Highlights

The world is at a crossroads. Economies are slowly recovering from the most severe economic downturn since the Great Depression. International competition from new players is eroding the lead of more established economies. Environmental pressures call into question the sustainability of current development models. Longer life expectancy is putting a greater strain on the capability of health systems to meet the needs of an ageing population. All these challenges are global, in the sense that they affect all countries regardless of income or geography. But they are also global because the scale of problems exceeds the capability of any one country and requires co-operation by all countries.

Increasingly, innovation is seen as a critical part of an effective response to these challenges. It will be one of the keys to emerging from the downturn and putting countries back on a path to sustainable – and smarter – growth.

How is the economic crisis affecting innovation efforts? How can innovation help to solve environmental and social threats? How are countries tackling these challenges? The *OECD Science, Technology and Industry Scoreboard 2009* provides the statistical information necessary to see the contours of these global challenges more clearly and to identify directions for responding to them. It considers these challenges in five chapters:

- Responding to the Economic Crisis
- Targeting New Growth Areas
- Competing in the World Economy
- Connecting to Global Research
- Investing in the Knowledge Economy

Responding to the economic crisis

R&D expenditures and venture capital are among the first to be cut during recessions

Research and development (R&D) expenditures are among the first to be cut during recessions. Preliminary data suggest that companies have reduced their R&D investment in the aftermath of the crisis. Companies quoted on the New York Stock Exchange report a reduction of about 7% in their R&D expenditures in the first quarter of 2009, with a slight increase in the subsequent quarter. The semiconductor industry, which is at the core of the information and communication technology (ICT) industries, appears particularly affected by the recession, with a drop in R&D over the first semester of 2009 exceeding 13%. These findings are consistent with historical trends showing that R&D expenditure exhibits larger variations than gross domestic product (GDP) over the business cycle. Hence, any drop in GDP would result in an even larger decrease in R&D expenditure.

The ***business enterprise sector*** remains the main source of R&D funding in the majority of OECD countries, accounting for around two-thirds of the total in 2007. R&D financed by the business enterprise sector is also the component most affected by the business cycle: over 1982-2006, the observed variations in the OECD area were significantly larger than the variations in total R&D. A similar pattern is likely to occur in the current crisis, with the largest decrease in business-financed R&D.

Venture capital, a key source of funding for innovative firms and technological start-ups, becomes rarer as venture capitalists wait out the crisis. In the United States, for example, venture investments started declining in early 2008. In the first quarter of 2009, they plunged 60% compared with the same period a year earlier. The drop was even more dramatic in communication industries, where venture investments decreased by over 80%. The small increase in the second quarter of 2009 remains too timid to indicate an inversion of this trend.

New trademarks, an indicator of product and marketing innovation, plunged 19% in 2008

Not only technological, but also non-technological innovation is cyclical. Product or marketing innovations, as measured by ***trademarks***, have been significantly affected by the crisis. Over 2008 the number of new trademarks went down by 20% and continued to plummet over the first half of 2009.

Innovation will be also negatively affected by the drop in ***foreign direct investment*** (FDI) due to the crisis. FDI inflows to G7 countries dropped by 25% in 2008. In the first quarter of 2009 the decrease accelerated in Canada (–97%), Germany (–67%), Italy (–41%), Japan (–59%) and the United States (–63%). On the contrary, FDI inflows to the United Kingdom more than doubled in the first quarter of 2009, back to the same level as the previous year. As foreign affiliates provide access to new technologies and generate knowledge spillovers for domestic firms, lower inflows of FDI will reduce innovation capabilities in the host country.

Growth in labour productivity will slow significantly as a result of the economic crisis, both in the short run, owing to labour hoarding, and in the medium run, owing to a decrease in innovation efforts. This decrease will contribute to the negative trend in labour productivity growth, which slowed significantly well before the crisis and indeed from 2002.

Targeting new areas of growth

In addition to being the primary driver of economic performance, innovation also plays an important role in improving social welfare. This role takes on increased importance as policy makers face challenges that are global in scale and for which technological innovation is envisioned as a crucial aspect of the solution.

Patented inventions in renewable energy and air pollution control grew fast over 1996-2006

For the ***environment***, investment in "clean" technologies can help achieve a wide range of objectives, from mitigating climate change to enhancing resource efficiency in general. Patents in ***renewable energy*** and ***air pollution control*** are the most dynamic groups of environmental technologies. Over 1996-2006, patented inventions in renewable energy (+20%) and air pollution control (+12%) increased more rapidly than total patents (+11%) filed under the Patent Co-operation Treaty (PCT).

More than 30% of environment-related patents had European inventors in the mid-2000s. The United States and Japan contributed shares of between 18% and 26% in the four technological areas. The BRIICS (Brazil, the Russian Federation, India, Indonesia, China and South Africa) are also substantially involved in waste management, water pollution control and renewable energy. In 2006, no less than 7% of world patents in these three technologies were invented by the BRIICS.

Ageing is another of the major challenges that most societies – OECD countries but also China – will face in the next decades. Innovation is an important way to meet this challenge by improving the performance of the ***health system*** and reducing its costs.

In 2006, R&D expenditure by the pharmaceutical industry represented around 0.3% of GDP in Belgium, Sweden, the United Kingdom and the United States and reached almost 0.5% in Denmark. Direct government support for health-related R&D in OECD countries was about 0.11% of their combined GDP in 2008.

Nearly 5% of all pharmaceutical patents in 2004-06 were invented in India and China

In 2004-06, the United States confirmed its world leadership in ***medical technologies,*** accounting for almost half of patented inventions worldwide, twice as many as the European Union. Israel accounted for 2.7%, twice its share in total patents (1.3%). Additionally, the United States had more than 42% of pharmaceutical patents in the mid-2000s. China and India together accounted for nearly 5% of patents in pharmaceuticals over the period.

A decline in productivity of the ***pharmaceutical*** sector has been evident since the mid-1990s, when increased R&D investment coincided with a decline in the number of new drugs approved for marketing.

Biotechnology research has received extensive investment from both the public and private sectors, with a growing impact on health care. New treatments and drugs, genetically modified foods, biologically controlled production processes, new materials, biologically based computing and many other applications are improving health, the environment, and industrial, agricultural and energy production.

Biotechnology R&D is over 10% of total business R&D in Ireland, Belgium, Canada and the United States

Biotechnology R&D accounts for about 22% of all business sector R&D in Ireland, and for above 10% in Belgium, Canada and the United States. Denmark, Japan and the United Kingdom also have substantial business sector capabilities in biotechnology, but data on biotechnology R&D expenditure are not available for these countries.

The surge in biotechnology patents in the late 1990s was partly due to patent applications pertaining to the human genome. The recent decrease observed in some countries raises concerns that more stringent criteria on the patenting of genetic inventions may discourage further research and reduce access to the benefits of the technology.

Nanotechnology – the science of the very small – is also likely to have a major economic and social impact in the years ahead. It may help further miniaturise information technology devices, resolve fundamental questions related to the immune system, accelerate advances in genomics and contribute to the generation of renewable energy.

Singapore is the country most specialised in nanotechnology

Inventive activities in nanotechnology have risen substantially since the end of the 1990s although the share of nanotechnology in total patenting remains relatively limited (1.1% of total patents on average). Singapore is the country most specialised in nanotechnology: its proportion of nanotechnology patents is nearly three times the average share of nanotechnology patents in all patents over 2004-06. During the same period, more than two-thirds of nanotechnology patents originated from the United States (43%), Japan (17%) and Germany (10%). Korea has also broadly invested in nanotechnology and ranks as the fourth producer of nanotechnology patents (3.7%).

Public policies are called to play an important role in orienting innovation efforts towards the solution of global challenges. ***Government R&D*** budget data provide an indication of the relative importance in public R&D spending of various socioeconomic objectives, such as defence, health and the environment.

Government R&D budgets as a share of GDP are the largest in Portugal, Spain and the United States. In 2008 defence accounted for 57% of the total government R&D budget in the United States, 30% in France and 24% in the United Kingdom. Together with Portugal and Spain, Denmark, Finland and Iceland had the largest government R&D budgets for civil programmes as a share of GDP in 2008.

Over 1998-2008, government R&D increased in all countries except Israel and France. The increase was above 10% a year in Estonia, Ireland, Korea and Spain and exceeded 20% a year in Luxembourg.

In the EU27, business financed over 7% of all R&D performed in public institutions and universities in 2006

Business funds an important share of the R&D performed in the higher education and government sectors, with an OECD-area average of 5.3% in 2006. In the EU27, companies financed 7.4% of all R&D performed in public institutions and universities, compared to only 3.2% in the United States and 2.2% in Japan.

Competing in the world economy

Progress in reducing tariff barriers, dismantling non-tariff barriers and liberalising capital markets has opened up opportunities for trade and international investment. ICTs have helped make it possible to slice up the value chain and to fragment the production of goods and services across countries. They have also enlarged the number of goods and services that can be traded internationally. These trends have increased competition in international markets and resulted in the emergence of new global players, such as China and India.

In 2007 high- and medium-high-technology manufactures accounted for over 60% of total manufacturing trade

High-technology goods have been among the most dynamic components of international trade over the last decade. Trade in manufacturing was in fact mostly driven by high-technology industries over the second half of the 1990s and until the beginning of 2005. From 2005, the value of trade in high-technology manufactures started to slow and trade in medium-low-technology manufactures surged owing to significant increases in commodity prices for oil, petroleum products and basic metals. Still, in 2007 high- and medium-high-technology manufactures accounted for 23% and 39%, respectively, of total manufacturing trade.

The ***manufacturing trade balance*** is an indicator of a country's comparative advantage. In 2007, 11 OECD countries and 2 non-members (Israel and Slovenia) had a strong comparative advantage in trade in high-technology manufactures. Switzerland had a trade surplus of over 7%, followed by Ireland with 5%. Trade in high-technology industries represented around 3% of total manufacturing trade in Korea, Mexico and the United States. Between 1997 and 2007, the comparative advantage in high-technology industries remained unchanged for most countries, although it dropped by 5 percentage points in Japan and by 3 percentage points in China and in India.

In the same period, more countries increased their comparative advantage in ***medium-high-technology manufactures***. Japan led with a trade surplus of 15%, followed by Germany and Ireland with 7% and 5%, respectively. Between 1997 and 2007, the contribution of trade in medium-high-technology industries increased by 13 percentage points in Indonesia, 11 percentage points in Turkey and 6 percentage points in China, despite these industries' continuous negative contribution to their overall manufacturing trade balance. In 2007, much of the manufacturing trade balance of these countries relied on low-technology industries.

The share of OECD countries in total world ICT trade decreased from 75% in 1997 to 52% in 2007

ICT goods and services have been among the most dynamic components of international trade over the last decade. Global trade in ICT goods (the sum of exports and imports) expanded strongly to USD 3.7 trillion in 2007. But the share of OECD ICT trade in total world ICT trade decreased steadily from 75% in 1997 to 52% in 2007 with the rapid rise in trade from non-OECD Asian countries. In 2007, ICT goods trade accounted for 11% of total trade within the OECD area. China has been the world's largest exporter of ICT goods since 2004 with exports growing by 30% a year from 1996 to almost USD 360 billion in 2007.

Business use of the ***Internet*** has become the standard in most OECD countries. Increasingly, access to broadband Internet is important to compete in the global economy. On average, 83% of all OECD firms with 10 or more employees use broadband but this share ranges from 46% in Mexico to 99% in Iceland. In a majority of OECD countries, over half of businesses have their own website.

Use of the Internet to sell goods or services varies across industries and countries. In OECD countries, on average, over 33% of all businesses (with 10 or more employees) use the Internet for purchasing and about 17% for selling goods or services.

In 2007, the share of foreign affiliates in total turnover in manufacturing varied from about 80% in Ireland to 3% in Japan

Foreign affiliates provide access to new markets and new technologies for domestic firms. In 2006, the share of firms under foreign control in total turnover in manufacturing varied from about 80% in Ireland to 3% in Japan. It exceeded 50% in Belgium, Canada, the Czech Republic, Hungary and the Slovak Republic. In services, the share of turnover under foreign control is over 30% in Belgium, the Czech Republic, Hungary, Ireland, Poland, the Slovak Republic and Sweden.

Connecting to global research

Today, scientific and technological innovation requires more complex and interactive processes. This added complexity has led innovators to partner to share costs, find complementary expertise, gain access to different technologies and knowledge quickly, and collaborate as part of an innovative network. This entails a need for individuals and institutions to adopt a more "open" perspective on innovation.

Over 15% of the patents filed by an OECD country in 2004-06 concerned inventions made abroad

In Belgium, Chinese Taipei and Switzerland, over 40% of the patents filed in the mid-2000s resulted from collaboration with at least one inventor from abroad. For France, Germany, Sweden, the United Kingdom and the United States between 11% and 24% of patents in 2004-06 involved ***international co-operation***. In Sweden and the United Kingdom, the share of co-invented patents increased by more than 5 percentage points from 1996-98 to 2004-06. Japan and Korea have the lowest shares of international co-invention, and these have declined from the mid-1990s.

Patent data show a significant degree of ***internationalisation of research activities***. On average, over 15% of the patents filed by an OECD country in 2004-06 under the Patent Co-operation Treaty (PCT) concerned inventions made abroad. Similarly, the share of inventions owned by another country accounted for just below 15% of all OECD filings.

In 2007, about 22% of scientific articles involved international co-authorship, a figure three times higher than in 1985.

These figures show that the mode of production of scientific knowledge has shifted from individuals to group, from single to multiple institutions, and from the national to the international level. Researchers are increasingly networked across national and organisation borders. Moreover, ***international co-authorship*** has been growing as fast as domestic co-authorship. In 2007, 21.9% of scientific articles involved international co-authorship, a figure three times higher than in 1985.

While scientific publications are concentrated in a few countries – over 80% of the articles in science and engineering published worldwide are from the OECD area – growth has recently been faster in ***emerging economies***. Scientific articles from Latin America have more than tripled since 1993 and those from south-east Asian economies (Indonesia, Malaysia, the Philippines, Thailand and Vietnam) expanded almost three times over the period.

The technology balance of payments provides a measure of ***international technology transfers***: licence fees, patents, purchases and royalties paid, know-how, research, and technical assistance. Unlike R&D expenditure, these are payments for production-ready technologies.

Between 1996 and 2006, the European Union transformed its technology balance of payments deficit into a surplus

In most OECD countries, technological receipts and payments increased sharply during the 1990s and up to mid-2000. Between 1996 and 2006, the European Union transformed its technology balance of payments deficit into a surplus, although this includes intra-EU flows. The US surplus increased slightly while the most spectacular improvement occurred in Japan. Overall, the OECD area maintained its position as net technology exporter *vis-à-vis* the rest of the world.

Technological development can be achieved either through domestic R&D expenditure or the ***acquisition of foreign technology***. In Greece, Hungary, Ireland, Poland and the Slovak Republic, among others, technology imports exceed technology exports.

R&D funding from abroad also plays quite an important role in the funding of business R&D. Most R&D investments still go to OECD countries; however, China and India, among other emerging countries, are increasingly considered as attractive locations for R&D. In the EU27, funding from abroad represented around 10% of total business enterprise R&D in 2006.

The share of ***foreign affiliates in industrial R&D*** varies widely across countries, ranging from 5% in Japan to over 60% in Ireland and the Slovak Republic. In Belgium, the Czech Republic, Portugal and Sweden the share of R&D expenditure by foreign affiliates is over 40%.

Collaboration with foreign partners can play an important role in the innovation process by allowing firms to gain access to a broader pool of resources and knowledge at lower cost and also offers a way to share the risks with partners. The share of European firms collaborating on innovation with partners across Europe ranges from less than 2% in Spain and Turkey to over 13% in Finland, Luxembourg and Slovenia. Collaboration with partners outside Europe is much less frequent and concerns between 1% and 5% of firms in most European countries. Overall, innovating firms from the Nordic countries and some small European economies (Belgium, Luxembourg and Slovenia) tend to collaborate more frequently with partners abroad.

The number of foreign students within the OECD has doubled between 2000 and 2006

International migration is another essential means of fostering global innovation. The importance of migrants in the innovation process has increased in recent years and there is growing global competition for talent. Moreover, mobility contributes to the creation and diffusion of knowledge.

As part of this trend, the number of ***foreign students*** within the OECD area has tripled since 1980 and doubled between 2000 and 2006. This trend is likely to continue, fuelled by the ease and decreasing costs of international travel and communication, by education and migration policy initiatives, and possibly by a labour market premium for those who have studied abroad.

International mobility of doctoral students has increased significantly since the early 2000s. The rise has been particularly strong in Canada and New Zealand, but also in Norway and in Spain. Non-citizens represent more than 40% of the doctoral population in New Zealand, Switzerland and the United Kingdom, but less than 5% in Italy and Korea. The United States hosted the largest foreign doctoral population, with more than 92 000 students from abroad in 2006, followed by the United Kingdom (38 000) and France (28 000).

Investing in the knowledge economy

In times of recession, education and the formation of human capital undergo opposing forces: on the one hand, budget constraints – in government, households and businesses – tend to reduce expenditure; on the other hand, rising unemployment leads to greater demand for training. Public policies, therefore, have an important role in ensuring continuous investments in education and training.

7.1 million degrees were awarded in the OECD area in 2007

New university graduates indicate a country's capacity to absorb, develop and diffuse knowledge and to supply the labour market with highly skilled workers. In 2006, more than one young person in three graduated at the first-stage university level in the OECD area. This represents 7.1 million degrees awarded.

Australia, Iceland and New Zealand had the highest graduation rates (over 50%). Japan (39%) ranks slightly above the OECD average (37%). The United States (36%) and the EU (35%), the two main university systems with 2.9 and 2.2 million degrees awarded, respectively, rank just below.

In China the number of graduates has almost tripled since 2000 but the graduation rate is only 12%

Emerging countries are also expanding their first-stage university system. Graduation rates in the Russian Federation (45%) are significantly above the EU average. In China the number of graduates has almost tripled since 2000, although the graduation rate (12%) is still low compared to the OECD average.

Most university degree recipients graduate in the social sciences. ***Scientific studies*** are more popular in Korea and the Nordic countries, where science and engineering (S&E) degrees account for 37% and 29%, respectively, of total awards. In most OECD countries, universities deliver more engineering than science degrees.

OECD governments are concerned about the low level of ***female participation in scientific studies***. The presence of women is overwhelming in humanities and the arts (67%), health (74%) and education (75%) but low in engineering (23%) or computing (23%).

40% of OECD doctoral students graduate in science and engineering

Doctoral graduates are key players in research and innovation. They have been specifically trained to conduct research and contribute to the diffusion of knowledge in society. Despite the declining share of S&E doctorates, 40% of OECD doctoral students graduate in scientific fields; the S&E orientation of doctoral programmes is even more pronounced in emerging countries.

In 2006, EU universities awarded half of the total OECD doctoral degrees; they are particularly strong in S&E disciplines. The United States and Germany awarded 28% and 13%, respectively.

Women are under-represented in advanced research programmes. They account for just 32% of the S&E programmes in OECD. However, the gender imbalance at the doctoral level is less pronounced than at lower levels of education.

In 2006, Brazil, China, India and the Russian Federation combined trained half as many doctoral graduates as OECD countries together

In many OECD countries ***doctoral degrees*** have multiplied faster than other university degrees. Since 2000 the number of OECD-area doctorates has increased by 5% a year and the number of first-stage university degrees has grown by 4.6%. In 2006, Brazil, China, India and the Russian Federation combined trained half as many doctoral graduates as OECD countries taken together. Although graduation rates are lower outside the OECD area, Brazil and the Russian Federation award more doctorates per inhabitant than the OECD average.

Human resources in science and technology represent over a quarter of total employment in most OECD countries

Human resources in science and technology (HRST) are major actors in innovation. In most OECD countries, they represented more than a quarter of total employment in 2008. Over the past decade, HRST occupations increased more rapidly than total employment in most OECD countries. In services, the average annual growth rate has always been positive, ranging from 1.1% in the United States to 6.3% in Spain. However, in manufacturing, the share of professionals and technicians decreased in Luxembourg (–2.1%), the United States (–1.3%), Japan (–1.2%) and Sweden (–0.5%).

A particular characteristic of HRST employment is the increasing share of women. Indeed, women are traditionally more numerous than men among HRST employees in OECD countries. In Hungary, Poland and the Slovak Republic, 60% of HRST in 2008 were women.

On average, 35% of persons employed in the OECD area had a tertiary-level degree in 2007

Employment of tertiary-level graduates is an indicator of the innovative potential of an economy and of the capacity of its labour market to allocate human capital to the production process. On average, 35% of persons employed in the OECD area had a tertiary-level degree in 2007. Canada (over 50%), Finland, Japan, New Zealand and the United States (over 40%) ranked far ahead of the European Union, where just over one worker in four holds a tertiary-level degree. In the Czech Republic, Italy, Portugal and the Slovak Republic tertiary-level graduates account for 20% of employment or less.

Between 1998 and 2007, employment of tertiary-level graduates rose on average almost three times faster than total employment. This growth is due in part to the increased presence of women in the labour market. Despite their greater propensity to graduate at tertiary level, women represent on average 46% of tertiary-level employment.

University graduates are also generally less likely than non-graduates to remain unemployed. However, the ***unemployment rate among university graduates*** is higher in Turkey (6.9%), Poland (6.2%), Greece (5.4%) and France (5.3%). Women with a university degree are less likely to be unemployed than women without one, yet their unemployment rate is higher than that of men with the same level of education.

Doctorate holders have a research qualification and are a pillar of the research system. Their presence is an indicator of a country's attractiveness for new and foreign talents. ***Employment of doctorate holders*** ranges from 97% to 99% and exceeds that of university graduates (83% to 89%). Many doctorate holders face temporary employment in the early stage of their careers. After five years of activity, 60% of doctorate holders in the Slovak Republic and over 45% in Belgium, Germany and Spain remain under temporary contracts. Yet permanent engagements account for over 80% of all jobs in almost all countries.

In some OECD countries, the average earnings premium for a tertiary-level diploma holder is above 75%

The ***earnings premium from education*** is an important incentive for individuals to enrol in tertiary education. In all OECD countries, annual earnings increase with educational attainment levels. In the Czech Republic, Hungary, Portugal and the United States, the average earnings premium for a tertiary-level diploma holder was no less than 75% in 2006. Such differentials are traditionally smaller in Nordic countries and lower than 30%.

Over the past decade, the earnings premium of highly skilled workers decreased the most in Italy (–6.4%), Ireland (–4.3%), Hungary (–4%), Germany (–3.4%) and Poland (–2.9%). The opposite trend is observed in Australia, New Zealand, Spain and Sweden it increased at an average annual rate of between 1% and 3%.

Earnings differentials between males and females still remain significant in all OECD countries. In Austria, Germany, Italy and the United States, women earn at least 40% less than men in HRST occupations. This gap seems smaller in Belgium, Spain and Turkey (22% less in each) and in Luxembourg, although the data do not control for part-time work.