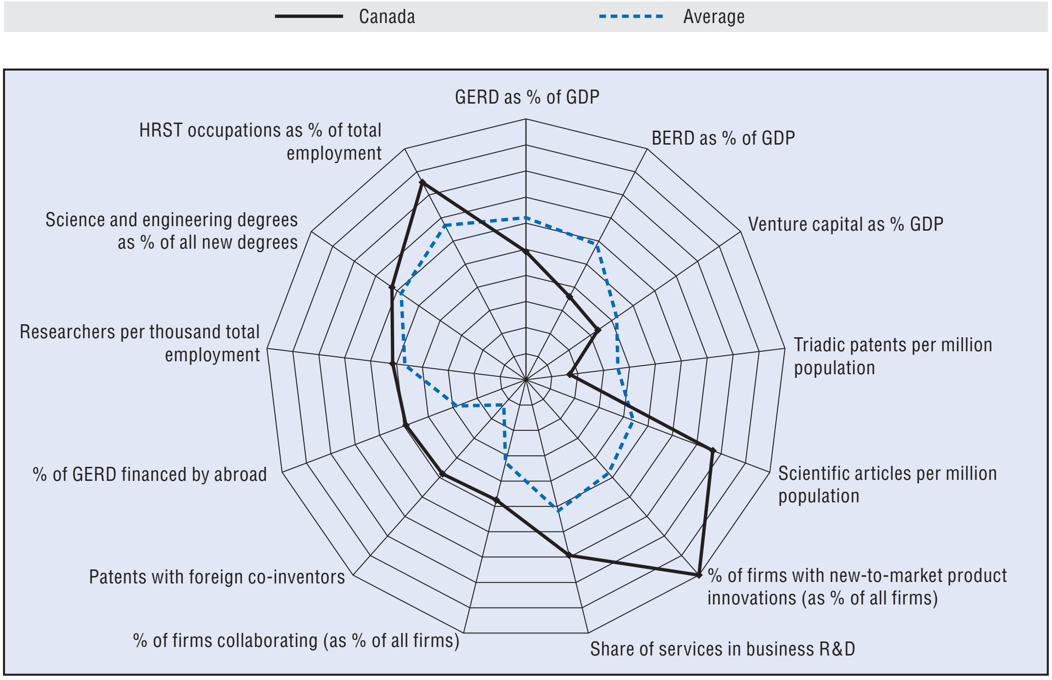
Canada displays sound linkages and collaboration. The percentage of manufacturing firms collaborating on innovation activities is above average, and in 2008 a relatively high 9% of GERD was financed from abroad. Almost 30% of patents were developed with foreign co-inventors in 2005-07.

Canada's average annual real GDP growth was around 2.4% between 2001 and 2008, but contracted by 2.6 % in 2009, while the unemployment rate increased to 8.5%. Relative to the United States, GDP per capita was 83% in 2008, and GDP per hour worked was 78%.

The 2007 Federal S&T Strategy, Mobilizing Science and Technology to Canada's Advantage, remains the main policy framework for Canada's innovation policies. It aims to foster competitiveness through investments in three key areas: entrepreneurial advantage, knowledge advantage and people advantage. It is founded on four core principles: promoting world-class excellence; focusing on priorities; fostering partnerships; and enhancing accountability.

In June 2009 the government released a progress report on the implementation of the strategy, expressing its commitment to bring forward investments to make Canada a world leader in science and technology.

Science and innovation profile of Canada



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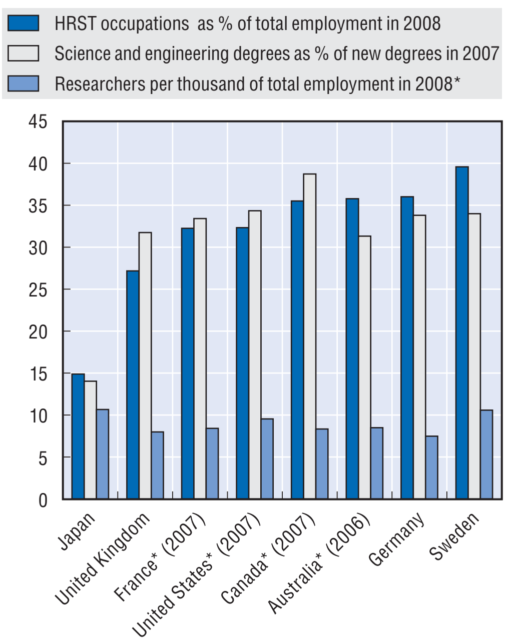
Human resources in science and technology (HRST)

Selected indicators, 2007-08



* Or nearest available year.

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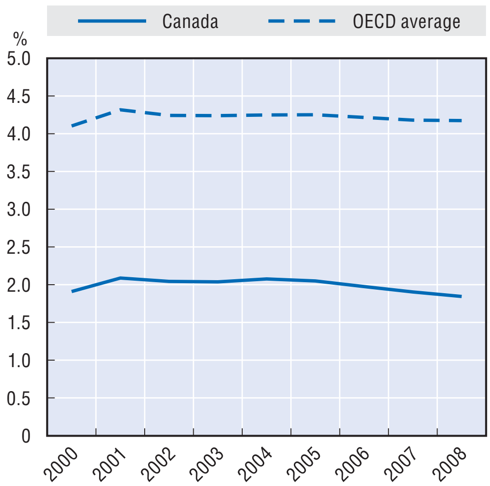
Gross expenditure on R&D

As a percentage of GDP, 2000-08



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CHILE

Chile joined the OECD on 7 May 2010. Its economy is characterised by a high level of foreign trade. It has a reputation for strong financial institutions and sound policy, and has the strongest sovereign bond rating in South America. Chile's science and innovation profile shows particular strengths and improvement over the two years to 2008, but also some weaknesses.

A relatively high 9% of gross expenditure on R&D (GERD) was funded from abroad in 2004 and an above average 17.5% of firms collaborated on innovation activities during 2004-06. In addition, almost 40% of Patent Cooperation Treaty (PCT) applications during 2005-07 involved foreign collaboration. Other indicators of openness are the quadrupling of foreign direct investment inflows in the five years to 2008, and the significant 20% contribution of exports to GDP in 2009.

Although the GERD intensity of 0.7% of GDP in 2004 is well below the OECD average, it exceeds that of OECD countries such as Greece, Mexico and the Slovak Republic. At 0.3% of GDP business expenditure on R&D (BERD) is also low. This is due to Chile's economic structure: the services sector makes up 64% of GDP, agriculture contributes 15% and a low-technology manufacturing sector, which includes energy, comprises 23%. Commodities account for almost three-quarters of total exports.

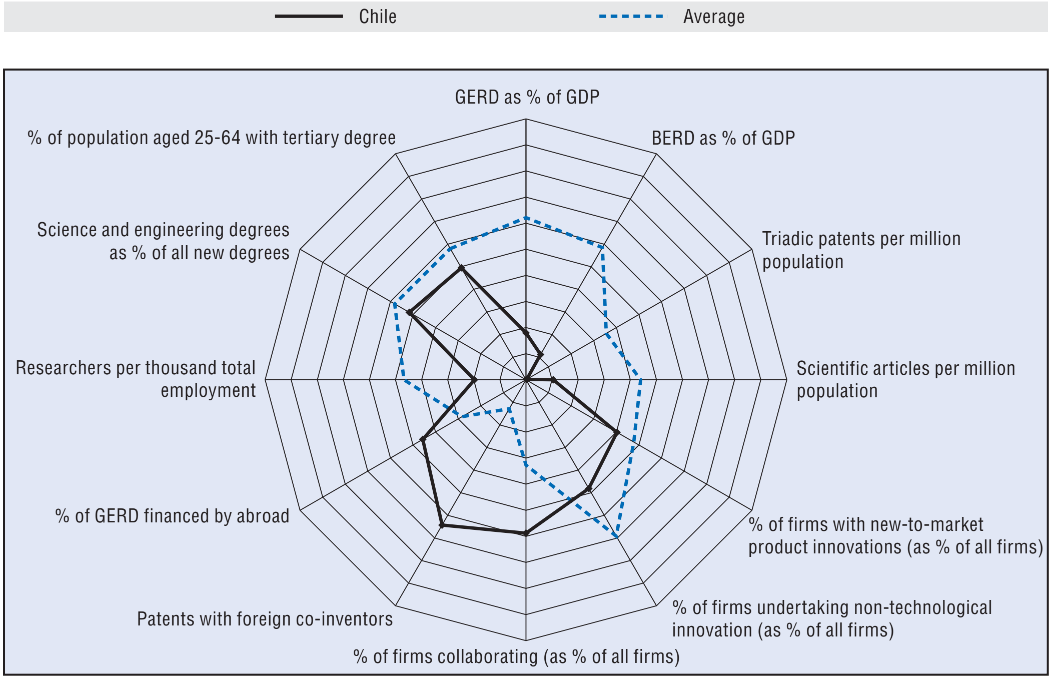
Chile produced 0.36 triadic patents per million population in 2008. It had only 185 scientific articles per million population in 2008, although these have been growing by a robust 10% a year since 1998. A comparatively low 12% of firms introduced new-to-market product innovations during 2004-06, while a below-average 33% of firms engaged in non-technological innovation.

Human resources in science and technology (HRST) indicators are below average. In 2004, Chile had 3 researchers per thousand total employment. The level of tertiary education attainment is below the OECD average; 24% of the population aged 25-64 had tertiary-level qualifications in 2008. However, a relatively high 18% of all new degrees, close to the OECD average, were in the science and engineering disciplines in 2007.

Chile's GDP grew by an average annual 4.5% during 2001-07. Growth slowed to 3.7% in 2008 and GDP contracted by 1.5% in 2009; the unemployment rate increased from 7.8% in 2008 to 10% in 2009. Relative to the United States, GDP per capita was 31% in 2008, while GDP per hour worked was 28%.

In recent years, the Chilean government has put in place a framework aimed at improving scientific and technological development. The two key agencies are the Chilean Economic Development Agency (CORFO) and the National Scientific and Technological Research Commission (CONICYT). CORFO's innovation component is focused on technology innovation for companies, technology transfer and promoting entrepreneurship, while CONICYT aims mainly at promoting and strengthening scientific and technological research through a scholarship programme.

Science and innovation profile of Chile



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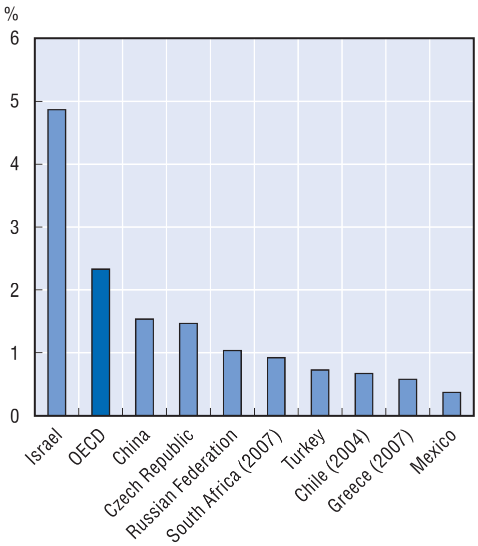
Gross expenditure on R&D

As a percentage of GDP, 2008



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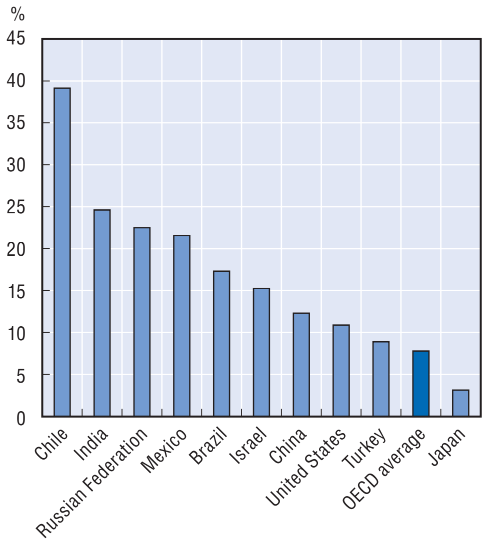
Patents with foreign co-inventors

As a percentage of PCT applications, 2005-07



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CHINA

Over the past three decades China's economy has moved from being largely closed to becoming a major global player. Its innovation system has undergone considerable change and its innovation performance has improved noticeably. Gross expenditure on R&D (GERD) increased consistently from 0.73% in 1991 to 1.5% of GDP in 2008, the equivalent of around 13% of total OECD GERD. Industry funded about 70% of GERD, and the government 24%. Business expenditure on R&D (BERD) was 1% of GDP in 2008, and increased by 27% a year in real terms in the decade since 1997. In 2007, business R&D was equivalent to almost 12% of OECD BERD, up from 2% in 1997.

China has few triadic patents, but its 1.1% share in triadic patent families in 2008 nonetheless ranked twelfth among the countries covered here. The publication of scientific articles in China grew by 23.4% a year in the decade to 2008, the fastest in the world over the period. Although its 156 articles per million population were below the average, China accounted in 2008 for 12% of the world's scientific articles, up from 3% ten years earlier and not far behind the United States' 16.3%. During 2004-06 almost 15% of firms introduced new-to-market product innovations.

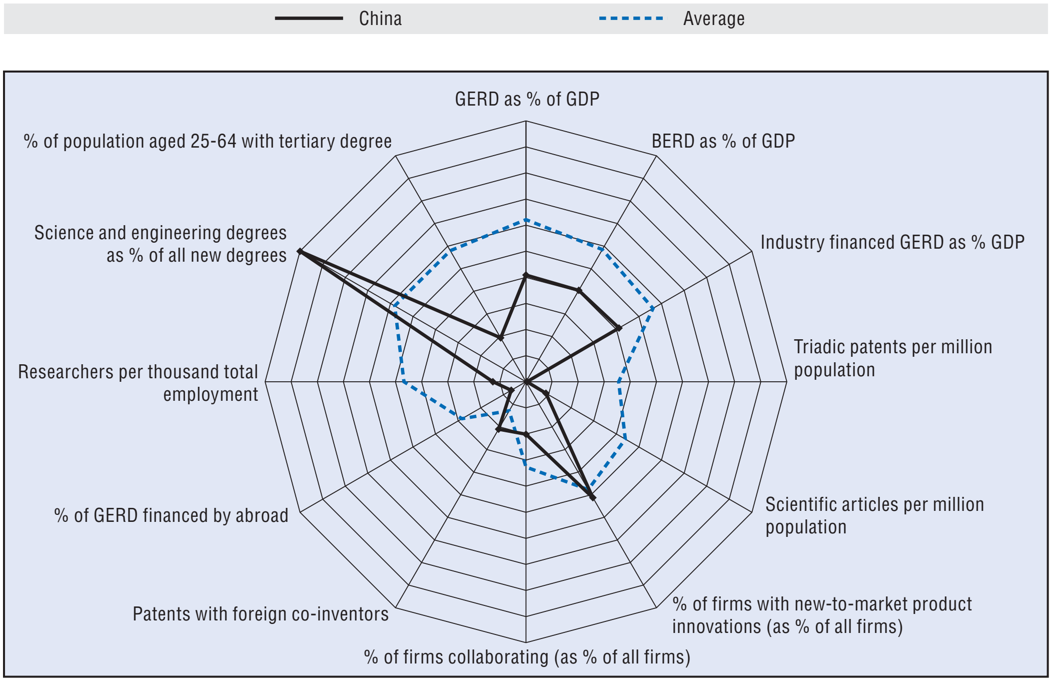
China has invested extensively in human resources in science and technology (HRST) in recent years. The number of first-stage university graduates has almost tripled since 2000, although the 12% graduation rate is still low compared to the OECD average. However, a substantial 39% of China's university graduates obtained degrees in science and engineering in 2005. Tertiary qualifications remain comparatively low; less than 10% of the age group 25-64 have a tertiary degree. Although researchers numbered only 2.1 per thousand total employment in 2008, China has as many researchers as the United States (1.4 million), and their numbers have grown by 9.4% a year since 2000.

Innovation linkages remain weak, but show potential. A small share of GERD was funded from abroad (1.2%) in 2008, and only 6% of firms collaborated on innovation activities during 2004-06. However, Patent Cooperation Treaty (PCT) applications with foreign co-inventors rose to 12.6% during 2005-07. While most R&D investment still flows to OECD countries, China is increasingly considered an attractive R&D location.

The restructuring of China's economy and efficiency gains have made it the world's second largest economy after the United States. Average annual GDP growth was 13% between 2000 and 2008, but slowed to 7.8% in 2009. GDP per capita was around 14% relative to the United States in 2009 and its urban unemployment rate was around 4.3%.

China's innovation policy, put forward in the Medium- and Long-Term Plan of Science and Technology Strategic Development: 2006-2020, aims to achieve an innovation-oriented society by 2020. Some recent policy actions, such as increasing export rebates, reducing property transaction taxes and interest rates, will help stimulate the domestic market. Moreover, a large portion of the stimulus package is expected to be invested in fixed infrastructure and human capital assets, and China's research budget will be pushed upward accordingly.

Science and innovation profile of China



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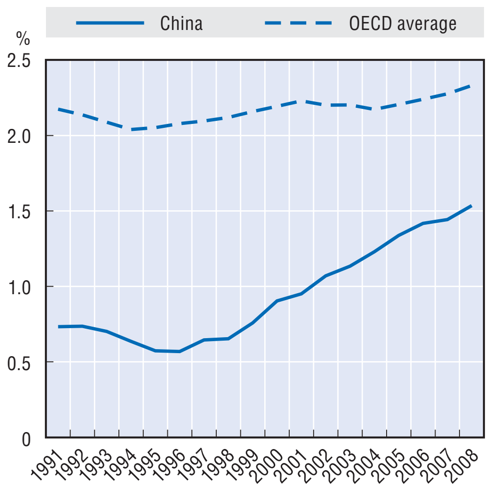
Gross expenditure on R&D

As a percentage of GDP, 1991-2008



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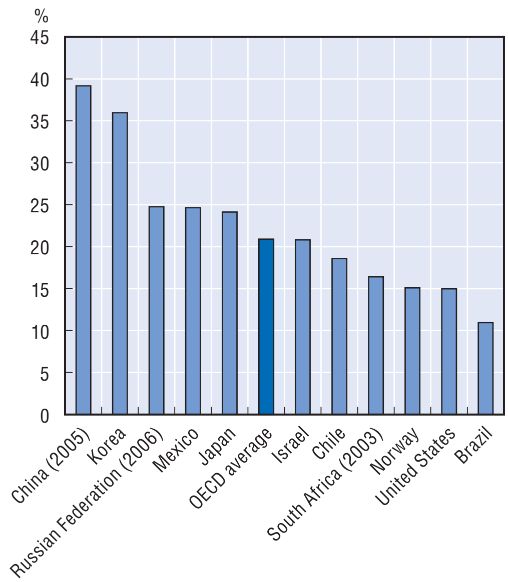
Science and engineering degrees

As a percentage of all new degrees, 2007



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CZECH REPUBLIC

The Czech Republic is rapidly catching up with key OECD countries and performs above east European OECD countries on a number of indicators. High-technology exports, for example, grew substantially faster than medium-high technology exports between 1998 and 2008. Inflows of foreign direct investment were also strong up to 2008.

Gross expenditure on R&D (GERD) has grown over the past decade. It peaked at 1.6% of GDP in 2006 and edged down to 1.5% in 2008. Although this is well up on the 1.15% a decade earlier, it is still well below the OECD average. Industry financed 52% of GERD in 2008 and government 41%. Business expenditure on R&D (BERD) has also increased in recent years, albeit to a comparatively low 0.9% of GDP in 2008. Just over one-third of BERD is performed by small and medium-sized firms, and 37% of total business R&D was performed in the services sector in 2007. In 2008, venture capital represented 0.12% of GDP, just above the average.

Triadic patents per million population are at a low level, but scientific publishing performs relatively better. In 2008, the Czech Republic produced 715 scientific articles per million population, contributing 0.4% of world output. An average 14% of firms introduced new-to–market product innovations in 2004-06, while a below-average 38% were non-technological innovators. Non-technological innovation was more prevalent among large firms and occurred predominantly in the services sector.

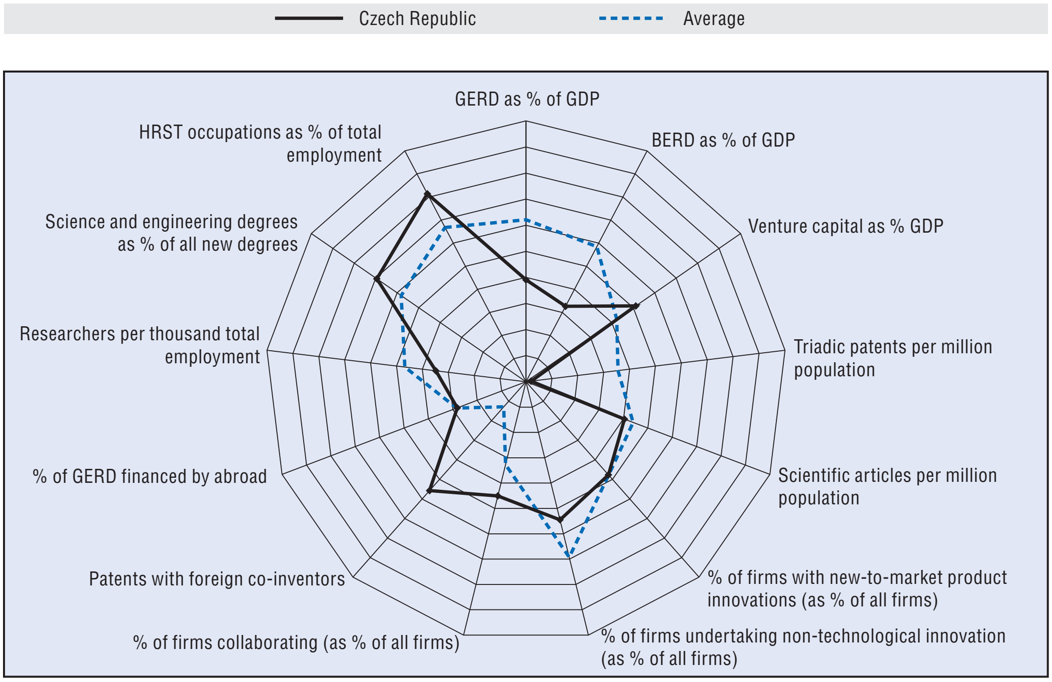
In 2005-07, 34% of Patent Cooperation Treaty (PCT) patent applications had international co-inventors, and 13% of firms collaborated on innovation during 2004-06. Although the share of GERD financed from abroad almost doubled to 5.4% between 2006 and 2008, it remained modest.

The Czech Republic's performance in human resources in science and technology (HRST) ranges from strong to below average. HRST occupations accounted for 34% of total employment in 2008, a level similar to those in key European countries, the United States and Canada, and higher than the average. In 2007, science and engineering degrees accounted for 25% of all new degrees, above the OECD average; however, there were a relatively low 5.6 researchers per thousand total employment.

The Czech economy has performed well in recent years. Real GDP grew at a compound annual rate of 4.5% between 2001 and 2008, but contracted by 4.2% in 2009, with unemployment increasing to 6.7%. Average annual labour productivity growth of 3.9% during 2000-08 exceeded the OECD average of 1.8%. GDP per capita in 2008 was significantly lower in comparison.

There is strong policy support for innovation in the Czech Republic. Currently three Operational Programmes focus on R&D and innovation issues, targeting improvements by 2013 in three key indicators: expenditures on R&D in the business sector, employment in R&D and high-technology production.

Science and innovation profile of the Czech Republic



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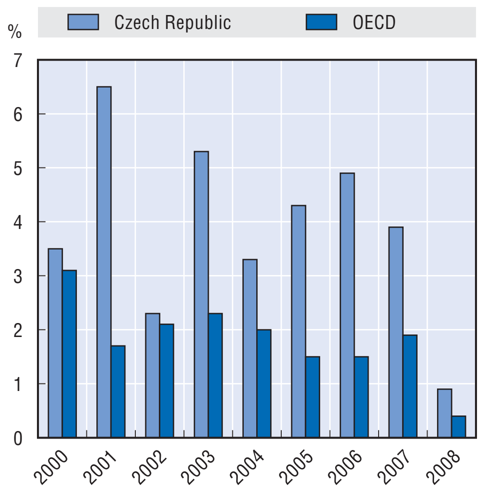
Labour productivity growth

Average annual growth rate, 2000-08



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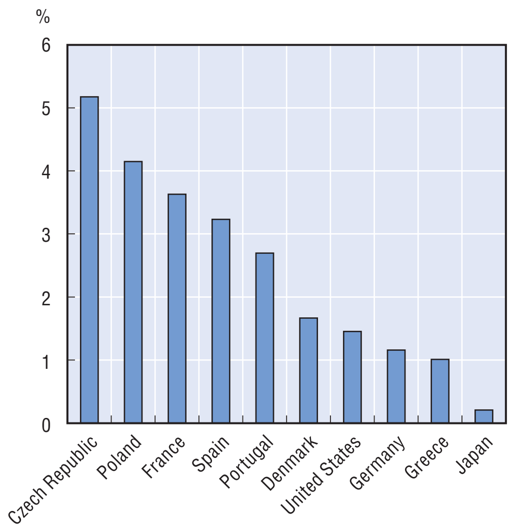
Foreign direct investment inflows

As a percentage of GDP, average 2003-08



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DENMARK

Denmark is one of the stronger OECD members on a number of science and innovation indicators. It has a modern open market economy featuring a high-technology agricultural sector and a sophisticated manufacturing industry, with world leaders in pharmaceuticals, maritime shipping and renewable energy. It has a large government R&D budget and high expenditure on biotechnology and pharmaceutical R&D. In 2008, Denmark's gross domestic expenditure on R&D (GERD) was 2.7% of GDP, firmly above the OECD average of 2.3%. Industry-financed GERD increased to 61%, while government-funded GERD declined to 25%. Business expenditure on R&D (BERD) was a comparatively high 1.9% of GDP in 2008; as a percentage of industry value added, this was almost double the OECD average. In that year, Denmark also had a high venture capital intensity of 0.16%, well above the average.

Denmark's R&D inputs translate into solid outcomes. It has a comparatively high 60 triadic patents per million population and its 1 359 scientific articles per million population are well above the average. During 2004-06 an above-average 16% of firms introduced new-to-market product innovations, while a close-to-average 47% of firms undertook non-technological innovation.

Innovation linkages are strong: in 2005-07, a relatively high 16% of firms collaborated on innovation activities, and a noteworthy 19% of patents were developed with foreign co-inventors. In 2008, 9.7% of GERD was financed from abroad, above the OECD average.

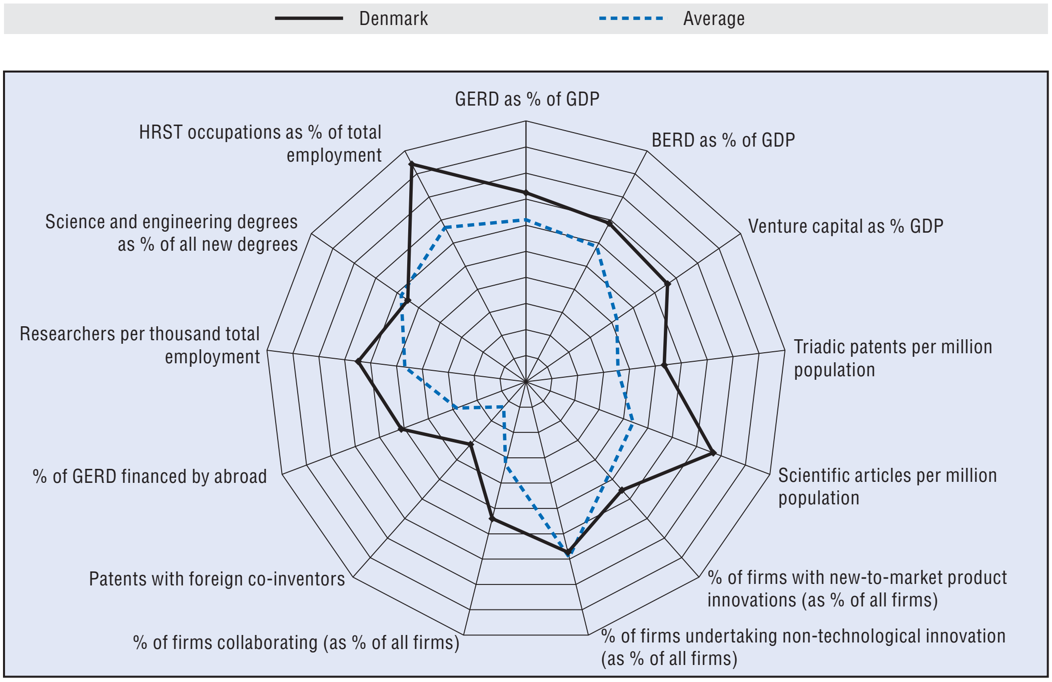
Denmark's indicators on human resources in science and technology (HRST) are quite robust. With ten researchers per thousand employment, it ranks fifth in the OECD area. Science and engineering degrees account for 20% of all new degrees, slightly below the OECD average, but the 39% of HRST occupations in total employment is the third highest in the OECD area.

During 2001-08, average annual growth of GDP eased compared to previous periods. The global financial crisis severely affected the economy, with GDP contracting by 1% in 2008 and by 5% in 2009. The historically low unemployment rate doubled to 6.5% in 2009.

GDP per capita was 78% relative to the United States in 2008. Denmark's labour productivity growth has been declining since the 1980s, and its average annual growth rate of 0.5% between 2001 and 2008 is well below the OECD average of 1.7%.

Denmark's Globalisation Strategy aims to invest more than DKK 40 billion by 2012 in research, education, innovation and entrepreneurship. R&D and innovation policies in Denmark have been broad-based. A period of co-ordination and evaluation is now under way.

Science and innovation profile of Denmark



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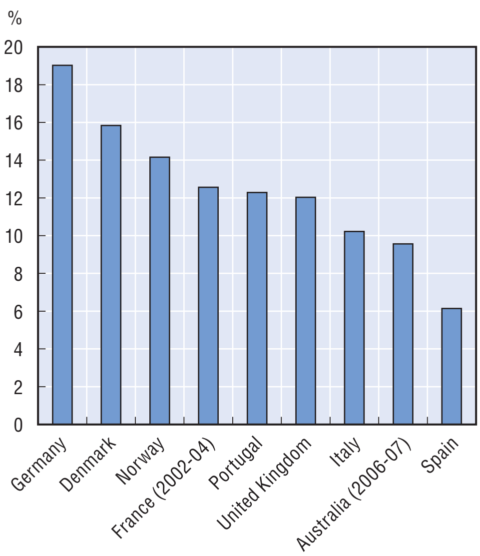
Firms with new-to-market product innovations

As a percentage of all firms, 2004-06



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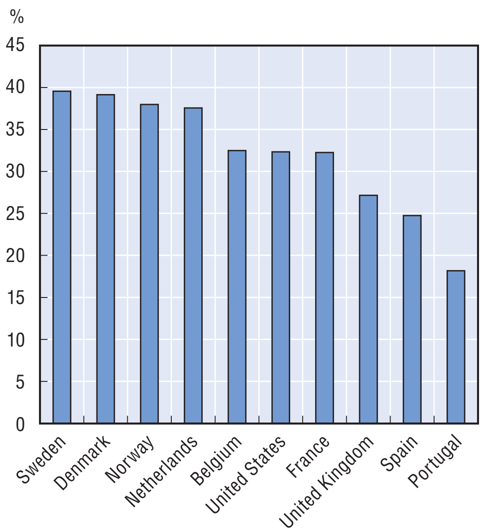
HRST occupations in total employment

As a percentage of total employment, 2008



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ESTONIA

Estonia has one of the higher per capita income levels in central Europe. Successive governments have carried out significant reforms. The economy benefits from strong electronics and telecommunications sectors and has strong trade ties with Finland, Germany and Sweden. The services sector has grown rapidly to account for 75% of GDP.

Estonia's economic growth outperformed most of the rest of Europe in the early 2000s, with robust average annual growth in GDP of 8.2% from 2001 to 2007. It slowed markedly and fell into recession in mid-2008. GDP contracted by nearly 15% in 2009, among the world's highest rates; unemployment rose from 5.7% in 2008 to more than 14% in 2009. Labour productivity grew by 6% during 2001-07, but declined by 2.3% in 2008. Relative to the United States, GDP per capita was 44% in that year.

Estonia's innovation profile reveals a few strong areas. In the decade to 2008, business R&D grew at a high annual rate of 27.5%, and the government's R&D budget grew by more than 10% a year. In 2006, gross expenditure on R&D (GERD) was 1.1% of GDP and business expenditure on R&D (BERD) was 0.5% of GDP. Health R&D is a strong growth area and has expanded by an average annual 36.3% since 2000.

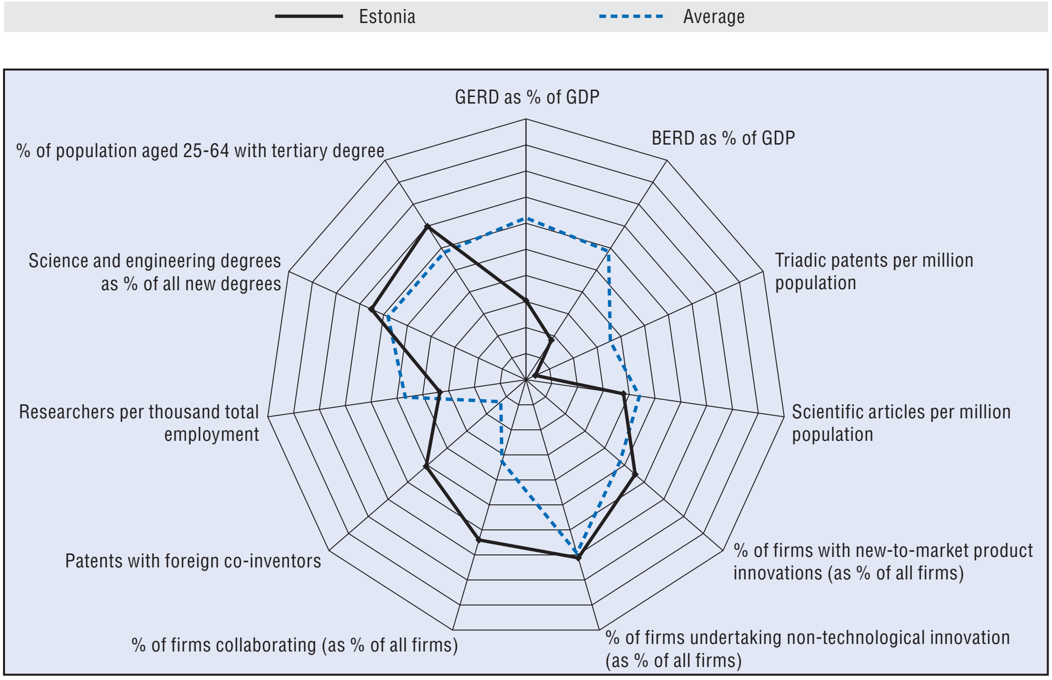
In 2008, Estonia's 4.5 triadic patents per million population were low, but still higher than in a few OECD countries and some prominent BRIICS economies. Other innovation outcomes performed around or above average. In that year, the 668 scientific articles per million population were just below the OECD average, but had increased by a robust 8.3% a year since 1998. Around 16% of firms introduced new-to-market product innovations during 2004-06, and almost 50% undertook non-technological innovation.

The average ratio of exports and imports to GDP increased by more than 160% in the decade to 2007 in this open economy. The share of high-technology manufactured exports is still relatively low. Almost one out of five firms collaborated on innovation activities during 2004-06, an indication of strong innovation linkages. During 2005-07 31% of patents were developed with foreign co-inventors, well above the average.

Indicators on human resources in science and technology (HRST) vary. In 2007, Estonia's 23.4% of science and engineering degrees among all new degrees exceeded the OECD average (20.9%). Business researchers increased by almost 15% during 1998-2007, among the highest growth rates in researcher numbers, although with 5.4 researchers per thousand employment in 2006 this was below the OECD average of 7.5.

Estonian innovation policy started formally in 2000 with Knowledge-Based Estonia 2002-06 which drew on Finland's experience. This has developed into the current policy document, Knowledge-Based Estonia: Estonian Research and Development and Innovation Strategy 2007-2013. Central to its innovation policy is the need to increase value added in manufacturing and services and to enhance the export capability of its small domestic market.

Science and innovation profile of Estonia



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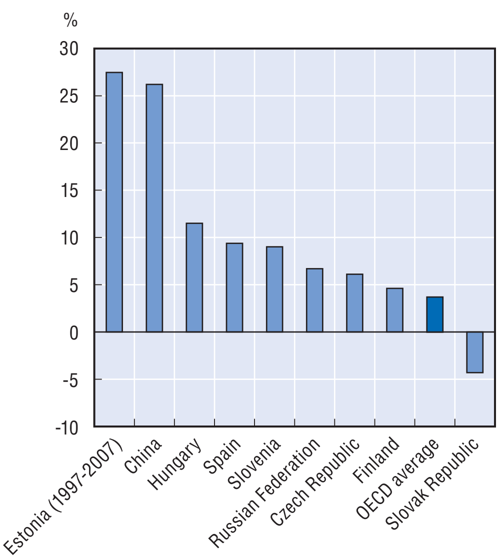
Growth in business R&D

Compound annual growth rate, 1998-2008



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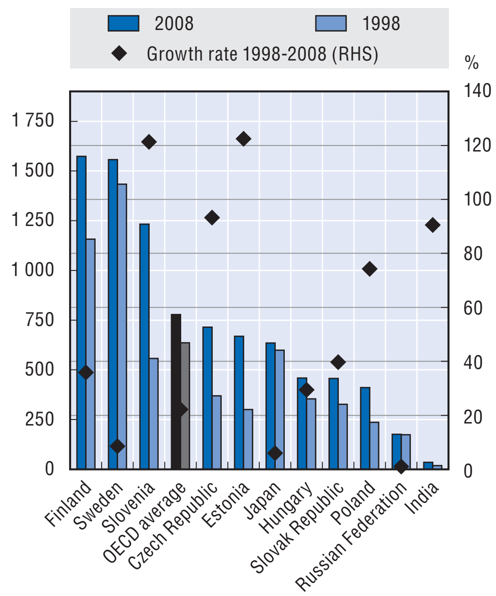
Scientific articles published, 1998 and 2008

Per million population, selected countries



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FINLAND

Finland's innovation investment and performance are among the strongest in the OECD area. Collaboration with other countries is at a high level, and a large proportion of the labour force has a tertiary qualification. Venture capital intensity is above average and the government's R&D budget is large.

Since 2000, gross expenditure on R&D (GERD) increased consistently to 3.7% of GDP in 2008. Finland aims at GERD intensity of 4% of GDP. In 2008, industry financed 70.3% of GERD, while government's share fell to 21.8%. Business expenditure on R&D (BERD) has remained above average over the past decade and peaked at 2.8% of GDP in 2008. Also in 2008, its venture capital intensity of 0.24% of GDP was the highest in the OECD area.

Finland's strong R&D investment is reflected in solid innovation-related outcomes. It had 64 triadic patents per million population in 2008, almost double the OECD average. With 1 573 scientific articles per million population in 2008, Finland ranks third among OECD countries and contributed 0.5% of the world share of scientific publications. Nearly one in four firms introduced new-to-market product innovations during 2004-06. Given the economy's focus on manufacturing, business R&D in the services sector was comparatively low. A below-average 42% of firms undertook non-technological innovation during 2004-06.

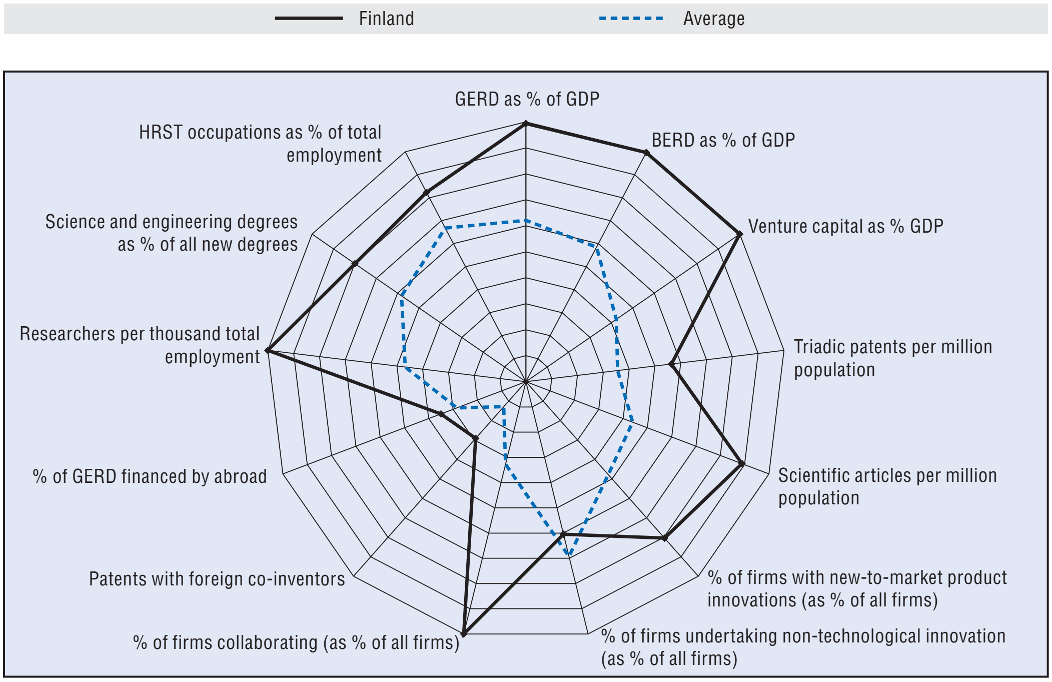
In 2004-06, Finland led the OECD with almost a third of all firms collaborating on innovation activities. During 2005-07 an above-average 18% of Patent Cooperation Treaty (PCT) applications had co-inventors located abroad. Around 6.6% of GERD was funded from abroad in 2008, after tripling in recent years.

Finland's indicators on human resources in science and technology (HRST) are strong. In 2008 it led the OECD with 16 researchers per thousand employment, and researcher numbers have increased by 2% a year since 2000. Almost 60% of all researchers were in the business sector. HRST occupations represented 34% of total employment and 29% of all degrees were in science and engineering; both were above the average.

Finland's key economic sector is manufacturing, principally the wood, metals, engineering, telecommunications and electronics industries. Exports account for over one-third of GDP and are concentrated in high technology, such as mobile phones. The global recession severely affected these sectors, as evidenced by a contraction in GDP of 7.8% in 2009, with GDP per capita falling by more than 8% and the unemployment rate increasing to 8.2%. Labour productivity has also slowed since 2006 and fell in 2008.

The Finnish government's Innovation Strategy, launched in 2008, still forms the basis of innovation policy in Finland. It includes measures to encourage innovation in non-technological business areas, especially in the services sector, and measures to increase demand and user orientation of R&D and innovation activities. The most recent significant reform was the Universities Act in 2009, which modified the legal status of universities and renewed structures through mergers.

Science and innovation profile of Finland



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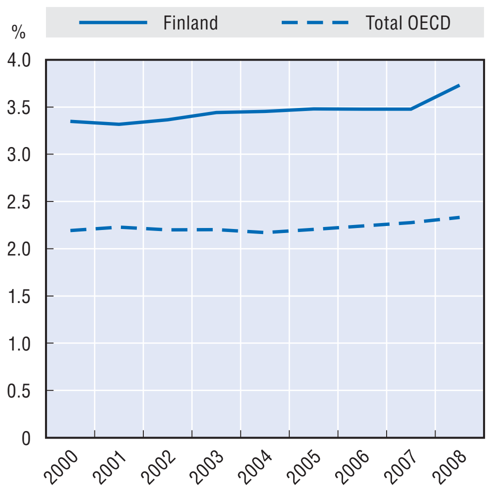
Gross expenditure on R&D

As a percentage of GDP, 2000-08



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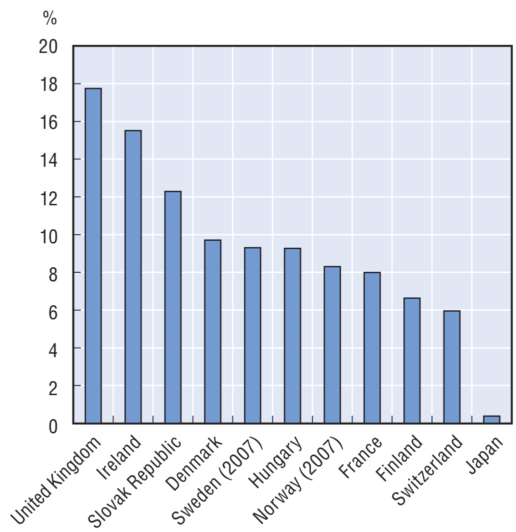
Gross expenditure on R&D financed from abroad

As a percentage of total GERD, 2008



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FRANCE

France demonstrates solid science and innovation performance in a number of areas, such as human resources in science and technology (HRST). It had 8.4 researchers per thousand employment in 2007. This is slightly above average; however, the growth rate has slowed in recent years. It also performs above the average in terms of the share of HRST in total employment and the 27.6% share of science and engineering degrees in all new degrees.

The 12.9% of firms collaborating on innovation activities is marginally above average, and the comparatively high 21.4% of patent applications with foreign co-inventors suggests strong links. In 2008, around 8% of GERD was financed from abroad.

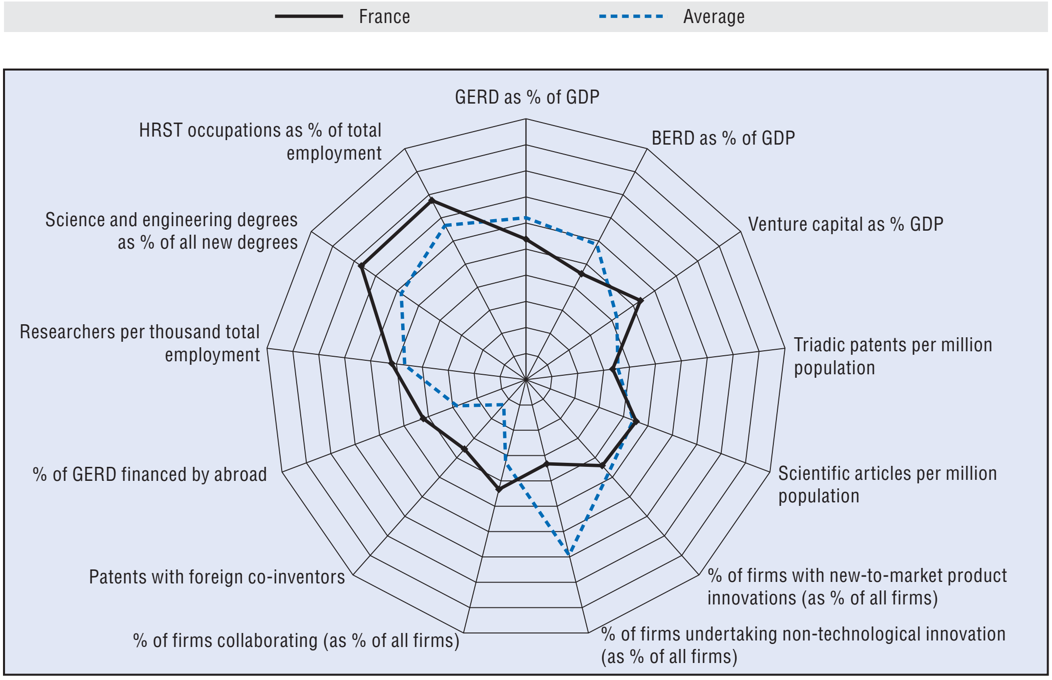
Some aspects of France's innovation performance have softened in recent years. Gross expenditure on R&D (GERD) has declined steadily since the 1990s and was below average at 2% of GDP in 2008. In constant terms, GERD declined by 0.4% in 2007 and by 0.6% in 2008. On a current purchasing power parity basis, GERD was USD 669 per capita in 2008, below the OECD average of USD 786. Government-financed GERD dropped from over 50% in the early 1980s to 39% in 2008. Industry financed about half of GERD. Business expenditure on R&D (BERD) was 1.3% of GDP in 2008 and has been declining since the 1990s. In real terms, BERD has fallen since 2003. Venture capital was 0.13% of GDP in 2008, above the average (0.1%).

In 2008, France had almost 5% of total triadic patent families, but at 38 per million population its triadic patents were marginally below the OECD average. France is in the top five for scientific articles published in 2008, with 800 per million population and 3% of world output. During 2002-04, 13% of firms undertook new-to-market product innovations, slightly below the average, and only one in five undertook non-technological innovation. Although the latest available average annual growth rate of high- and medium-high-technology exports was modest, France had a 17% export market share in the aerospace industry in 2008, second to the United States.

France's real GDP growth rate slowed from slightly more than 2% in 2006 and 2007 to only 0.4% in 2008. GDP contracted by 2.3% in 2009 and the unemployment rate increased to nearly 10%. Relative to the United States GDP per capita was 70% in 2008, but labour productivity was 94%.

France's innovation policy is based on legislation passed in 1999 and 2003. During 2008 and 2009 the implementation of the National Research and Innovation Strategy provided an overview of the state of play in innovation. The overall aim of innovation policies is to increase support to business R&D and innovation, focusing on three priorities: the strengthening of the incentives for the private sector; the setting up of synergies between key actors of the innovation process in competitive clusters; and support for competitiveness in small and medium-sized enterprises. The strategy will be updated every four years.

Science and innovation profile of France



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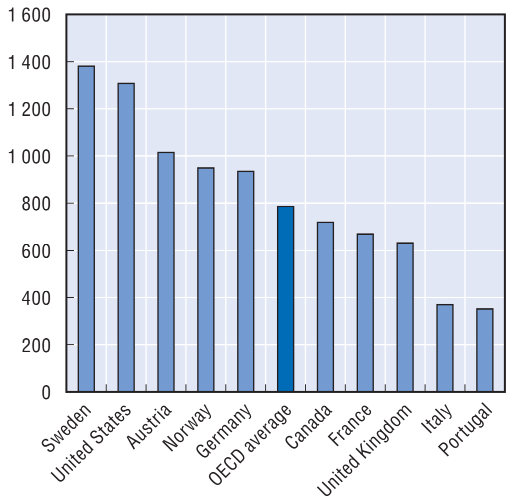
GERD per capita

Current PPP USD, 2008



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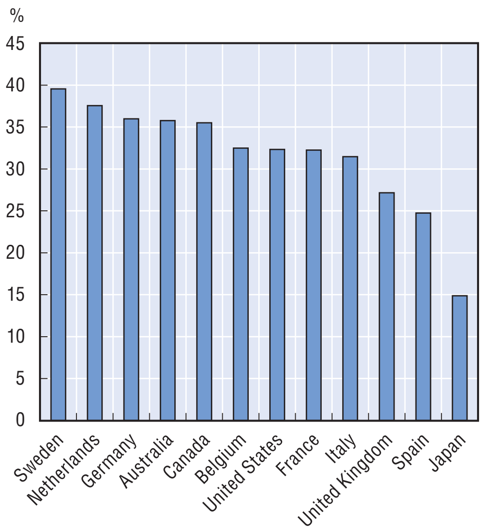
HRST occupations

As a percentage of total employment, 2008



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GERMANY

Germany's strong innovation profile has remained stable since the 2008 *STI Outlook*. Science and technology occupations are well represented in total employment, and medium and high-technology manufacturing exports have been robust for a number of years.

Gross expenditure on R&D (GERD) rose from 2.5% to 2.6% of GDP from 2007 to 2008. In constant terms, GERD has grown by an average 1.8% a year since 2000, and in 2008, GERD per capita was USD 935 in purchasing power parity (PPP), exceeding the OECD average by USD 149. Business expenditure on R&D (BERD) was 1.9% of GDP in 2008; 91% of BERD was funded by industry and a small 4.5% by government. In the same year, venture capital investment was 0.09% of GDP.

In terms of innovation outcomes, triadic patents were an above-average 73 per million population in 2007, and at 12.1%, Germany had the third highest share of triadic patent families, after the United States and Japan. In 2008, it had 820 scientific articles per million population, or slightly above the average, and accounted for a high 4% of world scientific publications. During 2004-06 a comparatively high 19% of firms introduced new-to-market product innovations and a very high 69% introduced non-technological innovations.

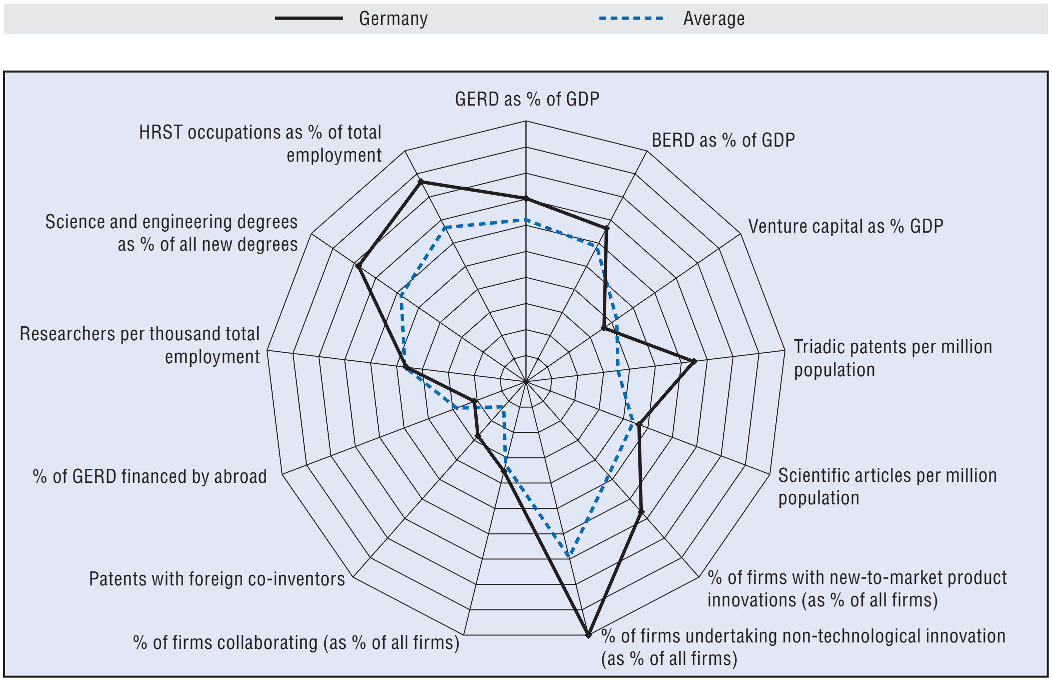
Innovation linkages in Germany show that during 2004-06, 10.5% of firms collaborated on innovation activities, that a relatively low 4% of GERD was financed from abroad in 2007, and that during 2005-07 an above-average 16.7% of patent applications were with foreign co-inventors.

On balance, Germany performs well on indicators of human resources in science and technology (HRST). The number of researchers has grown strongly in recent years, but its 7.5 researchers per thousand employment remain at around the average level. However, a relatively high 28% of new degrees were awarded in science and engineering in 2007 and a large share of students obtained doctorates in these disciplines. HRST occupations represented a solid 36% of total employment.

The economy grew at an average annual rate of 1.2% between 2001 and 2008. However, real GDP contracted sharply by 5% in 2009, although the unemployment rate increased only modestly to 7.5%. Germany's labour productivity increased by 1.2% annually between 2001 and 2008, but recorded no growth in 2008. GDP per capita is 75% relative to the United States.

Germany's most important policy document, the federal government's 2006 High-Tech Strategy, has recently been updated by the High-Tech Strategy 2020. The revised strategy focuses on health and nutrition, climate and energy, security and communication in addition to mobility as main global and societal challenges. It also identifies key technologies for emerging lead markets. In the same vein, the Excellence Initiative, which seeks to promote cutting-edge research at German universities, has been extended until 2017, with a 30% increase in funding volume.

Science and innovation profile of Germany



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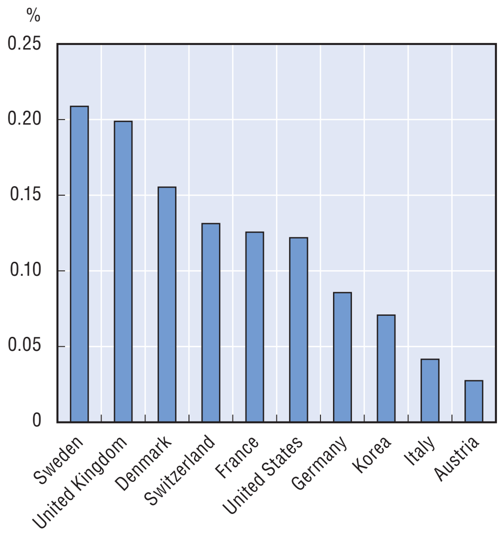
Venture capital investment

As a percentage of GDP, 2008



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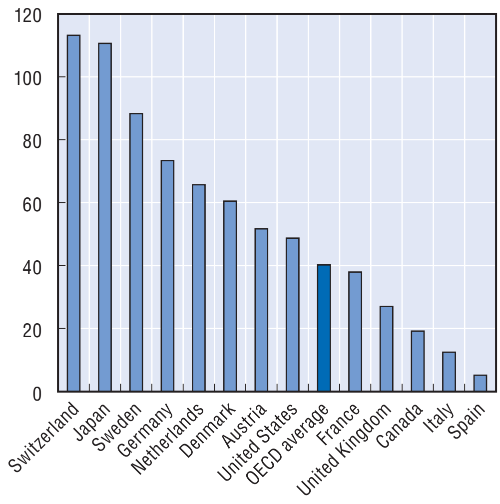
Triadic patents

Per million population, 2008



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GREECE

Greece's science and innovation profile shows some improvement over the two years to 2008. Indicators for human resources in science and technology (HRST) are mixed. Science and engineering degrees represent 23.4% of all new degrees, slightly above the OECD average (20.9%). Although Greece had a relatively low 4.4 researchers per thousand employment in 2007, researcher numbers had increased at an average annual 3.7% between 2001 and 2007. HRST occupations represented a relatively weak 23% of total employment, and unemployment among graduates was a relatively high 5.7% in 2008 compared to the OECD average of 3.2%.

Greece has made significant progress on some innovation outcomes over the past two years. While triadic patents stood at only 1.2 per million population in 2008, scientific articles published per million population improved to an above-average 902, and accounted for 0.6% of world output. Compared to the 2008 *STI Outlook*, a larger share of firms introduced new-to-market product innovations (20%) during 2004-06, and an above-average 52% introduced non-technological innovations.

The level of innovation inputs is relatively low. Gross expenditure on R&D (GERD), at 0.6% of GDP in 2007, lags the OECD average significantly, although in real terms, expenditure has grown by a robust average annual 4% since 2001. Government funded 47% of GERD, and industry 31%. More than a third of business R&D (BERD) went to SMEs with fewer than 50 employees. Venture capital investment was a low 0.01% of GDP.

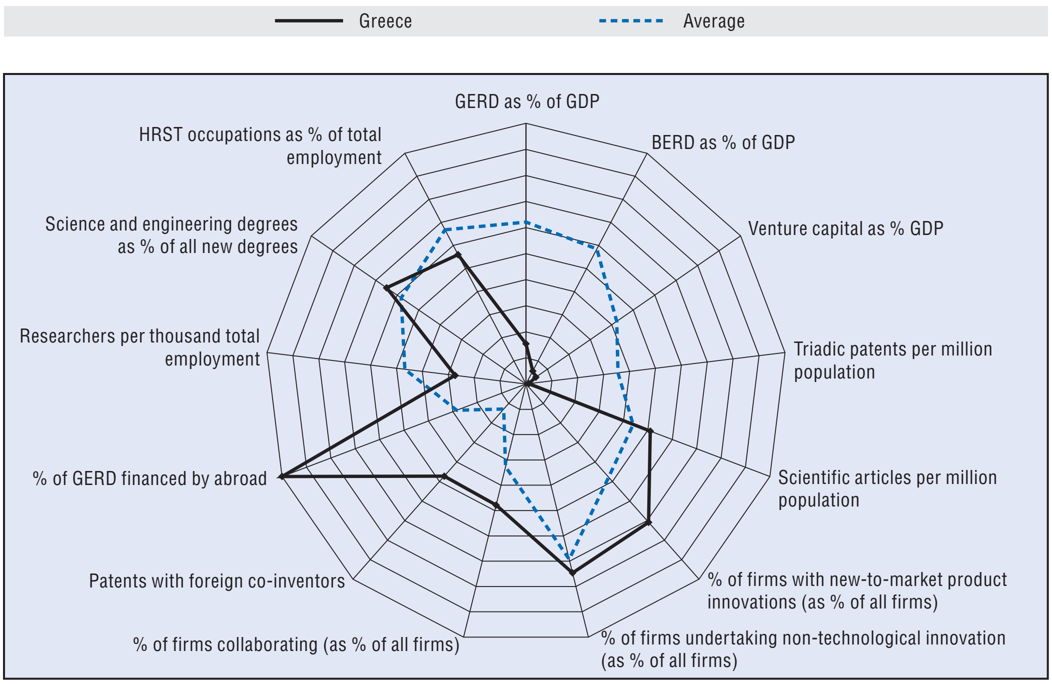
However, Greece's innovation linkages and international integration are strong. Some 14% of firms collaborated on innovation, and the 28.5% share of patent applications with foreign co-inventors is above average. In 2005, 19% of GERD was financed from abroad, the largest share in the OECD area.

Greece experienced strong average annual GDP growth of 3.8% during 2001-08, when per capita GDP grew by an average annual 2.8%. In 2009, however, real GDP contracted by 2%, and unemployment increased to 9.5%. Labour productivity grew strongly until 2004, but then slowed significantly to 2008. Relative to the United States, GDP per capita was 61% in 2008.

Greece faces significant challenges. The continuous rise of bond yield spreads in international markets led to extremely high borrowing costs. The Greek government requested the activation of the support mechanism of the euro zone governments and the International Monetary Fund, which pledged financing support of EUR 110 billion for the next three years.

The National Strategic Reference Framework 2007-13 forms the basis of innovation policy. It aims to make the economy more competitive, with a stronger international presence. The government implemented a series of Operational Programmes in 2009 to support restructuring up to 2013. Despite the global recession, and Greece's financial difficulties, innovation remains a priority for the Greek government, which has adopted measures to promote innovative investments for further development.

Science and innovation profile of Greece



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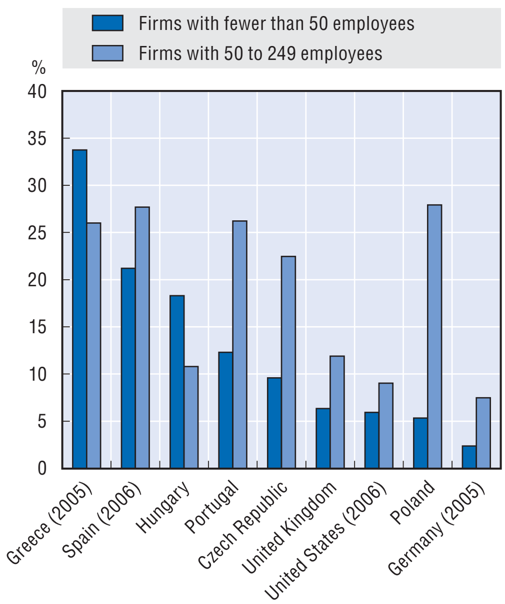
Share of business R&D, by firm size

As a percentage of total business R&D, 2007



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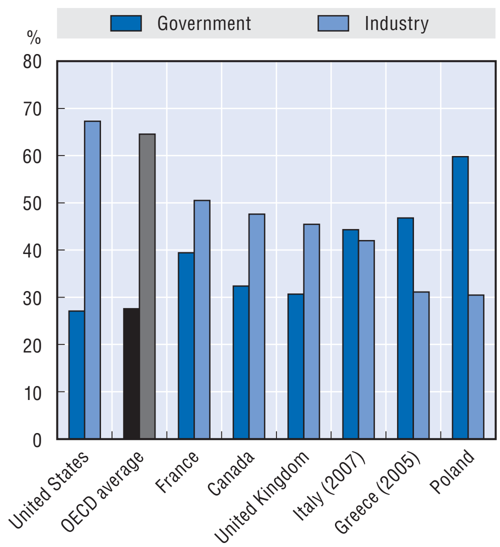
Gross expenditure on R&D by source of financing

Percentage share of total GERD, 2008



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HUNGARY

Hungary's science and innovation profile has remained largely unchanged over the past two years, with some improvements, particularly in human resources in science and technology (HRST) indicators. For example, science and engineering degrees have increased to 14.1% of all new degrees, although this is still well below the average. Although the number of researchers per thousand employment remained below average at 4.5 in 2008, researchers grew at a robust compound annual rate of 4.7% between 1998 and 2008. HRST occupations increased to 28% of the total population in 2008, and more than 60% of HRST occupations were filled by women.

Hungary's gross expenditure on R&D (GERD) was 1% of GDP in 2008, well below the OECD average. At USD 198 PPP, GERD per capita is also towards the lower end of the spectrum. However, in real terms, it has grown at a strong compound annual rate of 6.5% from 2000 to 2008. Industry financed 48% of GERD in 2008, and government financed 41%. More than 75% of government R&D funding is directed to SMEs. Business expenditure on R&D (BERD) was 0.5% of GDP in 2008. After growing rapidly from 2004 to 2006, real BERD growth slowed significantly in 2007, before growing strongly again (9%) in 2008. Venture capital as a percentage of GDP was 0.05% in 2008.

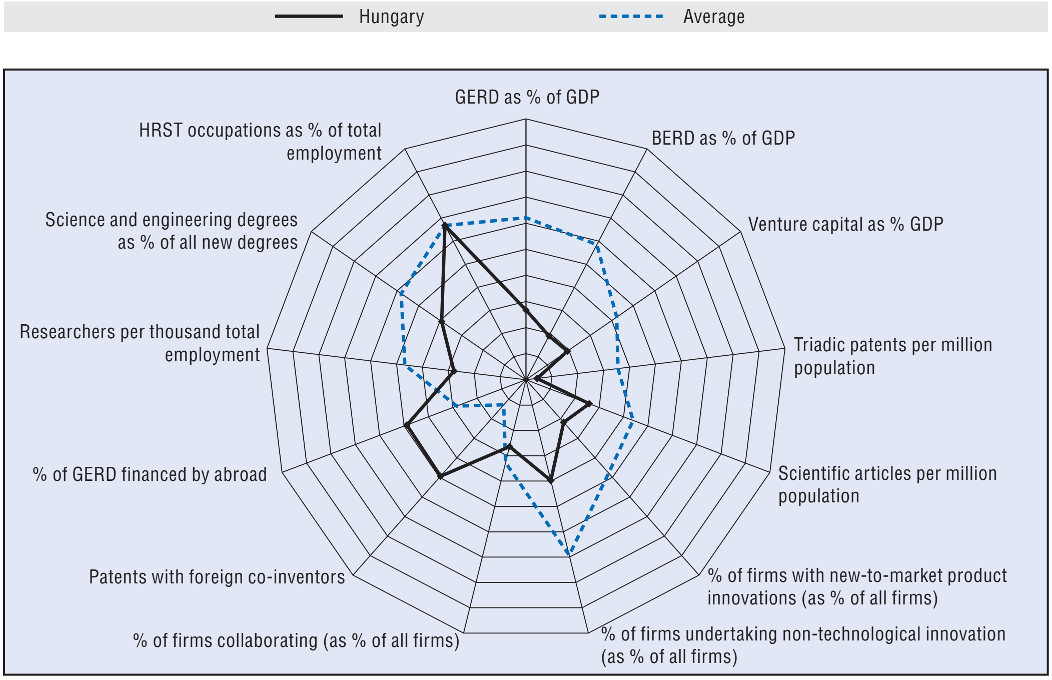
Hungary's innovation outcomes, while low, have showed some improvement. It had a below average 4.9 triadic patents per million population in 2008. Its 459 scientific articles per million population remains low, but moved closer to the average, growing by 2.6% a year in the ten years since 1998 to account for 0.3% of world output in 2008. During 2004-06, a comparatively small 6.2% of firms introduced new-to-market product innovations, and a low 27.6% of firms undertook non-technological innovation.

A comparatively high 9.3% of GERD was financed from abroad in 2008. In 2006, the share of manufacturing firms under foreign control exceeded 50%, while in the services sector foreign ownership exceeded 30%. While only 8% of firms collaborated on innovation during 2004-06, the share of patent applications with foreign co-inventors (30%) during 2005-07 was well above average.

Hungary has moved successfully to a market economy; its private sector accounts for more than 80% of GDP. The economy benefits from strong foreign direct investment inflows. GDP has grown by an average annual 3.2% since 2000, but contracted by 6.3% in 2009, when the unemployment rate increased to 10%. Labour productivity has been growing strongly since 2000. Per capita GDP is 42% relative to the United States.

Innovation policy in Hungary is based on the government's STI Policy Strategy and Action Plan, approved in 2007, which aims to put the Hungarian economy on a new development path by 2013. The global recession and short-term economic ramifications have impeded the achievement of these targets. It is critical for Hungary to strike a balance between tackling short-term tensions and addressing long-term issues.

Science and innovation profile of Hungary



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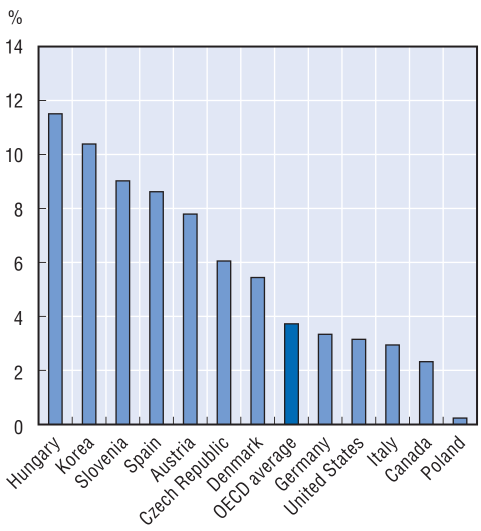
Growth of real business R&D

Compound annual growth rate, 1998-2008



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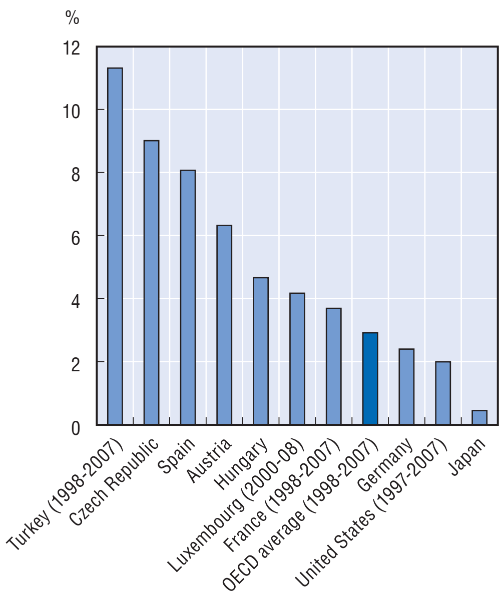
Growth of researchers

Compound annual growth rate, 1998-2008



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ICELAND

Iceland enjoyed high average annual GDP growth of 4.6% between 2000 and 2008, largely because of the performance of its financial sector. In late 2008, however, foreign exposure of Icelandic banks, whose loans and other assets totalled more than ten times the country's GDP, became unsustainable and Iceland's three largest banks collapsed. Real GDP and GDP per capita fell by 6.5% in 2009 and unemployment more than doubled to 7.2%.

Annual labour productivity growth, which was almost 3% between 2001 and 2007, fell by almost 1% in 2008. Relative to the United States, Iceland's GDP per capita was 78% in 2008.

In 2007 Iceland had the highest graduation rates in first-stage university courses (more than 50%), of which only 13% were science and engineering degrees, well below the OECD average. Tertiary-level graduates, equally distributed by gender, represent 31% of total employment. With almost 13 researchers per thousand employment, Iceland is close to the top OECD countries. The share of business-funded R&D in higher education and government is well above average.

Iceland's gross expenditure on R&D (GERD) decreased from a peak of 3% of GDP in 2006 to 2.7% in 2008. Real GERD grew by a compound annual 6.3% from 2000 to 2008, although it declined by 5% in 2007 and a further 0.3% in 2008. Real GERD per capita fell to USD 980 PPP in 2007 and held steady in 2008. Business expenditure on R&D (BERD) as a percentage of GDP also fell, from 1.6% in 2006 to 1.5% in 2008.

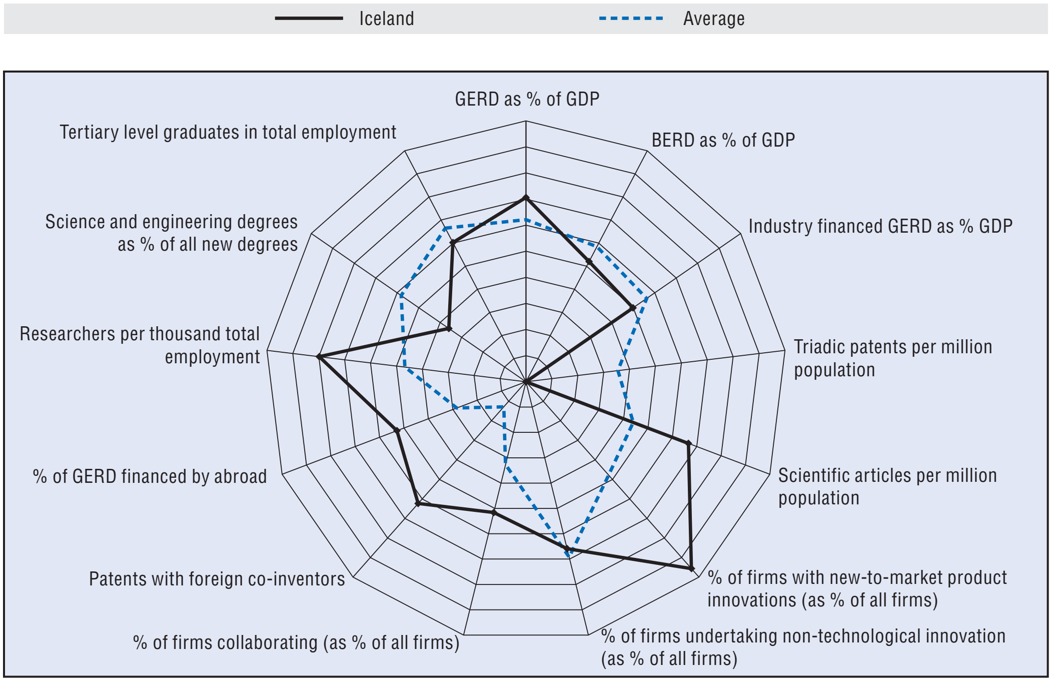
While Iceland's 12 triadic patents per million population were well below the OECD average in 2007, its 1 179 scientific articles per million population ranked comparatively high. A high 27% of firms introduced new-to-market product innovations, while a close-to-average 46% undertook non-technological innovation. Iceland's more than 30% share of services trademarks in 2007 was the highest in the OECD.

The small domestic market has encouraged many companies to internationalise, and collaboration is a prominent element of the innovation system. An above-average 15% of firms collaborated on innovation activities during 2002-04, and a relatively high 10% of GERD was financed from abroad. Almost 40% of patent applications in 2005-07 had foreign co-inventors.

In the aftermath of the financial crisis, the Minister of Science, Education and Culture established a task force to investigate Iceland's education, research and innovation policy. An expert panel report, *Education, Research and Innovation Policy: A New Direction for Iceland*, was presented to the government in May 2009.

It recommended maintaining high investment in education and reforming governance structures and systems. The 2009 budget increased funding for the main competitive funds: the Research Fund, targeted programmes and the Graduate Education Fund. Three organisations were selected for priority funding: the Icelandic Institute for Intelligent Machines, the Geothermal Research Group and the Centre of Excellence in Gender, Equality and Diversity Research.

Science and innovation profile of Iceland



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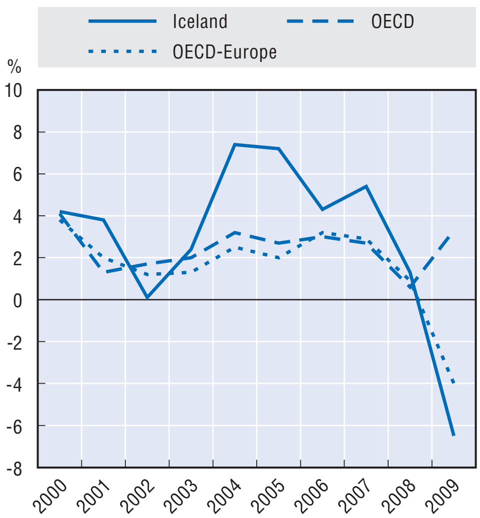
Gross domestic product

Annual real growth rates, 2000-09



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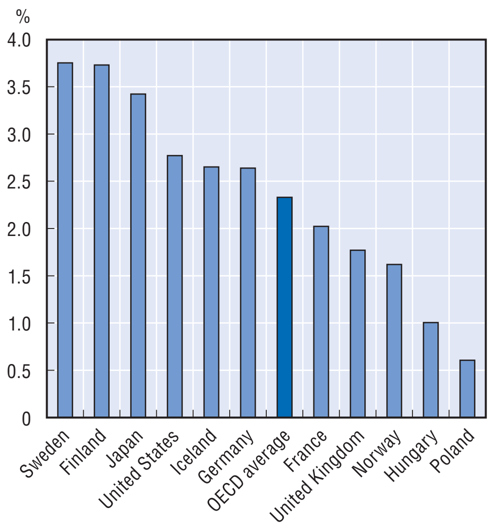
Gross expenditure on R&D

As a percentage of GDP, 2008



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INDIA

India's diverse economy includes traditional village farming, modern agriculture, handicrafts, a wide range of modern industries and a multitude of services. Slightly more than half of the workforce is employed in agriculture, but the services sector is the major source of economic growth, accounting for more than half of India's GDP. India's GDP grew on average by 7% a year in the decade to 2007, then eased in 2008 and slowed further to 5.6% in 2009. GDP per capita (in PPP terms) of USD 2 790 in 2008 was equivalent to just 6% of GDP in the United States. However, India is fast developing into a major global economy. Innovation can make a valuable contribution to India's long-term challenges: building physical and social infrastructure, creating employment opportunities and improving basic and higher education.

India's gross expenditure on R&D (GERD) was 0.7% of GDP in 2004, less than that of Brazil, China, Russia and South Africa. The government intends to increase this level to 2% over the coming years. While both public R&D and business R&D are low by international standards, growth rates have been strong over recent years. Business expenditure on R&D (BERD) was 0.14% of GDP in 2004, also below the BRICS and OECD averages.

India's triadic patents almost doubled over the last 20 years, with average growth of 20% since 2000. India is also developing patents in areas such as pollution abatement and waste management, and its shares in Patent Cooperation Treaty (PCT) patent applications are similar to those of Hungary, Poland and Russia. However, India's 0.14 triadic patents per million population in 2008 and 35 scientific articles per million population ranked last among the countries studied.

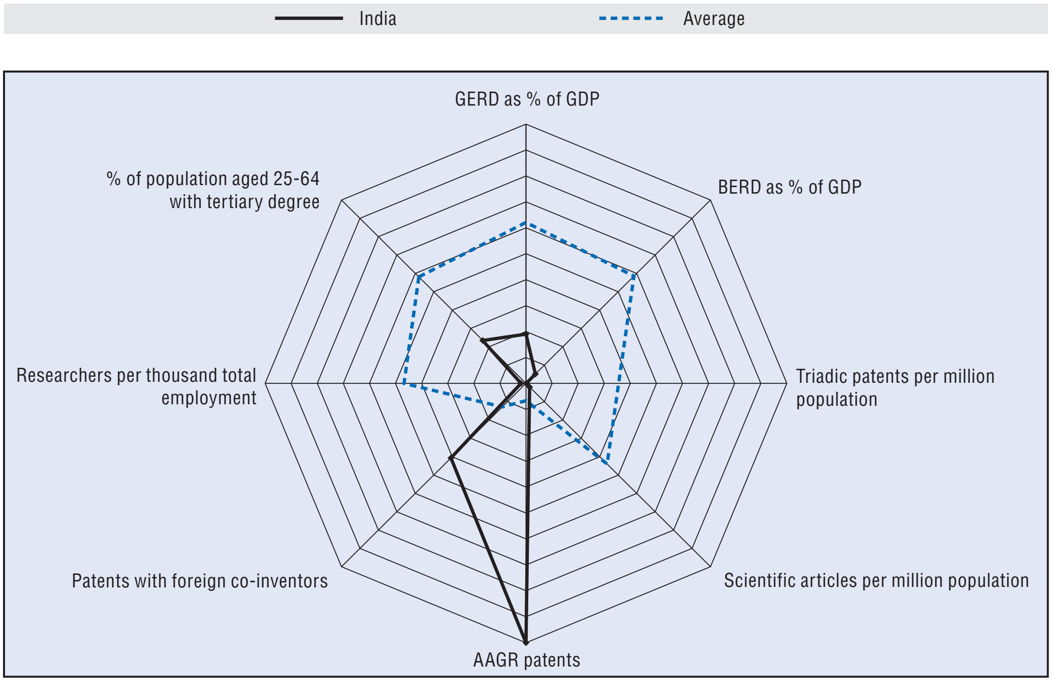
There is enormous potential to improve innovation linkages. India has already capitalised on its large educated population to become a major exporter of computer and information services. Its 25% of PCT patent applications with foreign co-inventors during 2005-07 is above the average. India's share of patents co-invented with the United States is at least twice as high as the share co-invented with European Union countries.

India's performance in human resources in science and technology (HRST) has significant development potential. There is less than one researcher per thousand employment and only 11.4% of the population aged 25-64 have a tertiary degree, a smaller share than in other non-OECD economies.

India has not yet formulated a national innovation policy, but in the framework of ministries and departments various sectors have articulated and budgeted for three main innovation policy challenges: enhancing innovation potential in new technologies; building technological capabilities and competitiveness in the manufacturing sector; and reconfiguring the formal and informal sectors.

Recent developments in India include the establishment of the National Science and Technology Nano Mission and the National Council for Skills Development which will focus on modernising training institutes. The 2009-10 budget also allocated funding to several programmes to boost innovation in order to meet the needs of economically weaker sections of society more efficiently.

Science and innovation profile of India



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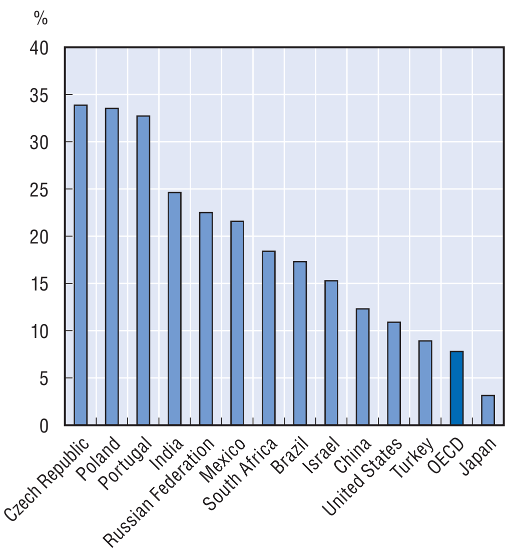
Patent applications with co-inventor located abroad

Percentage of all patent applications, 2005-07



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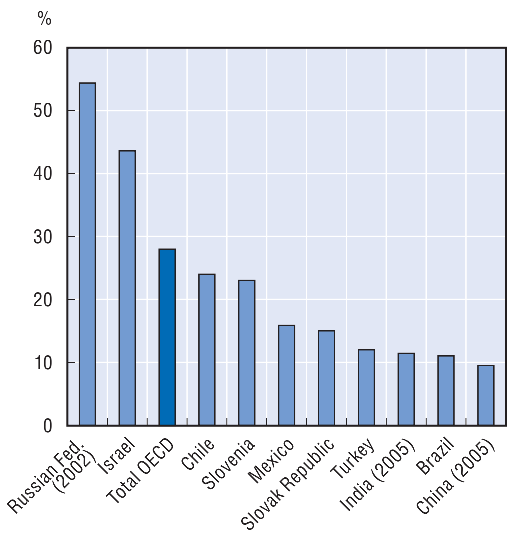
Educational attainment

Percentage of population aged 25-64 with a tertiary degree, 2008



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INDONESIA

Indonesia seems to have weathered the global financial crisis relatively well. Its GDP was just below USD 1 trillion in 2009. Although GDP growth slowed from more than 6% in 2007 and 2008 to 4.5% in 2009, it outperformed most of its regional neighbours. The official unemployment rate was 8.4% in 2008 and a moderate 7.7% in 2009. GDP per capita, however, is low by OECD standards at 8.6% relative to the United States in 2009.

Indonesia's innovation performance appears weak on various measures compared with other countries in Southeast Asia and catch-up countries such as India and China. Based on the available data, Indonesia's gross expenditure on R&D (GERD) is less than 0.1% of GDP and most R&D is performed by public research organisations (PROs). Numbers of patent applications and scientific and technical publications are relatively small. The rise in Indonesian doctoral students in the United States was a strong average annual 5.5% from 1997 to 2004.

Indonesia's manufacturing output expanded by an average of 12% a year from 1998 to 2008, faster than the OECD average (9%), but well short of the 22% average annual growth in the BRIICS group as a whole in 2000-08. In 2007, high-technology industries contributed a negative –0.9% to Indonesia's manufacturing trade balance. From 2000 to 2008, exports in medium-high-technology industries increased by 15%, below the 25% in the BRIICS group. Medium-high-technology industries contributed only modestly to trade during this period, and much of the manufacturing trade balance still relies on low-technology industries.

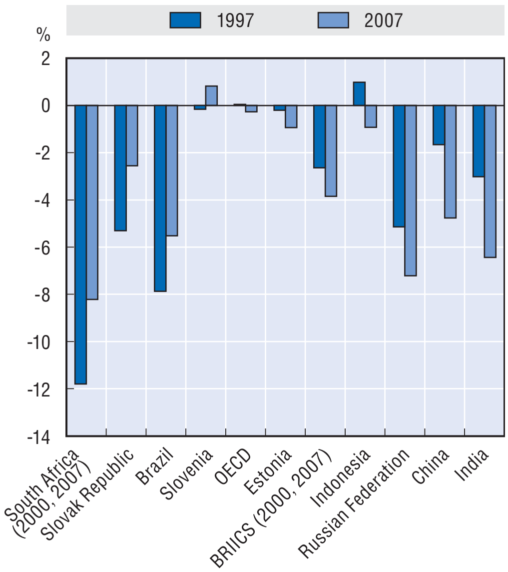
An increasing number of countries in Southeast Asia have made innovation a priority in recent years, and Indonesia is now emphasising science, technology and innovation (STI) as a source of future competitiveness. The National Medium-term Development Plan 2010-14 mentions "culture, creativity and technological innovation" among eleven development priorities. It highlights increasing the quality of human resources, including the promotion of science and technology, and strengthening the competitiveness of the economy.

The agenda of national research under the Long-Term National Development Plan 2005–25 includes seven research priority areas. Recently, a National Innovation Committee (KIN) was established, chaired by the President of Al-Azhar Indonesia University. The committee is an autonomous body consisting of 30 members and reports directly to Indonesia's President.

It is too early to say how effectively the KIN will resolve major issues, such as raising STI awareness, securing more resources for STI activities, and building a more cohesive national innovation system by better mobilising and linking innovation stakeholders. Looking forward, improving co-ordination between the research performed in PROs and the needs of industry and society remains a challenge, as does the integration of education, industry and science and technology policies.

Change in the contribution of high-technology industries to manufacturing trade balance

As a percentage of manufacturing trade, 1997 and 2007



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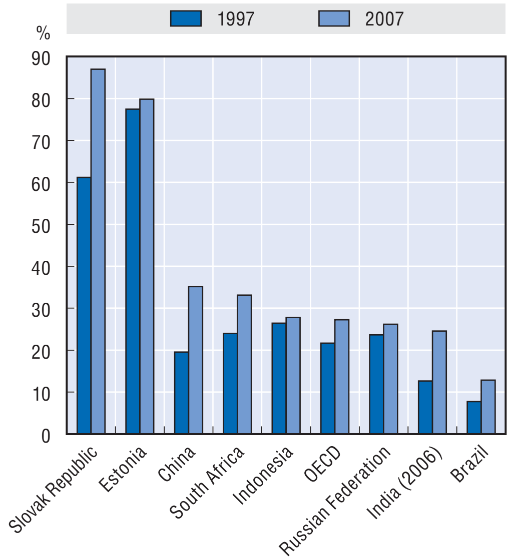
Total exports and imports

Average, as a percentage of GDP, 1997 and 2007



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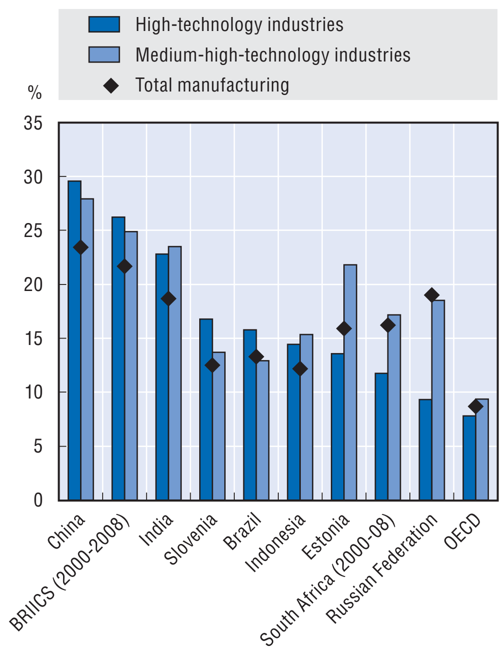
Growth of high- and medium-high-technology exports

Average annual growth rate, 1998-2008



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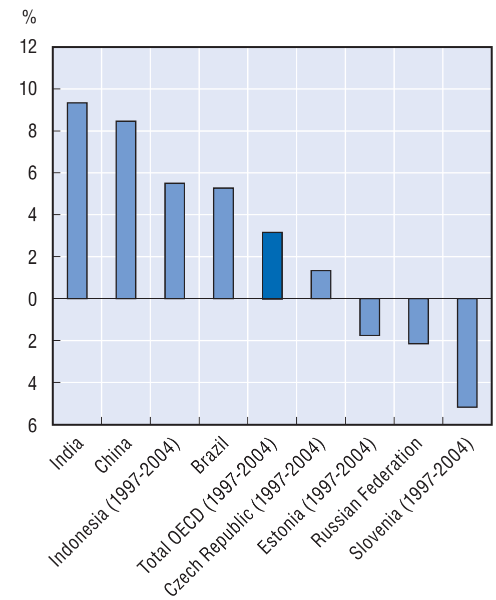
Growth of foreign scholars in the United States, by country of origin

Average annual growth rate, 1997-2007



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IRELAND

Ireland is a small, modern, trade-dependent economy. Its innovation system has been influenced by the openness of its economy and the extensive involvement of foreign multinationals. The global financial crisis severely affected the Irish economy and a recession was recorded for the first time in more than a decade.

Gross expenditure on R&D (GERD) increased to 1.4% of GDP in 2008. Between 2000 and 2008 GERD grew strongly in real terms at a compound annual rate of 7.6%, but because GDP grew relatively strongly for most of the period, GERD intensity increased slowly. In 2008, 49% of GERD was financed by industry, down from 58% in 2005; government funded 33%. Business expenditure on R&D (BERD) in 2008 was 0.9% of GDP. Venture capital was an above-average 0.13% of GDP in 2008, with most funds spent on early development and expansion.

On balance, Ireland performs well on innovation indicators. In 2008, it had 19 triadic patents per million population and a country share of 0.17% in triadic patent families. While these levels were low, it had a comparatively high 1 065 scientific articles per million population. In 2004-06 almost one in five firms introduced new-to-market innovation and 36% of firms undertook non-technological innovation.

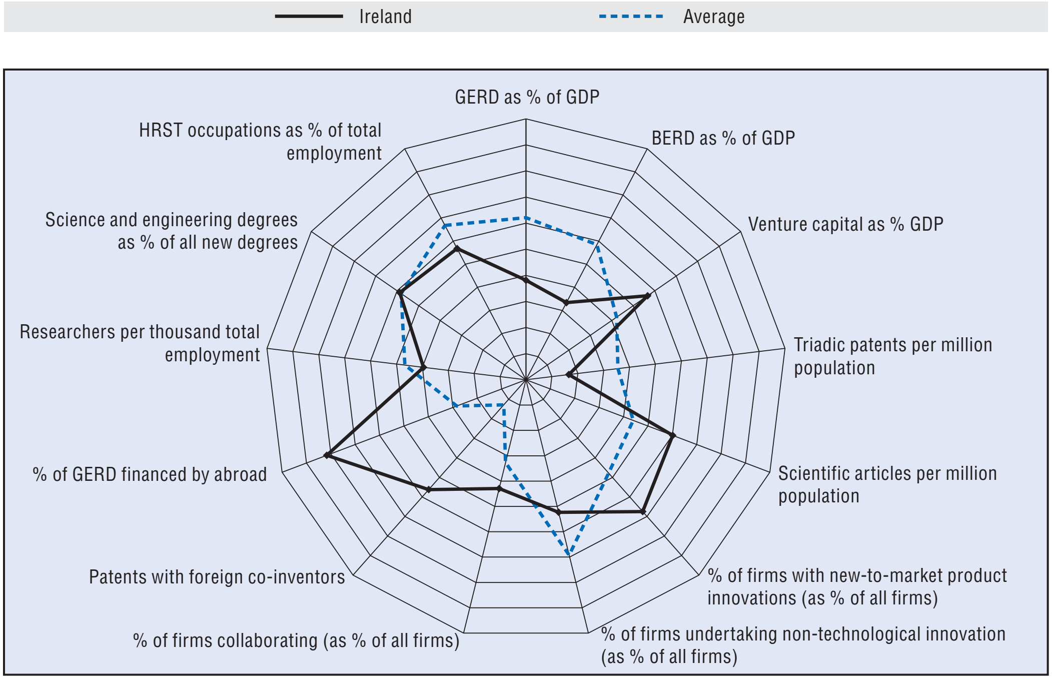
Ireland's economy is closely integrated with the international economy. The manufacturing trade balance – an indicator of competitive advantage – was 5% in 2007, and during the decade to 2008, high- and medium-high technology exports increased by 7-10% a year. In 2007, foreign affiliates accounted for 80% of manufacturing turnover and 60% of industrial research is tied to foreign affiliates. Around 13% of firms collaborated on innovation activities during 2004-06 and a third of Patent Cooperation Treaty (PCT) patent applications had foreign co-inventors. In 2008 a significant 16% of GERD was financed from abroad.

Human resources in science and technology (HRST) are not particularly strong. Researchers grew at a compound annual rate of 5.7% between 1998 and 2008, but in 2008, they only accounted for six per thousand employment, slightly below the OECD average. HRST employment was 24% of total employment, also below the average of 28%, but science and engineering degrees were 21% of new degrees, very close to the OECD average.

Ireland experienced strong economic growth for more than a decade, with GDP rising by an average annual 5.5% between 2001 and 2007, before contracting by 3% in 2008 and by nearly 8% in 2009. The unemployment rate increased from 4.6% in 2007 to 11.6% in 2009. Labour productivity increased consistently until 2007, but declined by 0.7% in 2008. Relative to the United States, GDP per capita was 88% in 2008.

The Irish government's vision, contained in its Strategy for Science, Technology and Innovation (SSTI) 2007-13, is that Ireland is to be internationally renowned for research excellence by 2013. It also aims to be a leader in generating and using new knowledge for economic and social progress. In June 2009 an SSTI indicators framework of 49 indicators was agreed in order to monitor its implementation.

Science and innovation profile of Ireland



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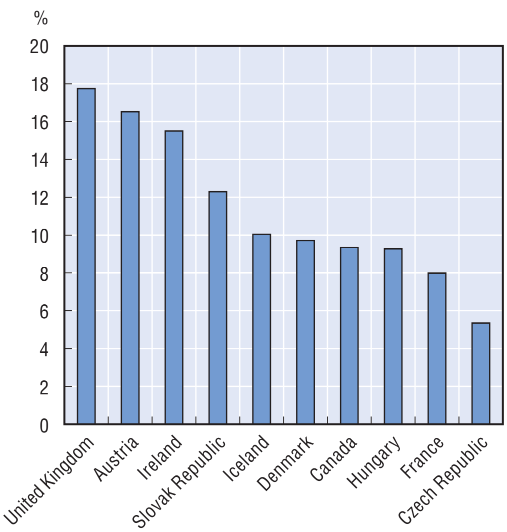
Gross expenditure on R&D financed from abroad

As a percentage of total GERD, 2008



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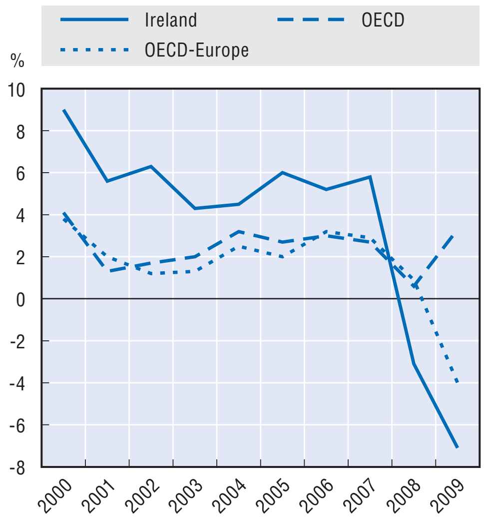
Gross domestic product

Annual growth rate, 2000-09



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ISRAEL*

Israel has a technologically advanced and open market economy, with highly developed agricultural and industrial sectors. Exports account for about 45% of its GDP. Its science and innovation profile shows strong performance. It had the highest gross expenditure on R&D (GERD) in 2008 at 4.9% of GDP. In 2006, 77% of GERD was funded by industry, and government funded 16%.

The business enterprise sector performed 81% of GERD in 2008, the second highest share among the countries analysed here. Business expenditure on R&D (BERD) was 3.9% of GDP in 2008, more than in all other countries. Other indicators are also strong. In 2008, Israel published 1 380 scientific articles per million population and produced 66 triadic patents, in both cases these were the fifth highest number. In 2006 industry-financed GERD reached 3.4% of GDP.

Although a comparatively small 3% of GERD was financed from abroad in 2006, a high 15% of Patent Cooperation Treaty (PCT) patent applications during 2005-07 were developed with foreign co-inventors, especially in the United States. Israel performs strongly in medical technology patents: in 2004-06, Israel accounted for 2.7% of patents in medical technologies, twice its 1.3% share in total patents.

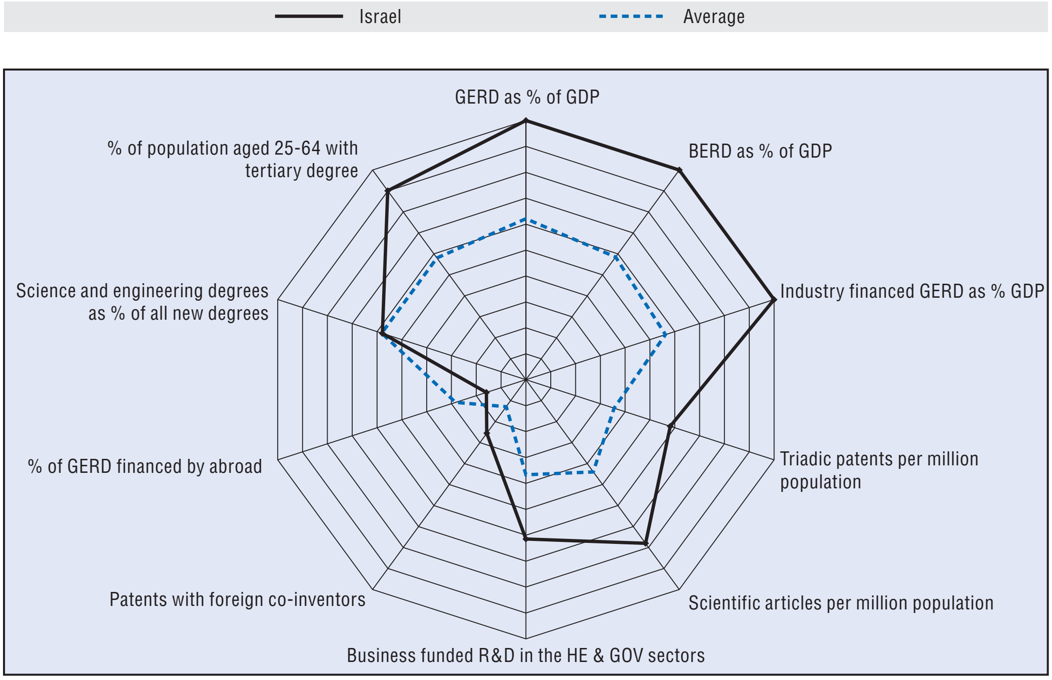
In 2007 Israel had a strong comparative advantage in trade in high-technology manufactures: high-technology industries contributed a positive 1.6% to the manufacturing trade balance.

Israel performs well on human resources in science and technology (HRST). Science and engineering degrees represent 21% of all new degrees, very close to the OECD average. It has a high level of educational attainment: in 2008 44% of the population aged 25-64 had a tertiary qualification. In an attempt to keep Israel's leading scientists from leaving the country, the government recently approved the creation and funding of 30 centres of academic excellence.

Between 2001 and 2007, Israel experienced strong average annual GDP growth of 3.5%. Growth slowed in 2008 and expanded by only 0.7% in 2009. Unemployment increased from 6.1% in 2008 to 7.4% in 2009. Average labour productivity growth between 2001 and 2008 was 1.4% but was flat during 2007 and 2008. Relative to the United States, GDP per capita was 59% in 2008.

To improve efficiency, the Ministry of Finance recently co-ordinated the budgeting process for all science, technology and innovation budgets, including higher education, basic research and industrial R&D. After years of a neutral policy, the Office of the Scientist has recently adopted a preferential policy to distinguish between high potential and high risk. The sectors currently considered for preferential treatment are biotechnology, nanotechnology and low-technology industries; support for clean-technology sectors, such as renewable energies, water and oil substitutes are being re-evaluated.

Science and innovation profile of Israel*



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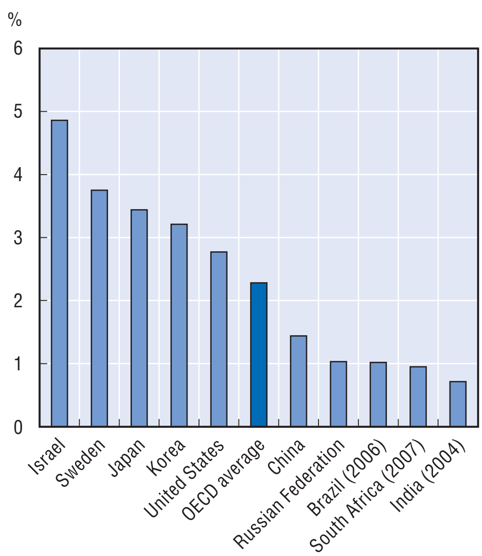
Gross expenditure on R&D

As a percentage of GDP, 2008



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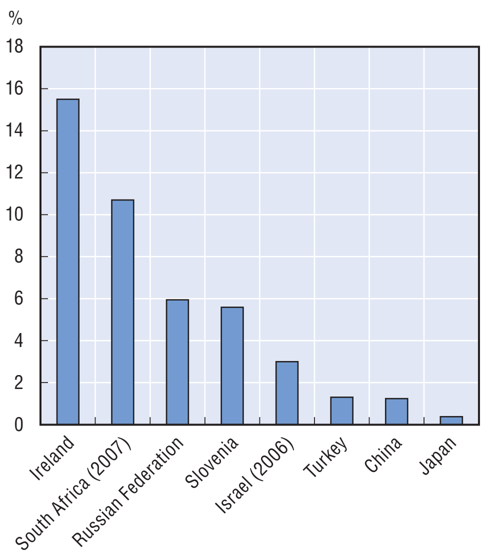
Gross expenditure on R&D financed from abroad

As a percentage of total GERD, 2008



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* 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.

ITALY

In 2008, Italy's gross expenditure on R&D (GERD) increased to 1.2% of GDP from 1.1% in 2006, but remained below the OECD average. Real GERD grew by almost 6% in both 2006 and 2007, but fell by 0.8% in 2008. GERD per capita was USD 369 in current PPP, below the OECD average. In 2007 industry financed 42% of GERD, well below the OECD average of 64%. In 2008, business expenditure on R&D (BERD) stood at 0.6% and venture capital intensity at 0.04% of GDP, both at the lower end of the spectrum.

Between 1998 and 2008, Italy had a stable 12.5 triadic patents per million population and it had a relatively low 1.5% country share in triadic patent families. Its 743 scientific articles per million population in 2008 were around the OECD average; output has grown by a robust average annual 4% since 1998. Italy's share in world scientific publishing was 2% in 2008. During 2004-06 a relatively small 10.2% of firms undertook new-to-market product innovation, and during 2002-04 a comparatively low 21.3% of firms performed non-technological innovation.

On balance, innovation linkages are above average. In 2004-06 only 5% of firms collaborated on innovation, but in 2005-07 the share of Patent Cooperation Treaty (PCT) patent applications with foreign co-inventors was above average at 14%. GERD financed from abroad was 9.5%, higher than the average.

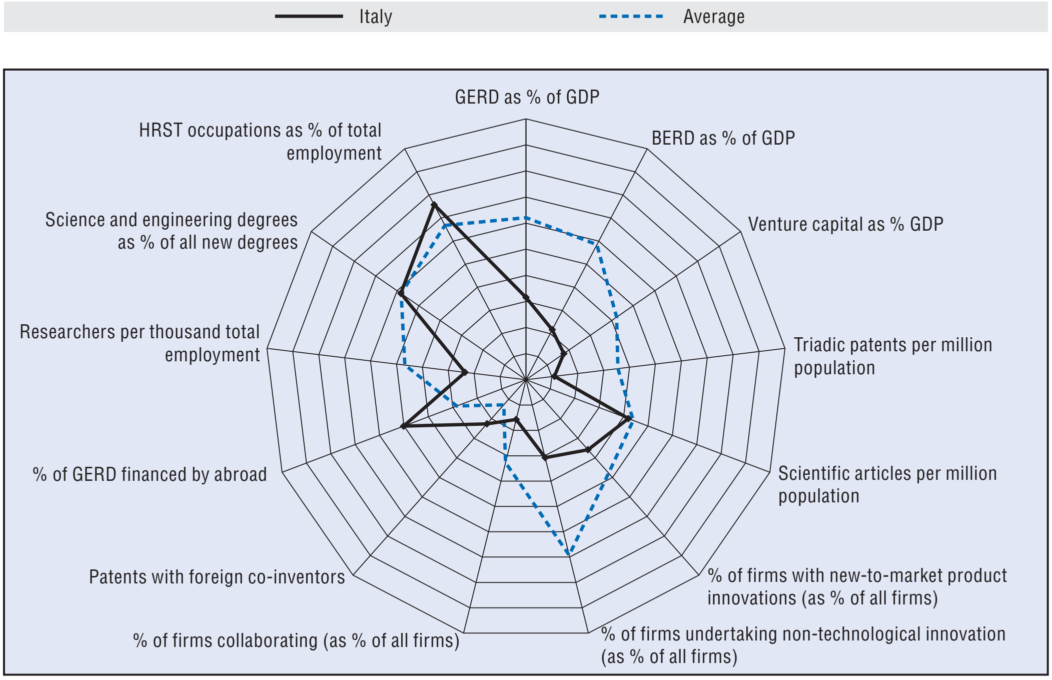
Human resources in science and technology (HRST) indicators vary. In 2008, researchers per thousand employment numbered only four, well below the OECD average; however, since 2000 researchers have increased at an average annual rate of over 5%. Science and engineering degrees were 21% of all degrees in 2007, equal to the OECD average. Overall educational attainment in Italy is low, with 14% of the workforce qualified at the tertiary level in 2008. In that year, almost one-third of total employment was in HRST occupations. In HRST occupations, women earn at least 40% less than men.

Italy's real GDP growth has slowed since 2001 and average annual GDP growth between 2001 and 2008 was a modest 0.7%. GDP contracted by 1.3% in 2008 and by 5% in 2009, while unemployment increased from 6.8% in 2008 to 7.7% in 2009. Labour productivity has stagnated since 2000. There was zero average annual growth up to 2008 and a decline of 0.5% in 2008. GDP per capita was higher than the OECD average, at 66% relative to the United States.

The global recession has introduced new short-term challenges, including sharp falls in foreign direct investment inflows. Improving the innovation environment could stimulate renewed economic growth. Research and innovation policies should therefore remain central to the policy agenda.

Policy challenges include the development of human capital and business innovation. Other measures that could boost Italy's innovation performance include better exchange and co-operation between public and private sector research and better co-operation among regions. Accelerating innovation in the public sector could act as a driving force for innovation and serve as a catalyst to increase investment in R&D.

Science and innovation profile of Italy



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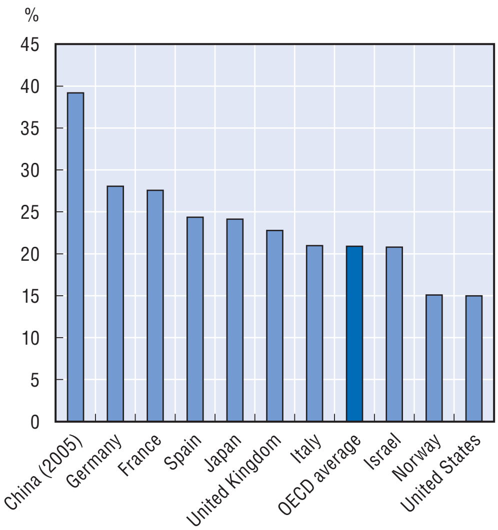
Science and engineering degrees

As a percentage of all new degrees, 2007



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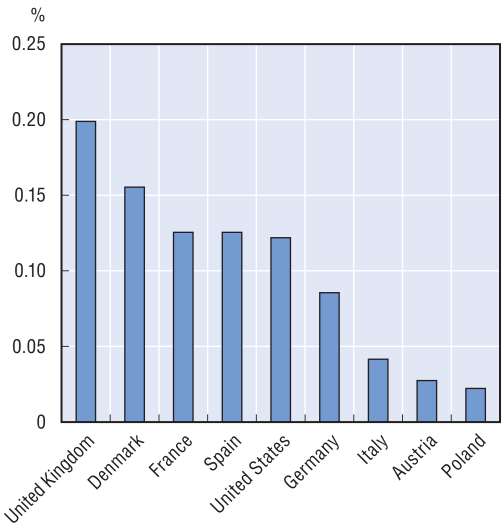
Venture capital investment

As a percentage of GDP, 2008



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JAPAN

Japan has a technologically advanced economy, with close and interlocking structures of manufacturers, suppliers and distributors. Its science and innovation profile demonstrates top performance in several areas. Japan's gross expenditure on R&D (GERD) edged higher to 3.4% of GDP in 2008 to be the third highest in the OECD. Real GERD growth was strong from 2005 to 2007 but turned negative in 2008 (–1.2%).

In 2008, GERD financed by industry increased to 78% and represented 2.7% of GDP, the highest in the OECD area. GERD funded by government declined steadily from 20% in 2000 to 16%. Business expenditure on R&D (BERD) was also a comparatively high 2.7% of GDP in that year.

With 111 triadic patents per million population in 2008, Japan ranked second in the OECD and its country share in triadic patent families was 28%, second after the United States. In the same year it had 81 000 scientific articles, the second highest number, and 4.8% of world output of scientific publications. However, it is below the OECD average at 635 per million population.

While a comparatively small 8% of firms introduced new-to-market product innovation during 1999-2001, a high percentage of firms undertook non-technological innovation.

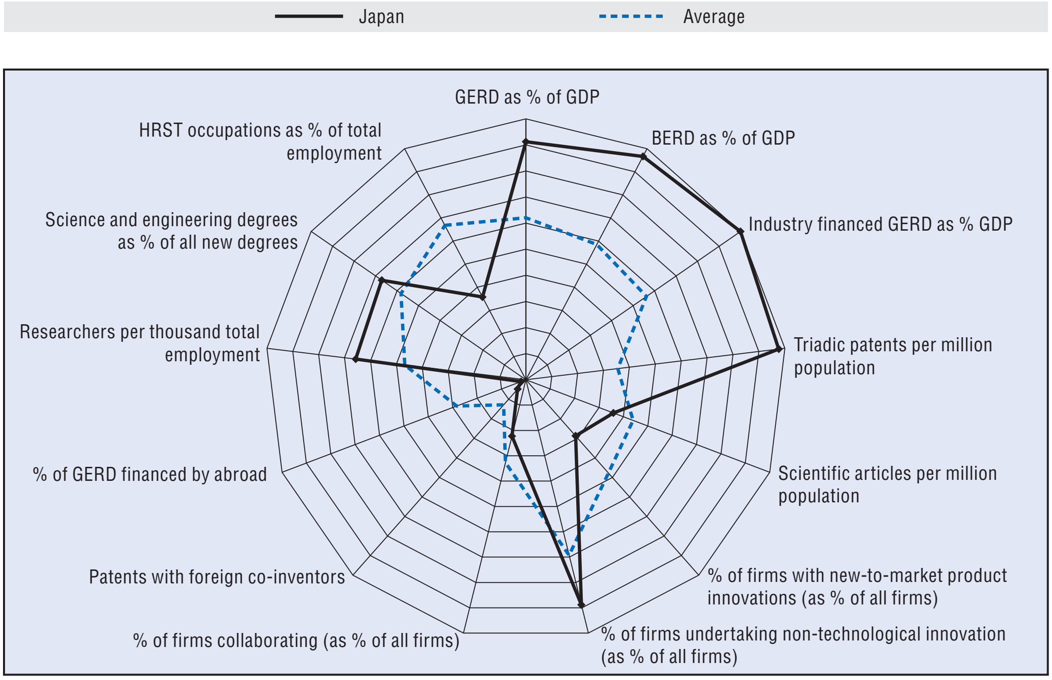
Only 7% of firms collaborated on innovation activities during 1999-2001, and in 2005-07 only 3% of Patent Cooperation Treaty (PCT) patent applications had foreign co-inventors. In 2008, only 0.4% of GERD was financed from abroad.

Japan's performance in HRST indicators has remained stable over the past two years. Its 11 researchers per thousand employment were above the OECD average, as were science and engineering (S&E) degrees as a share of all new degrees (24%). However, as a percentage of all new degrees S&E degrees fell by two percentage points from 1998 to 2007.

Japan is the one of the world's three largest economies. GDP grew by a modest but consistent average annual 1.8% from 2001 to 2007, but contracted by 1.2% in 2008 and by 5.2% in 2009. Unemployment increased only moderately to 5.1% in 2009. Labour productivity increased by an average annual 2% between 2001 and 2007, and slowed to 0.5% in 2008. GDP per capita is 72% relative to the United States.

Innovation policy in Japan continues to be set at the highest levels of government by the Council for Science and Technology Policy (CSTP). The New Growth Strategy was adopted by the Cabinet on 18 June 2010. The science and technology strategy includes targets for 2020. These include: more world-leading universities and research institutions; full employment for science and technology doctorates; utilisation of intellectual property of SMEs; more efficient use of information and communication technologies in both production and consumption; and increasing GERD to over 4% of GDP. Green innovation and "life innovation" form an integral part of this strategy.

Science and innovation profile of Japan



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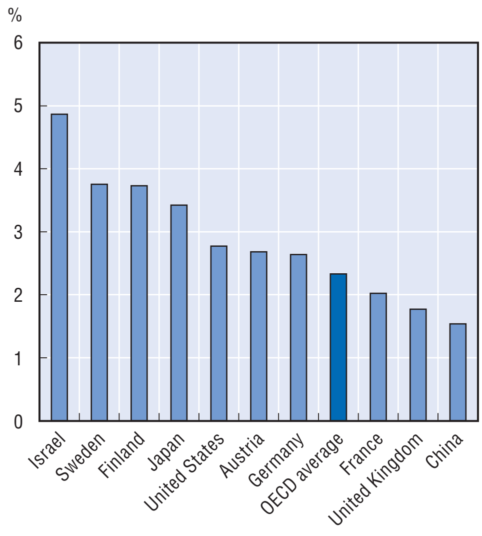
Gross expenditure on R&D

As a percentage of GDP, 2008



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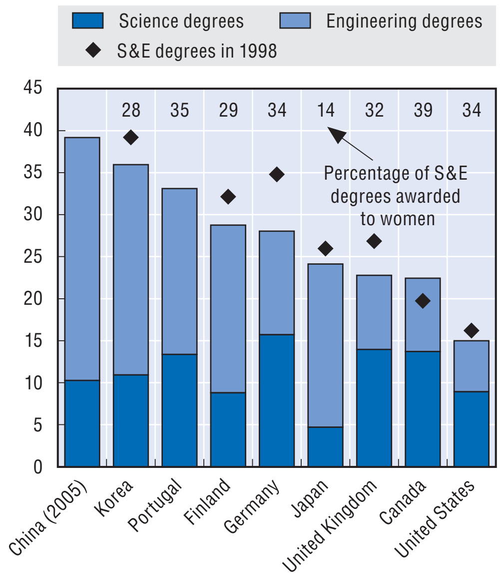
Science & engineering degrees

As a percentage of all new degrees, 2007



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KOREA

Korea has achieved remarkable growth and global integration as a high-technology industrialised economy. It has performed exceptionally well over the last few decades in catching up with leading OECD economies, and innovation has played an important role in narrowing the gaps.

Korea has the fourth highest R&D intensity in the OECD after Sweden, Finland and Japan, with gross expenditure on R&D (GERD) increasing from 3% of GDP in 2006 to 3.4% in 2008. Average annual growth in real GERD was almost 10% between 2000 and 2008, and in 2008 its GERD per capita of USD 931 (in current PPP) was above average. Industry financed 73% of GERD and the government funded 25%. GERD was also performed mainly by industry (76%), followed by the government (12%) and the higher education sector (11%). Business expenditure on R&D (BERD) was also high in 2008, edging up to 2.54% of GDP. In that year, venture capital investment was 0.07% of GDP, below the average.

In 2008, Korea's 44 triadic patents per million population was just above the OECD average, despite a country share in triadic patent families that had risen from 1.6% in 2000 to 4.3%. Its 762 scientific articles per million population was very close to the OECD average. A low 9% of manufacturing firms introduced new-to-market innovations during 2005-07, and a small 17.1% of manufacturing firms undertook non-technological innovation.

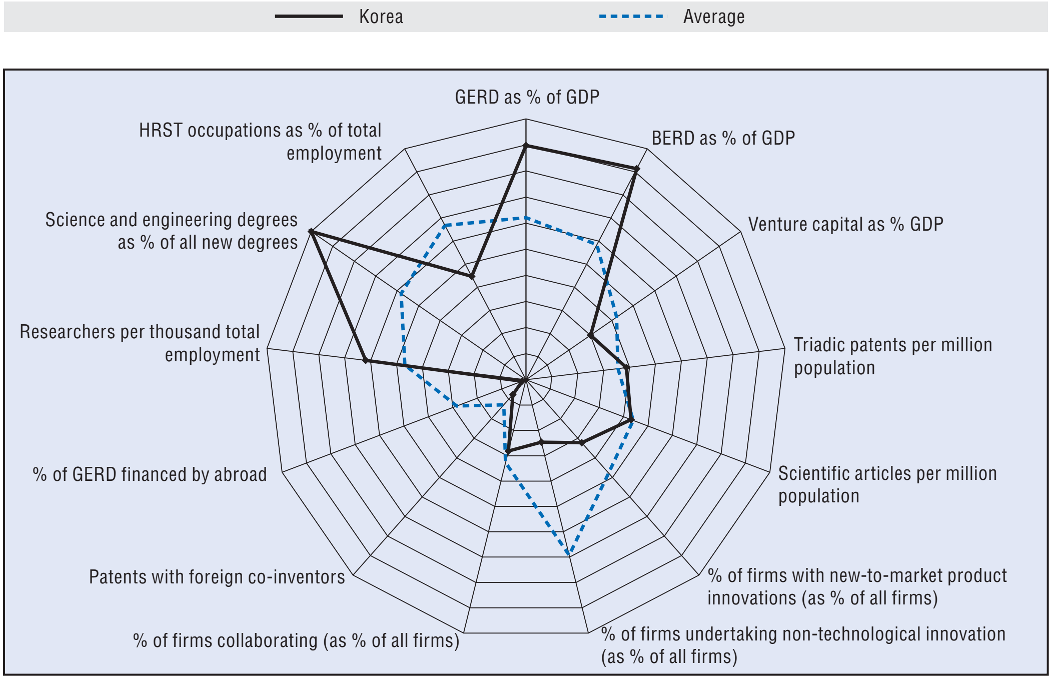
Korea's innovation landscape is dominated by the domestic private sector, with little apparent international integration. In 2005-07, 8% of manufacturing firms collaborated on innovation and 5% of Patent Cooperation Treaty (PCT) patent applications were with foreign co-inventors, both slightly below the average. The 0.2% of GERD financed from abroad in 2008 was the lowest in the OECD area.

Indicators on human resources in science and technology (HRST) are strong. Researchers per thousand employment have increased steadily from five in 2000 to ten in 2008, above the OECD average. From 1998 to 2008, researcher numbers increased at a compound annual rate of 9.8%. Science and engineering degrees accounted for 36% of all new degrees, the highest in the OECD. However, at 19% of total employment, HRST occupations ranked relatively low compared with other OECD countries.

Korea adopted various economic reforms following the Asian financial crisis of 1997-98, including greater openness to foreign investment and imports. The effect of the latest global financial and economic crisis was therefore comparatively moderate. Average annual GDP growth was 4.8% between 2000 and 2007, and then slowed to 2.3% in 2008 and 0.2% in 2009, while the unemployment rate increased moderately from 3.2% in 2006 to 3.6% in 2009. Labour productivity remained strong, growing by an average annual 4.7% from 2001 and declining slightly in 2009. Relative to the United States GDP per capita was 59% in 2008.

Some bottlenecks that hamper Korea's science and innovation performance include a relatively weak sector of small and medium-sized firms and weak performance in the services sector. It also faces increasing competition from newly industrialising economies.

Science and innovation profile for Korea



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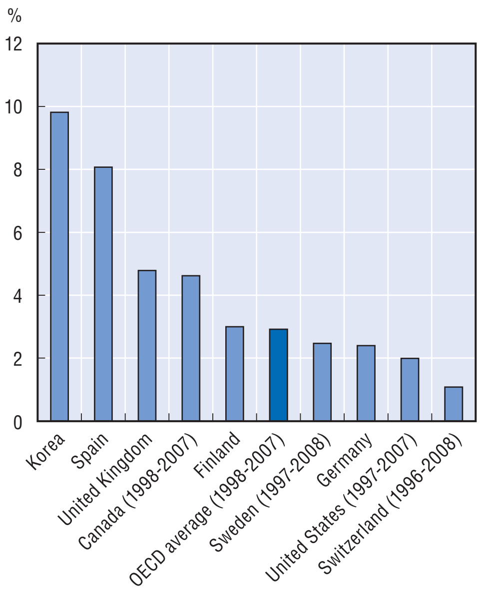
Growth of business researchers

Average annual growth rate, 1998-2008



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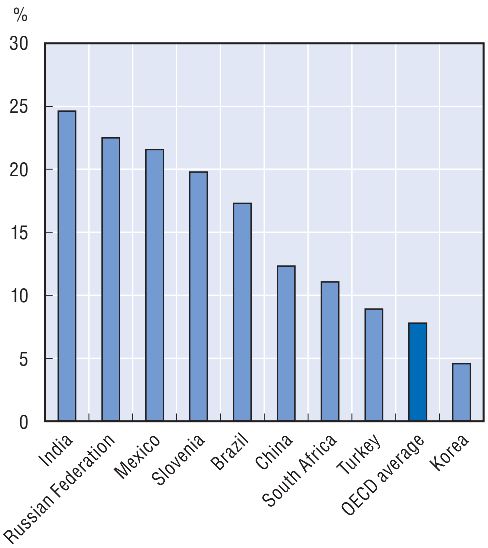
Patents with foreign co-inventors

Percentage of PCT applications, 2005-07



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LUXEMBOURG

Luxembourg is a small and stable high-income economy and has historically featured solid growth, low inflation and low unemployment. The economy has diversified from its roots in steel, and the value added by banks, insurance, real estate and other business services account for almost half of the economy's total value added: the financial sector alone accounts for 30% of GDP. The country's science and innovation profile demonstrates strong areas but also areas for improvement. Gross expenditure on R&D (GERD) is relatively modest, and in 2008 its 1.6% of GDP was below the OECD average. GERD per capita is quite high by comparison, and real GERD grew by 2.7% in 2008. In 2007, three-quarters of GERD were financed by industry, the second highest share after Japan. At 1.2% of GDP, however, this indicator was slightly below the average in 2007. Business expenditure was 1.3% of GDP in 2008, also below the average.

Luxembourg's innovation outcomes are, on balance, above average. While it had a small country share in triadic patent families in 2007, its 49 triadic patents per million population was above the OECD average (40.2). A very high 29% of firms introduced new-to-market product innovations and 62% introduced non-technological innovations during 2004-06; however, in 2008 the 385 scientific articles per million population was well below the average.

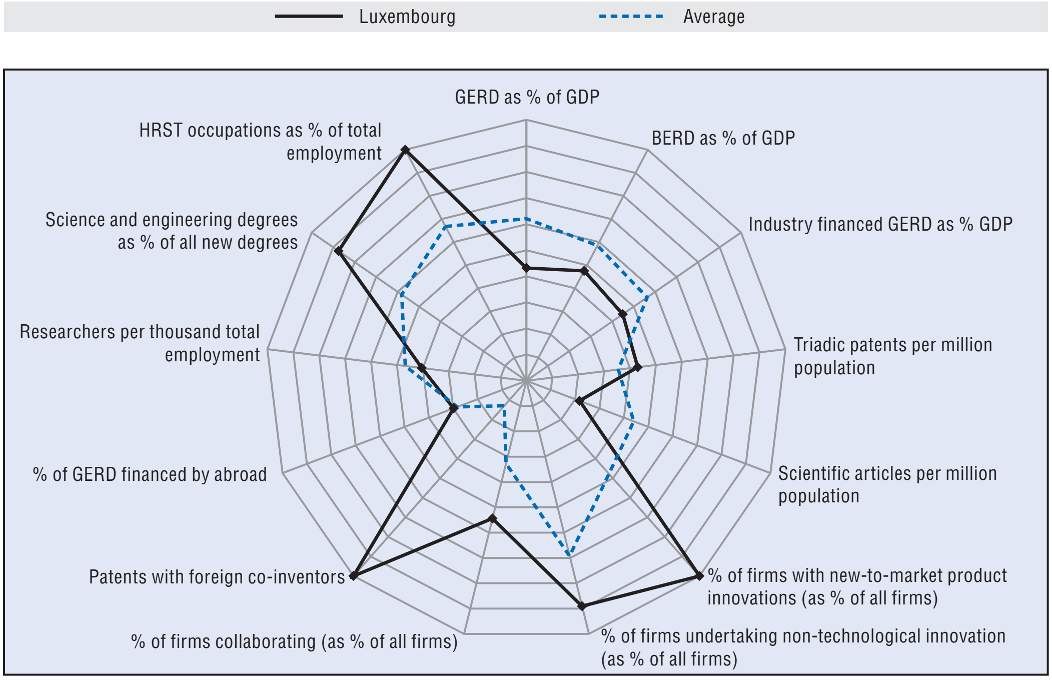
Luxembourg's economy depends on foreign and cross-border workers for about 60% of its labour force. Innovation linkage indicators, however, are mixed. The 6% of GERD financed from abroad is slightly above average, but the share of business-funded R&D performed in the higher education and government sectors was low. However, a high 16% of firms collaborated on innovation activities during 2004-06. The 60.3% of Patent Cooperation Treaty (PCT) patent applications with foreign co-inventors led the OECD during 2005-07, although the absolute number was small.

Luxembourg's overall performance in human resources in science and technology (HRST) has eased somewhat. In 2008, HRST occupations accounted for the largest share of total employment, with 42%. Science and engineering degrees were 31.5% of total degrees, the third highest in the OECD. However, researchers per thousand employment edged down from seven in 2005 to 6.5 in 2008.

GDP expanded by a strong average annual 4% from 2000 to 2007. Real GDP growth fell from 6.5% in 2007 to zero in 2008 and GDP contracted by 3.4% in 2009, while the unemployment rate increased modestly from 4.9% to 5.4%. Nonetheless, the country continues to enjoy an extraordinarily high standard of living and its GDP per capita is 180% relative to the United States, the highest in the OECD, although labour productivity growth has slowed in recent years.

The services sector represents more than 80% of Luxembourg's GDP and innovation in services has been a research priority. Other policy challenges include collaboration between public research and private companies and attracting and keeping highly skilled workers. One development has been to turn Luxembourg into an attractive destination for intellectual property. To reduce dependence on the banking sector, the government is accelerating the diversification of the economy into key technologies such as biotechnologies and green technologies.

Science and innovation profile of Luxembourg



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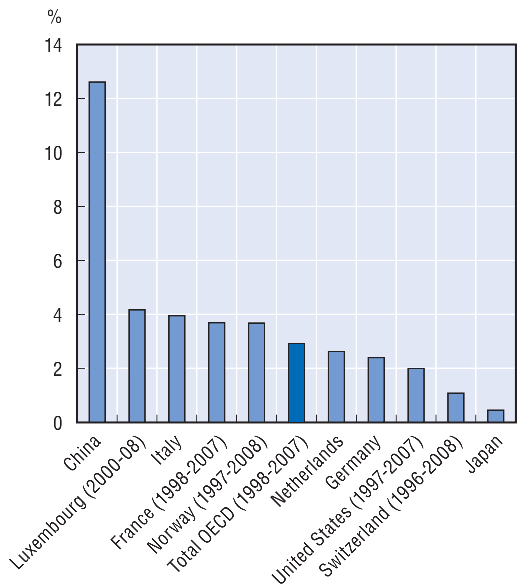
Growth in business researchers

Average annual growth rate, 1998-2008



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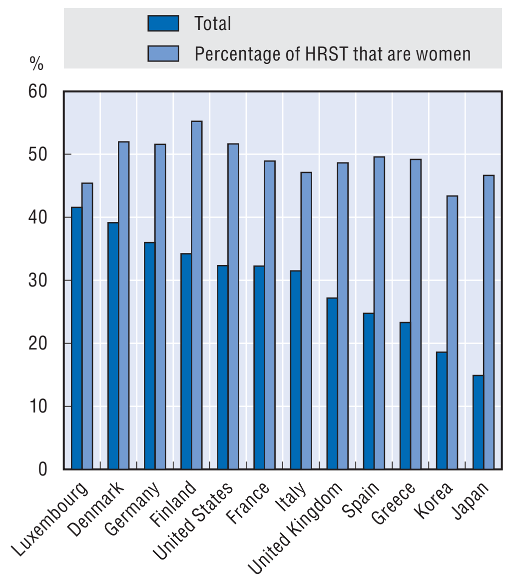
HRST occupations as a share of total employment

Selected countries, 2008



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MEXICO

Mexico's economy is undergoing structural change. Key challenges include improving the education system, upgrading infrastructure, modernising labour laws and fostering private investment in the energy sector. Innovation can play an important role in all these areas.

R&D intensity in Mexico is the lowest in the OECD area, with gross expenditure on R&D (GERD) at 0.4% of GDP in 2007; it has fluctuated around this level since 2000. GERD per capita is also the lowest in the OECD. Real GERD, however, grew at a robust average annual 6% between 2000 and 2005, before falling by –1.7% in 2006 and recovering with weak growth of 0.14% in 2007. A relatively low 45% of GERD was funded by industry in 2007; the government financed 50%, down from 63% in 2000. Industry-financed GERD was 0.2% of GDP in 2007, slightly above the average. Business expenditure on R&D (BERD) was 0.2% of GDP, having doubled from 0.1% in 2000. Mexico's business-financed R&D has historically been very responsive to the business cycle, which suggests that the global financial crisis may have a significant impact on R&D expenditure in Mexico.

Mexico's innovation outcomes are weak. Its 0.14 triadic patents per million population and 73 scientific articles per million population were the lowest in the OECD in 2008. However, 13% of firms introduced new-to-market product innovations, close to the average.

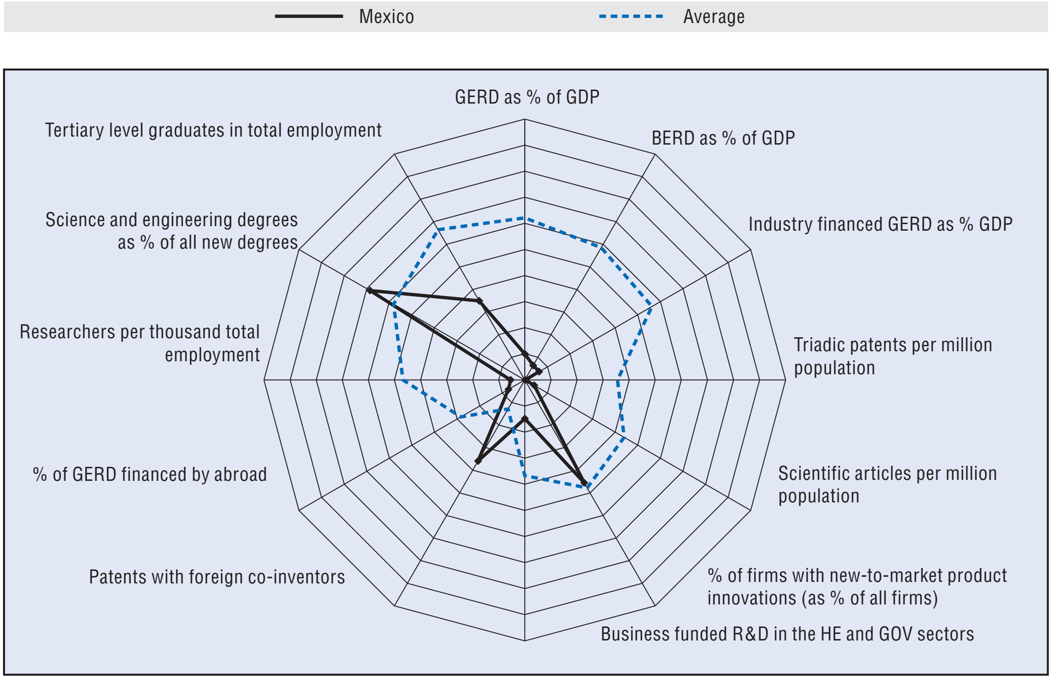
Mexico's innovation linkages are mixed. During 2005-07, 22% of Patent Cooperation Treaty (PCT) patent applications were with foreign co-inventors, well above the average. Over the decade to 2008, its high-technology manufactures increased by a strong average annual rate of 10%, higher than the growth in total manufacturing exports. The 1.4% of GERD financed from abroad in 2007 is comparatively low, however.

Indicators of human resources in science and technology (HRST) vary. Science and engineering graduates accounted for 24.7% of all new degrees, above the OECD average. However, there was less than one researcher per thousand employment, the lowest in the OECD. Tertiary-level graduates were a below-average 18% of total employment.

GDP grew by an average annual 3% between 2001 and 2007 and slowed to 1.5% in 2008 before contracting by a sharp 6.5% in 2009. The unemployment rate increased from 3.7% in 2006 to 5.5% in 2009. Labour productivity is low: average annual growth was a modest 1% between 2001 and 2007, then fell by 2.1% in 2008. GDP per capita, at 31% relative to the United States in 2008, is the lowest in the OECD.

Mexico's key challenge is to establish supportive conditions for innovation through a number of channels, including education and the competitive and regulatory environment. Recommendations in the OECD's 2009 Innovation Review include establishing better governance structures to ensure coherence in the formulation and implementation of innovation policies at the federal and state level, as well as sustained budgetary spending to support R&D.

Science and innovation profile of Mexico



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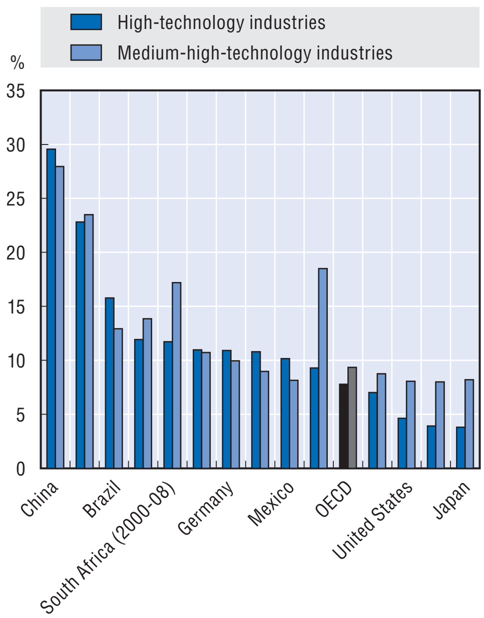
High and medium-high technology exports

Average annual growth rate, 1998-2008



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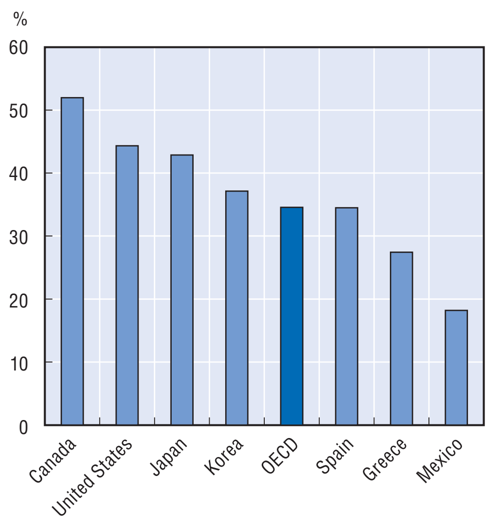
Tertiary-level graduates in total employment

As a percentage of total employment, 2007



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THE NETHERLANDS

Economic activity in the Netherlands is dominated by food processing, chemicals, petroleum refining, electrical machinery and a highly mechanised agricultural sector. Its science and innovation profile shows strong outcomes and sound linkages despite weak input indicators.

The Netherlands has one of the strongest patent intensities of all OECD countries. In 2008, it had 66 triadic patents per million population, well above the OECD average. It also had 1 331 scientific publications per million population, the eighth highest in the OECD, and accounted for 1.3% of world output. The 17% of firms that introduced new-to-market product innovations during 2004-06 was slightly above the average, while the 30% of firms undertaking non-technological innovation during that period was low compared to other countries.

Gross expenditure on R&D (GERD) was 1.8% of GDP in 2008, below the OECD average and lower than in 2006. This ratio has fallen consistently from a peak of 2% in the late 1980s. Industry financed 49% of GERD in 2007, and the government 37%. Venture capital investment was on the average at 0.1% of GDP. The low R&D intensity can be ascribed to the structure of the economy: a large services sector, a small high-technology sector and a high degree of concentration of R&D in a few multinational firms, some of which are active in low and medium-technology sectors. R&D investment is increasingly concentrated in information and communication technology and 85% of businesses have their own website. The Netherlands also invests intensively in regenerative medicine.

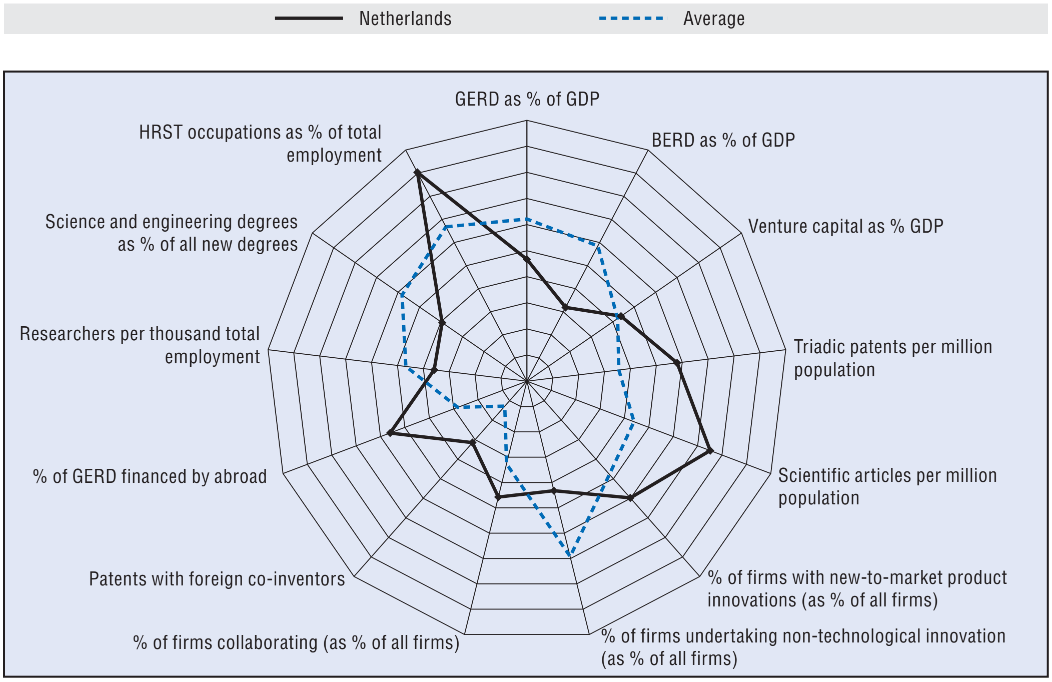
Innovation linkages in the Netherlands are strong. A higher than average 14% of firms collaborated on innovation activities during 2004-06. The share of Patent Cooperation Treaty (PCT) patent applications with foreign co-inventors during 2005-07 was almost 20% and the 10.7% of GERD financed from abroad exceeded the average (5.4%).

Performance in human resources in science and technology (HRST) are mixed. The Netherlands' six researchers per thousand employment and 14.2% of science and engineering degrees in all new degrees are both below the average. However, HRST occupations represented a high 38% of the workforce in 2008, and half of these positions were filled by women.

The Dutch economy expanded by an average annual 2% a year between 2001 and 2007. GDP slowed sharply from 3.6% in 2007 to 2% in 2008, and contracted by 4% in 2009; unemployment rose to 6.1%. Labour productivity growth has stagnated, falling by 1% a year since 2006. GDP per capita in 2008 was 87% relative to the United States.

Recent steps taken to strengthen innovation in the business sector include an expansion of the basic innovation package, which has been better aligned with the needs of business. The successful Innovation Voucher Scheme will be simplified and provided in digital format. In response to the global economic crisis, the government has allocated additional funds in its budget for the R&D Promotion Act (WBSO), to support the business sector. The government is pursuing a "key areas approach" focused on the development of strong and internationally prominent clusters.

Science and innovation profile of the Netherlands



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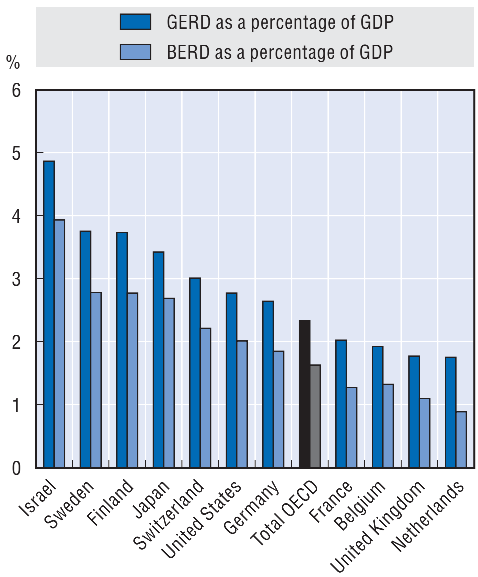
BERD and GERD intensity

As a percentage of GDP, 2008



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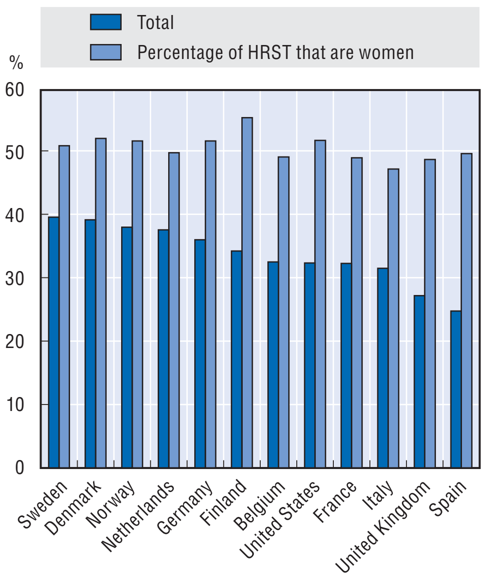
HRST occupations in total employment

As a percentage of total employment, 2008



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NEW ZEALAND

Over the past two decades the New Zealand economy has undergone substantial reform and has diversified significantly. This has broadened the technological capabilities of the manufacturing sector, although high-technology exports are still a relatively low share of total exports. The agricultural sector's contribution to GDP is higher than in most OECD countries.

New Zealand's indicators in human resources in science and technology (HRST) are strong. Tertiary graduation rates are high, but more than 40% of doctoral candidates are non-citizens. In 2007, 11 researchers per thousand employment was well above the OECD average. Only 17.3% of all new degrees were science and engineering degrees. HRST occupations accounted for 29% of total employment, just above average. Tertiary-level graduates are well represented in the workforce, and the earnings premium from tertiary education has increased significantly in recent years.

Gross domestic expenditure on R&D (GERD) was 1.2% of GDP in 2007, slightly up from 1% in 2000, but this still leaves New Zealand among the bottom ten OECD countries. GERD in real terms increased by a compound annual rate of 4.5% between 2001 and 2007, but GERD per capita remains comparatively low.

In 2007, industry financed a comparatively low 40% of GERD and the government funded 43%. At 0.5% of GDP, industry-financed GERD was below average (1.5%). Business expenditure on R&D (BERD) increased from 0.4% of GDP in 2000 to 0.5% of GDP in 2007, but also remains below the OECD average. In 2007, small and medium-sized enterprises performed almost 75% of business R&D in New Zealand.

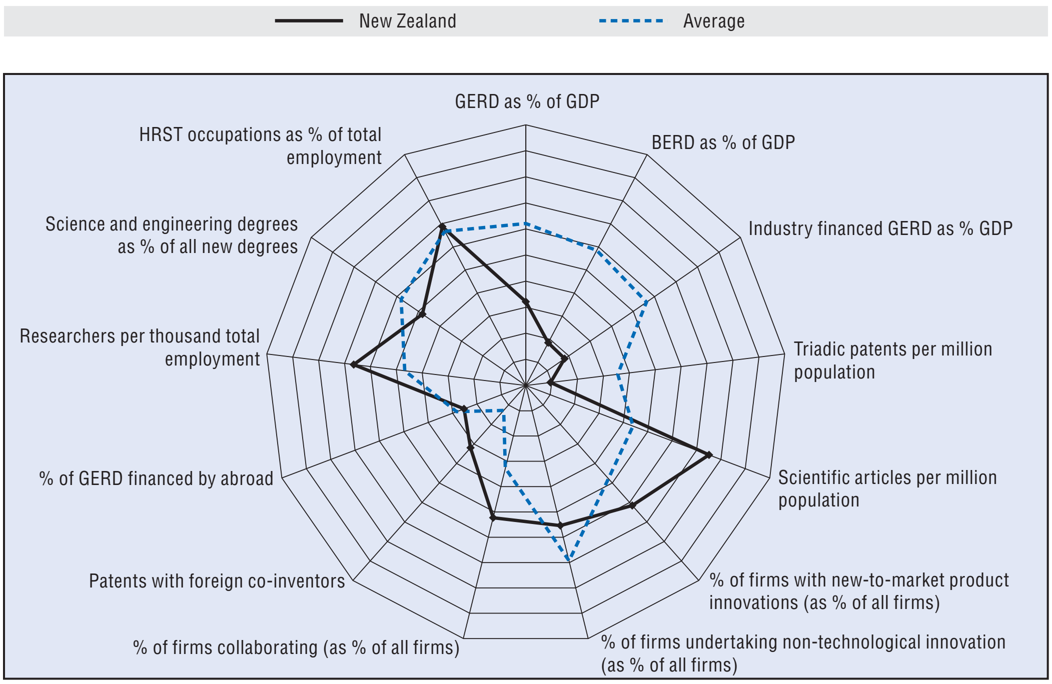
Despite weak input indicators, New Zealand performs well on innovation outcomes. Although its 11 triadic patents per million population were at the lower end of the spectrum in 2008, its 1 330 scientific articles per million population were well above the OECD average. A high 18% of firms introduced new-to-market product innovations during 2004-06, but a below-average 39% of firms undertook non-technological innovation.

Results for innovation linkages are mixed. An above-average 15.5% of firms collaborated on innovation activities, while one in five Patent Cooperation Treaty (PCT) patent applications during 2005-07 had foreign co-inventors. The 5% of GERD financed from abroad was slightly below the average.

New Zealand experienced robust average annual GDP growth of 3.5% between 2001 and 2007, but this fell to 1.8% in 2008. GDP contracted by 1.5% in 2009 and unemployment rose sharply from 3.7% in 2007 to 6.1% in 2009. Labour productivity slowed from high levels in the 1990s to around 1% in the 2000s.

The New Zealand government recognises the primary contribution of research to economic growth. A new investment structure for research, science and technology has identified new priority areas, which include high-technology industries, the biological economy, energy and minerals, hazards and infrastructure, the environment, health, along with top talent, international relationships and research infrastructure.

Science and innovation profile of New Zealand



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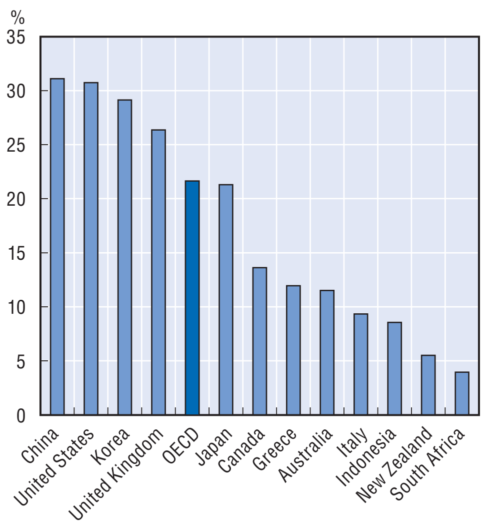
High-technology exports

As a percentage of total manufacturing exports, 2008



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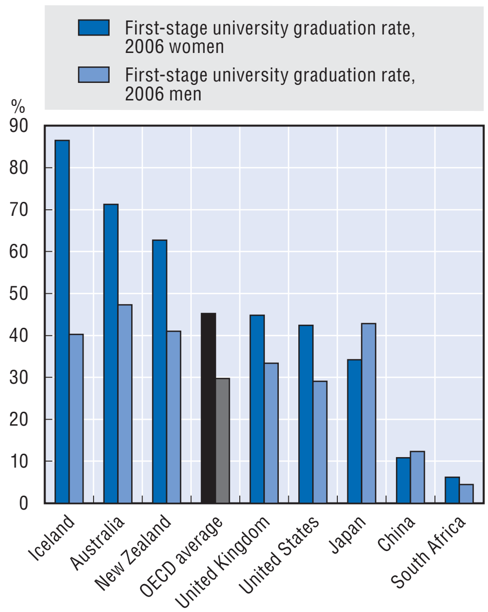
Graduation rates at first-stage university level

As a percentage of the relevant age cohort, 2006



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NORWAY

Norway is richly endowed with natural resources, such as petroleum, hydropower, fish, forests and minerals. The economy has continued to grow in recent years, but its ability to sustain long-term growth and prepare itself for a decline in oil reserves depends on continued productivity gains supported by innovation. The country's science and innovation profile presents a mixed picture.

Norway's indicators for human resources in science and technology (HRST) are, on balance, strong. In 2008, HRST occupations represented 38% of total employment. There were a relatively high ten researchers per thousand employment, and researcher numbers have grown by a strong average annual 4% since 2001, and even faster more recently. However, the 15% of science and engineering degrees in all new degrees in 2007 was relatively low.

Norway's performance on innovation outcomes is mixed. Scientific output is high: its 1 356 scientific articles per million population in 2008 places it among the top ten OECD countries. However, the 26 triadic patents per million population is below average, and Norway's country share in triadic patent families was also very low in 2008. In 2004-06, a comparatively small 23% of firms conducted non-technological innovation but 14% of firms introduced new-to-market product innovations.

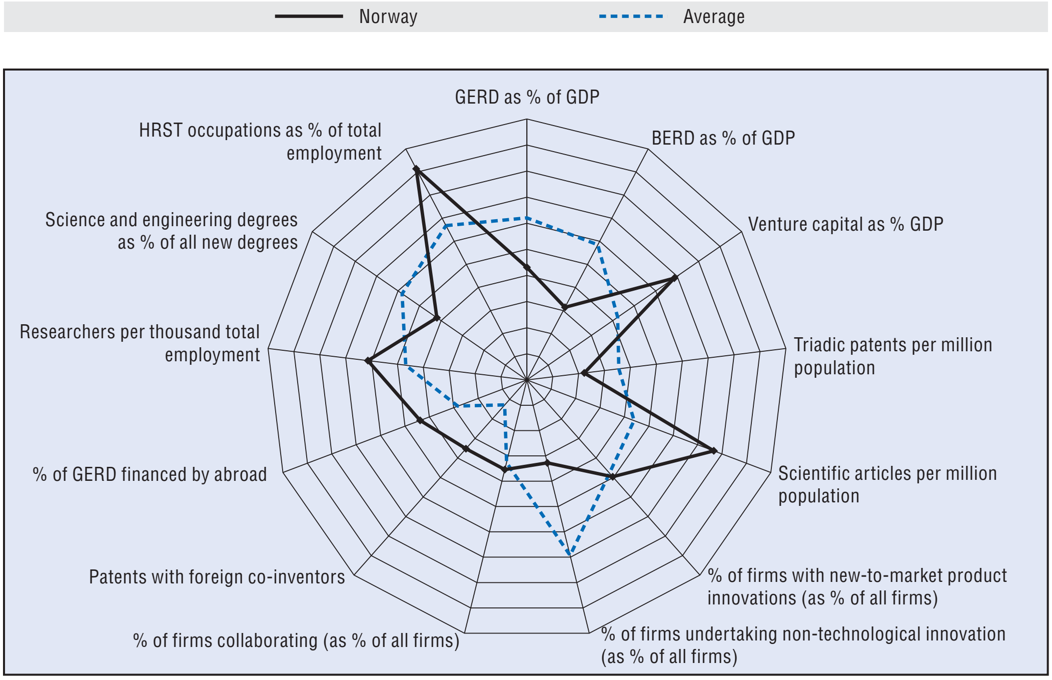
Gross expenditure on R&D (GERD) was 1.6% of GDP in 2008, below the OECD average. GERD in real terms has, however, grown strongly since 2001 at 5% a year on average, and in 2008 GERD per capita was an above-average USD 949 in current PPP. A relatively low 45% of GERD was financed by industry in 2007, with government also funding 45%. In 2008, industry performed 54% of GERD, the higher education sector 32% and government 15%. Business expenditure on R&D (BERD) in 2008 was 0.9%, also below the OECD average, but Norway's venture capital intensity of 0.16% of GDP was solidly above the average.

Innovation linkages are strong. In 2007, an above-average 8.3% of GERD was financed from abroad, and a comparatively high 21% of Patent Cooperation Treaty (PCT) patent applications were with foreign co-inventors during 2005-07. During 2004-06, 11% of firms collaborated on innovation activities, slightly above the average.

Norway's real GDP grew by an average annual 2.4% between 2001 and 2008, although it eased to 1.8% in 2008 and contracted by 1.5% in 2009 because of the slowing world economy and lower oil prices. Unemployment remained low and only edged up from 2.5% in 2007 to 3.2% in 2009. Labour productivity growth has been subdued since 2000 and has declined since 2006. GDP per capita exceeded that of the United States in 2008.

The 2009 re-elected government's priorities are a continuation of the policy outlined in the White Papers on research and innovation from 2008 and 2009. Important follow-up will include strategies for better impact from publicly funded research; strategies on generic technologies such as ICT, biotechnology and nanotechnology; and a stronger emphasis on EU research collaboration.

Science and innovation profile of Norway



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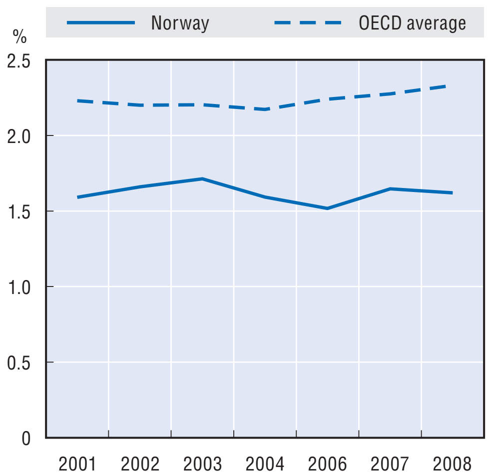
R&D intensity

GERD as a percentage GDP, 2001-08



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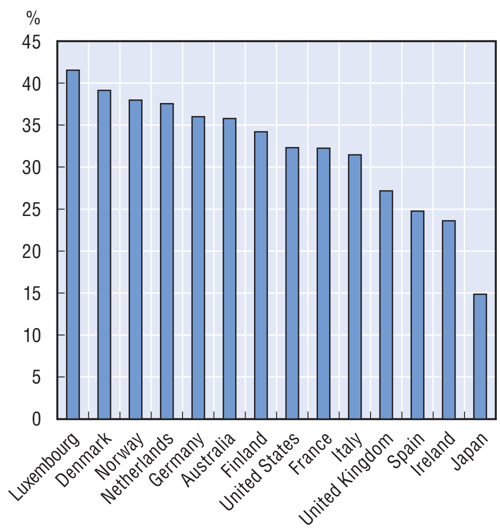
HRST occupations as a share of total employment

As a percentage of total employment, 2008



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POLAND

Poland has pursued a policy of economic liberalisation since 1990 and is a success story among transition economies. A growing services sector accounts for nearly two-thirds of GDP. The government has undertaken structural reforms in a number of areas to create a more efficient business environment and legal system, a more liberalised labour market, less red tape and a simpler tax system. A stronger focus on innovation can help to improve productivity and increase competitiveness.

Poland's gross expenditure on R&D (GERD) was 0.6% of GDP in 2008, down from 0.9% in 1990 when data were collected for the first time, but higher than a low of 0.5% in 2003. In 2004 GERD began growing strongly in real terms at an average annual rate of 7.8% to 2008, but GERD per capita at USD 104 in current PPP is the fourth lowest in the OECD area.

Industry financed 31% of GERD in 2008, and the government funded a hefty 60%. The business enterprise sector performed 31% of GERD, the higher education sector 34% and government 35%. Business expenditure on R&D (BERD) halved from 0.4% of GDP in the 1990s to 0.2% in 2008, the lowest in the OECD area. Poland's venture capital market is very underdeveloped.

The outcome indicators are mostly below average. Both the 0.6 triadic patents per million population and the 411 scientific articles per million population were low. During 2004-06, a small 7.5% of firms introduced new-to-market product innovations; 31% undertook non-technological innovation.

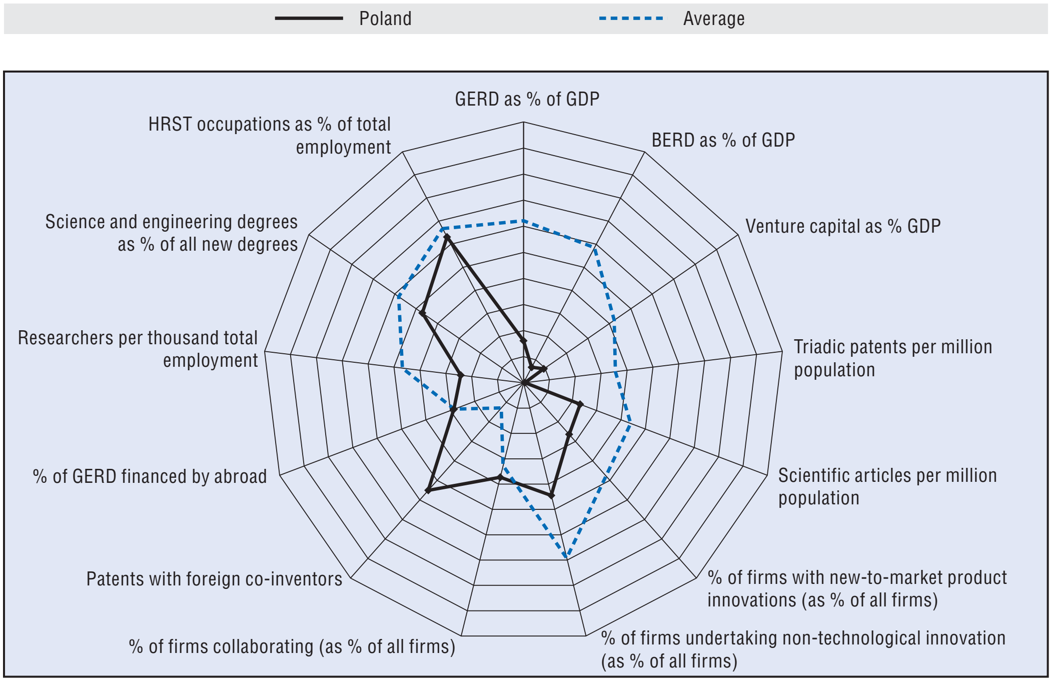
Poland's innovation linkages are more encouraging. During 2004-06, 11% of firms collaborated on innovation activities, and during 2005-07 33% of Patent Cooperation Treaty (PCT) patent applications were with a foreign co-inventor, both slightly above the average. The 5.4% of GERD financed from abroad is equal to the average.

Indicators for human resources in science and technology (HRST) are mixed. In 2007, the number of researchers per thousand employment declined to four and science and engineering degrees accounted for 17% of all new degrees, below the OECD average. In 2008, 60% of HRST occupations were filled by women, but HRST occupations were slightly below average, at 26% of total employment. Graduates faced a relatively high unemployment rate of 6.2%.

Poland was not severely affected by the global recession. GDP growth slowed from 6.8% in 2007 to 5% in 2008 and 1.8% in 2009. Unemployment increased by 1 percentage point to 8.2% in 2009. Labour productivity growth has remained around 3% a year since 2000, but slowed to 0.8% in 2008. Relative to the United States, GDP per capita is 37%.

Innovation policy in Poland is based on medium-term policy documents, among others the Innovation Strategy 2007-13. Its goals are to develop human resources to build a knowledge-based economy, link public R&D activities to the needs of the enterprise sector, improve intellectual property rights, mobilise private capital to create and develop innovative companies and build the infrastructure for innovation.

Science and innovation profile of Poland



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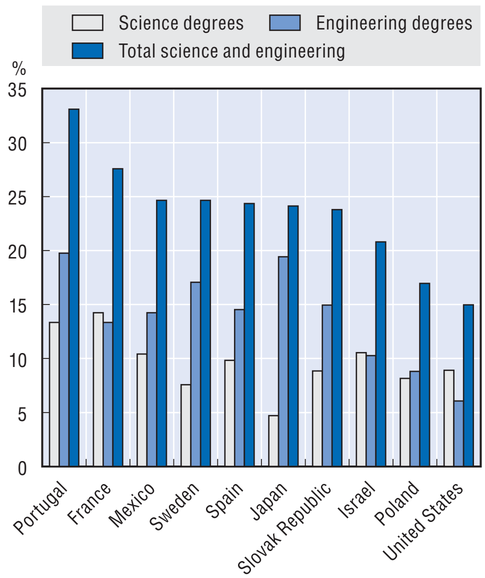
Science and engineering degrees

As a percentage of all new degrees, 2007



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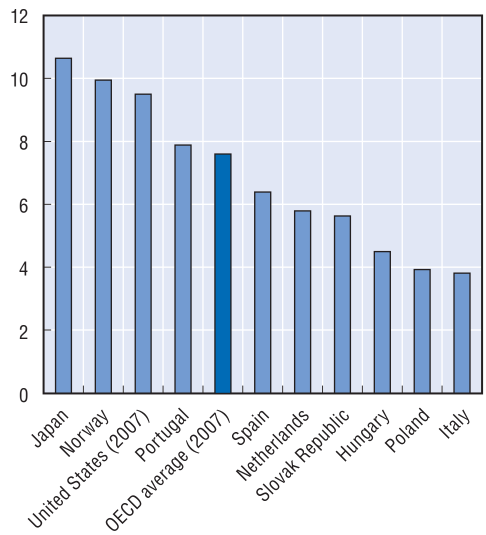
Researchers

Per thousand employment, 2008



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PORTUGAL

Portugal's science and innovation profile reveals both strengths and weaknesses. It has improved significantly over the past two years and four indicators now exceed the average, compared with two in the previous *STI Outlook*. Although still below the OECD average, gross expenditure on R&D (GERD) has almost doubled, from 0.8% of GDP in 2000 to 1.5% in 2008. Since 2005, GERD has grown in real terms by a strong average annual 25%. The funding of GERD has changed significantly: industry's share increased from 27% in 2000 to 47% in 2007, while the government's share fell from 65% to 45%. Business expenditure on R&D (BERD) increased from 0.2% of GDP in 2000 to 0.8% in 2008; in 2008 venture capital intensity (0.03% of GDP) was well below the average.

In 2007, Portugal had a very low 0.9 triadic patents per million population, but its 668 scientific articles per million population were closer to the OECD average. While the 12% of firms introducing new-to-market product innovations during 2004-06 was just below the average, a higher than average 54% of firms undertook non-technological innovation.

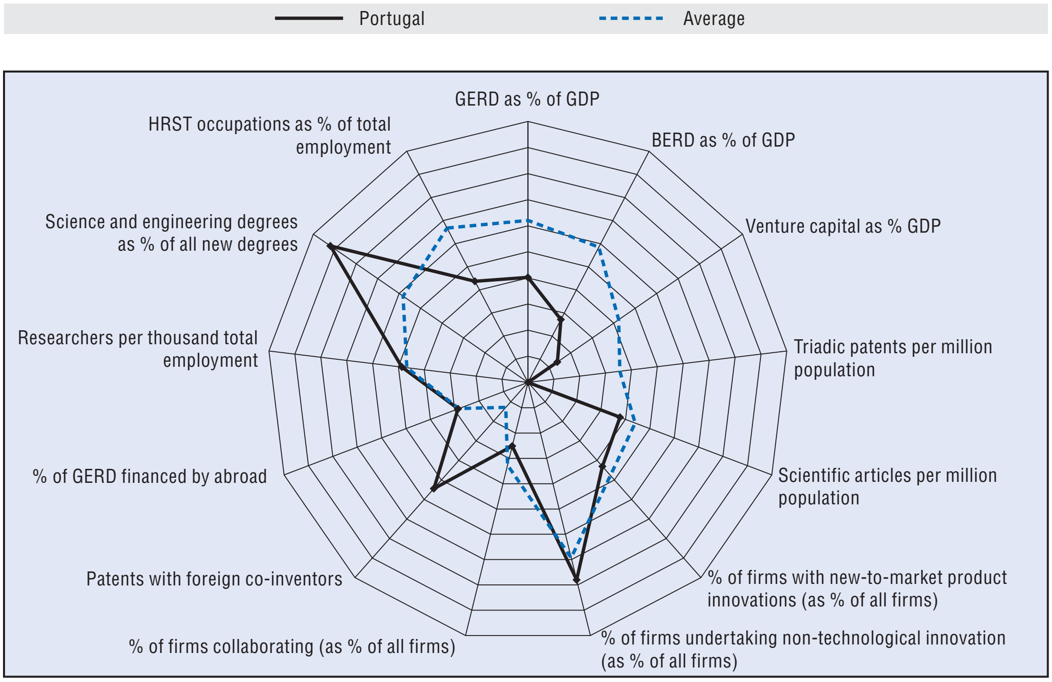
Innovation linkage indicators are mixed. During 2004-06, only 7.5% of firms collaborated on innovation activities, but the 5.4% of GERD financed from abroad was on the average and the 33% of Patent Cooperation Treaty (PCT) patent applications with international co-inventors exceeded the average by a substantial margin. The share of R&D expenditure by foreign affiliates is over 40%.

In 2008, Portugal had almost eight researchers per thousand employment, around the average; researcher numbers increased sharply by 17% in 2006 and 14% in 2007. Occupations in human resources in science and technology (HRST) were 18% of total employment, less than in other OECD countries, and women filled more than half of these. Graduates comprise less than 20% of Portugal's workforce, compared with 35% in the OECD overall. However, 33% of all new tertiary degrees were in science and engineering, the second highest in the OECD.

GDP has grown modestly at an average annual 0.9% between 2000 and 2007 and a mere 0.1% in 2008. In 2009 GDP fell by 2.7%, and unemployment jumped from 7.7% in 2008 to 9.6% in 2009. Labour productivity growth slowed from 3.8% in the 1990s to close to 1% a year during 2000-07 and declined by 1.5% in 2008. Relative to the United States, GDP per capita was 49%.

In April 2010, the Ministry of Science, Technology and Higher Education released a key report, *A New Landscape for Science Technology and Tertiary Education in Portugal*, which addresses the challenges of sustaining the growth of science and technology and outlines ways to participate in international knowledge networks. Important innovation initiatives are also contained in the government's 2008 Growth and Employment Initiative ((*Iniciativa para o Crescimento e o Emprego*), which includes the modernisation of schools, the promotion of renewable energy sources, supporting new generation broadband networks and supporting small and medium-sized firms.

Science and innovation profile of Portugal



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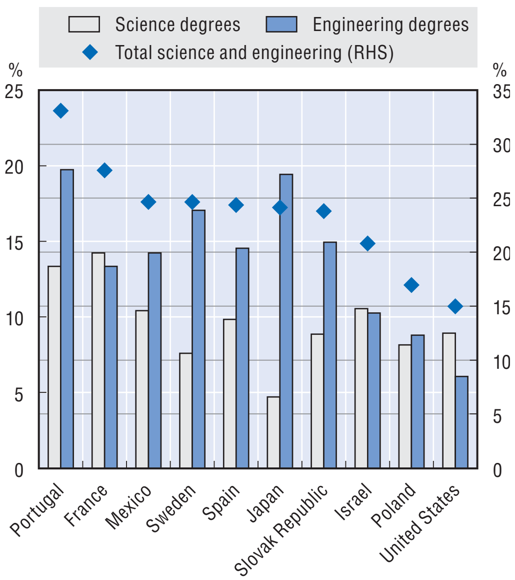
Science and engineering degrees

As a percentage of all new degrees, 2007



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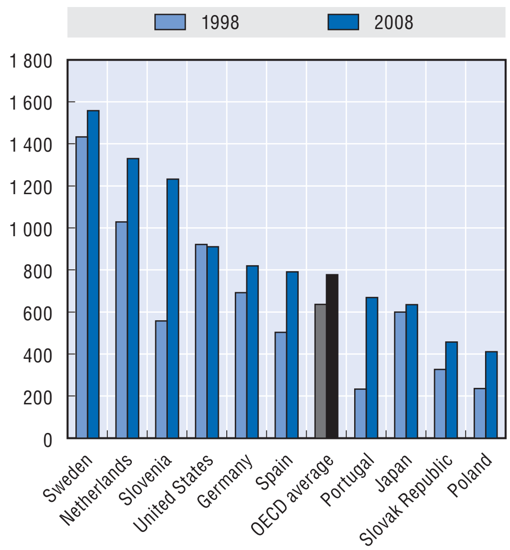
Scientific articles published

Per million population, 1998 and 2008



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RUSSIAN FEDERATION

Since 1990 the Russian Federation has moved rapidly to being a globally integrated economy. Russian industry includes a number of internationally competitive commodity producers and in 2009 it was a major exporter of natural gas, oil, steel and primary aluminium. This reliance on commodity exports makes Russia vulnerable to boom and bust cycles and also affects the focus of R&D and innovation policy. The Russian science and innovation profile demonstrates areas of strong performance, but also areas for future development.

Russia's human resources in science and technology (HRST) indicators show strengths and weaknesses. In 2008 Russia had a high graduation rate of 53% in first university type-A degrees, well above the OECD average of 38%. It also had 451 000 researchers and the world's largest number of R&D personnel. However, numbers of researchers and R&D personnel have declined at an average annual rate of 1% in the decade to 2008, as has the number of researchers per thousand employment (6.4 in 2008). Russia has a high level of academic attainment, with 54% of the population aged 25-64 qualified at the tertiary level in 2002. The 25% of science and engineering degrees as a percentage of all new degrees and doctorates per capita were both higher than the OECD average.

Gross expenditure on R&D (GERD) fell from 2% of GDP in 1990 to 1% in 2008, when industry financed 29% and the government 65%. The government's share has fluctuated, falling from 62% in 1994 to 51% in 1999, before rising again. Industry's share has fallen from 35% in 1994. Business expenditure on R&D (BERD) declined to 0.7% of GDP in 2008, below the OECD average of 1.6%. In the decade to 2008, the share of government funding of R&D in the business sector increased from 43% to 56% of total BERD. Industry-financed GERD was 0.3% of GDP, below the average of 1.5%.

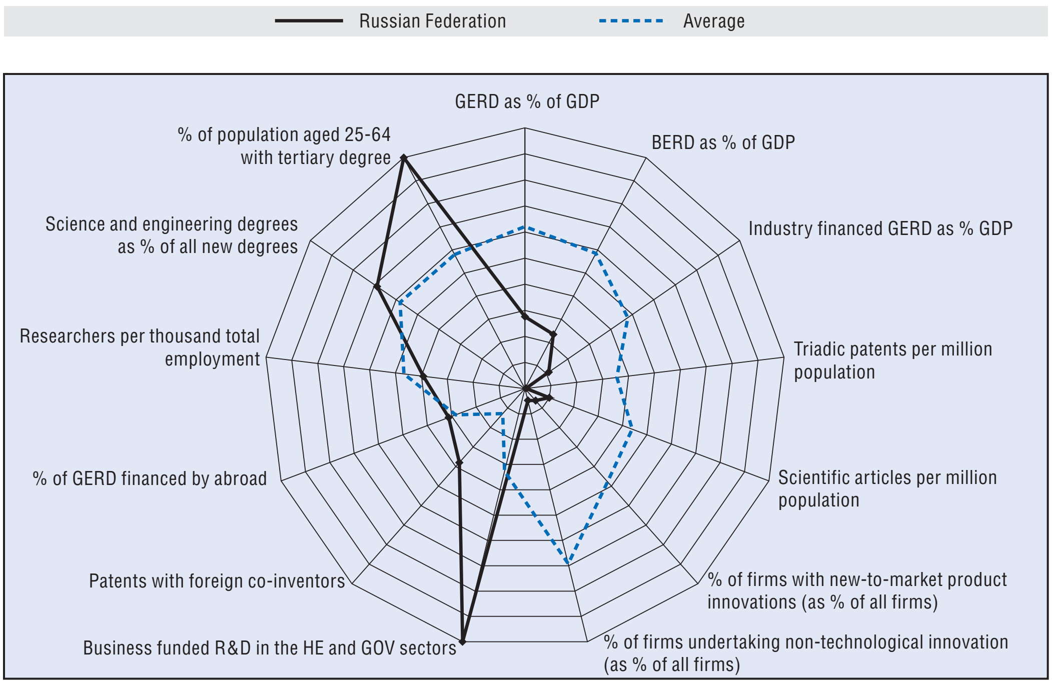
In 2008, Russia accounted for 0.13% of the world's triadic patent families, but both its 0.5 triadic patents per million population and 176 scientific articles per million population were relatively low. Russia's output of scientific publications has decreased, and its share of all scientific articles fell from 2.4% in 1998 to 1.5% in 2008. Only 1.8% of firms introduced new-to-market product innovations, while 3.3% of firms undertook non-technological innovation.

Indicators for international linkages are above average. In 2005-07, a high 23% of Patent Cooperation Treaty (PCT) patent applications were with foreign co-inventors and in 2008 6% of GERD was financed from abroad.

GDP growth has averaged 7% since 1998. The Russian economy has, however, been severely affected by the global recession and GDP growth slowed from 8.1% in 2007 to 5.6% in 2008. In 2009 the economy contracted by 7.9%. Unemployment increased from 6.5% in 2008 to 8.9% in 2009. In 2009 GDP per capita decreased slightly to 32% relative to the United States.

The government has adopted the Concept of Long-Term Socio-Economic Development of the Russian Federation CLTD 2020. It identifies several key targets and aims to implement initiatives to ensure science and technology breakthroughs and reduce the country's dependence on natural resources.

Science and innovation profile of the Russian Federation



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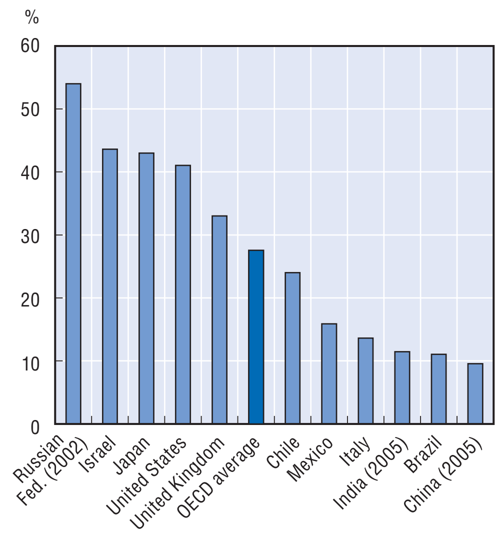
Educational attainment

Percentage of population aged 25-64 with a tertiary degree, 2008



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Gross expenditure on R&D

As a percentage of GDP, 1990-2008

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SLOVAK REPUBLIC

The Slovak Republic has undertaken significant economic reforms since 1993. Major privatisations are nearly complete, the banking sector is almost entirely in foreign hands, and the government has helped facilitate a foreign investment boom with attractive tax policies. Foreign investment has been strong in the automotive and electronic sectors.

The country's economic growth outperformed Europe in the early 2000s, with robust average annual GDP growth of 6.7% between 2001 and 2007. Growth slowed to 6.2% in 2008 and GDP contracted by 4.7% in 2009. The unemployment rate fell from double digits to 7.2% in 2008, but rose to 8.2% in 2009. Productivity growth was almost 6% during 2001-07, slowing to 3.6% in 2008. In 2008, GDP per capita was 47% relative to the United States.

Investment in R&D has been comparatively low. Gross expenditure on R&D (GERD) was 0.5% of GDP in 2008, the second lowest in the OECD. However, average annual real growth in GERD accelerated to nearly 6% between 2004 and 2008. Government funded around 52% of GERD in 2008, up from an average of 37% in the 1990s, while industry financed a comparatively low 35%, down from over 60% during much of the 1990s.

In 2008, industry-financed GERD was 0.2% of GDP, below the average of 1.5%. In that year, the business enterprise sector performed 43% of GERD, the higher education sector 24%, and government 33%. Business expenditure on R&D (BERD) was only 0.2% of GDP.

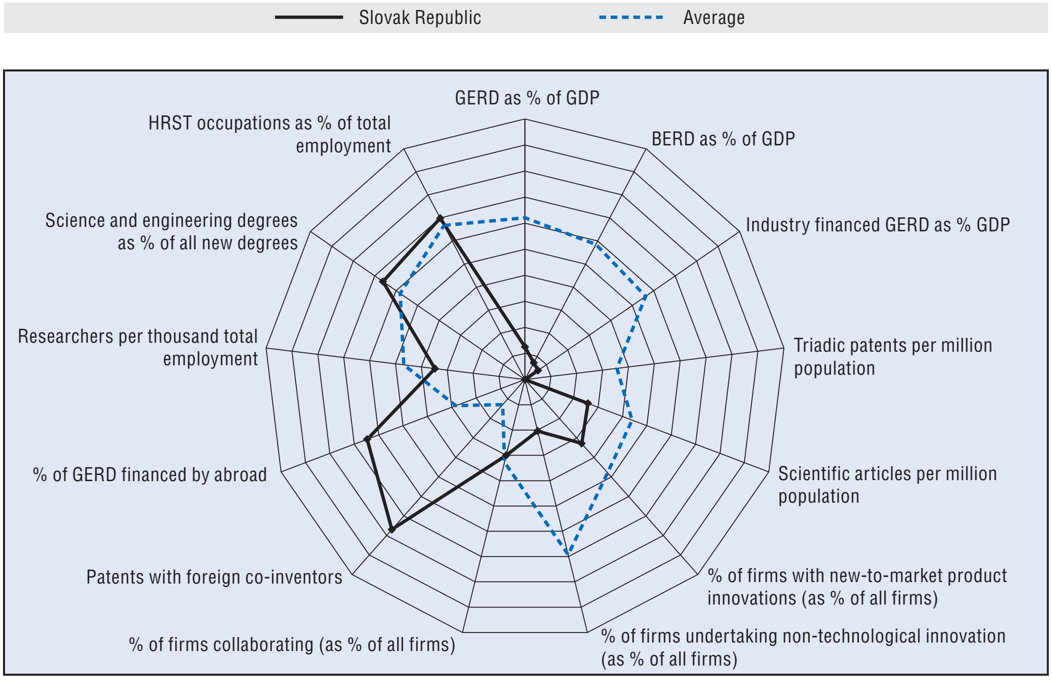
In 2008, both the 0.7 triadic patents per million population and the 457 scientific articles per million population were low. Other outcomes were also weak during 2004-06: 9.4% of firms introduced new-to-market product innovations and 14.1% of firms undertook non-technological innovation.

Technology is largely acquired from outside the country and a high 12% of GERD was financed from abroad. The share of manufacturing firms under foreign control exceeded 50% in 2006, and in 2007 the R&D expenditures of foreign affiliates accounted for 38% of total R&D spending, close to the average of 40%. An average 9% of firms collaborated on innovation activity during 2004-06. A very high 46% of Patent Cooperation Treaty (PCT) patent applications in 2005-07 were with foreign co-inventors.

The Slovak Republic performs above average on some indicators of human resources in science and technology (HRST). Science and engineering degrees accounted for 24% of all new degrees, exceeding the OECD average, and HRST occupations are well represented in total employment, with women holding 60% of these jobs. Researcher numbers have increased in recent years, albeit from a low base. Despite the robust growth, there were only six researchers per thousand employment in 2008.

Innovation policy is based on the 2007 Innovation Strategy, the 2008 Innovation Policy, and the Operational Programme Competitiveness and Economic Growth (OPCEG). The innovation strategy sets a number of explicit quantitative and qualitative targets. Financial assistance is currently directed to technology transfers, business and technology incubators, R&D co-operation and risk capital schemes that support small and medium-sized firms.

Science and innovation profile of the Slovak Republic



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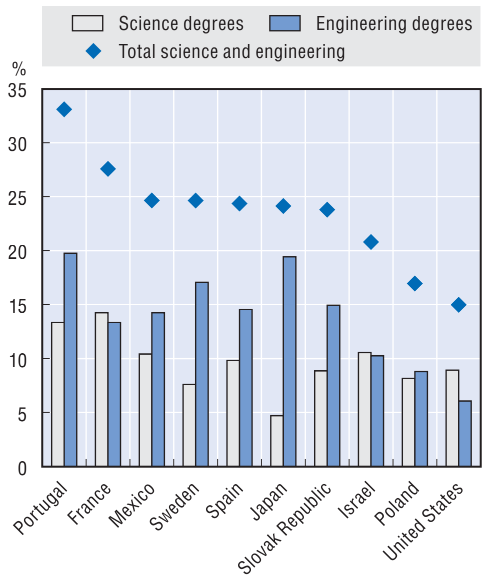
Science and engineering degrees

As a percentage of all new degrees, 2007



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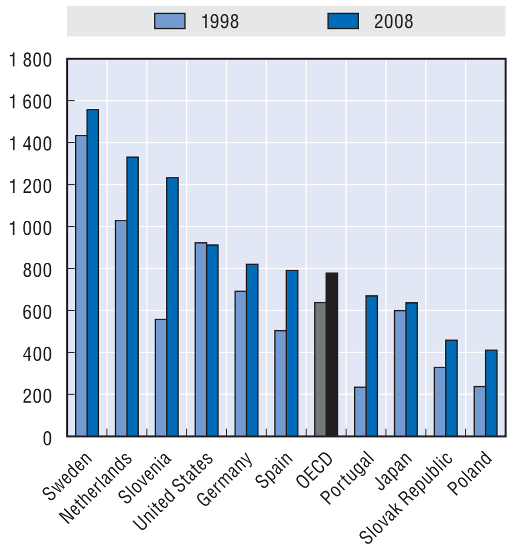
Scientific articles published

Per million population, 1998 and 2008



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SLOVENIA

Slovenia adopted the euro in January 2007 and joined the OECD in July 2010. It has good infrastructure and a well-educated workforce. Slovenia's science and innovation profile shows notable strengths.

Gross expenditure on R&D (GERD) was 1.7% of GDP in 2008. Real GERD has grown at a strong average annual 7.1% since 2000. In 2008, industry funded around 63% of GERD, up from 53% in 2000, and government funded 31%. The business enterprise sector performed 65% of GERD in 2008, the higher education sector 13.4% and the government sector 22%. In the same year, business expenditure on R&D (BERD) reached 1.1% of GDP and industry-financed GERD was 1.04% of GDP.

In 2008, Slovenia had a relatively high 1 233 scientific articles per million population, but a low 9.4 triadic patents per million population. A relatively high 18% of firms introduced new-to-market product innovations during 2004-06, while a low 27% undertook non-technological innovation.

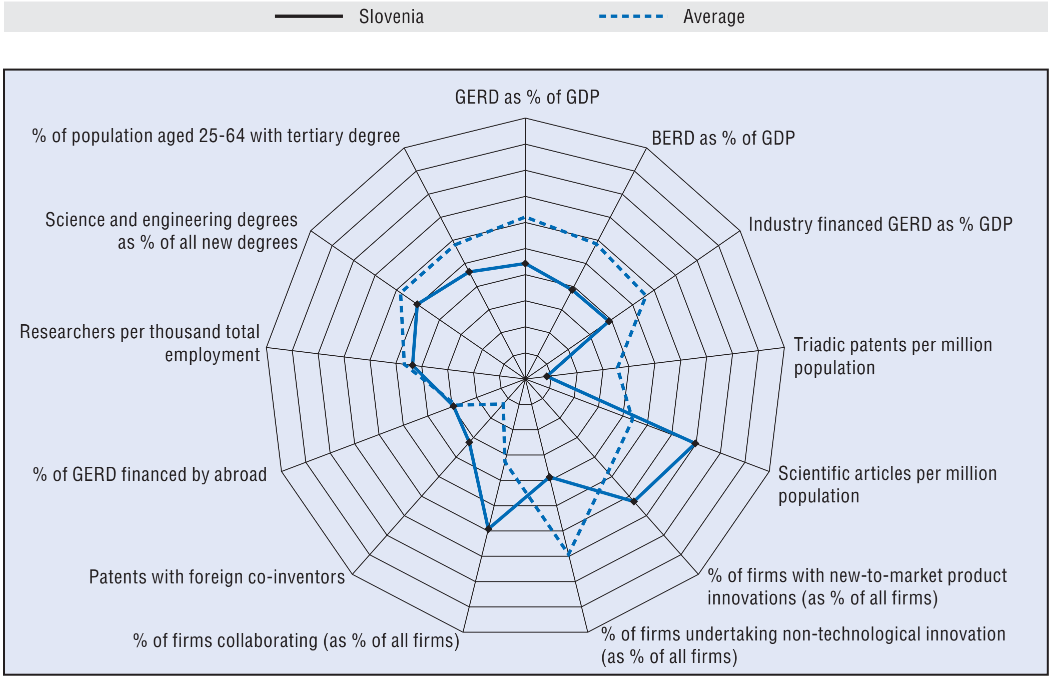
During 2004-06, 18% of all firms, mostly large ones, collaborated on innovation. More than half of these firms collaborated domestically, and around 13% collaborated with partners elsewhere in Europe. The share of GERD financed from abroad decreased from 11% in 2004 to 5.6% in 2008. One in five Patent Cooperation Treaty (PCT) patent applications during 2005-07 had foreign co-inventors.

Slovenia's human resources in science and technology (HRST) indicators are close to the average. Researcher numbers have increased by 13.2% a year since 2003 to seven researchers per thousand employment in 2008. The 18% of science and engineering degrees in all new degrees were slightly below the OECD average. In 2008, 23% of the population aged 25-64 had a tertiary degree, below the OECD average of 28%.

Economic growth slowed from 6.8% in 2007 to 3.5% in 2008 and GDP contracted by 7.3% in 2009. Unemployment rose from 6.7% in 2008 to 9.4% in 2009. Labour productivity grew by an average annual 4% between 2001 and 2007 and slowed to 0.7% in 2008. Slovenia has the highest per capita GDP in central Europe, at 59% relative to the United States.

The government's innovation policy was developed during 2005-08. The most important element is the Slovenian Development Strategy 2006-13 (SDS). This is complemented by the Resolution on the National Research and Development Programme (NRDP), the National Reform Programme for Achieving the Lisbon Strategy Goals (NRP), the National Development Programme 2007-13 (NDP) and the National Strategic Reference Framework (NSRF). One focus area for policy is the large proportion of small and medium-sized firms that do not innovate.

Science and innovation profile of Slovenia



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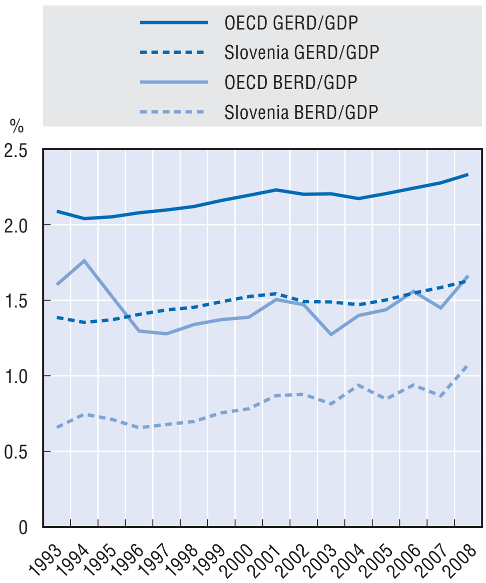
R&D intensity

GERD and BERD as a percentage of GDP, 1993-2008



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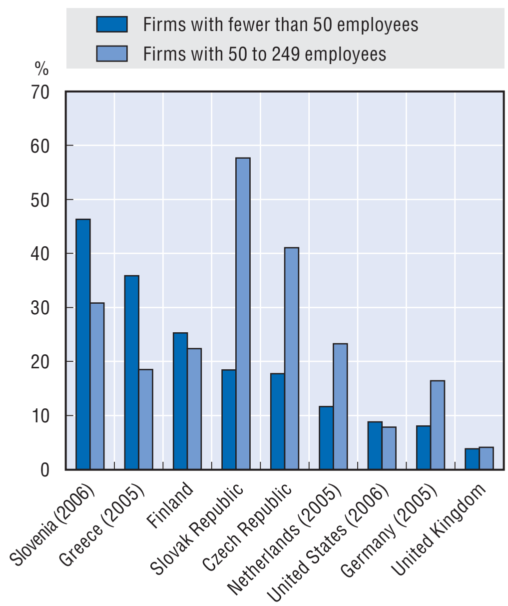
Government-financed business R&D by firm size

Percentage share, 2007



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SOUTH AFRICA

South Africa's science and innovation profile shows some distinct strengths. The country's trade in high-technology industries increased by 4 percentage points between 1997 and 2007, indicating a shift away from primary production. During 2002-04, a very high 61% of firms engaged in non-technological innovation, and an above-average 21% introduced new-to-market product innovations. In 2008 the country had a relatively low 110 scientific articles per million population, but scientific publications have grown by an average annual 4.5% since 1998, placing it among the 20 fastest-growing countries in this respect.

Almost one in every four firms collaborated on innovation activities in 2002-04. Although gross expenditure on R&D (GERD) financed from abroad declined from 13.6% in 2005 to 11% in 2007, this is the highest of all non-OECD countries analysed here. The 11% of Patent Cooperation Treaty (PCT) patent applications with foreign co-inventors during 2005-07 is also above average.

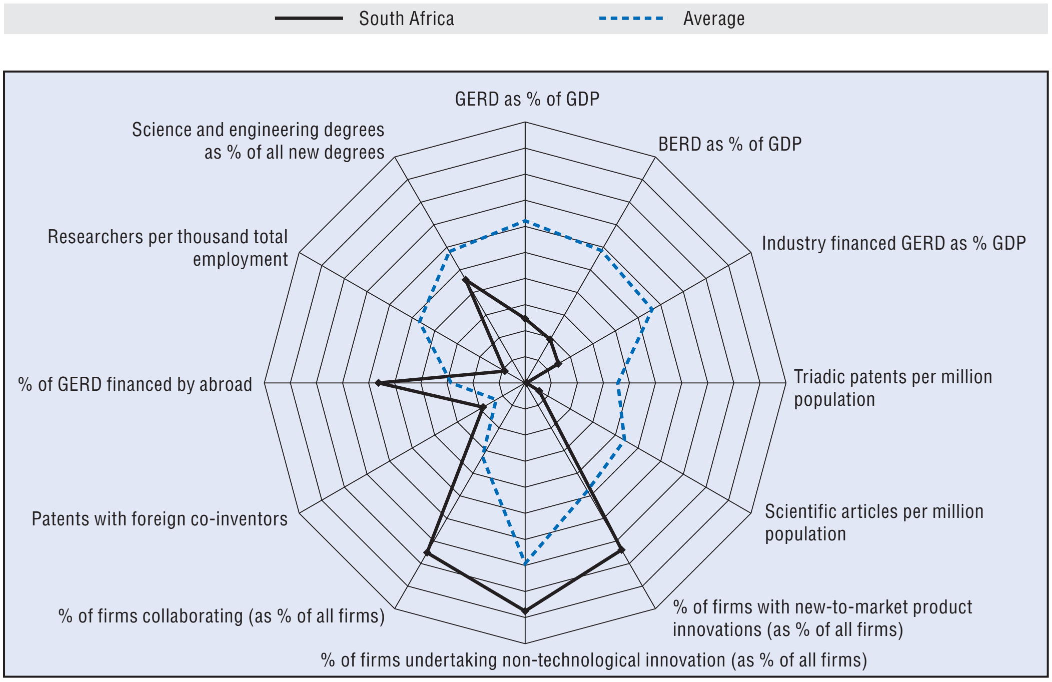
GERD rose from 0.73% of GDP in 2000 to 0.9% in 2007 and increased, in real terms, at a strong annual compound rate of 8.4% between 1997 and 2007. Industry financed 43% of GERD in 2007, down from 56% in 2001, while the share funded by government increased to 46% over the same period. Industry-financed GERD was 0.4% of GDP in 2007. In November 2006, South Africa introduced an enhanced R&D tax incentive which included a 150% tax deduction on current expenditure. Business expenditure on R&D (BERD) remained steady at 0.53% of GDP in 2005 and 2006. The country had less than one triadic patent per million population, well below average, and its share in triadic patent families in 2007 was also small. However, it is active in patent development in waste management, water pollution and renewable energy.

South Africa's indicators for human resources in science and technology (HRST) are weak. It has 1.5 researchers per thousand employment and a small 16% of science and engineering degrees in all new degrees.

With the global commodities boom, GDP growth was robust from 2004 to 2008, but slowed in 2008. In 2009 GDP fell by 1.8%. Unemployment remains high and outdated infrastructure continues to constrain growth. GDP per capita was 22% relative to the United States in 2009.

Three major innovation policy and related legislative developments have taken place from 2008 to 2010. South Africa's Ten-Year Innovation Plan (TYIP): 2008-2018 has commenced, with five "grand challenges": to strengthen the country's bio-economy; to develop space science and technology; to focus on energy security; to engage in efforts to address climate change; and to contribute to a greater understanding of the role of science in stimulating growth and development. In addition, the Technology Innovation Agency (TIA) was established to be operational in 2013, and work on a National Space Agency is currently under way.

Science and innovation profile of South Africa



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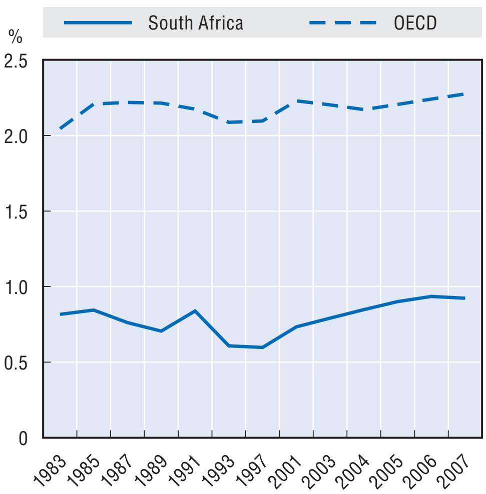
Gross expenditure on R&D

As a percentage of GDP, 1983-2007



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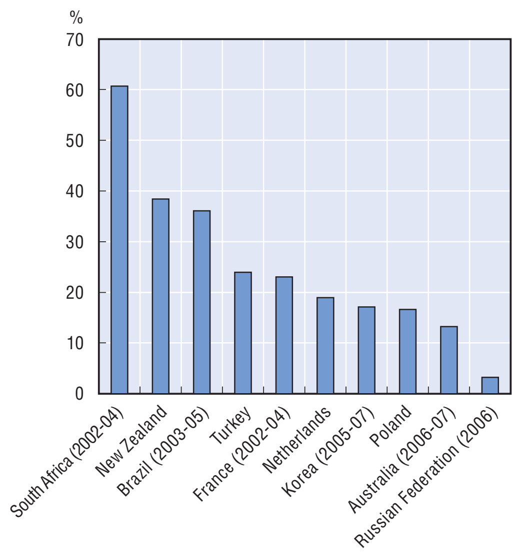
Firms undertaking non-technological innovation

As a percentage of all firms, 2004-06



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SPAIN

Spain's science and innovation profile demonstrates a number of strengths, and shows improvements over the two years to 2008 despite difficult economic circumstances. Gross expenditure on R&D (GERD) increased consistently from 0.9% of GDP in 2000 to 1.4% in 2008, with strong average annual real growth of 8.4%. In 2007 the business sector financed 46% of total GERD, slightly more than a decade earlier, and government funding increased from 39% in 2000 to 44%. Spain's business expenditure on R&D (BERD) was 0.74% of GDP, also below the OECD average. However, venture capital intensity has risen substantially, and in 2008 was above the average at 0.13% of GDP.

Triadic patents were a low 5.1 per million population in 2008. While only 6% of firms introduced new-to-market product innovations during 2004-06, 21% undertook non-technological innovation. Spain's 791 scientific articles per million population were marginally above average.

During 2004-06, a low 6% of firms collaborated internationally on innovation activities, with less than 2% collaborating with European partners. However, the 19% of Patent Cooperation Treaty (PCT) patent applications with foreign co-inventors during 2005-07 was higher than average, and in 2007 an above-average 7% of GERD was financed from abroad.

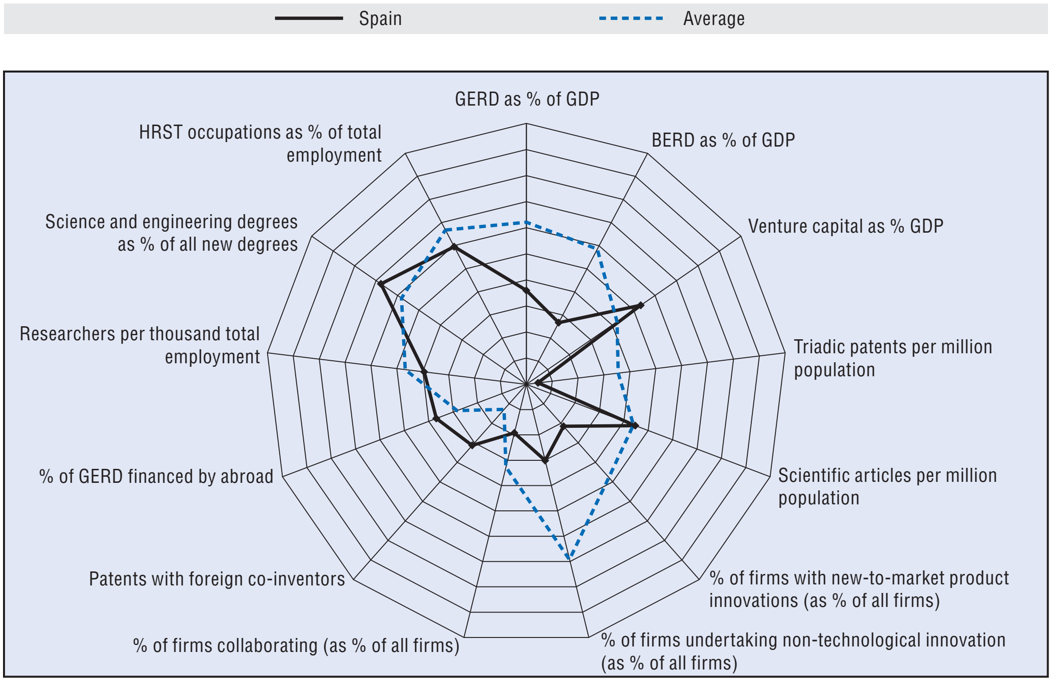
Performance on human resources in science and technology (HRST) indicators is mixed. In 2007 24% of all new degrees were in science and engineering. At 25% of total employment HRST occupations were lower than the average in 2008, as were the 6.4 researchers per thousand employment, although this ratio increased sharply from 4.7 in 2000. HRST occupations rose by a particularly strong 6.3%; the wage gap between men and women narrowed significantly over the past decade.

GDP increased at an average annual 3% between 2001 and 2007, but slowed to 0.9% in 2008 and contracted by 3.6% in 2009. Unemployment rose very severely, rising from 8.3% in 2007 to 18% in 2009. Labour productivity growth averaged around 1% between 2001 and 2008. GDP per capita was 67% relative to the United States in 2008.

The government is currently working on a Science and Technology Act to create a new framework for research funding and to improve co-ordination between state and regional administrations. The State Innovation Strategy, based on core areas of action, aims, among others, to increase the number of innovative businesses and strengthen their commitment to innovation.

The national R&D&I Plan 2008-11 includes specific public funding instruments to support strategic research in health, biotechnology, energy and climate change, telecommunication and information societies, nanotechnology, new materials and new industrial processes.

Science and innovation profile of Spain



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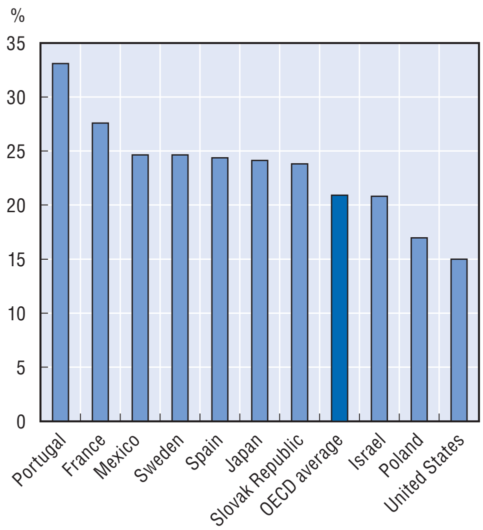
Science and engineering degrees

As a percentage of all new degrees, 2007



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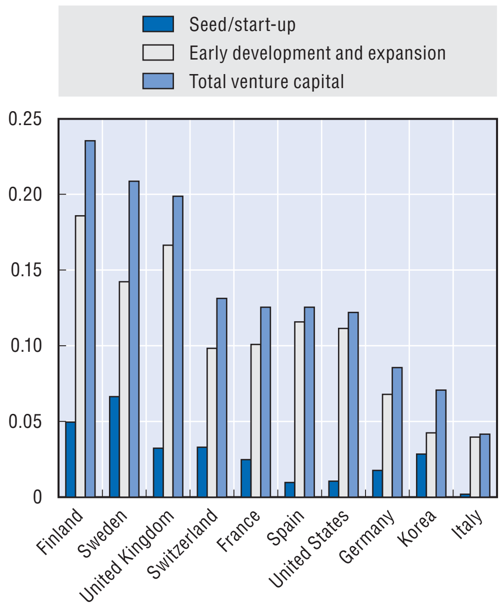
Venture capital intensity by stage

As a percentage of GDP, 2008



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SWEDEN

Sweden's science and innovation profile is one of the strongest in the OECD area. Gross expenditure on R&D (GERD) was 3.75% of GDP in 2008, the highest in the OECD area, although down from 4.2% in 2001. Industry funded 64% of GERD in 2007 (down from 72% in 2001), while government financed 22%. GERD per capita is USD 1 380 in current PPP, the highest in the OECD area. Venture capital intensity is well above average.

The composition of GERD by performance sector has remained fairly steady in recent years: business enterprises performed 74% of GERD in 2008, the higher education sector 21% and the government 4.4%. In 2008, business expenditure on R&D (BERD) was 2.8% of GDP, the highest in the OECD area. Venture capital intensity in 2008 was 0.2% of GDP, the second highest level in the OECD area.

Sweden's 88 triadic patents per million population were the third highest in the OECD area in 2008. Patenting, as well as international co-operation on patenting, increased during 2004-06. The share of co-invented patents has increased substantially since 1996-98. The 1 558 scientific articles per million population in 2008 were exceeded by only three countries. During 2004-06, a high 23% of firms introduced new-to-market product innovations.

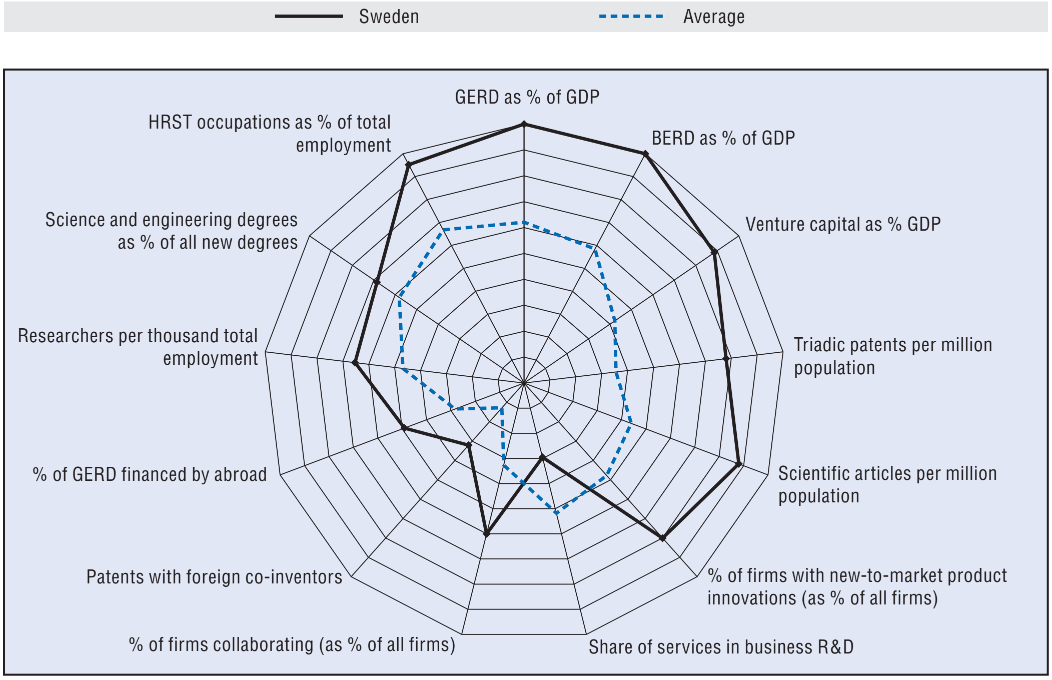
In 2007, the services sector, a sector strongly marked by the presence of foreign affiliates, conducted a comparatively low 15.3% of R&D. A high 18% of firms collaborated on innovation activities during 2004-06, and one-fifth of Patent Cooperation Treaty (PCT) patent applications in 2005-07 involved international co-inventors. In 2007, the 9.3% of GERD financed from abroad was three times higher than in 2001.

Sweden's performance on human resources in science and technology (HRST) indicators is strong. In 2008 its 11 researchers per thousand employment was the fourth highest in the OECD area, and the 25% of science and engineering degrees in all new degrees was above the OECD average. At 40%, HRST occupations are well-represented in total employment and equally distributed between technicians and professionals. Women account for half of these positions.

Sweden's GDP grew at an average annual rate of 3.1% between 2001 and 2007, but economic activity contracted by 0.4% in 2008 and 5.2% in 2009. Unemployment increased from 6.1% in 2007 to 8.3% in 2009. Labour productivity increased between 3% and 4% from 2001 and 2006, but declined in 2007 and 2008. Relative to the United States, Sweden's GDP per capita was 78% in 2008.

In 2008, the government introduced a five-year Research and Innovation Bill, stipulating that new funding will be allocated to a number of strategic areas on a competitive basis. Sustainable future growth depends on relying less on the limited number of large firms and focusing more on developing SMEs and attracting green investment.

Science and innovation profile of Sweden



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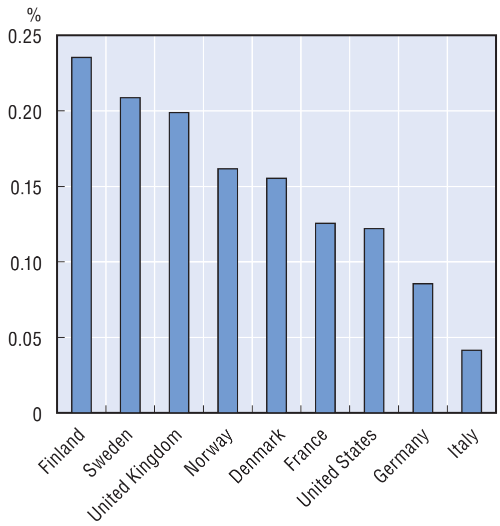
Venture capital investment

As a percentage of GDP, selected countries, 2008



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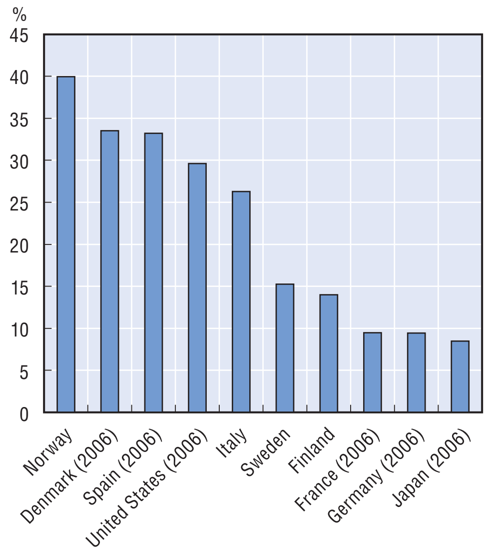
BERD performed in service industries

As a percentage of total BERD, 2007



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SWITZERLAND

Switzerland's economy enjoys stable economic growth and low unemployment. It has a highly skilled labour force and its per capita GDP is among the highest in the world. Its gross expenditure on R&D (GERD) was 3% of GDP in 2008. Industry financed 68% of GERD, while the government funded 23%. The main beneficiaries were small and medium-sized firms, which received more than 40% of government R&D funding. The business enterprise sector performed 74% of GERD and the higher education sector 24%. In 2008, Switzerland's business expenditure on R&D (BERD) was 2.2% of GDP, the fifth highest in the OECD, and venture capital intensity increased to 0.13% of GDP.

These strong inputs translate into above-average outcomes. Patent intensity in particular has increased over recent years, and Switzerland's 186 triadic patent families per billion USD of industry-funded R&D were the second highest in the OECD area. In 2008, its 113 triadic patents per million population and its 1 770 scientific articles per million population were the highest in the OECD area. Switzerland ranks in the top three countries on scientific publications in environmental sciences. Other prominent research is conducted in biosciences such as brain research, genomics, and regenerative and plant science. However, Switzerland recorded a low average annual growth of 0.9% in triadic patents over the decade to 2008.

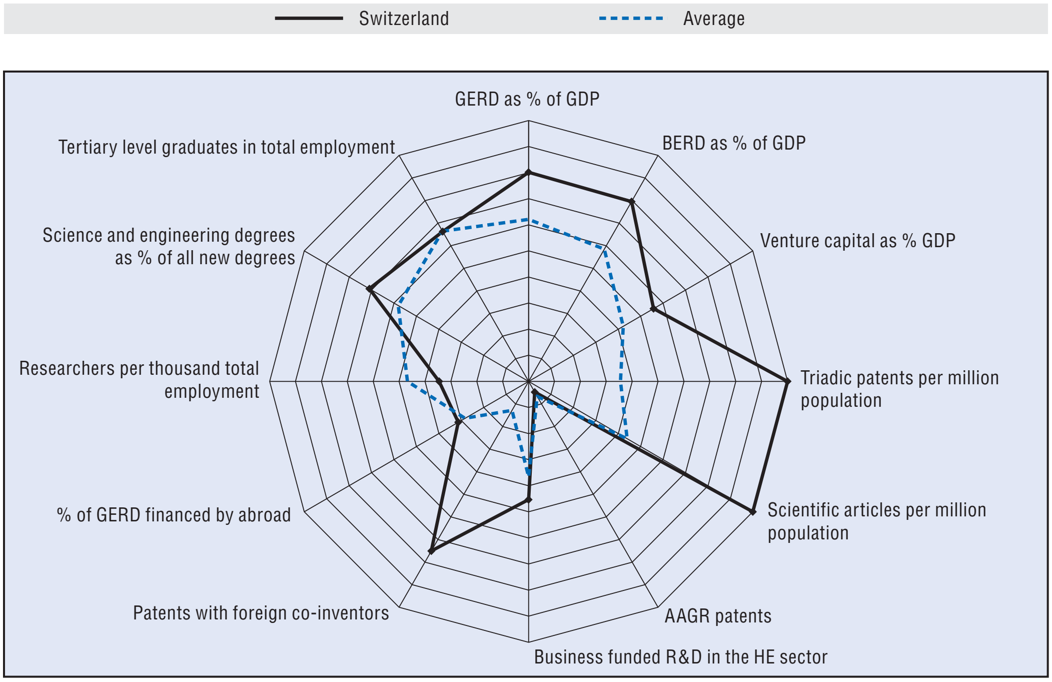
Indicators measuring innovation linkages are generally strong. The 6% of GERD financed from abroad was slightly above the average (5.4%). A very high 45% of Patent Cooperation Treaty (PCT) patent applications in 2005-07 had foreign co-inventors. The 6.9% of business-funded R&D performed in the higher education sector was slightly above the average.

Switzerland's performance in human resources in science and technology (HRST) indicators is mixed. The country attracts many foreign students: more than 40% of doctoral students are foreigners. However, its six researchers per thousand employment is below the average. In 2007, science and engineering degrees were 26% of all new degrees, above the OECD average, and tertiary graduates accounted for around one-third of total employment.

Switzerland's GDP grew at an average annual rate of 2.1% between 2001 and 2007. Growth slowed to 1.8% in 2008 and GDP contracted by 1.5% in 2009. Unemployment increased modestly from 3.6% in 2007 to 4.2% in 2009. Average annual labour productivity increased by about 1% during 2001-07, slowing in late 2007 and stagnating in 2008. GDP per capita was 91% relative to the United States in 2008.

The most important innovation policy document is the Statement to the Promotion of Education, Research and Innovation 2008-2011 (ERI Message). It is the government's medium-term policy in the form of a four-year plan for education, research and technology at the federal level. Investment in human capital should also be encouraged to strengthen higher education outcomes.

Science and innovation profile of Switzerland



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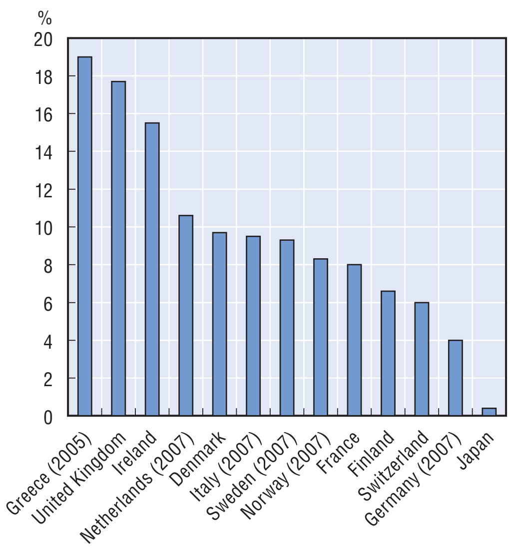
Gross expenditure on R&D financed from abroad

As a percentage of total GERD, 2008



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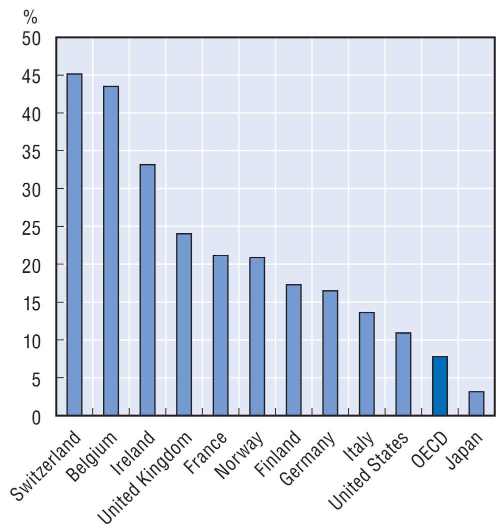
PCT patent applications

As a percentage of applications with co-inventors located abroad, 2005-07



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TURKEY

Turkey has a dynamic economy, characterised by a complex mix of modern industry and commerce and a traditional agriculture sector. The largest industrial sector is textiles and clothing and accounts for one-third of industrial employment. The automotive and electronics industries are growing in importance and have surpassed textiles in Turkey's export composition. While Turkey's science and innovation indicators lag those of most OECD countries, there has been some strong performance in recent years.

Turkey's gross expenditure on R&D (GERD) in 2008 was 0.73% of GDP and has increased substantially from 0.37% in 1998. GERD in real terms increased by an average annual 11% since 1998 and by 15% since 2003. Industry financed 47% of GERD in 2008, and the government funded 32%. Industry-financed GERD was a small 0.3% of GDP in 2008 but has doubled in the past decade. Turkey's business expenditure on R&D (BERD) totalled 0.3% of GDP in 2008, the fifth lowest in the OECD, but has increased sharply. BERD in real terms has grown by an average annual 18% in the ten years to 2008.

In 2008 Turkey had less than one triadic patent per million population and 272 scientific articles per million population. However, growth in scientific articles has been strong, with output more than tripling in the decade to 2008; triadic patents have also grown strongly at a compound annual rate of 9%. An above-average 19% of firms introduced new-to-market innovations during 2004-06 and an also above-average 51% of firms introduced non-technological innovations.

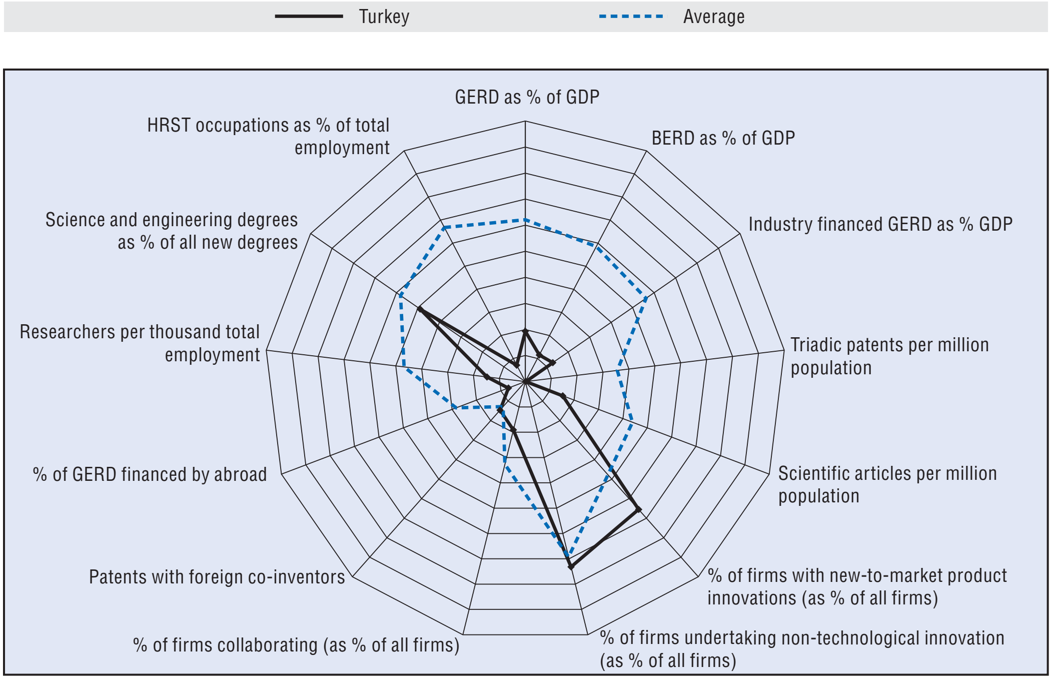
Indicators measuring innovation linkages are weak. Only 1.3% of GERD was financed from abroad in 2008, and a small 6% of firms collaborated on innovation activities in 2004-06. However, an above-average 9% of Patent Cooperation Treaty (PCT) patent applications in 2005-07 were with foreign co-inventors.

Turkey's indicators measuring human resources in science and technology (HRST) are weak. In 2007, it had only 2.4 researchers per thousand employment, but researcher numbers have grown by more than 12% over the past decade. Unemployment among graduates remains high at 6.9%. The 18% of science and engineering degrees in all new degrees was low, as was the 12.7% of HRST occupations in total employment in 2008.

Turkey's GDP grew at a robust average annual rate of 6.8% between 2001 and 2007. Growth slowed to 0.7% in 2008 and GDP contracted by 4.7% in 2009; unemployment increased from 8.8% in 2007 to 12.6% in 2009. GDP per capita was 30% relative to the United States in 2008.

The goals and objectives of innovation policy in Turkey are encapsulated in the Ninth Development Plan (2007-13), the Medium-Term Programme (2008-10), the Implementation Plan for the National Science and Technology Strategy (2005-10) and the National Innovation Strategy (2008-10). The second implementation plan for 2011-16 (National Science, Technology and Innovation Policies Implementation Plan) is in preparation and focuses on energy, water and food.

Science and innovation profile of Turkey



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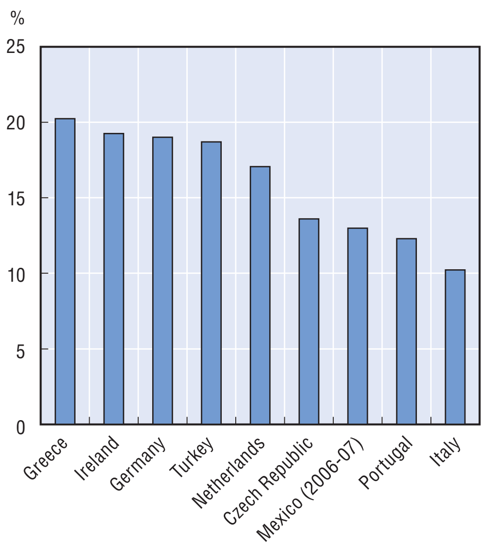
Firms with new-to-market product innovation

As a percentage of all firms, 2004-06



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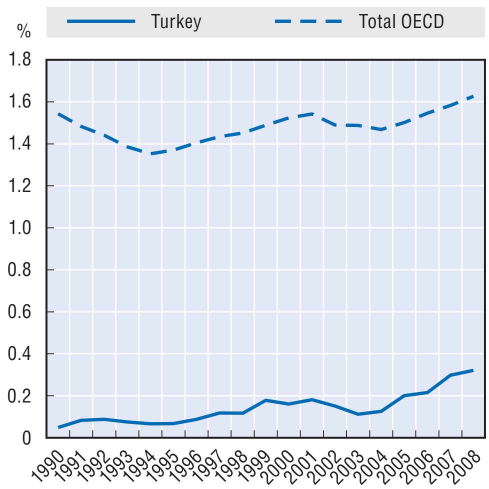
Business expenditure on R&D

As a percentage of GDP



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UNITED KINGDOM

The United Kingdom has the world's sixth largest economy and performs strongly on a range of science and innovation indicators. In 2008 it contributed almost 12% of OECD-area venture capital funds, and venture capital intensity was double the average at 0.2% of GDP. Also in 2008, the United Kingdom published 76 683 scientific articles, the third highest in the OECD area after the United States and Japan; at 1 250 per million population, this is well above the OECD average.

Gross expenditure on R&D (GERD) was below the OECD average in 2008, with GERD at 1.8% of GDP. Growth in real GERD strengthened to an average annual 3.3% over 2004-08. In 2008 industry financed 45% of GERD and government funded 31%. Business expenditure on R&D (BERD) was 1.1% of GDP in the same year. Most R&D in the United Kingdom is performed by large firms. With 4% of Patent Cooperation Treaty (PCT) patent applications in 2007, the United Kingdom had the sixth highest country share, but its 27 triadic patents per million population in 2008 were below average. During 2004-06 12% of firms introduced new-to-market product innovations, slightly below the average of 14%, and 44% conducted non-technological innovation.

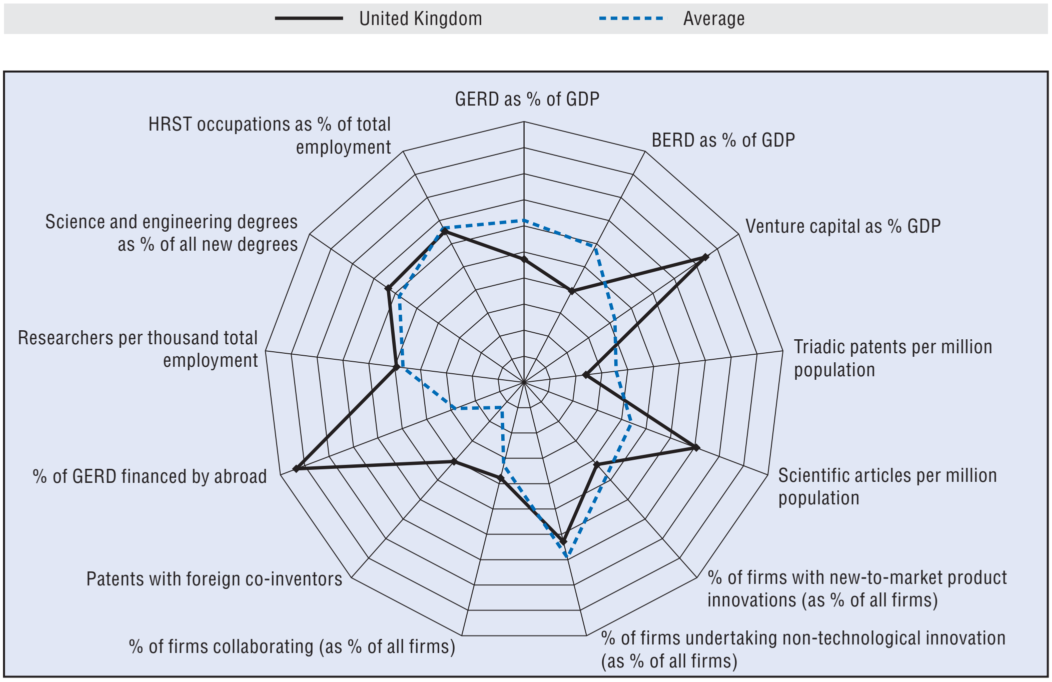
Innovation linkages are mostly strong. Around 11% of firms collaborated on innovation during 2004-06 and one in four Patent Cooperation Treaty (PCT) patent applications during 2005-07 had foreign involvement. Almost 18% of GERD was financed from abroad in 2008, more than three times the average.

In 2008, the country's eight researchers per thousand employment were slightly above average, as were the 23% of science and engineering degrees in all new degrees. The United Kingdom has the highest international doctoral student enrolment after the United States. Human resources in science and technology (HRST) occupations reached 27% of total employment.

GDP expanded by 2.5% a year between 2001 and 2007. In 2008, however, the global financial crisis hit the economy particularly hard. Because of the importance of the financial sector, growth slowed to 0.5% in 2008. In 2009 GDP contracted by 4.9% and unemployment rose to 7.6%. Labour productivity growth slowed from 2.1% during 2001-07 to 1% in 2008.

With the election of a new government in May 2010, innovation policies in the United Kingdom are subject to change. Before 2010 the United Kingdom's innovation policy was based on the Science and Innovation Investment Framework (SIIF). In 2006 the Sainsbury Review recommended an annual innovation review, the latest was published in early 2010. In 2009 the Department of Business Innovation and Skills (BIS) merged two departments dealing with industry, enterprise and innovation into one. In March 2008, BIS published a White Paper, *Innovation Nation*. Another White Paper, *Building Britain's Future: New Industry, New Jobs*, sets out ways to strengthen competitiveness. Focus areas include maximising the economic impact of research and creating business opportunities in future growth areas such as advanced manufacturing, clean technology, life sciences and the digital economy.

Science and innovation profile of the United Kingdom



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Complementary innovation strategies in services

As a percentage of all services firms, 2004-06

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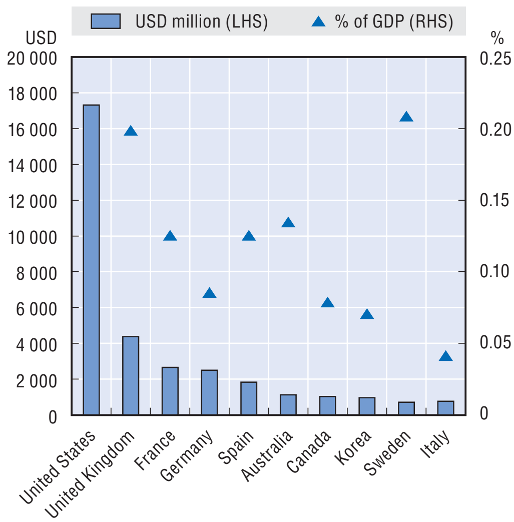
Venture capital investment

Selected countries, USD million, and % of GDP, 2008



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UNITED STATES

The United States has the world's largest economy, with GDP exceeding USD 14 trillion and GDP per capita of USD 46 400 in 2009. US firms are at or near the forefront of technological advances in a number of areas and the country has quite a strong science and innovation profile.

In 2008, gross expenditure on R&D (GERD) increased to 2.8% and GERD per capita was USD 1 307 in current PPP, the fourth highest in the OECD area after Sweden, Luxembourg and Finland. In 2008, two-thirds of GERD was financed by industry and 27% by government. In the same year, business enterprises performed 73% of GERD, the higher education sector 13% and the government sector 11%. Business expenditure on R&D (BERD) increased to 2% of GDP in 2008, the highest level since 2000. BERD is skewed in favour of larger firms and high-technology manufacturing, the latter accounting for 67% of total manufacturing R&D; a low 15% is performed by small and medium-sized firms. Business R&D performed in the services sector declined from 41% in 2002 to 30% in 2006. In 2008, venture capital intensity was 0.12% of GDP, above the average.

Although its triadic patents grew at a modest 0.2% average annual rate in the decade to 2008, the United States recorded 49 patents per million population. It accounts for a significant 43% of all pharmaceutical patents, half of all medical patents and almost 20% of all environmental patents. It published 277 446 scientific articles, the highest in the world, and accounted for 16% of world scientific publishing, although this share has been falling in recent years. In 2008, its 911 scientific articles per million population was above average.

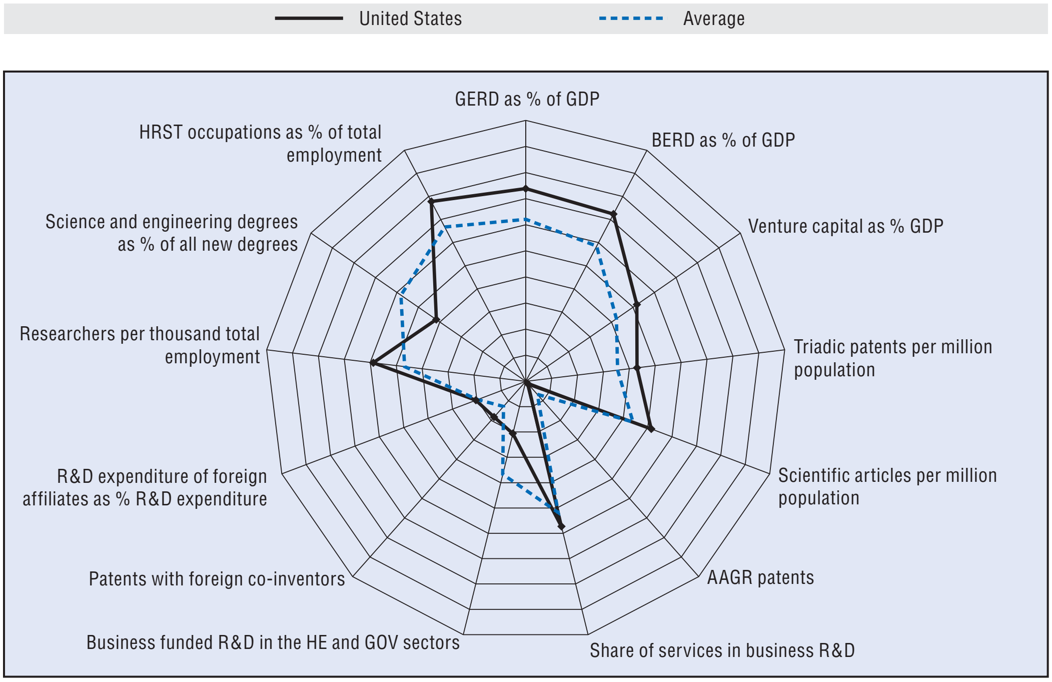
Indicators for international linkages vary. R&D expenditures of foreign affiliates are a comparatively low 15%. However, during 2005-07 the 11% of patents with a foreign co-inventor was above average. In 2008 the higher education and government sectors performed a modest 3.1% of business-funded R&D.

Human resources in science and technology (HRST) indicators are mostly strong. In 2006 the United States had 1.4 million researchers, or ten per thousand employment. More than one-third of all new university students graduated successfully, and the United States awards 28% of all doctorates in the OECD area. Science and engineering degrees are 15% of all new degrees, however, below the OECD average. HRST occupations comprise around one-third of total employment.

GDP expanded by 2.6% a year between 2001 and 2007, followed by a recession in mid-2008. GDP contracted by 4% in 2009 and unemployment rose to 9.3%. In January 2009, the government enacted a stimulus package, the American Recovery and Reinvestment Act 2009, which includes nearly USD 100 billion in science, technology and innovation investments.

In September 2009, a White Paper, *Strategy for American Innovation: Driving towards Sustainable Growth and Quality Jobs*, outlined the key science, technology and innovation policies of the Office of Science and Technology Policy. The most recent budget announced the doubling of the funding for three key science agencies: the National Science Foundation (NSF), the Department of Energy's Office of Science (DOE SC) and the National Institute of Standards and Technology (NIST) laboratories.

Science and innovation profile of the United States



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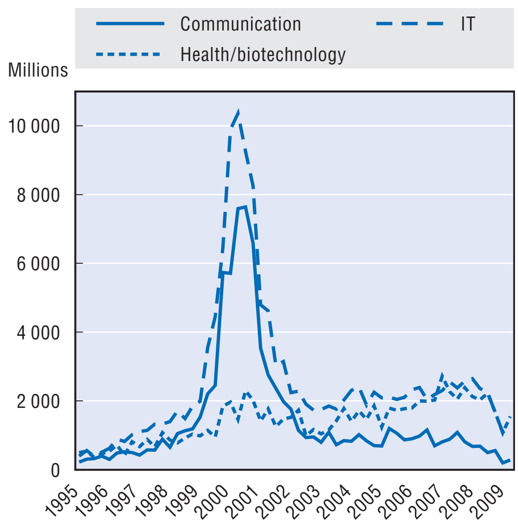
US venture capital investment by industry

USD million, 1995-2009



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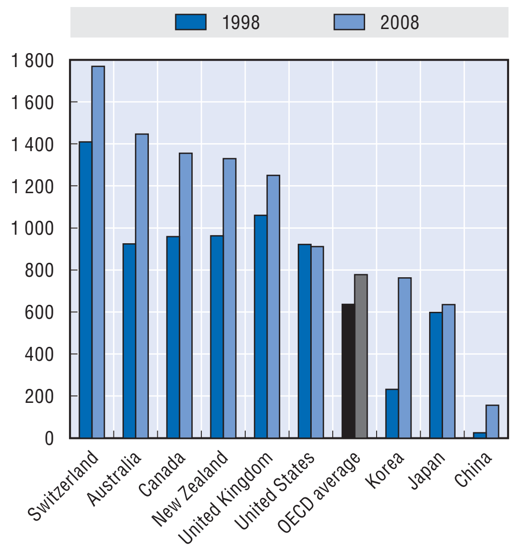
Scientific articles published

Per million population, 1998 and 2008



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ANNEX 3.A1

Description of indicators and method

The first graph for each country, the radar graph, illustrates its position against the average performance on a set of common indicators. Where possible, the OECD average is used. Data for non-OECD countries are not included in the average. The selected indicators are based on policy relevance, as well as on the availability of comparable data for the majority of countries in order to provide a broad snapshot of science and innovation performance. They focus on research and innovation inputs, scientific and innovation outcomes, linkages and networks, including international linkages and human resources. As an overview:

- *Gross expenditure on R&D (GERD) as a percentage of GDP* is the main aggregate used for international comparison of R&D expenditures. It represents a country's domestic R&D-related expenditure for a given year.
- *Business enterprise expenditure on R&D (BERD) as a percentage of GDP* is an indicator of R&D activities carried out in the business sector by performing firms and institutes, regardless of the origin of funding. Industrial R&D is most closely linked to the creation of new products and production techniques, as well as to a country's innovation efforts.
- *Venture capital as a percentage of GDP* is a measure of one important source of funding for new technology-based firms. Venture capital plays a crucial role in promoting the radical innovations often developed by such firms and is one of the decisive determinants of entrepreneurship.
- *Triadic patents per million population* is an indicator of innovation outputs, adjusted to account for the size of the country. Triadic patents are a set of patents taken at the European Patent Office, the Japan Patent Office and the US Patent and Trademark Office that protect the same invention. The use of triadic patents as an indicator eliminates the problems of home advantage and influence of geographical locations that are encountered with single-office patent indicators and thus improves the international comparability of the data.
- *Scientific articles per million population* is an indicator often used to highlight the scientific "productivity" of countries and is an important measure of research output, since publication is the main means of disseminating and validating research results. Article counts used in this publication are based on all subject disciplines contained in the Elsevier Scopus Database. Articles are sourced from journals and conference proceedings and include: articles, reviews, conference papers, conference reviews, and notes. Calculations are based on the address of the institution to which authors belong, and fractional counts. Some caveats regarding this indicator should be noted: the journals have good international coverage, although journals of regional or local importance may not be included; there is an English-language bias; the propensity to publish differs across countries and fields of study; and incentives to publish can lead to questions about quality.
- *Percentage of firms with new-to-market product innovations* provides a measure of innovation and novelty. Firms that first develop innovations can be considered as drivers of the process of

innovation. Many new ideas and knowledge originate from these firms, with the full economic impact of their innovations depending on their adoption by other firms.

- *Percentage of firms undertaking non-technological innovation* looks more closely at marketing and organisational innovations, an important dimension of many firms' innovation activities. They are particularly relevant for service firms.
- *Percentage of firms collaborating on innovation* aims to highlight the extent of active participation in joint innovation projects with other organisations. Collaboration is an important part of the innovation activities of many firms, and can involve the joint development of new products, processes or other innovations with customers and suppliers, as well as horizontal work with other enterprises or public research bodies.
- *Patents with foreign co-inventors* is one measure of the internationalisation of research. It constitutes an indicator of formal R&D co-operation and knowledge exchange between inventors located in different countries. It highlights how institutions seek competences or resources beyond their national borders.
- *Percentage of GERD financed by abroad* is another measure of internationalisation. Foreign funding of R&D is an important source of financing for many countries.
- *Researchers per thousand total employment* measures one of the central human resource elements of the research and development system. Researchers are professionals engaged in the conception and creation of new knowledge, products, processes, methods and systems and are directly involved in the management of projects.
- *Science and engineering degrees as a percentage of all new degrees* is an indicator of a country's potential for assimilating, developing and diffusing advanced knowledge and supplying the labour market with human resources that possess critical skills for research and development.
- *HRST occupations as a percentage of total employment* is an indicator of the extent of innovation-related skills in the workforce. This category of workers corresponds to professionals and technicians as defined in the International Standard Classification of Occupations (ISCO-88).

To construct the radar graphs, the raw data for each indicator (shown in Table 3.A1.1 of Annex 3.A1) was transformed into an index, with the OECD country with the maximum value of the indicator taking an index value of 100 and the other countries taking values below this as appropriate. For example, for the indicator on *Gross expenditure on R&D (GERD) as a percentage of GDP*, Israel was the country with the highest value (4.86%) but, at the time of writing, was not yet an OECD country. Sweden had the highest OECD value (3.75%), and therefore took the index value of 100. Following the transformation of the raw data into indices, an OECD average for each indicator was obtained where possible. This allowed the construction of an average value for each indicator (the dotted line in the radar graphs) against which individual country results were plotted (the solid line in the radar graphs). It should be noted that in some cases, OECD countries were excluded from the average due to data comparability (*e.g.* when the data only represented a particular sector, see notes to Table 3.A1.2). In addition, in some cases, it was not possible to construct an "OECD average" because the data were unavailable, *e.g.* not all countries run an innovation survey, so an "average" was constructed with available data.

In some instances of data unavailability, alternative indicators were used, if considered a suitable replacement. These alternative indicators are specified in

Table 3.A1.1. For example, for the indicator on *Venture capital as a percentage of GDP*, the alternative indicator *Industry-financed GERD as a percentage of GDP* was used for a number of countries. To calculate the radar indicator in this case, an index for *Industry-financed GERD as a percentage of GDP* was constructed in the same manner as described above. The index values yielded for these countries were then used as an alternative for *Venture capital as a percentage of GDP*.

Table 3.A1.1. **Radar graph indicators and values (non-OECD countries are in shaded rows)**

Country	GERD as % of GDP	BERD as % of GDP	Venture capital as % GDP	Triadic patents per million population	Scientific articles per million population	% of firms with new-to-market product innovations (as a % of all firms)	% of firms undertaking non-technological innovation (as a % of all firms)	% of firms collaborating (as a % of all firms)	% of patents with foreign co-inventors	% of GERD financed by abroad	Researchers per 1 000 total employment	Science and engineering degrees as % of all new degrees	HRST occupations as % of total employment
Australia													
Value	1.97	1.22	0.13	14.63	1 447.60	9.56	42.74	11.84	15.62	2.41	8.48	20.39	35.77
Reference year	2006	2007	2008	2008	2008	2006-07	2006-07	2006-07	2005-07	2006	2006	2007	2008
Austria													
Value	2.68	1.89	0.03	51.66	973.34	23.01	55.99	19.70	26.66	16.52	8.39	31.18	29.85
Reference year	2008	2008	2008	2008	2008	2004-06	2004-06	2004-06	2005-07	2008	2008	2007	2008
Belgium													
Value	1.92	1.32	0.10	38.63	1 110.36	21.59	34.87	18.25	43.71	13.00	8.16	22.85	32.48
Reference year	2008	2008	2008	2008	2008	2004-06	2004-06	2004-06	2005-07	2007	2008	2007	2008
Brazil													
Value	1.09	0.50	–	0.34	141.37	3.56	36.10	2.91	17.72	–	1.48	10.95	% pop. aged 25-64 with tertiary degree (10.80)
Reference year	2008	2008	–	2008	2008	2003-05	2003-05	2003-05	2005-07	–	2006	2007	% pop. aged 25-64 with tertiary degree (2008)
Canada													
Value	1.84	1.00	0.08	19.16	1 356.15	31.20 (manuf. only)	Share of services in business R&D (35.81)	14.10 (manuf. only)	29.08	9.34	8.34	22.44	35.51
Reference year	2008	2008	2008	2008	2008	2002-04 (manuf. only)	Share of services in business R&D (2006)	2002-04 (manuf. only)	2005-07	2008	2007	2007	2008

Table 3.A1.1. **Radar graph indicators and values (non-OECD countries are in shaded rows)** *(cont.)*

Country	GERD as % of GDP	BERD as % of GDP	Venture capital as % GDP	Triadic patents per million population	Scientific articles per million population	% of firms with new-to-market product innovations (as a % of all firms)	% of firms undertaking non-technological innovation (as a % of all firms)	% of firms collaborating (as a % of all firms)	% of patents with foreign co-inventors	% of GERD financed by abroad	Researchers per 1 000 total employment	Science and engineering degrees as % of all new degrees	HRST occupations as % of total employment
Chile													
Value	0.67	0.31	–	0.36	185.02	11.50	33.40	17.46	38.79	8.67	3.20	18.57	% pop aged 25-64 with tertiary degree (24.19)
Reference year	2004	2004	–	2008	2008	2004-06	2004-06	2004-06	2005-07	2004	2004	2007	% pop aged 25-64 with tertiary degree (2008)
China													
Value	1.54	1.12	Industry-financed GERD as % GDP (1.10)	0.39	156.23	14.64	–	5.98	12.6	1.24	2.06	39.18	% pop aged 25-64 with tertiary degree (9.48)
Reference year	2008	2008	Industry-financed GERD as % GDP (2008)	2008	2008	2004-06	–	2004-06	2005-07	2008	2008	2005	% pop aged 25-64 with tertiary degree (2005)
Czech Republic													
Value	1.47	0.91	0.12	2.24	714.55	13.60	37.79	13.38	33.61	5.35	5.63	24.99	33.81
Reference year	2008	2008	2008	2008	2008	2004-06	2004-06	2004-06	2005-07	2008	2008	2007	2008
Denmark													
Value	2.72	1.91	0.16	60.47	1 359.22	15.84	46.68	16.05	19.35	9.71	10.49	19.80	39.14
Reference year	2008	2008	2008	2008	2008	2004-06	2004-06	2004-06	2005-07	2008	2008	2007	2008
Estonia													
Value	1.14	0.50	–	4.47	668.30	15.81	49.38	19.01	30.56	–	5.40	23.44	% pop aged 25-64 with tertiary degree (34.12)
Reference year	2006	2006	–	2008	2008	2004-06	2004-06	2004-06	2005-07	–	2006	2007	% pop aged 25-64 with tertiary degree (2008)

Table 3.A1.1. **Radar graph indicators and values (non-OECD countries are in shaded rows)** *(cont.)*

Country	GERD as % of GDP	BERD as % of GDP	Venture capital as % GDP	Triadic patents per million population	Scientific articles per million population	% of firms with new-to-market product innovations (as a % of all firms)	% of firms undertaking non-technological innovation (as a % of all firms)	% of firms collaborating (as a % of all firms)	% of patents with foreign co-inventors	% of GERD financed by abroad	Researchers per 1 000 total employment	Science and engineering degrees as % of all new degrees	HRST occupations as % of total employment
Finland													
Value	3.73	2.77	0.24	63.87	1 573.30	22.97	41.94	29.70	17.59	6.64	16.19	28.75	34.20
Reference year	2008	2008	2008	2008	2008	2004-06	2004-06	2004-06	2005-07	2008	2008	2007	2008
France													
Value	2.02	1.27	0.13	37.90	799.55	12.57	23.08	12.87	21.44	7.99	8.39	27.58	32.25
Reference year	2008	2008	2008	2008	2008	2002-04	2002-04	2002-04	2005-07	2008	2007	2007	2008
Germany													
Value	2.64	1.85	0.09	73.40	819.98	19.02	69.36	10.48	16.74	4.01	7.48	28.05	35.99
Reference year	2008	2008	2008	2008	2008	2004-06	2004-06	2004-06	2005-07	2007	2008	2007	2008
Greece													
Value	0.58	0.16	0.01	1.20	902.16	20.23	51.77	14.21	28.50	18.99	4.43	23.35	23.29
Reference year	2007	2007	2008	2008	2008	2004-06	2004-06	2004-06	2005-07	2005	2007	2007	2008
Hungary													
Value	1.00	0.53	0.05	4.86	458.96	6.21	27.59	7.83	29.79	9.27	4.50	14.12	27.77
Reference year	2008	2008	2008	2008	2008	2004-06	2004-06	2004-06	2005-07	2008	2008	2007	2008
Iceland													
Value	2.65	1.45	Industry-financed GERD as % GDP (1.33)	11.65	1 178.51	27.30	45.70	15.34	37.59	10.04	12.92	12.92	Tertiary level graduates % in total employment (31.31)
Reference year	2008	2008	Industry-financed GERD as % GDP (2008)	2008	2008	2002-04	2002-04	2002-04	2005-07	2008	2008	2007	Tertiary level graduates % in total employment (2007)
India													
Value	0.71	0.14	–	0.14	35.05	AAGR patents (23.45)	–	–	24.54	–	0.35	–	% pop. aged 25-64 with tertiary degree (11.43)
Reference year	2004	2004	–	2008	2008	AAGR patents (1997-2007)	–	–	2005-07	–	2005	–	% pop. aged 25-64 with tertiary degree (2005)

Table 3.A1.1. **Radar graph indicators and values (non-OECD countries are in shaded rows)** *(cont.)*

Country	GERD as % of GDP	BERD as % of GDP	Venture capital as % GDP	Triadic patents per million population	Scientific articles per million population	% of firms with new-to-market product innovations (as a % of all firms)	% of firms undertaking non-technological innovation (as a % of all firms)	% of firms collaborating (as a % of all firms)	% of patents with foreign co-inventors	% of GERD financed by abroad	Researchers per 1 000 total employment	Science and engineering degrees as % of all new degrees	HRST occupations as % of total employment
Ireland													
Value	1.43	0.93	0.13	18.74	1 064.63	19.26	36.28	12.76	33.91	15.51	6.40	21.14	23.60
Reference year	2008	2008	2008	2008	2008	2004-06	2002-04	2004-06	2005-07	2008	2008	2007	2008
Israel													
Value	4.86	3.93	Industry-financed GERD as % GDP (3.40)	65.86	1 380.41	–	–	Business-funded R&D in HE and GOV (9.28)	15.37	3.02	–	20.80	% pop. aged 25-64 with tertiary degree (43.98)
Reference year	2008	2008	Industry-financed GERD as % GDP (2006)	2008	2008	–	–	Business-funded R&D in HE and GOV (2006)	2005-07	2006	–	2007	% pop. aged 25-64 with tertiary degree (2008)
Italy													
Value	1.19	0.60	0.04	12.46	742.79	10.22	21.34	4.66	13.61	9.52	3.81	20.96	31.47
Reference year	2008	2008	2008	2008	2008	2004-06	2002-04	2004-06	2005-07	2007	2008	2007	2008
Japan													
Value	3.42	2.69	Industry-financed GERD as % GDP (2.68)	110.62	635.13	8.20	61.60	6.61	2.87	0.38	10.64	24.14	14.88
Reference year	2008	2008	Industry-financed GERD as % GDP (2008)	2008	2008	1999-2001	1999-2001	1999-2001	2005-07	2008	2008	2007	2008
Korea													
Value	3.37	2.54	0.07	43.93	762.16	9.20 (manuf only)	17.10 (manuf. only)	8.37 (manuf. only)	4.60	0.31	10.02	35.96	18.59
Reference year	2008	2008	2008	2008	2008	2005-07 (manuf only)	2005-07 (manuf. only)	2005-07 (manuf. only)	2005-07	2008	2008	2007	2008

Table 3.A1.1. **Radar graph indicators and values (non-OECD countries are in shaded rows)** *(cont.)*

Country	GERD as % of GDP	BERD as % of GDP	Venture capital as % GDP	Triadic patents per million population	Scientific articles per million population	% of firms with new-to-market product innovations (as a % of all firms)	% of firms undertaking non-technological innovation (as a % of all firms)	% of firms collaborating (as a % of all firms)	% of patents with foreign co-inventors	% of GERD financed by abroad	Researchers per 1 000 total employment	Science and engineering degrees as % of all new degrees	HRST occupations as % of total employment
Luxembourg													
Value	1.62	1.32	Industry-financed GERD as % GDP (1.20)	48.67	384.93	28.54	61.76	16.16	60.31	5.66	6.54	31.47	41.55
Reference year	2008	2008	Industry-financed GERD as % GDP (2007)	2008	2008	2004-06	2004-06	2004-06	2005-07	2007	2008	2000	2008
Mexico													
Value	0.37	0.18	Industry-financed GERD as % GDP (0.17)	0.14	73.35	13.00	–	Business-funded R&D in HE and GOV (2.24)	21.66	1.38	0.88	24.65	Tertiary-level graduates % in total employment (18.19)
Reference year	2007	2007	Industry-financed GERD as % GDP (2007)	2008	2008	2006-07	–	Business-funded R&D in HE and GOV (2007)	2005-07	2007	2007	2007	Tertiary-level graduates % in total employment (2007)
Netherlands													
Value	1.75	0.89	0.10	65.67	1 330.51	17.07	30.01	13.59	18.98	10.65	5.79	14.18	37.55
Reference year	2008	2008	2008	2008	2008	2004-06	2004-06	2004-06	2005-07	2007	2008	2007	2008
New Zealand													
Value	1.21	0.51	Industry-financed GERD as % GDP (0.48)	10.79	1 329.52	17.56	38.39	15.52	19.26	4.81	10.76	17.31	28.59
Reference year	2007	2007	Industry-financed GERD as % GDP (2007)	2008	2008	2004-06	2004-06	2004-06	2005-07	2007	2007	2007	2008

Table 3.A1.1. **Radar graph indicators and values (non-OECD countries are in shaded rows)** *(cont.)*

Country	GERD as % of GDP	BERD as % of GDP	Venture capital as % GDP	Triadic patents per million population	Scientific articles per million population	% of firms with new-to-market product innovations (as a % of all firms)	% of firms undertaking non-technological innovation (as a % of all firms)	% of firms collaborating (as a % of all firms)	% of patents with foreign co-inventors	% of GERD financed by abroad	Researchers per 1 000 total employment	Science and engineering degrees as % of all new degrees	HRST occupations as % of total employment
Norway													
Value	1.62	0.87	0.16	25.08	1 356.10	14.16	22.73	10.51	21.25	8.31	9.94	15.08	37.97
Reference year	2008	2008	2008	2008	2008	2004-06	2004-06	2004-06	2005-07	2007	2008	2007	2008
Poland													
Value	0.61	0.19	0.02	0.59	410.57	7.53	30.85	11.08	33.20	5.42	3.93	16.95	26.23
Reference year	2008	2008	2008	2008	2008	2004-06	2004-06	2004-06	2005-07	2008	2008	2007	2008
Portugal													
Value	1.51	0.76	0.03	0.89	668.07	12.29	54.09	7.47	32.81	5.44	7.88	33.10	18.18
Reference year	2008	2008	2008	2008	2008	2004-06	2004-06	2004-06	2005-07	2007	2008	2007	2008
Russian Federation													
Value	1.03	0.65	Industry-financed GERD as % GDP (0.30)	0.45	176.06	1.76	3.26	Business-funded R&D in HE and GOV (15.35)	22.89	5.94	6.36	24.77	% pop. aged 25-64 with tertiary degree (54.37)
Reference year	2008	2008	Industry-financed GERD as % GDP (2008)	2008	2008	2006	2006	Business-funded R&D in HE and GOV (2008)	2005-07	2008	2008	2006	% pop. aged 25-64 with tertiary degree (2002)
Slovak Republic													
Value	0.47	0.20	Industry-financed GERD as % GDP (0.16)	0.68	457.21	9.36	14.13	8.89	46.41	12.29	5.63	23.80	29.05
Reference year	2008	2008	Industry-financed GERD as % GDP 2008	2008	2008	2004-06	2002-04	2004-06	2005-07	2008	2008	2007	2008

Table 3.A1.1. **Radar graph indicators and values (non-OECD countries are in shaded rows)** *(cont.)*

Country	GERD as % of GDP	BERD as % of GDP	Venture capital as % GDP	Triadic patents per million population	Scientific articles per million population	% of firms with new-to-market product innovations (as a % of all firms)	% of firms undertaking non-technological innovation (as a % of all firms)	% of firms collaborating (as a % of all firms)	% of patents with foreign co-inventors	% of GERD financed by abroad	Researchers per 1 000 total employment	Science and engineering degrees as % of all new degrees	HRST occupations as % of total employment
Slovenia													
Value	1.66	1.07	Industry-financed GERD as % GDP (1.04)	9.35	1 232.77	17.90	26.86	17.60	19.55	5.59	7.06	18.11	% pop. aged 25-64 with tertiary degree (22.64)
Reference year	2008	2008	Industry-financed GERD as % GDP (2008)	2008	2008	2004-06	2004-06	2004-06	2005-07	2008	2008	2007	% pop. aged 25-64 with tertiary degree (2008)
South Africa													
Value	0.92	0.53	Industry-financed GERD as % GDP (0.39)	0.56	109.86	21.10	60.70	22.32	11.23	10.67	1.46	16.41	–
Reference year	2007	2007	Industry-financed GERD as % GDP (2007)	2008	2008	2002-04	2002-04	2002-04	2005-07	2007	2007	2003	–
Spain													
Value	1.35	0.74	0.13	5.13	790.59	6.14	20.90	5.70	18.87	7.01	6.39	24.37	24.75
Reference year	2008	2008	2008	2008	2008	2004-06	2002-04	2004-06	2005-07	2007	2008	2007	2008
Sweden													
Value	3.75	2.78	0.21	88.33	1 557.53	22.85	Share of services in business R&D (15.27)	17.83	19.34	9.32	10.58	24.64	39.55
Reference year	2008	2008	2008	2008	2008	2004-06	Share of services in business R&D (2007)	2004-06	2005-07	2007	2008	2007	2008

Table 3.A1.1. **Radar graph indicators and values (non-OECD countries are in shaded rows)** *(cont.)*

Country	GERD as % of GDP	BERD as % of GDP	Venture capital as % GDP	Triadic patents per million population	Scientific articles per million population	% of firms with new-to-market product innovations (as a % of all firms)	% of firms undertaking non-technological innovation (as a % of all firms)	% of firms collaborating (as a % of all firms)	% of patents with foreign co-inventors	% of GERD financed by abroad	Researchers per 1 000 total employment	Science and engineering degrees as % of all new degrees	HRST occupations as % of total employment
Switzerland													
Value	3.01	2.21	0.13	113.24	1 769.77	AAGR patents (0.85)	–	Business-funded R&D in HE (6.85)	45.28	5.95	5.59	25.52	Tertiary level graduates % in total employment (34.45)
Reference year	2008	2008	2008	2008	2008	AAGR patents 1998-2008	–	Business-funded R&D in HE (2008)	2005-07	2008	2008	2007	Tertiary level graduates % in total employment (2007)
Turkey													
Value	0.73	0.32	Industry-financed GERD as a % of GDP (0.34)	0.25	271.57	18.70	50.77	5.66	8.81	1.31	2.40	17.61	12.74
Reference year	2008	2008	Industry-financed GERD as a % of GDP (2008)	2008	2008	2004-06	2004-06	2004-06	2005-07	2008	2007	2007	2008
United Kingdom													
Value	1.77	1.10	0.20	27.01	1 249.93	12.03	43.60	11.22	24.46	17.75	7.98	22.78	27.16
Reference year	2008	2008	2008	2008	2008	2004-06	2007	2004-06	2005-07	2008	2008	2007	2008
United States													
Value	2.77	2.01	0.12	48.69	911.07	AAGR patents (0.24)	Share of services in business R&D (29.60)	Business-funded R&D in HE and GOV (3.11)	11.03	R&D exp. of foreign affiliates as a % of R&D exp (14.78)	9.53	14.98	32.32
Reference year	2008	2008	2008	2008	2008	1998-2008	Share of services in business R&D (2006)	Business-funded R&D in HE and GOV (2008)	2005-07	R&D exp. of foreign affiliates as a % of R&D exp (2007)	2007	2007	2008

1. The table shows actual indicator values and reference years. For each indicator in the radar graph, the OECD country with the maximum Value is set at 100 and the average is calculated by taking into account all OECD countries with available data. If a non-OECD country has a Value higher than the OECD Value, it is set as equivalent to the highest OECD Value.

Table 3.A1.2. **Radar graph country with maximum value**

Indicator	All countries	OECD countries
Gross expenditure on R&D (GERD) as % of GDP	Israel[1]	Sweden
Business expenditure on R&D (BERD) as % of GDP	Israel[1]	Sweden
Venture capital as % GDP	Finland	Finland
Industry-financed GERD as % GDP*	Israel[1]	Japan
Triadic patent families per million population	Switzerland	Switzerland
Scientific articles per million population	Switzerland	Switzerland
% of firms with new-to-market product innovations (as a % of all firms)	Luxembourg[2]	Luxembourg[2]
Average annual growth rate (AAGR) patents 1998-2008*	China	Poland
% of firms undertaking non-technological innovation (as a % of all firms)	Germany[3]	Germany[3]
Share of services in business R&D*	Slovak Republic	Slovak Republic
% of firms collaborating (as a % of all firms)	Finland	Finland
Business funded R&D in the higher education (HE) and government (GOV) sectors	Russian Federation	Turkey
Patents with foreign co-inventors	Luxembourg	Luxembourg
R&D expenditure of foreign affiliates as % R&D expenditure*	Ireland	Ireland
% of GERD financed by abroad	Greece	Greece
Researchers per 1 000 total employment	Finland	Finland
Science and engineering degrees as % of all new degrees	Korea	Korea
Human resources for science and technology (HRST) occupations as % of total employment	Luxemburg	Luxemburg
Tertiary-level graduates in total employment*	Canada	Canada
Educational attainment as a % of population aged 25 to 64 with tertiary degree*	Russian Federation	Canada
Triadic patents average annual growth rate 1997-2007*	Turkey	Turkey

* Represents alternative indicators.

1. On 7 September 2010, Israel became a member of the OECD. However, references to OECD historical averages in this chapter do not yet include Israel.
2. Canada had the highest value in the OECD; however, the data refer to manufacturing only and were therefore excluded from the average. Luxembourg's value was used to set the maximum. See Table 3.A1.3.
3. Japanese data refer to the period 1999-2001 and were therefore excluded from the average.

Table 3.A1.3. **Radar graph data sources and methodological notes**

Indicator	Notes	Source
Gross expenditure on R&D (GERD) as % of GDP	See MSTI for full notes. Data collected from national sources might not be fully compatible with OECD data.	OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1; data for Brazil, Chile, Estonia and India have been compiled from national sources.
Business expenditure on R&D (BERD) as % of GDP	See MSTI for full notes. Data collected from national sources might not be fully compatible with OECD data.	OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1; Data for Brazil, Chile (CONICYT), Estonia and India compiled from national sources.
Venture capital as % GDP	The OECD defines venture capital (VC)as the sum of "seed/ start-up stages" and "early development and expansion stages". The coverage of VC stages within these two broad groups differs across countries and the data may therefore not be fully comparable. For example, "early development and expansion stages" includes: For Australia, early expansion, late expansion and turnaround; for Canada, other early stage, expansion and turnaround; for Korea, initial-early stage, middle stage-early (firms 3-5 years), and middle stage-late (firms 5-7 years); for the United Kingdom, other early stage and expansion; for the United States and Israel, early stage and expansion; for European countries (except United Kingdom), growth and rescue/ turnaround. The OECD is currently revising its VC data and the future definition of VC is likely to exclude turnaround, rescue and late expansion stages. Due to data availability, the average does not include Chile, Iceland, Japan, Luxembourg, Mexico, New Zealand, Slovak Republic, Slovenia, or Turkey.	OECD, based on data from Thomson Financial, PwC, EVCA, National Venture Capital Associations, and Venture Enterprise Centre. OECD, *Entrepreneurship Financing Database*, 2009. Australia's data are sourced from the Australian Bureau of Statistics. Its preferred definition of VC includes investment at the pre-seed, seed, start-up and early expansion stages of development only.
Industry-financed GERD as % GDP	See MSTI for full notes.	OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1
Triadic patents per million population	Patent counts are based on the earliest priority date, the inventor's country of residence and fractional counts. Triadic patents refers to patents filed at the European Patent Office (EPO), the US Patent and Trademark Office (USPTO) and the Japan Patent Office (JPO) which protect the same invention.	OECD, *Patent Database*, 2010, based on *EPO Worldwide Statistical Patent Database* (PATSTAT, 2010). Population data sourced from OECD, *Main Science and Technology Indicators (MSTI) Database* 2010-1. For Brazil, Chile, Estonia, and India: population data come from the International Monetary Fund, *World Economic Outlook Database*, April 2010.
Scientific articles per million population	Calculations based on the address of the institution to which authors belong, and fractional counts. The calculations include articles, reviews, conference papers, conference reviews and notes sourced from journals and conference proceedings.	OECD Calculations, based on Scopus Custom Data, Elsevier, December 2009. Population data sourced from OECD, *Main Science and Technology Indicators (MSTI) Database*, December 2009. For Brazil, Chile, Estonia, and India: population data come from the International Monetary Fund, *World Economic Outlook Database*, April 2010.
% of firms with new-to-market product innovations (as a % of all firms)	Innovation survey data from Canada, France, Korea and Japan were not included when calculating the average. Data collected from national sources might not be fully compatible with the OECD Innovation Microdata Project.	OECD, Working Party of National Experts in Science and Technology (NESTI) Innovation Microdata Project based on CIS-2006, June 2009, and national data. For Australia (2006-07), Business Characteristics Survey 2006-07; Canada (2002-04, manufacturing), Survey of Innovation 2005; Iceland (2002-04), CIS-4; Japan (1999-2001), J-NIS 2003; Korea (2005-07, manufacturing), Korean Innovation Survey 2008; Mexico (2006-07), Research and Technological Development Survey 2008; New Zealand (2006-07), Business Operations Survey 2007; South Africa (2002-04), South African Innovation Survey 2005. Data for Brazil, the Russian Federation and China have been compiled from national sources.
Average annual growth rate (AAGR) patents 1997-2007	Patent counts are based on the earliest priority date, the inventor's country of residence and fractional counts. Triadic patents refers to patents filed at the European Patent Office (EPO), the US Patent and Trademark Office (USPTO) and the Japan Patent Office (JPO) which protect the same invention.	OECD, *Patent Database*, 2010.

Table 3.A1.3. **Radar graph data sources and methodological notes** *(cont.)*

Indicator	Notes	Source
% of firms undertaking non-technological innovation (as a % of all firms)	Innovation survey data from Australia, Canada, France, Ireland, Italy, Korea, Japan, the Slovak Republic and Spain were not included in the average. Data collected from national sources might not be fully compatible with the OECD microdata project.	OECD, Working Party of National Experts in Science and Technology (NESTI) Innovation Microdata Project based on CIS-2006, June 2009 and national data sources. For Australia (2006-07), Business Characteristics Survey 2006-07; Canada (2002-04, manufacturing), Survey of Innovation 2005; Iceland (2002-04), CIS-4; Japan (1999-2001), J-NIS 2003; Korea (2005-07, manufacturing), Korean Innovation Survey 2008; New Zealand (2006-07), Business Operations Survey 2007; South Africa (2002-04), South African Innovation Survey 2005. Data for Brazil, the Russian Federation and China have been compiled from national sources.
Share of services in business R&D	–	OECD, *ANBERD Database*, 2009.
% of firms collaborating (as a % of all firms)	Innovation survey data from Canada, France, Korea and Japan were not included in the average (manufacturing data only and old data). Data collected from national sources might not be fully compatible with the OECD microdata project.	OECD, Working Party of National Experts in Science and Technology (NESTI) Innovation Microdata Project based on CIS-2006, June 2009 and national data sources. Data for Brazil and China have been compiled from national sources.
Business-funded R&D in the higher education (HE) and government (GOV) sectors (as a % of R&D performed in these sectors – combined)	Switzerland, only in the higher education sector.	OECD, *R&D Database*, June 2010.
Patents with foreign co-inventors	Patent counts are based on the earliest priority date, the inventor's country of residence, using simple counts. Share of patent applications to the European Patent Office (EPO) with at least one foreign co-inventor in total patents invented.	OECD, *Patent Database*, 2010.
R&D expenditure of foreign affiliates as % of R&D expenditure	See MSTI for full notes.	OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.
% of GERD financed by abroad	See MSTI for full notes Data collected from national sources might not be fully compatible with OECD data. Due to data availability, the average does not include Chile, Greece, Switzerland and the United States.	OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1; CONICYT for Chile.
Researchers per 1 000 total employment	See MSTI for full notes. Data collected from national sources might not be fully compatible with OECD data.	OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1, data for Brazil, Chile and Estonia have been compiled from national sources; for India, from UNESCO based on national sources.
Science and engineering degrees as % of all new degrees	Data collected from national sources might not be fully compatible with OECD data.	OECD, *Education Database* 2009, UNESCO Institute for Statistics and *China Statistical Yearbook.*
Human resources for science and technology (HRST) occupations as % of total employment	*OECD Science, Technology and Industry Scoreboard 2009* and OECD calculations. Total HRST for Japan are likely to be underestimated. Owing to data availability, the OECD average does not include Chile, Iceland, Mexico, Slovenia or Switzerland.	OECD, *Science and Technology and Industry Scoreboard 2009.* OECD calculations, based on data from the EU Labour Force Survey; US Current Population Survey; Australian, Canadian, Japanese and New Zealander labour force surveys, as well as Korean Economically Active Population Survey.
Tertiary-level graduates in total employment	–	OECD, *Educational Attainment Database*, 2009.
% population aged 25-64 with tertiary degree	Includes tertiary type-A and type-B degrees as well as advanced research programmes.	OECD, *Education Database* 2010.

Table 3.A1.4. **Country-specific figures, data sources and notes**

Countries	Left figure	Right figure
Australia	Scientific articles published, per million population, 1998 and 2008. Source: OECD, Main Science and Technology Indicators, June 2010; OECD Calculations, based on Scopus Custom Data, Elsevier, December 2009.	Firms with collaboration on innovation, 2004-06, or latest available years. As a percentage of innovative firms. Industries included are: Mining and quarrying; manufacturing; electricity, gas and water; wholesale trade; transport and storage; communications; financial intermediation; computer and related activities; architectural and engineering activities; technical testing and analysis. Sources: OECD, Innovation Microdata Project based on CIS-2006, June 2009 and national data sources (for Australia: Business Characteristics Survey 2006-07; Iceland (2002-04), CIS-4; Japan (1999-2001, J-NIS 2003; New Zealand (2006-07), Business Operations Survey 2007; South Africa (2002-04), South African Innovation Survey 2005)..
Austria	Firms collaborating internationally on innovation, as a percentage of all firms, 2004-06, or latest available years. OECD, NESTI Innovation Microdata Project based on CIS-2006, June 2009 and national data sources.	Venture capital investment, as a percentage of GDP, 2008. OECD, *Entrepreneurship Financing Database*, 2009.
Belgium	Foreign ownership of domestic inventions, 2004-06, percentage. *OECD Science, Technology and Industry Scoreboard 2009*; OECD, *Patent Database*, June 2009.	Percentage of BERD financed by government, share of total BERD, 1991-2008. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.
Brazil	Patents with foreign co-inventors, percentage of PCT applications, 2005-07. *OECD Science, Technology and Industry Scoreboard 2009*; OECD, *Patent Database*, June 2009.	Gross expenditure on R&D, as a percentage of GDP, selected countries, 2008, or latest available year. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1; data for Brazil, Chile, Estonia and India have been compiled from national sources.
Canada	Human resources in science and technology indicators, 2007 and 2008. *OECD Science, Technology and Industry Scoreboard 2009*; OECD calculations.	Gross expenditure on R&D, as a percentage of GDP, 2000-08. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.
Chile	Gross expenditure on R&D, as a percentage of GDP, 2007 or latest available year. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.	Patents with foreign co-inventors, percentage of PCT applications, 2005-07. *OECD Science, Technology and Industry Scoreboard 2009*; OECD, *Patent Database*, June 2009.
China	Gross expenditure on R&D, as a percentage of GDP, 1991-2008 OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1	Science and engineering degrees, as a percentage of all new degrees, 2007, or latest available year. OECD, *Education Database*, September 2009; *China Statistical Yearbook 2008*.
Czech Republic	Labour productivity growth, average annual growth rate, 2000-08. *OECD.Stat Database, Productivity: Labour productivity-Total economy.*	Foreign direct investment inflows, as a percentage of GDP, average 2003-08. *OECD, Science, Technology and Industry Scoreboard 2009*; IMF, *Balance of Payments Statistics*, July 2009.
Denmark	Firms with new-to-market product innovations, 2004-06, or latest available years, as a percentage of all firms. *OECD Science, Technology and Industry Scoreboard 2009*; Eurostat, CIS-2006, May 2009.	HRST occupations in total employment, as a percentage of total employment, 2008. *OECD Science, Technology and Industry Scoreboard 2009*; OECD calculations.
Estonia	Growth in business R&D, 1998-2008, compound annual growth rate. *OECD Science, Technology and Industry Scoreboard 2009*; OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1	Scientific articles published, 1998 and 2008, per million population. OECD, *Main Science and Technology Indicators*, June 2010; OECD calculations, based on Scopus Custom Data, Elsevier, December 2009; International Monetary Fund, *World Economic Outlook Database*, April 2010.
Finland	Gross expenditure on R&D, as a percentage of GDP, 2000-08 OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.	Gross expenditure on R&D financed from abroad, as a percentage of the total, 2008. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.
France	GERD per capita (current USD PPP), 2008. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1	HRST occupations as a percentage of total employment, 2008. *OECD Science, Technology and Industry Scoreboard 2009*; OECD calculations.

Table 3.A1.4. **Country-specific figures, data sources and notes** *(cont.)*

Countries	Left figure	Right figure
Germany	Venture capital investment as a percentage of GDP, 2008. OECD, *Entrepreneurship Financing Database* 2009.	Triadic patents per million population, 2008. OECD, *Patent Database*, January 2010. Population data sourced from OECD, *Main Science and Technology Indicators (MSTI) Database*, 2010-1.
Greece	Share of business R&D, by firm size, as a percentage of total business R&D, 2007, or latest available year. *OECD Science, Technology and Industry Scoreboard 2009*.	GERD funding by source of financing, share of the total, 2008, or latest available year. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.
Hungary	Growth of real business R&D, compound annual growth rate, 1998-2008. *OECD Science, Technology and Industry Scoreboard 2009*; OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1	Growth of researchers, average annual growth rate 1998-2008, or nearest available years. *OECD Science, Technology and Industry Scoreboard 2009*; OECD, *R&D Database*, May 2009.
Iceland	Gross domestic product, annual real growth rates, 2000-09 *OECD.Stat Database, Key Short-Term Economic Indicators*.	Gross expenditure on R&D, as a percentage of GDP, 2008. *OECD Science, Technology and Industry Scoreboard 2009*; OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.
India	Patent applications with co-inventor located abroad, percentage of all patent applications, 2005-07. *OECD Science, Technology and Industry Scoreboard 2009*; OECD, *Patent Database*, 2010.	Educational attainment, percentage of population aged 25-64 with tertiary degree, 2008, or nearest available year. OECD, *Education Database* 2010.
Indonesia	**Top left:** Change in contribution of high-technology industries to manufacturing trade balance, as a percentage of manufacturing trade, 1997 and 2007. OECD, *STAN Indicators Database*, 2009 edition. Underlying series from *STAN Bilateral Trade Database*. **Bottom left:** Growth of high- and medium-high technology exports, average annual growth rate, 1998-2008, or nearest available years. OECD, *STAN Indicators Database* 2010 edition. Underlying series from *STAN Bilateral Trade Database*.	**Top right:** Total exports and imports, average, as a percentage of GDP, 1997 and 2007. OECD, *National Accounts Database*, June 2009 and International Monetary Fund. **Bottom right:** Growth of foreign scholars in the United States, by country of origin, average annual growth rate, 1997-2007, or nearest available years. OECD, based on Institute of International Education (IIE); OECD, *Research and Development Statistics*, June 2009.
Ireland	Gross expenditure on R&D financed from abroad, as a percentage of total GERD, 2008. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.	Gross domestic product, average annual growth rate, 2000-09. *OECD.Stat Database, Key Short-Term Economic Indicators*.
Israel	Gross expenditure on R&D, as a percentage of GDP, 2008, or latest available year. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.	Gross expenditure on R&D financed from abroad, as a percentage of total GERD, 2008, or latest available year. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.
Italy	Science and engineering degrees, as a percentage of all new degrees, 2007, or latest available year. OECD, *Education Database*, September 2009.	Venture capital investment, as a percentage of GDP, 2008. OECD, *Entrepreneurship Financing Database* 2009.
Japan	Gross expenditure on R&D, as a percentage of GDP, 2008 OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.	Science and engineering degrees, as a percentage of all new degrees, 2007, or latest available year. OECD, *Education Database*, September 2009.
Korea	Growth of business researchers, average annual growth rate, 1998-2008, or nearest available years. OECD, *MSTI Database* 2010/1.	Patents with foreign co-inventors, percentage of all PCT applications, 2005-07. *OECD Science, Technology and Industry Scoreboard 2009*; OECD, *Patent Database*, 2010.
Luxembourg	Growth in business researchers, average annual growth rate, 1998-2008. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.	HRST occupations as share of total employment, selected countries, 2008. *OECD Science, Technology and Industry Scoreboard 2009*; OECD calculations.
Mexico	High- and medium-high-technology exports, average annual growth rate, 1998-2008. OECD, *STAN Indicators Database* 2010 edition. Underlying series from *STAN Bilateral Trade Database*.	Tertiary-level graduates in total employment, 2007, as a percentage of total employment. OECD, *Educational Attainment Database*, 2009.
Netherlands	BERD and GERD intensity, as a percentage of GDP, 2008. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.	HRST occupations as share of total employment, 2008. *OECD Science, Technology and Industry Scoreboard 2009*; OECD calculations.

Table 3.A1.4. **Country-specific figures, data sources and notes** *(cont.)*

Countries	Left figure	Right figure
New Zealand	High-technology exports, as a percentage of total manufacturing exports, 2008. OECD, *STAN Indicators Database*, 2010 edition. Underlying series from *STAN Bilateral Trade Database*.	Graduation rates at first-stage university level, as a percentage of relevant age cohort, 2006. *OECD Science, Technology and Industry Scoreboard 2009*; OECD, *Education at a Glance 2008*; *OECD Indicators*, 2008; UNESCO Institute for Statistics 2009; *China Statistical Yearbook 2008*.
Norway	R&D intensity, GERD as a percentage of GDP, 2000-08. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.	HRST occupations as share of total employment, 2008, or latest available year. *OECD Science, Technology and Industry Scoreboard 2009*; OECD calculations.
Poland	Science and engineering degrees, as a percentage of all new degrees, 2007. OECD, *Education Database*, September 2009.	Researchers, per thousand employment, 2008 or latest available year. OECD, *Main Science and Technology Indicators* 2010-1.
Portugal	Science and engineering degrees, as a percentage of all new degrees, 2007. OECD, *Education Database*, September 2009.	Scientific articles published, per million population, 1998 and 2008. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1; OECD calculations, based on Scopus Custom Data, Elsevier, December 2009.
Russian Federation	Educational attainment, percentage of population aged 25-64 with tertiary degree. OECD, *Education Database*, 2010.	Gross expenditure on R&D, as a percentage of GDP, 1990-2008. OECD, Main Science and Technology Indicators (MSTI) Database 2010/1.
Slovak Republic	Science and engineering degrees, as a percentage of all new degrees, 2007. OECD, *Education Database*, September 2009.	Scientific articles published, per million population, 1998 and 2008. OECD, Main Science and Technology Indicators (MSTI) Database 2010/1; OECD calculations, based on Scopus Custom Data, Elsevier, December 2009.
Slovenia	R&D intensity, GERD and BERD as a percentage of GDP, 1993-2008. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.	Government-financed business R&D by firm size, percentage share, 2007. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.
South Africa	Gross expenditure on R&D, as a percentage of GDP, 1983-2007. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.	Firms undertaking non-technological innovation, as a percentage of all firms, 2004-06, or latest available year. Eurostat, Community Innovation Survey (New Cronos) 2009; data for Australia, Brazil, Japan, New Zealand, the Russian Federation and South Africa have been compiled from national sources.
Spain	Science and engineering degrees, as a percentage of all new degrees, 2007. OECD, *Education Database*, September 2009.	Venture capital intensity by stage, as a percentage of GDP, 2008. OECD, *Entrepreneurship Financing Database* 2009.
Sweden	Venture capital intensity, as a percentage of GDP, 2008. OECD, *Entrepreneurship Financing Database* 2009.	Share of BERD performed in service industries, as a percentage of total BERD, selected countries, 2007 or latest available year. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1; OECD, *ANBERD Database*, 2009
Switzerland	Gross expenditure on R&D financed from abroad, selected countries, percentage of total GERD, 2008, or latest available year. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1.	PCT patent applications, percentage of applications with co-inventors located abroad, 2005-07. *OECD Science, Technology and Industry Scoreboard 2009*; OECD, *Patent Database* 2010, based on *EPO Worldwide Statistical Patent Database* (PATSTAT, 2010)
Turkey	Firms with new-to-market product innovation, as a percentage of all firms, 2004-06. Eurostat, Community Innovation Survey (New Cronos) 2009 and national data sources.	Business expenditure on R&D, as a percentage of GDP, 2008, or latest available year. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1; Data for Brazil, Chile (CONICYT), Estonia and India compiled from national sources.
United Kingdom	Complementary innovation strategies in services, 2004-06, as a percentage of all services firms. OECD, Innovation Microdata Project based on CIS-2006, June 2009 and national data sources.	Venture capital investment, USD million and percentage of GDP, 2008. OECD, *Entrepreneurship Financing Database* 2009.
United States	US venture capital investment by industry, USD million, 1995-2009. *OECD Science, Technology and Industry Scoreboard 2009*; PricewaterhouseCoopers/National Venture Capital Association MoneyTree(tm) Report	Scientific articles published, per million population, 1998 and 2008. OECD, *Main Science and Technology Indicators (MSTI) Database* 2010/1; OECD calculations, based on Scopus Custom Data, Elsevier, December 2009.

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Outlook 2010

Chapter 4

The Innovation Policy Mix

In recent years, the concept of an innovation policy mix has become an increasingly popular way of thinking about the balance and coherence of the strategic tasks for policy and of the range of policy instruments deployed. This chapter further elaborates the concept and explores its utility for innovation policy assessment and design. The analytical framework outlined will be an important component of the new innovation policy handbook currently being prepared as a follow-up to the OECD Innovation Strategy.

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.

Introduction

The understanding of what governments can do to stimulate innovation and to influence the pace and direction of technological change is evolving. The recent example of successful emerging economies – but also of many of the most advanced innovative nations – has shown that governments continue to play an important role in fostering science, technology and innovation (STI). At the same time, various factors lead governments to reconsider how to achieve the best results with available resources. Fiscal consolidation will create constraints although efforts will be made to safeguard areas of expenditure that are considered to play a key role for countries' future innovation performance and competitiveness.

A better understanding of the impact of policy measures adopted in specific national (or regional) contexts contributes to a more realistic assessment of what can be expected from government interventions. During the past few decades, an increasing number of countries have made an impressive effort to assess and evaluate specific programmes and instruments aimed at fostering STI. Yet, despite these advances, the challenge of finding an appropriate policy mix, one which combines policies ranging from framework policies to dedicated STI policies and is well adapted to the prevailing environment and national objectives, remains. Moreover, this is not a task to be solved once and for all, since the scope and content of government policies evolve, driven by changes in external factors (such as globalisation and technical advances) as well as in the level of economic and institutional development. These in turn influence both the set of attainable goals and the ability to achieve them, including the level of sophistication of government itself.

Ideally, the task of STI policy makers is to develop an optimal mix of policies and instruments for stimulating innovation performance that takes into account possible positive and negative interactions among instruments and ensures balanced support for the range of challenges faced by a nation's innovation system. In practice, given the uncertainties and limitations faced, the policy mix should be sufficiently good in terms of the overall net benefits. Furthermore, it should be adapted to national circumstances, *e.g.* industry structure in terms of activities and firm size, the role of universities and government research laboratories, etc.

In assessing policy mixes, the key issues revolve around whether the mix is appropriate, efficient and effective. For example, does the policy mix address the country's main innovation challenges or are there obvious gaps? Is the balance of the main policy domains consistent with the relative magnitude of the innovation challenges? At the level of instruments, are there too many or too few, and is the scale appropriate? Are individual instruments well-designed and effective (*i.e.* is the right type of instrument used to address the particular problem to be solved and does it build on good practice)? Are there synergies between and among individual instruments?

Questions surrounding the policy mix are not confined to assessing existing policy arrangements. They also extend to the design of new ones. From this perspective, some of the questions above can be rearticulated, such as: How to implement a policy mix that meets the innovation challenges of the country? How to adapt international good practice to local conditions and settings? How to resolve the tradeoffs associated with the pursuit of multiple goals? How to sequence policy goals and instruments to best effect?

Answers to these questions are not straightforward, and the solutions proposed are often difficult to implement. Furthermore, the expansion of the range of objectives of innovation policy and of the bundles of instruments deployed has made for an increasingly complex policy landscape. In part, this has reflected changes in the understanding of the determinants of innovation; these go beyond the production of knowledge through research and development (R&D) to a host of factors known to influence the innovation activities of firms. With the widespread adoption of the systems of innovation perspective over the last few decades, policy makers and analysts have taken a broader view of the actors and factors responsible for a country's, region's or sector's innovation performance. This widening of the "frame" of innovation policy has led to new rationales for policy intervention and has opened up a larger toolbox of policy instruments. This in turn has led to issues related to the selection of policy instruments and to concerns over the balance and coherence of the policy mix in support of innovation, in light of the interaction between different instruments in specific national contexts.

At the same time, many OECD countries have been affected by a growing regionalism, with more control over policy and resources devolved to sub-national authorities. Their interest in promoting local socioeconomic development has led to the emergence of innovation and increasingly of sub-national science agendas. Matters are further complicated by the growth of international governmental organisations and international regulations which increasingly shape governance regimes. This is especially true in Europe, where the European Commission plays a prominent role in supporting research and innovation agendas, mostly at the European, but also at the sub-national level. Co-ordination of levels – what has been termed multi-level governance – tends to be underdeveloped, despite their often obvious interdependence. This may constrain the effectiveness of policies at different levels and constitute a significant source of inertia.

A further driver of change is the types of policy instruments deployed. In recent years, many governments have put relatively less emphasis on direct funding and more on indirect support measures. Each of these instruments has its own operating procedures, skill requirements and delivery mechanism, which means that public managers must master a host of policy techniques. In particular, many of the newer indirect measures tend to rely heavily on a wide assortment of third parties for their design and delivery. The result has been the emergence of often elaborate governance complexes of governmental and non-governmental actors, working together in public-private partnerships. This means that public policy makers must "weigh a far more elaborate set of considerations in deciding not just whether, but also *how*, to act, and then how to achieve some accountability for the results" (Salamon, 2002).

This chapter builds upon empirical work carried out as part of the OECD's country reviews of innovation policy, as well as conceptual work undertaken in preparation for the OECD's planned handbook for innovation policy. It sets out to explore the meanings and scope of the policy mix concept with a view to making it more useful for policy assessment and design, as well as more effective as a basis for international policy learning. The chapter first introduces a framework that permits the mapping of interactions between policies and between policies and their wider environment. This is an essential starting point for assessing and designing policy mixes. Using this framework, the sections that follow explore the combination and balance of policies through four dimensions: policy areas, policy rationales, policy strategic tasks and policy instruments. The chapter then considers the problems of policy co-ordination in distributed governance arrangements, together with some examples of current practices for enhancing policy coherence. A final section looks at the prospects for improved international learning about the design and implementation of policy mixes.

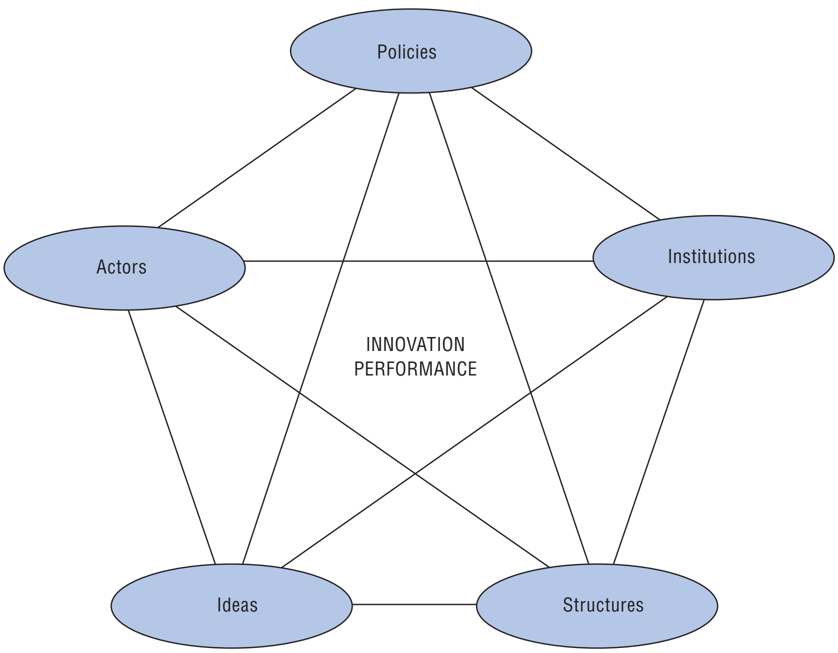
What is the policy mix and how is it useful?

The term policy mix has become increasingly popular in recent years and has been widely adopted by international organisations, such as the OECD and the European Commission, when advising governments on their innovation policies. The term would nonetheless benefit from further clarification, in terms of its meaning (Flanagan *et al.*, 2010) and its implications for policy making. This section therefore presents a variety of meanings for the term and links them in a framework that should prove useful in policy assessment and design.

The introductory section has already explained the growing interest in the innovation policy mix: essentially, it reflects an appreciation of interdependency and an understanding that the performance or behaviour of innovation systems requires the adoption of more holistic perspectives. Also, policy interventions aimed at improving performance or changing behaviour should be based upon an understanding of how they will interact with existing arrangements – for example, whether they will be complementary, neutral or conflicting.

In the first instance, a more holistic perspective can be achieved by adopting a systems of innovation perspective in which the influence and dynamics of a combination of actors and factors are considered as shaping innovation performance. As Figure 4.1 shows, these

Figure 4.1. **Interdependent actors and factors shaping innovation performance**



include various structures, institutions, ideas and existing policies that contribute to innovation performance. These are briefly defined in Box 4.1. Their interactions and interdependencies account for many properties of the innovation system, which is more complex than the sum of its actors and factors. As such, they constitute the wider political

Box 4.1. **Brief definitions of the actors and factors (excluding policy) which shape innovation performance**

Actors include a wide range of types of organisation, including firms (large and small, multinational and domestic), universities, public research labs, government ministries and agencies, various intermediary bodies, such as industry associations, private consultants, etc. The ways in which actors perform domain area activities are determined by their motivations and interests and by their resources: finance, skills and various dynamic capabilities.* These attributes not only determine the roles that actors assume, but also the sorts of interactive relationships they enter into with other actors, *e.g.* through networks, markets and hierarchies. Obviously, any single actor may perform various roles, either within a single domain area or across two or more domains.

Structures constitute the material (and other resource) factors that shape the opportunities and constraints for innovation. For example, countries' innovation systems and their performance are, at least in the short and medium term, shaped by their current state of economic development, resource endowments and specialisation patterns in production and international trade, as well as other structural factors. Firm demography – the structure of the population of business enterprises as well as their interrelations in the economy – also has a strong impact on firms' capabilities and constraints or opportunities for learning.

Institutions refer to the rules of the game and codes of conduct that reduce uncertainty in the innovation system. Institutions are emergent, in that they are generated by the activities of actors and their interactions with one another. At the same time, they also structure these activities and interactions. A distinction is often drawn between hard and soft institutions (North, 1991). Hard institutions are the formal institutional mechanisms that may stimulate or hinder innovation. They include formal written laws and regulations, such as those around technical standards, labour laws, the general legal system relating to contracts, intellectual property rights (IPR), etc. By contrast, soft institutions are the implicit rules of the game that can enable or hinder innovation. They include social norms, the willingness to share resources with others, the entrepreneurial spirit in organisations and countries more generally, tendencies to trust, risk averseness, etc.

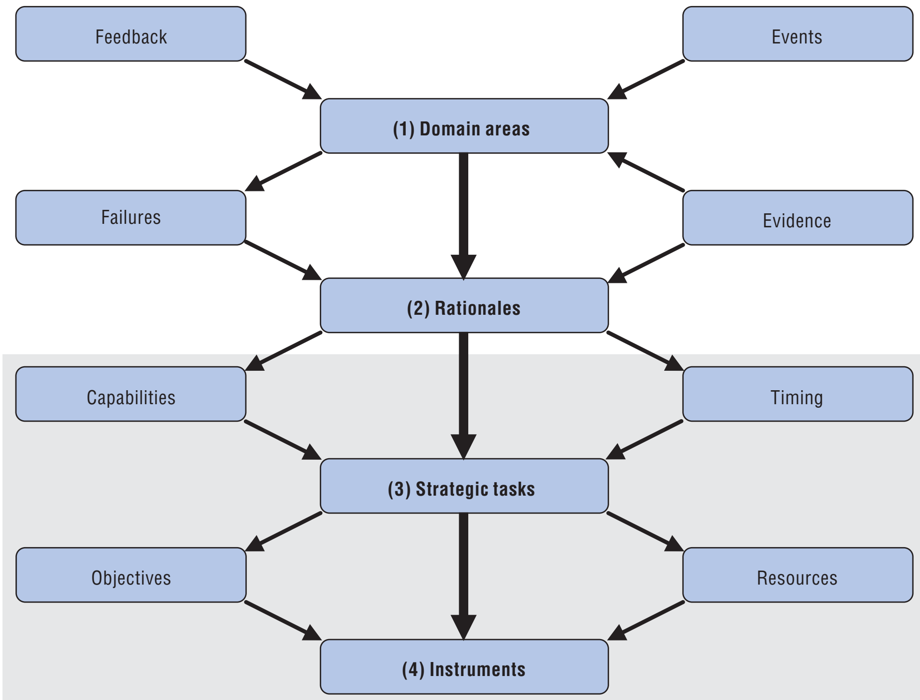
Ideas constitute the socio-cognitive frameworks within which actors carry out their activities. They include, for example, world views, normative beliefs and values, and the logics of appropriateness held by actors and embodied in institutions. As with institutions, ideas are emergent in that they structure the behaviours of actors and are at the same time generated by them. They are often expressed in the form of analogies, metaphors, myths, expectations, future visions, concepts and heuristics, guidelines, etc., and are instrumental in shaping actors' identities, institutional arrangements and policy frames. While the last two decades have seen ideas growing in importance as explanations of socioeconomic phenomena – particularly in political science, institutional economics and organisational sociology – they are still relatively neglected by innovation studies analysts. This should change, since these factors play a not insignificant role in shaping innovation performance.

* Dynamic capabilities are those that enable actors to achieve *i)* internal and external co-ordination; *ii)* learning; and *iii)* transformation. They are unique to each organisation and are technical and organisational in nature (Teece *et al.*, 1997).

and socioeconomic circumstances in which policies are framed and implemented, enabling and constraining the feasibility of particular policy interventions.

In this context, the term policy mix is generally taken to refer to the balance and interactions among policies. As the meaning of the term policy is rather diffuse, it needs to be more precisely defined before the nature and dynamics of these balances and interactions can be appreciated. In this regard, policy can be viewed as comprising four different dimensions, namely: *i)* the *domain areas* addressed; *ii)* the *rationales* offered in support of policy intervention; *iii)* the *strategic tasks* pursued; and *iv)* the *instruments* deployed (see Figure 4.2 and Box 4.2 for definitions). In theory at least, these dimensions exist in "nested" relationships, *i.e.* the domain areas addressed shape the rationales for policy intervention, which in turn influence the strategic tasks pursued by policy makers, which then orient the choice of appropriate instruments. This is indicated in the uni-directionality of the arrows in Figure 4.2, which flow from domain areas through to instruments. Such a perspective is commonly used to assess the appropriateness of choices within dimensions, given preceding choices and conditions. Thus, one meaning of policy mix refers to the *alignment of different dimensions of policy*, particularly between supporting rationales, strategic tasks and instruments deployed.

Figure 4.2. **From domain areas to instruments: the dimensions of policy**



Note: The shaded area indicates policy dimensions which offer a greater choice of alternative options and which therefore tend to vary more among countries.

The logical flow shown in Figure 4.2 suggests that, as a matter of principle, it should be possible to match particular instruments to types of strategic tasks, rationales and/or domain areas. However, the contingency of policy interactions with the specific actors and factors of each innovation system has made this very difficult. Furthermore, rationales,

Box 4.2. **Brief definitions of the elements of policy design**

For the purpose of operationalising the concept of policy mix, it is useful to distinguish between the following four policy dimensions:

Domain areas refers to the variety of policy sub-systems associated with innovation performance. These can be broadly divided into two groups: policies in support of the framework conditions for innovation and policies dedicated to science, technology and innovation (STI). External events and the internal feedback dynamics of innovation systems drive developments in domain areas and subsequently shape policy agendas. Furthermore, evidence about the performance of the innovation and/or wider socioeconomic system, for example in the form of internationally comparable indicators, can implicate different policy sub-systems in innovation policy agendas.

Rationales provide the justification for policy intervention and relate to the underlying causes understood to be responsible for under-performance in particular domain areas. Rodrik (2007) provides a model for identifying binding constraints that act as obstacles to better performance. Typically they are expressed in terms of various types of market and governance failures.

Strategic tasks refer to the broad direction of policy intent and are, in theory at least, derived from the rationales for policy intervention. They should take into account issues of timing – for example, some tasks should be addressed before others or perhaps in parallel. They should also take account of capabilities, *i.e.* the knowledge and skills of both policy managers and the groups they seek to target through intervention. For example, where rationales seek to increase demand for R&D-intensive goods and services, the strategic task might focus on public procurement, regulatory change, supply-chain management, etc. Evidently, any given rationale for intervention may point to several strategic tasks, while any single strategic task may reflect more than one rationale.

Instruments are identifiable techniques for structuring collective action to meet strategic tasks. In this sense, they are widely considered the means for achieving the goals of strategic tasks. The choice of instruments is somewhat dependent on the preceding dimensions of policy outlined here. Nevertheless, there is still considerable leeway in the choice of instruments, at least in theory. For example, for the strategic task of promoting the establishment of new R&D-performing firms, instruments may include loans for start-up firms, grants for the establishment of commercialisation units in public-sector research institutes, regulations that allow academics to benefit financially from commercialisation activities, information campaigns to promote spin-offs from public and academic institutes, etc. In fact, it is not uncommon for a mix of such instruments to be deployed in pursuit of strategic tasks.

strategic tasks and instruments often take on a life of their own and a certain autonomy, thereby disrupting any representation that seeks to impose a rational logic flowing from an assessment of domain area issues to the ultimate selection of appropriate instruments. This is because coalitions of interests collect around strategic tasks and instruments; they gradually become institutionalised and therefore relatively impervious to influences from other, higher-level dimensions. In fact, they may even shape the articulation of dimensions at preceding levels, *i.e.* existing instruments may shape the strategic tasks pursued, the strategic tasks already pursued may shape the rationales for intervention, and the latter may implicate particular domain areas in policy agendas. Seen in this way, the arrows in Figure 4.2 would point in the opposite direction. The argument being made here is that there is in fact a *co-determination* of mutually influencing policy dimensions. Appreciating this possibility and understanding the dynamics involved are important for assessing and designing policy mixes.

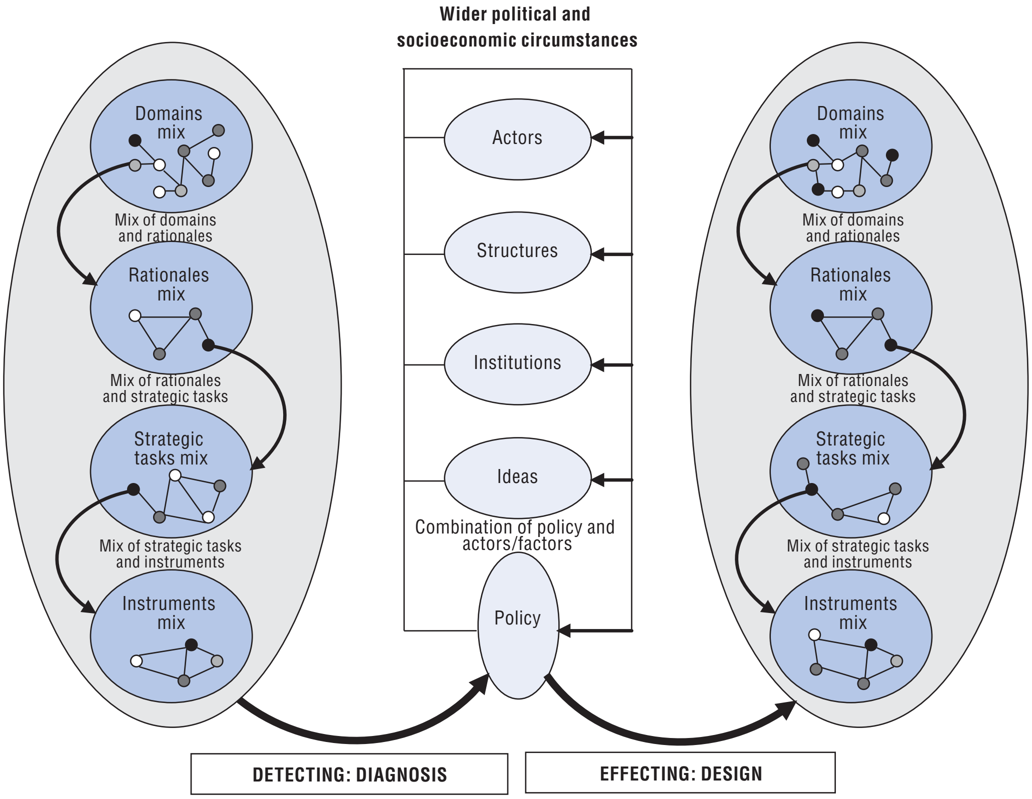
Besides alignment between the four dimensions of policy, the concept of policy mix is perhaps most commonly understood to refer to interactions (coherence) and balance within each dimension. Thus, a second meaning of policy mix concerns balance and coherence: *i)* among different domain areas with a stake in innovation; *ii)* among different rationales; *iii)* among different strategic tasks; and *iv)* among different policy instruments. Interactions within each dimension might be complementary, neutral or conflicting and are likely to demonstrate emergent properties in terms of their effects and impacts, which has made their study difficult.[1]

To summarise, the term policy mix can have two different meanings. A first emphasises the nested relations *between* four dimensions of policy, namely the policy domain areas covered, the rationales for policy intervention, the strategic tasks pursued, and the policy instruments deployed. It provides a useful perspective for exploring the alignment and appropriateness of choices within dimensions, given the choices already made or the prevailing conditions in other dimensions. A second meaning focuses upon interactions *within* each of the policy dimensions. It is useful for considering issues of balance and coherence, for example, between different types of policy instruments. These two meanings of policy mix should not be viewed as alternatives. In fact, for the purposes of policy assessment and design they are complementary and interdependent. To illustrate this point, consider discussions of appropriate mixes of policy instruments, where issues of gaps and balances in instrument portfolios are often raised (*e.g.* Guy *et al.*, 2009). It is obvious that discussions of gaps and balances are meaningless in the absence of some yardstick of what an appropriate policy instrument mix should look like. This yardstick is provided largely by the other dimensions of policy (*i.e.* by the strategic tasks pursued, the rationales offered for intervention, and the domain areas covered), as well as by assessments of wider circumstances. Accordingly, the expectations of appropriateness and performance associated with the first meaning of policy mix constitute a baseline for assessments of gaps and balances in the second meaning.

Figure 4.3 shows these two complementary meanings of policy mix and their relation to the wider political and socioeconomic situation. It also distinguishes between the use of the policy mix concept for assessing (detecting) existing innovation policy arrangements and its use for designing (effecting) new ones. Their use in the context of innovation policy instrument mixes can be described as follows:

- *Detecting*: The policy mix concept can be deployed as an analytical device for understanding the dynamics and performance of existing innovation policies. In this use, the starting point is an appreciation of innovation performance (or certain aspects of it), exploration of the various factors that shape this performance – in the form of general root cause analysis – and consideration of the contributions made by the existing mix of policies to this performance. The aim is to diagnose policy gaps or failures (including policy mix problems) that appear to account for weaknesses in innovation performance.
- *Effecting*: The policy mix concept can also be deployed as a framework for designing and taking policy action. Armed with a diagnostic assessment and/or a normative sense of appropriate action, the policy mix concept can, in theory, provide a roadmap that

Figure 4.3. **The various meanings of policy mix and their relation to wider political and socioeconomic conditions**



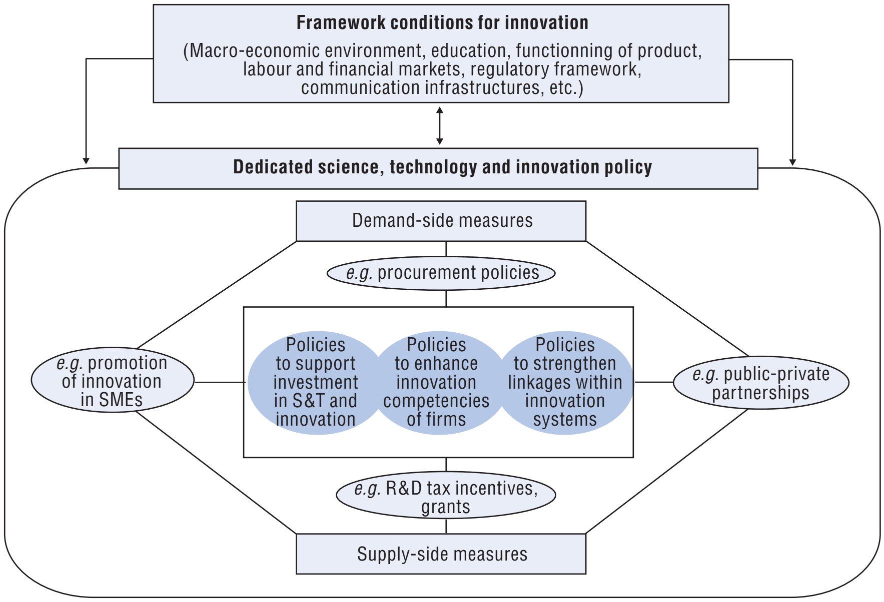
sequences the deployment of a broad array of interdependent policy measures and instruments that address failures in the system. This broad framing of policy mix design is associated with attempts to shift whole systems or sub-systems to more desirable states of performance. However, more modest aims can also be pursued: for example, the policy mix concept is more likely to be used as part of an *ex ante* assessment of single or small numbers of new instruments when their interactions with existing policies are an important selection and design criterion.

Overall, the benefit of introducing the concept of policy mix is to help to open up to greater scrutiny the choice of policy domain issues taken up, of rationales for intervention, of strategic tasks pursued and of instruments deployed. It draws attention to the appropriateness and coherence of these elements in the context of assessments of the changing nature of innovation systems and the failures that characterise them. In the sections that follow, attention is paid to the second, more common meaning of policy mix, *i.e.* mixes of types of domain areas, mixes of types of rationales, mixes of types of strategic tasks and mixes of types of instruments.

The policy domains mix

At a fundamental level, a distinction can be drawn between policies that shape and affect the broad economic framework conditions that are relevant for innovative performance – in the following referred to as framework conditions for innovation – as distinct from dedicated science, technology and innovation policies (Figure 4.4). While the

Figure 4.4. **Scope of innovation policy**



latter aim directly at fostering innovative performance (or some dimensions thereof) by addressing a specific kind of market or systemic failure, the former are, in general, designed to meet primary objectives other than fostering innovation. Supportive framework conditions enable and facilitate innovation throughout the economy. Some of the key framework conditions for innovation relate to major aspects of broader economic governance.[2] Good framework conditions – and related policies – can be viewed as necessary, but not always sufficient, conditions for good innovative (and economic) performance.

In recent years, and with a broadening base of policy experience, it is increasingly acknowledged that policies relating to framework conditions for innovation need to be explicitly considered as part of the overall STI policy mix.[3] The inclusion of policies aimed at shaping framework conditions for innovation in the discussion and development of the overall policy mix is supported by the results of recent empirical research indicating that both sets of policies – framework policies and dedicated STI policies – have an impact on innovation performance, both in isolation and in their interaction. This OECD work has contributed to identifying the policies, institutions and framework factors that can provide effective means of supporting innovation (*e.g.* Jaumotte and Pain, 2005a, 2005b, 2005c and 2005d). The OECD country reviews of innovation policy offer rich information on the evolution of the policy mix in an increasing number of countries[4] which differ in terms of their level of economic development, size, institutional characteristics, policy orientations, etc.

The complementarities and tradeoffs between policies are not always fully understood, but there is evidence that they are very important for assessing a country's STI policy and its impact on innovative and economic performance. For example, framework conditions and policies that are conducive to fixed capital formation are likely to have some influence on the level of business R&D expenditure. Acknowledging these interdependencies from a macro perspective, Aghion *et al.* (2009, p. 689) propose focusing on the more "tightly coupled" elements and "to give priority to identifying those that are strong complements of the activities or institutional structures that the policy intervention seeks to affect". This "calls for complementary policy interventions in order to promote positive feedback responses in the tightly coupled parts … or at least to mitigate the force of negative feedbacks" that may reduce or effectively cancel the intended effects of policy interventions.

To be more specific, boosting R&D and innovation through policy intervention is unlikely to be successful when too little attention is paid to the specific context shaped by policies relating, for example, to general macroeconomic policy, education, product markets (notably competition policy), labour markets, financial development, infrastructure, the regulatory framework and intellectual property rights (Box 4.3). For example, the real effect of boosting R&D activity through public programmes may – at least in the short term – be limited by an inelastic supply of specialised human resources (Golsbee, 1998).

Box 4.3. **Examples of framework policies**

Although they are not primarily focused on innovation, policies which shape the following areas, among others, have a major influence on innovation performance:

Policies which promote a favourable *macroeconomic environment* – notably strong and stable rates of output growth – encourage business enterprises to take the long-term perspective that is conducive to investment in R&D and more radical forms of product, process and organisational innovation. These types of investments also tend to be encouraged by low and stable rates of inflation and a reduction in the level and volatility of real interest rates (Jaumotte and Pain, 2005a). A lack of stability in the institutional system and in regulations tends to undermine business confidence and prompts actors to focus on short-term, rather than on long-term, strategic goals.

A well-performing *education* system which turns out sufficient numbers of people equipped with the range of skills necessary to support and drive innovation throughout the economy. These include highly skilled personnel in science, engineering, mathematics and management, but also medium-level skills.

Competitive *product markets* give firms powerful incentives to innovate in order to survive and prosper (Baumol, 2002). Product market competition is a driver of innovation, at least up to a certain intensity of competition.* Empirical evidence points to a robust relationship between product market competition and productivity growth that is, in the long term, closely related to innovation (Ahn, 2001, 2002). Vigorous competition has a long-lasting impact on firms' behaviour. Low barriers to entry are essential for the emergence of new innovative firms. Regulatory reform and openness of the economy help maintain well-functioning, competitive product markets.

Sufficiently flexible *labour markets*, and related institutions, support the reallocation of resources towards new economic activities and smoothly adjust the composition of the labour force as new products and processes are introduced.

A high level of financial development allows *financial markets* to manage the inherent risk and provide sufficient funding for innovative projects and new firms entering the market. The interaction between competition in product, labour and financial markets has an important influence on innovation and growth.

Box 4.3. Examples of framework policies *(cont.)*

A high-performing *infrastructure* includes a communication infrastructure that allows firms to acquire and exchange information easily and at low cost. The network industries themselves are important actors in innovation but given their character, they also tend to have a strong impact on the innovation capabilities of the large "downstream" parts of the economy.

Developments in the telecommunications sector make clear that the *regulatory framework* is of crucial importance for the speed of diffusion as well as for the generation of new technologies.

Protection of *intellectual property rights*, through patents or other instruments (trademarks, copyrights, etc.) stimulates R&D by enabling successful innovators to reap rewards and prevents free riding. The publication requirements for patents contribute to the dissemination of scientific and technological knowledge and help prevent costly duplication of research efforts. These benefits have to be weighed against the social costs arising from delayed diffusion and reduced use of the invention over the lifetime of the patent, administrative costs, etc.

* Aghion *et al.* (2005) established an inverse U-shaped relationship between competition and innovation. The model predicts, among others, that liberalisation (measured by an increase in the threat of entry), "encourages innovation in industries that are close to the frontier and discourages innovation in industries that are far from it. Productivity, output, and profits should thus be raised by more in industries that are initially more advanced" (Aghion and Howitt, 2009, p. 279).

Yet, their importance notwithstanding, supportive framework conditions are in many instances insufficient to induce an optimal level of innovation if market and systemic failures remain. Even when they are generally supportive, specific policy measures are needed to address specific market or systemic failures that hamper R&D and innovation. A well-known case is the failure of perfectly competitive markets owing to the intrinsic public-good characteristics of information (often referred to as non-rivalry and limited excludability) and thus suboptimal investment in R&D. This type of market failure was analysed in early studies on the economics of R&D, most prominently by Arrow (1962) and Nelson (1959). These offered support for policy interventions to lift R&D to a socially optimal level. In addition, beyond the public-good characteristics of R&D, imperfections in financial markets, a shortage of skilled researchers and engineers, or a lack of information about opportunities arising from scientific and technological advances in other parts of the economy or other countries can mean that gainful innovation projects will not be undertaken in the absence of policy intervention.

Sometimes, dedicated STI policies are aimed at compensating for shortcomings in the framework conditions for innovation. However, there are limits to this approach, as such dedicated policies cannot make up for seriously flawed framework conditions such as the absence or the serious malfunctioning of markets or other fundamental economic institutions. For example, it seems unlikely that a marked lack of competition can be compensated for. Overall, the quality of framework conditions has an impact on the effectiveness of dedicated innovation policies.

The policy rationales mix

The idea that *market failure* leads to underinvestment in research has been the principal rationale for public funding of R&D for the last half-century (Stoneman, 1987).

The pioneering work on market failure related to the production of knowledge (R&D) was rigorously elaborated in the framework of neo-classical welfare economics by Arrow (1962) and Nelson (1959), and has been further extended since.[5] Arrow highlighted three fundamental causes for failure of competitive markets in the context of the production of new knowledge (R&D): externalities, indivisibilities and uncertainty, notably:

- Knowledge has properties of a *public good*. This implies that performers of R&D can only imperfectly appropriate the results of their effort and that the use of a piece of knowledge does not preclude its simultaneous use by others. A lack of appropriability is reflected in positive externalities (evidenced by a wealth of empirical studies), with social returns exceeding the private returns to R&D. Under these circumstances, underinvestment in the production of new knowledge occurs. Traditional responses to market failure due to non-appropriability of the results of R&D include strengthening IPRs (notably the patent system), R&D subsidies to private producers of knowledge, and the internationalisation of externalities through horizontal R&D co-operation (Geroski, 1995).[6]
- High fixed costs and learning by doing through R&D activity give rise to static and dynamic or inter-temporal *economies of scale* (Grossman, 1990; Grossman and Helpman, 1991).
- Investment in R&D is inherently risky, and *information asymmetries* abound in markets for knowledge and technology where they exist (Stiglitz, 1994).

Owing to advances in the understanding of innovation processes and systems, the rationale of STI policies has been revisited since the 1990s (OECD, 1998). The innovation systems approach – which highlights interactions between institutional actors (such as 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, as a result, reduce the overall efficiency of the system-wide R&D and innovation effort. Such 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, of course, 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 approaches have a greater potential for identifying 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 *per se* mutually exclusive. Indeed, market failure remains the basic rationale for innovation policy in many instances. At the same time the need for innovation policy to address systemic failure has become widely accepted.

The rise of the innovation systems framework for analysing innovation has been complemented by the emergence of a more comprehensive understanding of innovation processes. These developments – the adoption of an innovation systems perspective and a broader view of what innovation encompasses – have revealed a greater variety of failures relating to the generation, distribution and use of knowledge. In addition to failures relating to deficiencies in the broader framework conditions for innovation discussed earlier, Arnold (2004), for example, has identified other types of failure: *capability failures* (innovation capabilities may be lacking, owing, for example, to managerial deficits, lack of technological understanding, the ability to learn, or the absorptive capacity necessary to make use of externally generated technology); and *network failures* (problems exist in the interaction among actors in the innovation system which relate to phenomena such as weak linkages among actors, missing complementary assets in clusters, etc.).

Not all potential failures in innovation systems make government intervention a requirement or even desirable. There is no guarantee that government policy can address each market or systemic failure in a way that effectively improves the outcome, *e.g.* in welfare terms. Even when governments may potentially improve welfare, it does not always have the means to do so in practice (Dixit, 1996). Governments' space of action may be limited, and information constraints limit their ability to intervene effectively. Indeed, policy or *government failures* often occur because the government is subject to similar and sometimes even more stringent information constraints than private actors. Indeed, if government interventions are not carefully designed, they may be counterproductive.[7] For these reasons, the soundness of the foundations and the achievements of government intervention need to be scrutinised *ex ante* and *ex post*. Transparency, built-in feedback (*e.g.* through competitive mechanisms or, in their absence, evaluation, etc.) and associated learning processes may help keep policy on track and avoid locking in wasteful activities.

Yet, there are many areas in which governments do, in practice, make a difference through their support for STI. These include the funding of basic and strategic research; the development of absorptive capacity of firms; support for innovative small and medium-sized enterprises (SMEs); the fostering of networks and other system linkages; the provision of strategic intelligence as a public good to inform actors throughout the innovation system, etc. Awareness of the possibility of government failure helps to limit the risk of costly and ineffective intervention. The more recent innovation policy rationales (*e.g.* based on systemic failure) do not invalidate the objectives and choices of instruments associated with earlier rationales, notably market failure. Instead, the overall effect of broadening concepts and rationales tends to be another layer of strategic tasks (and policy instruments) which complement those that exist, thereby increasing policy complexity and the need for co-ordination and coherence.

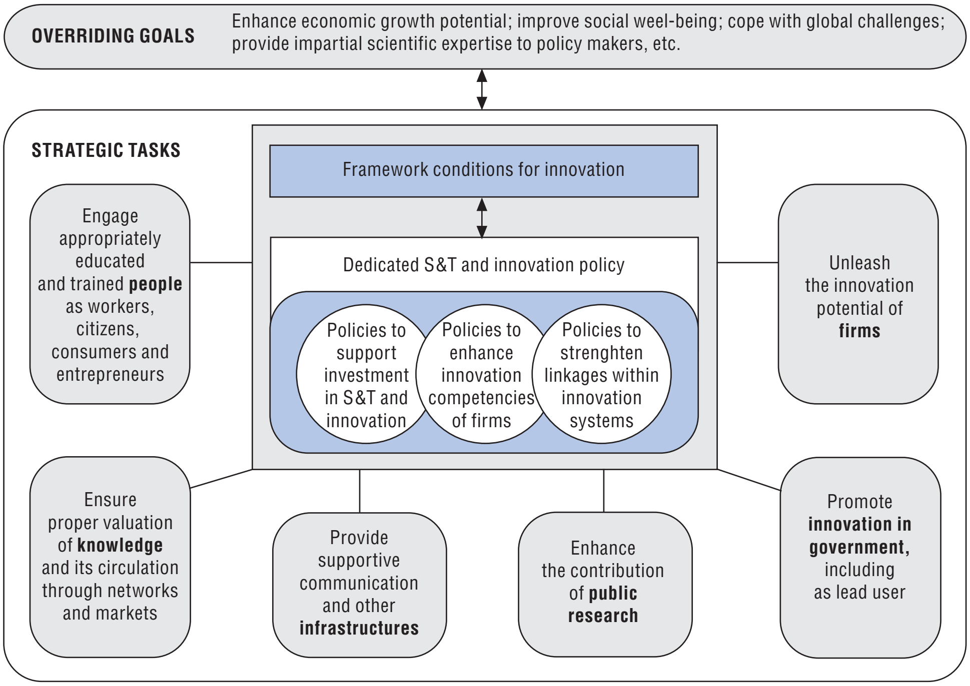
The policy strategic tasks mix

Major issues identified and to be tackled in a given innovation system are reflected in the broad strategic tasks derived from a diagnosis of the state of the system, a vision of its future and a rationale for government intervention to improve the current situation. Figure 4.5 gives a stylised picture of such strategic tasks. Typically, each strategic task requires the application of a range of instruments – or types of instruments – as each is usually multi-dimensional and has multiple objectives. Policy instruments are combined to pursue a set of (immediate) objectives and operate through different mechanisms.

Two strategic tasks that appear in one way or another in practically all contemporary innovations systems are singled out as examples:

- *Unleashing the innovation potential of business firms* is one important strategic task. Many countries have addressed this task, especially lagging countries which seek to boost their innovation performance. Yet, advanced and highly innovative countries, too, need to maintain and continuously expand the innovativeness of their firms. What is meant by innovation may differ, however, depending on the specific state and performance of the national innovation system. The concept – and the operational definition of

Figure 4.5. **Overriding goals and strategic tasks of innovation policy**

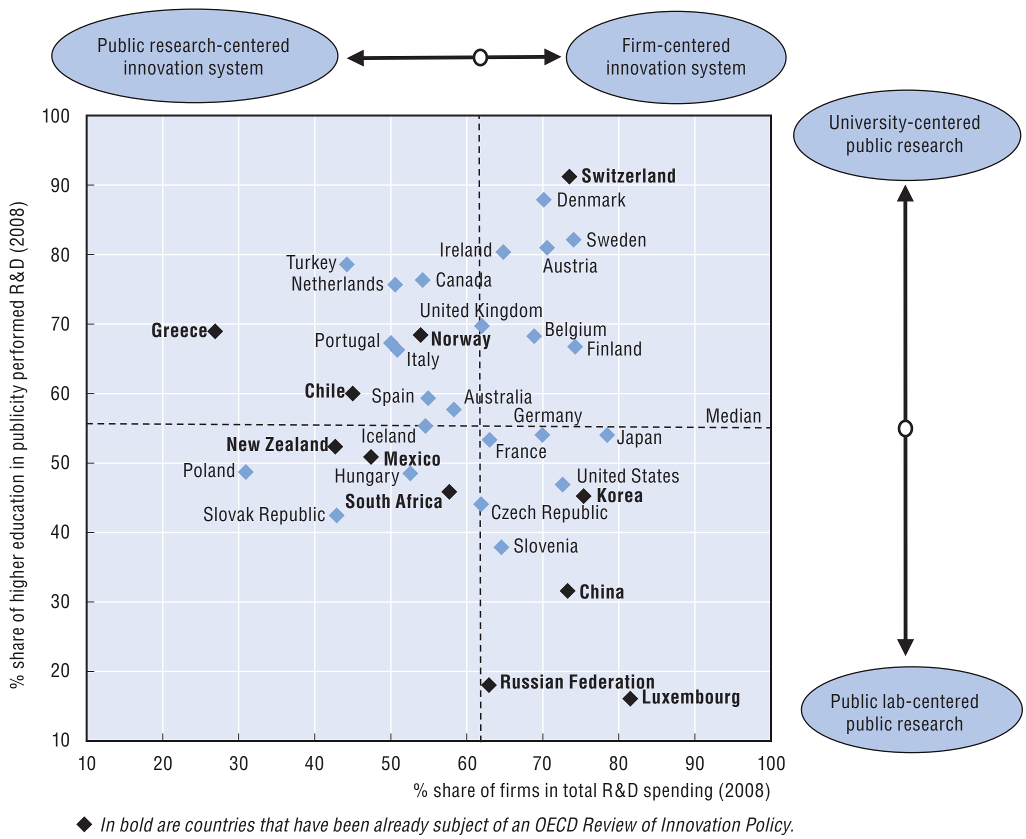


innovation in the *Oslo Manual* (OECD, 2005a) – is sufficiently flexible to accommodate these differences. It covers not only cutting-edge innovation which is "new to the world" but, at a minimum, the bulk of mostly incremental product innovations and often productivity-enhancing process innovations which are "new to the firm".

- *Enhancing the contribution of public research organisations* to the country's innovation performance is another strategic task of key importance. It is important because many countries encounter difficulties at the interface between the public research and the business enterprise sectors. Some kind of systemic failure is often the reason for weak links between the public research and the business enterprise sectors. In some cases this requires new investment in research infrastructure or human capital so that public research organisations (PROs) are better able to fulfil their tasks. Sometimes it is necessary to set clear rules of the game and to modify the incentives of public research actors, for example through appropriate funding mechanisms, remuneration, career paths, etc. Moreover, as the boundary between public and private domains is shifting, the role of PROs is changing. For example, markets have emerged for services previously provided by public research, and this has necessitated an adaptation of PROs' missions. In many countries the linkages between public research and the business sector are hampered not just by shortcomings in PROs but also by a lack of business demand. This is the case in many less advanced countries, but also in economies that lack a thick layer of innovative domestic companies (*e.g.* Greece and Hungary). In this case, there is a clear link between enhancing the contribution of PROs and the strategic task of unleashing the innovation potential of firms, and this makes policies to enhance firms' innovative capabilities important. This may be accompanied by policy measures which affect more directly the demand of businesses for certain services supplied by PROs (through vouchers, tax incentives for R&D outsourced to PROs, etc.)

The role of PROs differs widely across countries (OECD, 2005b). In some they make up for a lack of scale in terms of firm size (*e.g.* New Zealand and Norway). In others, most prominently in the former communist countries, most research, including industrial research, traditionally took place in PROs. Many advanced countries now look back at an extended period of restructuring of their public research system; in other countries this process is just starting. Countries also differ regarding the extent to which their innovation systems are public-research centred or firm-centred, measured by the share of business in total R&D expenditure (Figure 4.6). Today's top-performing countries in innovation do not have a predominantly public research system, even though a heavily firm-based system may not be sufficient. The extent to which countries' public research system is public lab-centred or university-centred plays a role. Some catching-up economies have relied on the former but it is fair to say that there is a general movement towards more university-centred public research. It appears clear that actions taken to unleash the innovation potential of business firms and enhance the contribution of public research are influenced by the country's position in this respect. Some countries have made an explicit choice to move from one type of system to the other. China, which is clearly shifting towards a firm-based system, is a prominent example.

Figure 4.6. **Archetypes of innovation systems**



Note: Data for Chile are 2004 estimates based on CONICYT data.

Source: OECD, *Main Science and Technology Indicators (MSTI) Database*, December 2009.

StatLink http://dx.doi.org/10.1787/888932335362

The policy instruments mix

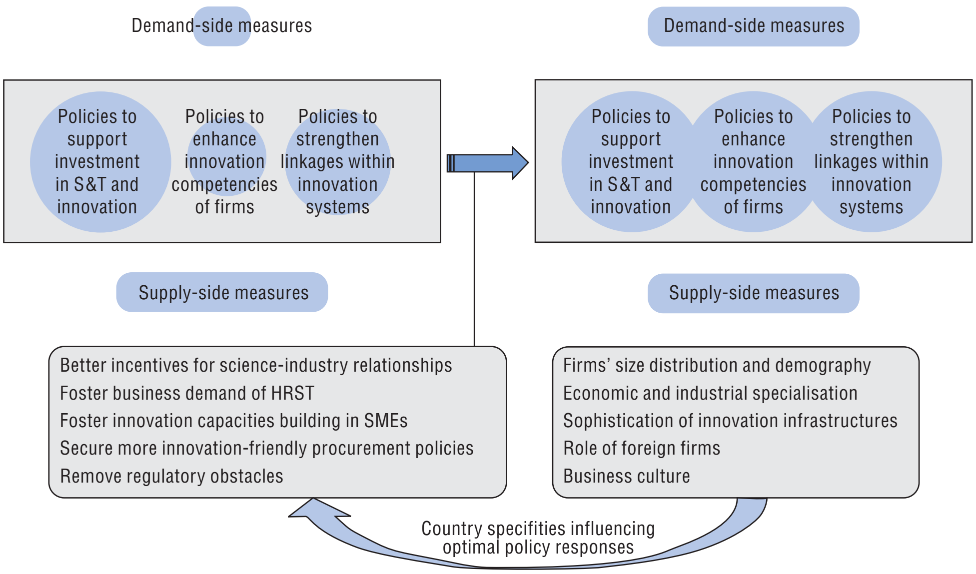
Differences in strategic tasks will generally be reflected in different instrument mixes. But even if strategic tasks and objectives are (broadly) the same, the instrument mixes adopted can be expected to differ, as these are adapted to the wider political and socioeconomic circumstances in which they are applied. As outlined earlier, this environment includes structural features but also different institutions and preferences, *e.g.* a strong preference for a simple, transparent tax system may rule out tax incentives for R&D. The presence of corruption may constrain the choice of instruments. A low level of financial development may also influence the choice of instruments. For example, direct subsidies for R&D appear to be mostly used in some (dynamic) emerging and a segment of advanced countries. The exceptions at the top end tend to be countries with strong defence-related R&D activity. A similar point could probably be made for tax incentives for R&D. As discussed, the potential (*ex ante*) and actual (*ex post*) impacts of dedicated policies for innovation are likely to vary depending on existing framework conditions and their interaction with framework policies. In addition, there are interdependencies within the set of dedicated innovation policies.

Policies and associated instruments can be characterised in several ways, such as their target groups, their desired outcomes, or the funding mechanism employed. Many of the most popular characterisations are binary in nature. A key challenge is to strike an appropriate balance, taking into account the current state and a vision for the future of the innovation system concerned. These instruments include:

- *Direct and indirect support measures for R&D and innovation.* In the past, direct public support for business R&D and innovation activities was more popular than indirect fiscal incentives such as tax credits or concessions. Today, more than 20 OECD countries offer tax relief for business R&D, up from 12 in 1995, and most have tended to make it more generous over the years. The appeal of R&D tax credits derives from their non-discriminatory, neutral nature in terms of research and technology fields or industrial sectors. Ideally, the two types of measures should be complementary in order to make the best use of their respective advantages. There may also be a case for recognising interdependencies. Guellec and van Pottelsberghe (2000) examined direct public support on the one hand and fiscal incentives for R&D on the other as an example of interaction between different types of R&D subsidies.
- *Institutional and competitive funding instruments*. Up until the 1990s in most countries, public funding for public-sector research institutions – including government laboratories and universities – tended to be predominantly non-competitive, institutional funding (block grants). However, in a bid to raise research quality and, in some instances, to limit research spending to a few centres of excellence, governments increasingly turned to competitive modes of funding. For the most part, this has had the desired effect by providing government laboratories and universities incentives to improve their research effectiveness and efficiency. Nonetheless, in some instances the use of competitive funding modes may have gone too far and jeopardised the maintenance of core capabilities by exposing research institutions to too much instability and leading to unintended side effects (such as the retention of units likely to have been spun off under different incentive regimes).
- *Supply-side and demand-side measures*. Innovation policy has traditionally been more supply-side oriented, with policies to enhance innovation competences in firms receiving

less attention than policies to support investment in S&T and innovation. Today, the role of demand as a major driver of innovation has become better recognised and there is growing policy interest in stimulating and articulating public demand for innovative solutions and products, in part to improve the delivery of public policy and services. This has been an emphasis of government stimulus packages in the recent economic crisis. Public procurement is therefore emerging as a potentially powerful instrument to drive research and innovation by providing lead markets for new products and technologies, which may then be adopted in private-sector markets. Such demand-side policies can lead to innovative solutions for tackling today's societal and global challenges (OECD, 2010a). Strengthening the demand side is important not only for many less advanced economies, but more generally for economies with relatively low innovation activity in parts of the business sector, *e.g.* among SMEs. When devoting more attention to demand-side measures, the specific conditions of the country concerned should be carefully taken into account in specifying and designing such instruments (Figure 4.7).

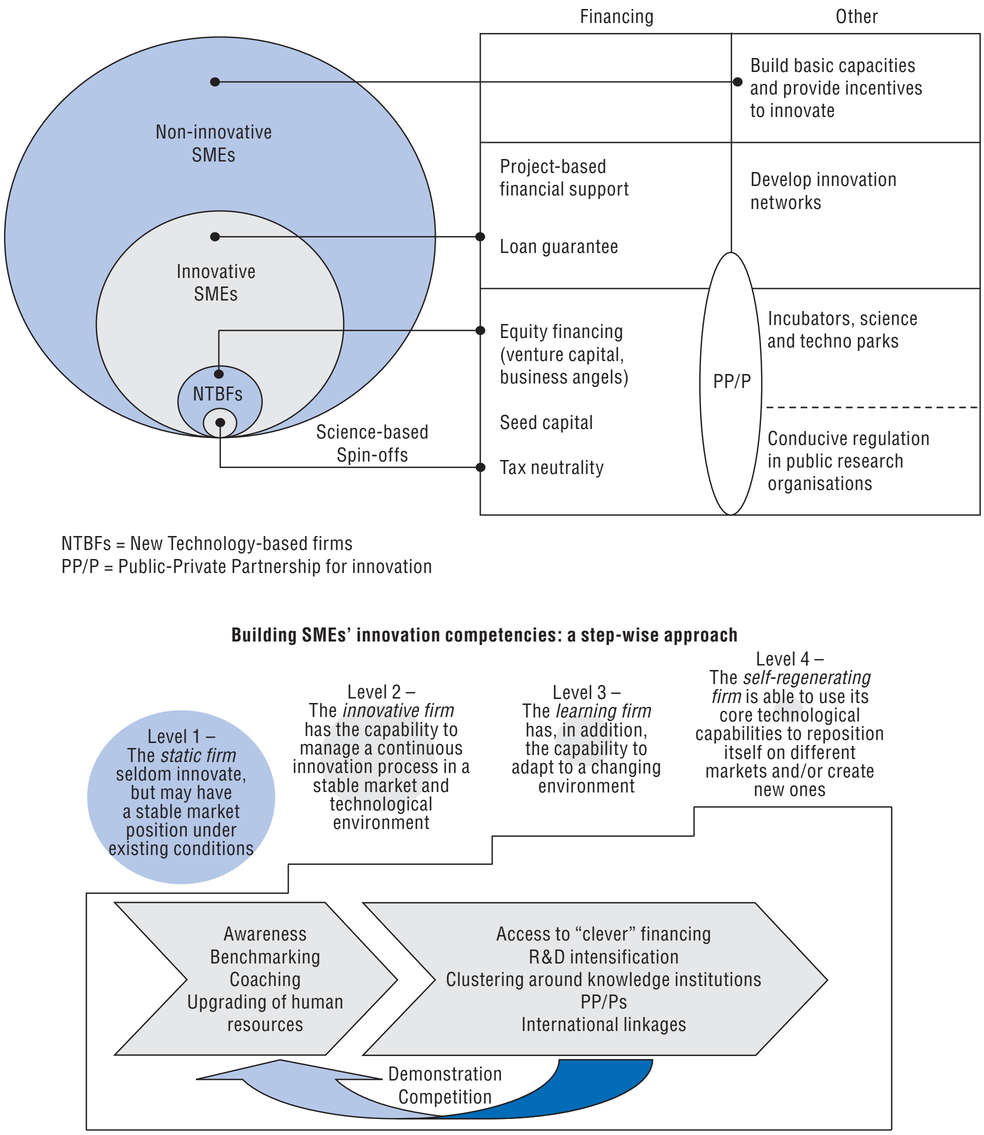
Figure 4.7. **Balance of supply and demand orientation of innovation policy**



As mentioned, a country's specific characteristics will influence the optimal policy response for setting its strategic tasks and instruments. In the current context, these characteristics include the size distribution and demography of firms, the specialisation of the economy, the role of foreign firms, the quality of innovation infrastructures, the business culture, etc. For instance, most countries have an important sector of SMEs. It is well known that this category of enterprises faces specific problems, and it receives special policy attention in many countries. At the same time, the population of SMEs varies greatly, not least in terms of their innovation performance. While some countries have an SME sector that supplies mostly unsophisticated products for local markets, others – such as Switzerland – have developed a strong segment of innovative SMEs and an expanding core of new technology-based firms, some of them created through spin-offs, *e.g.* from public research institutions. Clearly, the needs of SMEs vary considerably, and, to be effective, policy needs to take due account of these differences (Figure 4.8). While non-innovative

Figure 4.8. **SME policies**

Different policy priorities for different types of SMEs



firms often need to develop basic capabilities as well as incentives and framework conditions that help them to engage in innovation activity, support for highly innovative and science-based firms takes very different forms. The supportive role of government changes with the level of economic development and the level of firms' own capacities.

New policy instruments are typically introduced into settings which contain an array of other instruments, often with the same or overlapping targets. Moreover, the effectiveness of a policy instrument almost always depends upon its interaction with other instruments, sometimes enacted at different times and for somewhat different purposes. Bressers and O'Toole (2005) distinguish five forms of interaction associated with policy mixes, as shown in Table 4.1. The selection and design of policy instruments should take account of such interactions, as these may conflict with as well as reinforce each other. Yet, few studies have documented the interactive effects of instruments, which remain, for the

Table 4.1. **Five forms of influence or confluence in policy instrument blends or mixes**

Increased intensity of policy intervention	Multiple instruments targeting *a specific actor or group* of actors
Integration of multiple instruments into one interactive process between government and target groups	Multiple instruments targeting different actors/actor groups involved *in the same process*
Instruments and actions at different levels of governance	Interactions between instruments and actions taken at *different levels of multi-level governance*
Competition and co-operation between different but interdependent policy fields	Interactions and tensions *across policy areas/domains*
Mutual strengthening or weakening of the effects of interventions at different points of action in the broader system	Interactions mediated through processes in a broader system

Source: Flanagan, K., E. Uyarra and M. Laranja (2010),The Policy Mix' for Innovation: Re-thinking Innovation Policy in a Multi-level, Multi-actor Context, *Manchester Institute of Innovation Research Working Paper Series*, University of Manchester, based on Bressers, H. and L. O'Toole (2005) Instrument Selection and Implementation in a Networked Context, in P. Eliadis, M. Hills, M. Howlett (eds.), *Designing Government: From Instruments to Governance*, McGill-Queens University Press, Montreal.

most part, poorly understood. However, policy instrument mixes are likely to create synergies, insofar as they represent more than the sum of the individual instruments.

A balance also needs to be struck concerning the number of policy instruments adopted. The tradeoff here is the need for a set of instruments that is sufficiently differentiated to meet the needs of complex innovation systems. At the same time, it is important to avoid inefficiencies arising from operating too many schemes at too small a scale.[8] This is a real concern, since instruments can develop a certain autonomy and in effect become ends in themselves (Vedung, 1998; Ringeling, 2005), making them less amenable to change or cancellation, even when that would make sense. The incremental accretion of policy instruments, if widespread and long-lasting, can result in complex and dense policy mixes. Although these mixes may sometimes have a unifying overall logic, the build-up of instruments over time normally reflects differing conceptions of the causes of specific problems as well as variations in how problems are framed.[9] Achieving policy coherence under these circumstances can be very difficult, but using the policy mix concept in policy assessment and design work should help draw attention to such inconsistencies and redundancies.

Coherence in the policy mix

A variety of interrelated developments – analysed in some detail in OECD (2010a) – have led most OECD countries to deploy a more comprehensive and differentiated set of policies and associated programmes and instruments. This has drawn greater attention to the need for policy coherence or consistency, that is, the extent policies act to support rather than detract from one another. Coherence can be viewed as a policy mix goal, with co-ordination the means to achieve it and good communication the basis for effective co-ordination, which is a central concern of the policy mix concept (Guy *et al.*, 2009).

As the preceding discussion has highlighted, the policy mix concept – and, by extension, policy coherence – points to the co-ordination of a multitude of policy actions in the core set of innovation policies, such as S&T and education. It also requires an evaluation of their possible interaction with policies pursuing other primary objectives, *e.g.* tax policy, competition law, etc., *i.e.* those policies that shape the framework conditions for innovation. For example, attracting foreign students or university staff requires close co-ordination of education and immigration policies. Fostering innovation and a cleaner environment to help guide economies towards greater sustainability requires closer integration of many policies, *e.g.* in transport, energy, environment, etc. Such policies may, in some instances, be inherently complementary (see the earlier discussion of Aghion *et al.,* 2009), but in others they may be incompatible. This can reduce their overall effectiveness or at least involve some tradeoff.

Achieving policy coherence is therefore crucial for success in several areas of innovation policy. At the same time, however, the scope for achieving coherence has been made more difficult by a number of developments (OECD, 2005c; Peters, 1998):

- As governments have become involved in more aspects of the economy, the likelihood that any one programme will affect others has increased.
- The adoption of the tenets of new public management has seen a proliferation in agencification, which has created a more fragmented landscape of policy actors which are expected to act more or less autonomously.
- Regionalism and internationalisation of policy has led to the emergence of multi-level governance.
- Fiscal crises in states have led governments to search for and reduce apparent redundancies and inconsistencies across programmes in a push for greater efficiency.
- Issues are becoming increasingly cross-cutting and do not fit neatly into traditional departmentalised structures.

A comprehensive innovation policy therefore 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. It must nonetheless be acknowledged that the behaviour of policy-making organisations is guided by their own logic of appropriateness.[10] Insofar as these organisational logics are unaligned, co-ordination and coherence will be difficult. Furthermore, co-ordination will be inhibited because each organisation serves its own networks (clientele), and demands often vary from one network to another. As part of their network-building activities, organisations invest in creating elaborate sets of mutual agreements and understandings; they are unlikely to want to upset those arrangements through active (positive) co-ordination efforts. The best outcome that might be expected under these circumstances is for negative co-ordination between organisations, whereby each respects the others' commitments but does nothing to integrate its actions (Peters, 1998). This raises difficulties when problems are large-scale and cross-cutting, as in the case of innovation policy. The risk is that a number of different organisations will attempt to parcel out components among themselves, thereby reducing the overall effectiveness of policy interventions. The end result may be policy instrument choices that grow haphazardly out of bureaucratic turf battles rather than out of clear-headed analysis of the policy problems involved (Peters and Hoornbeek, 2005).

Accordingly, a number of arrangements have emerged for increasing the overall coherence of policies, programmes and instruments across a range of departments and agencies. These include the articulation of strong guiding national visions or strategies (*e.g.* through the use of national foresight exercises, as in many OECD countries); the merger of policy-making organisations, for example, into super-ministries (*e.g.* the Korean government recently merged several ministries, including science and education, with the aim of improving policy coherence); and the adoption of joint programming practices (*e.g.* around cross-cutting challenges, such as healthy ageing, environmental sustainability, etc.). In addition, in recent years, a substantial number of countries have set up high-level policy councils, in a number of cases emulating the experience of the Finnish Science and Technology Council with the Prime Minister at the helm, which has been perceived as international best practice. Such councils can play an important role in agenda setting, prioritisation and as a platform for overall policy co-ordination (Box 4.4).

It has become evident, however, that simply establishing such a council is insufficient in itself to achieve greater policy coherence and is certainly not a panacea. Indeed, the role

Box 4.4. **STI policy councils**

Several countries have established science, technology and innovation policy councils as key elements in their 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.
- In Germany, the Expert Commission for Research and Innovation (EFI) presents to the federal government annual proposals for national research and innovation policy making based on a comprehensive analysis of the strengths and weaknesses of the German innovation system.
- 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.
- Hungary's Science and Technology Policy Council (chaired by the Prime Minister) has a varied history. In recent years it has 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.
- 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.

Source: OECD (2010a), *The OECD Innovation Strategy. Getting a Head Start on Tomorrow*, OECD, Paris.

and performance of existing councils has sometimes been limited, often owing to some deep-rooted problems. Their tasks may have been ill-defined in the context of the country's innovation system or measured against what such a council can be expected to deliver. Policy makers may not have been prepared to take on their assigned role. This highlights the need for precision about the concrete role of councils and the need to gear them towards the strategic tasks to be fulfilled in the innovation system as well as to social and political realities. There are some general lessons to be drawn from international experience. For example, it appears counterproductive for a council tasked with providing strategic advice to become closely involved in the budget allocation process. The council's composition, too, needs to be considered in view of the specific 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.* through the nomination of members from beyond national boundaries or otherwise exposed to international practices) and, of course, to new ideas and newly emerging innovation actors in the innovation system. This implies that councils should not be overly biased towards vested interests (both in the business community and academia).

As the example of STI policy councils shows, there is plenty of scope for international learning about appropriate mechanisms for achieving enhanced policy coherence and their design. However, it is also important to acknowledge the limitations of what can be realistically achieved in terms of policy coherence. In this regard, work carried out by the OECD in the 1990s on the management of policy making (OECD, 1996) identified five key lessons relevant to efforts to enhance policy coherence:

- *There is a gap between the need for coherence and the capacity to achieve it*. This gap largely results from the complexity of governing contemporary societies, which are characterised by an increasing globalisation and regionalism, by the expanding availability of information, by growth in the number of actors involved in policy processes, and by the framing of problems as cross-cutting.
- *Governing in a democratic political system necessarily involves a degree of incoherence*. Coherence is but one quality of good governance; the OECD's Innovation Strategy (OECD, 2010a) identifies several others, including stability, adaptability and legitimacy, which may be in tension. Democratic societies require governments to be responsive to competing interests which rarely converge towards coherent sets of policies. The challenge for governments is to manage these contradictions rather than to avoid them.
- *No single governance system can guarantee improved policy coherence*, i.e. *there is no best practice*. This parallels messages in other parts of the chapter that emphasise the importance of local contingencies. Different systems can achieve similar degrees of coherence with different governance mechanisms. Indeed, the levels of performance of apparently similar mechanisms, *e.g.* S&T councils, in different countries can be very different on account of wider political and socioeconomic factors. Coherence should therefore be considered more a guiding principle than a fixed set of widely applicable arrangements.
- *There nevertheless exist good practices and tools of coherence*. These are organisational in nature and concern the process rather than the substance of policy making. They reflect the need for a strong strategic capacity at the centre of government; the need

for organisational flexibility; and the need for effective information-gathering and processing systems.

- *The paramount tool of coherence is informed decision making*. Policy makers need to know what their realistic options are, what inconsistencies might result from their decisions, how the costs of those inconsistencies can be mitigated, and how the tradeoffs they have had to make can be explained. In an environment characterised by complexity, change and the availability of vast quantities of information, a high premium is put on developing information systems and analytical capacities that allow decision makers to govern as coherently as possible.

This last point is taken up in the final section of the chapter, which sets out proposals for developing information systems and analytical capacities in support of innovation policy design.

International policy learning and the policy mix

The previous sections have highlighted the significance of local contingencies in appropriate policy design. This might lead to the conclusion that the scope for interventions based on international learning is somewhat limited. While it is appropriate to abandon the belief that policies (and especially policy instruments) are in essence technical in nature and largely independent of their context, knowledge of their uses elsewhere can nonetheless be enlightening if considered in the context of wider political and socioeconomic circumstances, including existing policy mixes. The difficulty, of course, lies in gaining a measure of these wider circumstances in shaping the performance of a given policy instrument in another national setting. It also lies in gaining an appreciation of how the policy instrument might work in one's own setting given its political and socioeconomic circumstances and existing policy mix. Such difficulties are widely documented in the international literature on policy transfer and policy learning (*e.g.* Rose, 1993; Dolowitz and Marsh, 2000; James and Lodge, 2003), and they are recognised as accounting for a great deal of the policy failure associated with inappropriate or incomplete transfer. International organisations, such as the OECD, can help to minimise the risks of such failures by supplying detailed case studies and principles of policy design and implementation, and by providing forums for the exchange of lessons between different countries.

The fundamental analytical question is how to cope with multi-attribute problems and the varying forms these problems and their solutions may take in different political and socioeconomic circumstances (Peters and Hoornbeek, 2005). One approach would be to rely largely upon technical analysis to model the factors involved, but this has limitations. First, quantitative indicators that aid in such assessments are lacking in many instances. While further indicator development could be helpful, it has to be acknowledged that certain important phenomena are not suited to expression in terms of quantitative indicators; this limits the scope for quantitative data-driven analysis. Second, the knowledge necessary to make such assessments tends to be distributed and thus to require a more deliberative approach to policy design. This does not deny a role to technical analysis but instead situates it in multi-actor forums involving a more transparent deliberation process. Such forums are also crucial in providing opportunities for policy learning among policy designers, implementers and target groups. Third, innovation systems are complex and adaptive, as the outcomes of policy interventions are uncertain and characterised by unintended consequences. This again points to a more open approach to policy design, one which involves a great deal of experimentation and monitoring and the participation of many actors.

In the end, of course, processes of open deliberation in designing policies may involve no more than simply recognising the multiplicity of the criteria and the tradeoffs that are involved and relying upon the good judgement of participants in multi-actor forums (Peters, 2005). This still leaves open the challenge of ordering and structuring such criteria and tradeoffs to permit their systematic consideration in policy design efforts. The challenge, in fact, is to develop an analytical framework that can accommodate this multiplicity of criteria while remaining accessible and useful to multi-actor policy-making forums. There is scope for international learning in building such an analytical framework, irrespective of differences in the wider political and socioeconomic circumstances (including existing policy mixes) that shape countries' innovation performance. In this regard, and in the wake of its recently launched Innovation Strategy, the OECD has committed to provide more operational advice and guidance on formulating innovation policy through a policy handbook which includes such an analytical framework (Box 4.5).

Box 4.5. **The innovation policy handbook**

The policy handbook's main purpose is to provide insight and guidance to inform practical policy decisions relating to a broadly conceived notion of innovation. It will have at its core an analytical framework along the lines set out above, together with case materials and briefing notes, to aid policy makers and analysts to learn more about the current performance of their innovation systems and to discern pathways to more desirable states. The expected benefits of creating an innovation policy handbook are as follows:

- Assemble in one place current knowledge of innovation dynamics and policy measures and use this to provide policy-relevant guidance and data support.
- In doing so, take due account of factors that are important for innovation policy making and encourage a better appreciation of their connectedness.
- Encourage recognition of the need to tailor policy interventions to specific contexts and to take account of past and existing policy actions.
- Shift policy-making paradigms towards more active and open collective learning processes which acknowledge the limits of current knowledge and make available spaces for policy experimentation.
- Highlight the need to nurture the capabilities necessary for continual reflexive governance of innovation systems.

The policy handbook's architecture is modular to allow for the incorporation of new content on a continuous basis. Member countries and other users will be encouraged to contribute case materials and other analyses to support the information base underpinning the guidance contained in the policy handbook. In this way, its growth will be organic, drawing upon the experiences and conceptual thinking of the wider innovation policy community. Furthermore, it will link to the extensive data already gathered by various EU-funded projects, *e.g.* ERA-Watch, PRO-INNO Europe and Regional Innovation Monitor. The policy handbook's analytical framework will be sufficiently broad to accommodate analysis and synthesis of all relevant areas of policy for innovation and will be applicable in a wide variety of settings, including OECD and non-OECD countries and at national, regional and sectoral levels.

Conclusion

This chapter has set out to elaborate on the policy mix concept, with the aim of making it more operational and useful to policy makers and analysts. It has assigned two complementary and interdependent meanings to the concept. One emphasises the nested relations between four dimensions of policy, namely the policy domain areas considered relevant to innovation performance, the rationales for policy intervention, the strategic tasks set for policy action, and the policy instruments deployed. It has broadly characterised each of these dimensions and provided examples that demonstrate both the commonality and variety of policies found across OECD countries. A second meaning of the policy mix concept focuses upon interactions within each of the policy dimensions, such as issues of coherence and balance between different types of policy instruments. In this regard, the chapter has argued that the scope for achieving policy coherence is limited by the very nature of modern systems of governance. Nevertheless, coherence can be improved through the establishment of multi-actor forums that are strongly supported by information systems and advanced analytical capacities. A more operational conceptualisation of policy mix can bolster such analytical capacities, providing a useful entry point for assessing the dynamics of innovation policy and for designing new policy arrangements.

This is the starting point for the OECD's work on developing a policy handbook in support of innovation policy making. The handbook will utilise an analytical framework based upon a concept of policy mix that can accommodate the contingencies of local political and socioeconomic circumstances. To recall, these include the capabilities of innovation system actors (including policy actors), the rules of the game, the incentives and ideas that shape actors' behaviour and their patterns of interaction, and the resources at their disposal. They also include existing policy and governance arrangements that influence innovation performance. Each of these factors is, to some extent, path-dependent and a legacy of historical events and arrangements that are unique to individual countries, regions and sectors. This is an important point to bear in mind in international policy learning, where the dangers of inappropriate policy transfer often loom large. At the same time, however, the opportunities offered by international policy learning are too great to be neglected. The handbook therefore sets out to utilise the policy mix concept to provide an open and dynamic platform for more informed international policy learning and to introduce a more strategic basis for policy formulation and implementation.

Notes

1. In fact, it would not be unfair to claim that much of the empirical work around innovation policy mixes has so far been concerned, for the most part, with discussing only balances (and by extension, policy gaps). Much less attention has been paid to researching interactions, particularly between instruments, no doubt on account of the conceptual and practical challenges involved.
2. Economic governance – *i.e.* the governance of economic activity more generally – can be defined as encompassing the "structure and functioning of the legal and social institutions that support economic activity and economic transactions by protecting property rights, enforcing contracts, and taking collective action to provide physical and organizational infrastructure" (Dixit, 2009, p. 5). The latter guarantees an adequate provision of public goods.
3. At the same time it appears useful to maintain the distinction. One argument in favour of this is that innovation policy makers have only limited control over these policies and special

co-ordination mechanisms have to be put in place in order to achieve the necessary degree of coherence and co-ordination.

4. To date the following reviews of innovation policy have been carried out: Chile (OECD, 2007a), China (OECD, 2008a), Greece (OECD, 2010b), Hungary (OECD, 2008b), Korea (OECD, 2009a), Luxembourg (OECD, 2007b), Mexico (OECD, 2009b), New Zealand (OECD, 2007c), Norway (OECD, 2008c), South Africa (OECD, 2007d) and Switzerland (OECD, 2006). A number of reviews are currently under way.
5. See, for example, the surveys by Geroski (1995), Metcalfe (1995) and Scotchmer (2004).
6. There are potential tradeoffs involved since co-operation in R&D may lead to anticompetitive behaviour in downstream product markets.
7. For example, measures to raise the necessary finance for public expenditure and fiscal incentives such as tax credits or concessions for R&D may incur economic costs and involve substantial deadweight losses. The existence of support programmes for particular types of innovative activity may at times also lead to a diversion of resources from productive uses, *e.g.* from direct innovation activity towards lobbying.
8. To some extent, organisational arrangements, *e.g.* bundling the operation of these instruments in specialised arm's-length agencies that can serve different principals may help mitigate this problem. Yet, there is no substitute for scrutinising instruments as much as feasible for their net social benefit.
9. Howlett and Rayner (2007) distinguish between two types of instrument accretion, namely layering and drift. Layering is a situation in which new objectives and instruments are added without abandoning previous ones. This often leads to incoherence among the objectives and inconsistency with respect to the instruments. Drift is a situation in which new objectives are added but the instruments remain the same. In this setting, the policy instrument mix is inconsistent with the new objectives and is most likely ineffective in achieving them.
10. This is the situation in which policy makers are said primarily to use criteria of similarity and congruence rather than rely upon rational anticipation of value (referred to as a logic of consequence) in selecting and designing policy strategic tasks and instruments (March and Olsen, 1989).

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