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OECD Science, Technology and Industry Scoreboard 2007

Highlights

This eighth edition of the ***Science, Technology and Industry Scoreboard*** brings together the latest data and indicators on trends in knowledge, on globalisation and on its impact on economic performance in OECD and non-member economies. In this edition, the focus broadens to include emerging countries, with a special focus on the BRICS (Brazil, Russia, India, China and South Africa). New data document trends in public support for knowledge creation and diffusion, and new indicators point to the changing landscape of countries' scientific specialisation and innovation performance. New sources of data on the international mobility of the highly skilled provide a more complete picture of the role of scientific and technological human capital as an engine of growth. Information on emerging fields (biotechnology, nanotechnology and the environment) reveals the increasing linkages between science and technology.

First are analysed the inputs and mechanisms that aim to stimulate innovation: the current situation of investment in research and development (R&D), the continuing growth of human resources in science and technology (HRST), and recent policy changes in the field of research and innovation. Next are examined the outputs of investment in knowledge and advances in information and communication technologies (ICT) and other technology fields (biotechnology, nanotechnology and environmental technologies). There follows an overview of recent patterns in scientific and technological research and economic globalisation. Finally, consideration is given to the impact of investment in knowledge and innovation on productivity and trade.

Investment in knowledge has grown at the same pace as GDP

Since 2001, R&D expenditure in the OECD area has kept pace with the growth of GDP, at about 2.25% of overall GDP

Investment in knowledge is the basis of innovation and technological progress. As measured by R&D expenditure, software and education, it continues to rise in most OECD economies. Since 2000, in most of the countries surveyed, growth has been more rapid in education and R&D than in software. Across the OECD, however, R&D has grown more slowly than in the second half of the 1990s, owing in part to a readjustment of investment following the acceleration of the late 1990s and the slowdown of investment in R&D in the United States.

In 2005, China took third place world wide in terms of R&D expenditure

In both Japan and the EU, R&D intensity (R&D expenditure relative to GDP) picked up in 2005 to 3.3% and 1.7%, respectively, following a drop in 2004. In the United States, R&D intensity declined from a peak of 2.7% in 2001 to 2.6% in 2006, mainly owing to stronger growth in GDP than in the other main regions. In 2005, China became the third R&D spender world wide (in purchasing power parity terms) after the United States and Japan, with growth of more than 18% a year in 2000-05.

The business enterprise sector accounts for the bulk of R&D in OECD countries in terms both of performance and of funding (at 63 and 68%, respectively, of the total), and, except in the United States, its share has risen over the past few years. Compared to 1995, the share of business-funded R&D in GDP in 2005 is much higher in Japan (2.5%), the United States (1.7%) and the EU (0.9%).

Venture capital is a major source of funding for new technology-based firms and a decisive determinant of entrepreneurship and innovation. It represented about 0.12% of OECD-wide GDP in 2005, up from 0.10% in 2003. It was much higher in Nordic countries (and growing rapidly), but it still remains concentrated in the United Kingdom and the United States. In 2005, these two countries attracted half of all OECD venture capital.

Employment of HRST has expanded due notably to increases in female employment and expansion of the services sector

Human resources in science and technology are a major factor in countries' ability to generate and adopt new technology and new business practices. According to the most recent figures, employment of HRST continues to grow much faster than total employment in all countries, at an average annual rate of 2.5% in the United States and 3.3% in the EU15. This expansion has been mainly driven by increases in female employment and the expansion of service industries (with a share of HRST in employment that is on average twice that of manufacturing). Nordic countries report the highest shares of R&D personnel and highly skilled workers in total employment.

The share of foreign doctoral students in total doctoral enrolments is particularly high in Switzerland, Belgium and English-speaking countries. It rose significantly between 1998 and 2004 in all countries (less so in the United States). Among the OECD countries which report these figures, the United States has the largest number of foreign doctoral students. About 10 000 foreign citizens obtained a doctorate in S&E in the United States in 2004 and in 2005 and represented 38% of S&E doctorates awarded there. In 2005, Asians accounted for more than two-thirds of non-US doctorates (Chinese students accounted for 30% and Koreans for 10%). Doctorate recipients, particularly from China and India, often remain in the United States on a post-doctoral position or take a job.

Innovation policies: increased focus on tax incentives and industry-university linkage

In 2006, 20 OECD countries offered tax relief for R&D compared to 12 in 1995

OECD countries' policy mix for fostering innovation is changing. In 2005, direct government funds financed an average of 7% of business R&D, down from 11% in 1995, with a shift away from public procurement (direct subsidies) and towards tax relief. In 2006, 20 OECD countries offered tax relief for business R&D, up from 12 in 1995 (18 in 2004), and most have tended to make it more generous over the years. In this way, governments create an incentive to undertake R&D but leave the choice of types of projects to market forces. Government revenue forgone as a result of R&D tax credits can be substantial, *e.g.* USD 5 billion in the United States, about USD 1 billion in France and the United Kingdom, and some USD 300-400 million in the Netherlands, Mexico, Australia, Belgium and Spain (2005 figures). These sums represent 23% of direct subsidies in the United States, 43% in France, twice the total amount of direct subsidies in the Netherlands and 1.2 and 1.3 times the amount in Ireland and Australia.

In most of OECD countries, university patenting is increasing

In order to stimulate technology transfer from universities to businesses, many OECD governments have encouraged universities to patent their inventions. OECD-wide, between 1996-98 and 2002-04, the share of patents filed by universities has been stable. While decreasing slightly, to about 7%, in the countries that pioneered such policies (Australia, Canada and the United States), the share has increased markedly in Japan and the European Union, notably in France and in Germany, although levels remain modest (1.5% in Japan, 3% in the EU, but more than 5% in France). The four OECD countries with the highest rate of university patenting are Ireland, Spain, the United Kingdom and Belgium. It is not known what share of these patents is actually exploited.

Business funding of university research gives companies a way to watch out advances in science and acquire new knowledge. European companies (EU27) finance 6.4% of R&D performed by public institutions and universities compared to 2.7% in the United States and 2% in Japan.

Co-operation between industry and public research institutions (government laboratories and universities) has also been a major policy target in recent years. Information on collaboration on innovation is collected in innovation surveys. In spite of numerous obstacles (*e.g.* embryonic stage of inventions, difficulty in negotiating exploitation of intellectual property rights), co-operation with universities is a frequent innovation strategy, especially in large companies. The Nordic countries (especially Finland) and Belgium are ahead of other countries for which data are available.

S&T and innovation performance: the rise of new players

Investment in knowledge leads to S&T outputs, and in turn to new products and services and new modes of organising business. This technological and organisational innovation determines economic performance.

China ranks sixth world wide in terms of publications and has raised its share in triadic patents from close to zero in 1995 to 0.8% in 2005

The United States, Europe and Japan remain at the forefront of world science with 30, 33 and 8%, respectively, of total scientific publications; they also lead in patenting of important inventions, as measured by triadic patents (each had 30% of the total in 2005). In per capita terms, however, Switzerland takes first place, followed by the Nordic countries, and emerging countries still lag far behind the OECD average. In terms of specialisation, patent data show that emerging economies (India, China, Israel, Singapore) and the United States focus their innovative efforts on high-technology industries (computers, pharmaceuticals) while continental Europe concentrates on medium-high-technology industries (automobiles, chemicals).

In service industries new types of organisation and marketing are a major source of innovation

Innovation surveys show that large firms have a greater tendency to innovate than small ones. In terms of non-technological innovation (organisation, marketing), service industries are as strong as manufacturing industries, but they account for much less technological innovation. For service firms, non-technological innovation is a strong driver of performance.

The renewal of the population of businesses, through the birth and death of firms, is an indicator of the process of "creative destruction", a major characteristic of innovation. The creation of start-ups is a manifestation of innovation and frequently reflects the emergence of new technologies and other forms of technological change. In 2003, rates of creation varied widely, from 14 to 18% (New Zealand, Germany, Canada and the United Kingdom) to 4 to 6% (Japan, Iceland, Sweden and Portugal). Destruction rates also differed and were lower than creation rates in most countries.

The patents-to-R&D ratio is an indicator of the cost of developing technology and has been fairly constant in most countries since 1995. OECD-wide, a triadic patent family corresponds to R&D expenditures of USD 8 million on average; it is USD 11 million in the United States, USD 7 million in Europe, and USD 5 million in Japan. Since 1995, the cost has decreased in the Netherlands (to USD 3 million) and in Korea (USD 6 million), but has increased in the United States (USD 9 million in 1995).

California and Tokyo are by far the most inventive regions in ICT and biotechnology

In all OECD countries, inventive activities are more geographically concentrated than population, owing to the existence of local clusters of innovation and the dynamics of

regional economies. For ICT and biotechnology, Europe shows less geographical concentration of innovative activity, as several regions have quite similar performance.

After the explosion of the late 1990s, steadier diffusion of ICT

Technological advances and the diffusion and use of ICT have boosted economic change over the past decade. ICT has become a strategic enabler of companies' organisational and technological innovation.

In 25 OECD countries over 89% of businesses use the Internet

ICT is diffusing at a more regular pace than in the late 1990s and early 2000s, as confirmed by Internet use in households and e-commerce, although the level of the latter remains modest. The penetration of broadband among households has progressed rapidly over the past three or four years in all countries but penetration rates vary. For households, Korea, Japan and the Nordic countries feature rates of 50 to 80%, while those for Italy and Ireland are around 10 to 15%. The take-up of broadband depends on computer penetration, but also on the level of competition and availability of service. Business use of the Internet has become fairly standard in OECD countries: in 25 countries more than 89% of businesses with ten or more employees have access to the Internet and over half have their own website.

OECD-wide, the finance and insurance industry has the highest rate of Internet connectivity, followed by wholesale trade and the real estate, renting and business services industries. Between 1995 and 2004, more ICT specialists are employed in all countries except Portugal and all countries have consistently more ICT users in total employment. Such sustained pace of diffusion is supported by the fact that ICT has maintained its technological dynamism, as reflected in higher shares of patenting in national totals in most OECD countries.

The emergence of biotechnology, nanotechnology and environmental technologies

Certain fields deserve special scrutiny, in view of their current or expected impact on society and the economy, notably in terms of industrial innovation and applications, health and the environment. Data on S&T outputs and activities in biotechnology, nanotechnology and environmental technologies clearly reveal the differences in specialisation among countries.

The United States has the most biotechnology firms (close to 2 200), followed by Japan and France (around 800 each). In most countries, biotechnology represents 2 to 6% of business R&D but the share is higher in the United States, Switzerland and Canada, and above all in some smaller countries where it exceeds 20% (Denmark, New Zealand, Iceland). In the ten reporting countries, most biotechnology firms are active in health (45%), followed by agro-food and industry-environmental applications (around 25% each). In terms of R&D expenditure as well, health is by far the most important field. The number of biotechnology-related patents has been declining since 2000 in most countries, after a sharp increase in the late 1990s, notably owing to the more restrictive criteria applied by

patent offices and the end of the wave of patenting following the decoding of the human genome.

While the United States and Japan take the lead in biotechnology and nanotechnology, the EU leads the way in environment-related technology

The United States and Japan have a comparative advantage in biotechnology and nanotechnology patenting and in the relevant scientific fields, while the EU is the world leader in environment-related technologies (solid waste, renewable energy and motor vehicle abatement), with Germany playing a very active role. Japan is second to the EU in all three environmental technology fields. However, while patenting in renewable energy and motor vehicle abatement has been increasing rapidly since the mid-1990s, patenting in solid waste technologies has declined.

Innovation is an increasingly collective and international endeavour

There has recently been a sharp rise in the globalisation of scientific and technological activities, including research. Innovation has increasingly become a collaborative endeavour on a global scale, it has taken new non-technological forms, and it diffuses more rapidly because of new information technologies. The advent of global value chains, differences in R&D costs, increased flexibility in handling cross-border R&D projects (owing to ICT), and major policy changes (such as stronger intellectual property rights or the tax treatment of R&D) have all favoured this trend. Helping to drive this phenomenon are the creation of alliances (to obtain synergies and complementarities) and the search for new knowledge competencies.

Since the early 1990s cross-border ownership of inventions has expanded from 11 to 16% of total patented inventions

International co-authorship of scientific publications increased by a factor of three between 1995 and 2005. Cross-border co-operation on inventions (share of patents with co-inventors located in two or more countries) nearly doubled as a share of total inventions world wide (from less than 4% to more than 7% between 1991-93 and 2001-03). Foreign ownership of domestic inventions (patents) increased by 50% between the early 1990s and the early 2000s. It reflects the importance of multinationals' R&D labs located in a country different from that of their headquarters. EU countries interact most often with each other and are less globalised than the United States, while Japan and Korea are less internationalised overall.

In a majority of reporting countries, foreign affiliates' share of total expenditure on manufacturing R&D is now higher than their share in total manufacturing turnover

The surge in the internationalisation of research is corroborated by multinationals' recent patterns of investment. R&D performed abroad and by foreign affiliates represents

on average well over 16% of total industrial R&D expenditure in the OECD area. Furthermore, the average R&D intensity of affiliates under foreign control is higher than the R&D intensity of domestically controlled firms in most countries. This is the case in Japan, Sweden, the United States and the United Kingdom and confirms the increasingly global dispersion of R&D activities as they move closer to markets and to sources of knowledge (poles of excellence).

International flows of technology, as reflected in the technology balance of payments, nearly doubled in the OECD area between 1995 and 2005, and their share of GDP increased from 0.32% to 0.52%. Japan has experienced the fastest growth and has almost caught up with the United States, where flows have remained nearly constant, while the EU had by far the largest, and rapidly increasing, flows.

Value chains as a centrepiece of globalisation

As reflected in available indicators the internationalisation of economic activity – trade, investment, technology trade – is trending upwards. Investment flows, notably portfolio investment, increased rapidly in 2003-05 and represented the equivalent of 12% of OECD GDP. Trade in goods represented 19% of OECD GDP in 2001-05, while trade in services represented about 5%, a significant increase over the early 1990s.

For its part, foreign direct investment has progressed steadily in most countries since the mid-1990s. Among large OECD countries, it represents a greater share of GDP in the United Kingdom and in France than in Germany, the United States and Japan. In the manufacturing sector firms under foreign control represent between 3% (Japan) and 75% (Ireland) of total turnover. In all countries they have a smaller share in employment than in turnover, as they are more capital-intensive than firms under domestic control, and their share in exports is higher as they usually serve the international more than the local market.

Intermediates represent 20 to 30% of total imports in OECD countries, reflecting the globalisation of value chains

The globalisation of value chains, which divides production processes up among different countries, is an important aspect of globalisation. It is reflected in the growing international trade of intermediates, which represented in 2000 between 20 and 30% of total imports in most OECD countries. The "import content of exports", which qualifies the export performance of countries, is also on the rise and represents some 20 to 30% of the value of exports in most OECD countries.

The weight of imported inputs in exports is greater in basic industries (which import primary goods and export transformed goods) and in ICT-related industries, in which the design and manufacturing of sophisticated components is often separated from the less technology-intensive assembly process. China is the most notable example of the growth in the level of import content of exports (20% in 2000).

The share of intra-firm trade in these transactions remains prominent in countries such as the United States and the Netherlands, where intra-firm exports continue to represent around 50% of total exports of manufacturing affiliates under foreign control.

Knowledge and innovation leading productivity and trade

GDP per capita is the most commonly used measure of welfare. It is the highest in the United States and most OECD countries are at 70-85% of US income levels. Differences in GDP per capita reflect a combination of labour productivity, measured as GDP per hour worked, and labour utilisation, measured as hours worked per capita. The latter largely reflects working time and conditions on the labour market (unemployment). In terms of productivity, several European countries have the highest levels (Belgium, Ireland, France, the Netherlands) but have much lower levels in terms of labour participation.

Productivity growth in the OECD area is increasingly dependent on ICT and on business service

From 0.3 to 0.7 percentage points of annual GDP growth in Australia, Denmark, Sweden, the United Kingdom and the United States over 1995-2005 were due to investment in ICT, which had a smaller impact in other countries. As the share of business services in the economy has increased, their contribution to productivity growth has also risen in most OECD countries since 2000, the major exceptions being Finland, Germany, Korea and Sweden.

Due notably to the globalisation of value chains, the share of high and medium high tech in manufacturing has decreased in most OECD countries

Parallel to this evolution, the share of high and medium-high-technology industries in total manufacturing has declined over the past decade in most OECD countries. This is due in part to changes in global value chains (notably offshoring) which are helping to reconfigure industrial structures and trade. High-technology industries, together with medium-high-technology industries (notably motor vehicles, chemicals and machinery and equipment), still represent just under 65% of OECD manufacturing trade. Medium-high-technology industries represent around 40% of total manufacturing trade and medium-low-technology industries represent 18%, a rise of three points since 2000. The notable spurt in the value of medium-low-technology trade is partly due to the recent significant increases in commodity prices for oil and basic metals, particularly those in great demand for the manufacture of ICT goods.

High- and medium-high-technology manufacturing accounts for significant shares of exports from Ireland, Japan and Switzerland (shares of over 75%) as well as from Germany, Hungary, Korea and the United States. Among the BRIICS (Brazil, Russia, India, Indonesia, China and South Africa), these industries' exports are most important in China and Brazil, accounting for 55 and 32%, respectively, of total exports of manufactured and primary products. Because of the globalisation of value chains, a country such as China imports more high-technology goods than it exports; much of these imports are components that are assembled in Chinese factories.