OECD Science, Technology and Innovation Outlook 2016 — Methodology

Methodological Annex to the 2016 OECD STI Outlook Country Profiles

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Introduction

The OECD Science, Technology and Innovation Outlook[1] is a biennial publication that reviews key global trends in science, technology and innovation (STI) and related policies and offer insights on recent national STI policy developments in OECD countries and key emerging economies, including Brazil, the People's Republic of China, India, Indonesia and the Russian Federation (BRIICS). In particular, the country profiles of the OECD STI Outlook (Chapter 12) present the main features, strengths and weaknesses of national STI systems and major recent changes in national STI policy along a standardised and cross-country comparable structure. This annex describes the conceptual background used to design these profiles, as well as indicators, sources and benchmarking methodology.

The statistical framework of the STIO has been extended in its 2012 edition, from around 20 indicators to over 300 indicators as to include a broader range of STI areas. The policy dimension has also been reinforced through a more systematic and comprehensive use of national STI policy information. that is collected on a biennial basis through the EC (European Commission)/ OECD International Survey on STI Policies (STIP), formerly the OECD STI Outlook Policy Questionnaire.

The country profiles are at the interface of two main streams of work carried out under the auspices of the Committee for Scientific and Technological Policy (CSTP):

✓ The policy research conducted by the Working Party on Technology and Innovation Policy (TIP), on the links between innovation and sustainable growth and the evaluation of national STI public support schemes, and the work of the former Working Party on Research Institutions and Human Resources (RIHR), on the main institutional, regulatory and management conditions needed to strengthen the knowledge base for innovation and the research capabilities of public research institutions (PRIs). The policy dimension of the country profiles has also benefited from experience gained through the OECD Country Reviews of Innovation Policy and previous OECD work on national innovation systems (NIS). The main and most recent source of country-specific STI policy information is provided by countries' responses to the EC/OECD STIP Survey. The latest STIP Survey has been conducted between November 2015 and February 2016 to CSTP delegates and the Delegates of the European Research Area and Innovation Committee (ERAC). Official documents and external sources, such as the EU Riowatch reports were also used when appropriate.

✓ The statistical work and empirical analysis conducted by the Working Party of National Experts on Science and Technology Indicators (NESTI) on measuring innovation and developing internationally comparable S&T indicators for policy analysis. The statistical dimension of the country profiles has also drawn on data collections and empirical work carried out by the Committee on Industry, Innovation and Entrepreneurship (CIIE) and the Committee for Digital Economy Policy (CDEP), in their respective areas of work. Finally, the biennial *OECD Science, Technology and Industry Scoreboard* is a key reference (OECD, 2009, 2011a, 2013a, 2015a).

This methodological annex first introduces the conceptual framework used to characterise and assess national innovation systems (NIS). It then presents the key indicators chosen to gauge their performance. It reviews the reasons for the choices made, the sources used, some limitations on interpretation of the data and certain technical aspects (calculations, normalisation criteria, etc.).

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[1] Formerly OECD Science, Technology and Industry Outlook.
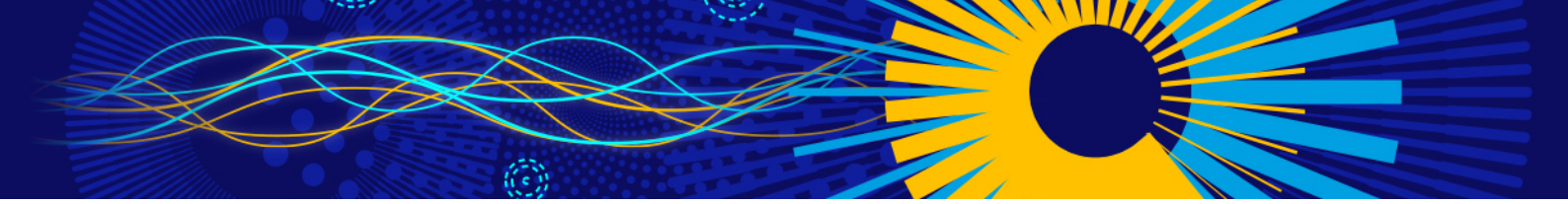
What should be measured: A conceptual framework

A particular effort has been made to improve evidence on how innovation systems function and perform by mapping and measuring input, output and outcomes (OECD, 2010a).

The following framework provides the standard structure used to describe the NIS and to map the innovation policy mix (Kergroach, 2010; Kergroach *et al.*, forthcoming-a). It is used throughout the *OECD STI Outlook 2016*, in particular to relate the policy profiles (thematic approach) to the country profiles (country approach). It served a role in the design of the policy questionnaire used to collect information and official data on major STI policy programmes and on recent changes in national STI policy.

Public intervention may seek to: *i)* improve STI policy governance; *ii)* improve the competences and capacity of STI actors to innovate in universities and public research institutes (PRIs), on the one hand, and firms, on the other; *iii)* improve interactions among STI actors to accelerate technology transfer and increase their capacity to connect to international knowledge networks; and *iv)* improve skills for innovation.

STI policy governance

As the portfolio of innovation policy instruments has broadened, STI policy has become increasingly sophisticated. The accumulation of STI policy initiatives over time has raised the risk of government failures and the dispersal of state power to supra- and sub-national, quasi-state and non-state actors; it has also favoured the emergence of new forms of multi-level and multi-actor governance (Flanagan *et al.*, 2010) that make the possible side effects of public intervention increasingly difficult to detect and anticipate. Moreover, in the aftermath of the 2008 financial crisis, governments are under strong pressure to find new sources of growth, to meet societal and global challenges and to consolidate their fiscal accounts (OECD, 2014a). Good governance requires identifying strategic priorities, combining the right instruments and making the most of stable, or even shrinking, resources.

More detailed information about the rationale for and major aspects of STI policy intervention, as well as recent STI policy trends, can be found in "Part II: STI policy profiles" of this volume (only accessible online).

STI actors' competences and capacity to innovate

Universities and public research

Public-sector research is considerably smaller than business research and development (R&D) in the majority of OECD countries; higher education and government expenditure on R&D account for about 30% of total OECD expenditures on R&D (OECD, 2016a). However, PRIs and research universities play an extremely important role in innovation systems by providing new knowledge, especially in areas in which economic benefits are uncertain or less immediate. Public research also meets specific needs of national interest, such as defence, and of the population at large, e.g. health care (see the policy profile *Public research missions and orientation*). In addition public research tends to be counter-cyclical and to serve as a buffer by complementing funding gaps arising from declines in private R&D investment during economic downturns (OECD, 2014a). Gross domestic expenditures on R&D (GERD) declined by 1.3% in 2009 in the OECD area, driven by a sharp contraction of business R&D spending (-4.2%), while expenditure by higher education (+4.9%) and government (+4.0%) kept growing. The same occurred in 2002 after the explosion of the IT bubble, although to a lesser extent.

Innovation in firms

Firms are major actors in national innovation systems (See Chapter 8 on *Innovation in firms*). They turn ideas into economic value, account for the largest share of domestic R&D in many countries and also carry out non-technological innovation. In addition, start-ups can exploit knowledge that is not used or is underused by existing companies and draw on existing knowledge to enter new or established markets (Acs *et al.*, 2009). This is especially true in knowledge-intensive sectors.

Public sector innovation

Increasingly sophisticated public demand and new challenges due to fiscal pressures require innovative public-sector approaches. Public-sector innovation involves significant improvements in public services delivery in terms both of the content of these services and of the instruments used to deliver them. Many OECD countries intend to create services that are more user-focused, better defined and better target user demand. However, there is limited knowledge and awareness of the full range of tools available to policy makers for accelerating innovation in this area and the STI Outlook focuses on the other types of STI actors (see the policy profile *Public sector innovation*).

STI actors' interactions

Science is the basis of most innovation, especially in frontier fields (such as biotechnology). Innovation is increasingly achieved through the convergence of scientific fields and technologies (OECD, 2010c). The rapidly increasing amount of knowledge required for innovation has encouraged STI actors to co-operate and connect to global knowledge flows.

ICT and scientific infrastructure

Empirical studies point to a positive link between increased adoption and use of ICTs and economic performance at the firm and macroeconomic level (OECD, 2012a). Governments see ICTs and the Internet as a major platform for research and innovation (see the policy profile Innovation and the digital economy).

To conduct scientific research and to attract and retain world-class researchers requires a critical mass of large-scale scientific infrastructures, costly equipment and modern facilities and thus large amounts of public and private investments.

Clusters

Clusters are geographic concentrations of firms, universities, PRIs, and other public and private entities that facilitate collaboration on complementary economic activities. Clusters facilitate knowledge spillovers and a collective pool of knowledge that result in higher productivity, more innovation and more competitive firms. Governments promote clusters through investments in ICT, scientific infrastructure and knowledge, networking activities and training (see the policy profile *Cluster policy*).

Knowledge flows and the commercialisation of public research results

Various mechanisms facilitate knowledge valuation, circulation and commercialisation. Intellectual property rights (IPRs), such as patents or trademarks, facilitate the transfer of knowledge and technologies by ensuring that the knowledge generated will not be misappropriated and that much of the benefits can be internalised (see the policy profile *Patent policies*). Technology transfer from academia is encouraged to increase the economic impact of investments in public research. The commercialisation of public research results via the cession of intellectual property (IP), the establishment of new ventures (e.g. academic spin-offs), contracting to universities and PRIs by industrial actors or the setting up of collaborative R&D projects may also create additional financial resources for universities and PRIs (see the policy profile *Commercialisation of public research*). IPRs are therefore increasingly traded in markets and the number of intermediaries that broker commercialisation activities, notably IP services, has risen. Open science also increases the channels for transferring and diffusing research results (e.g. ICT tools and platforms, alternative copyright tools) and open innovation in firms creates a division of labour in the sourcing of ideas and their exploitation (see the policy profile Open science).

Globalisation of STI systems

Trade, investment and research systems are increasingly globalised (OECD, 2014a). Countries and firms engage in international co-operation in STI with a view to tapping into global pools of knowledge, HR and major research facilities, to sharing costs, to obtaining more rapid results, and to managing the large-scale efforts needed to address challenges of a regional or global nature effectively (see Chapter 6 on *Globalisation of innovation policies*).

Human resources for innovation

Education

Because it raises attainment levels and the general level of education, can inspire talented young people to enter innovation-related occupations and equip people with the highest skills, formal education remains the main vehicle for improving the supply of the diverse and complex skills required for innovation. In addition to scientific, technological, engineering and mathematics skills innovation requires soft skills (entrepreneurship, creativity, leadership etc.) (see the policy profile *Strengthening education and skills for innovation*).

Employment and lifelong learning

The supply of the highly skilled can be further enlarged by improving the attractiveness of research and entrepreneurial careers, by facilitating the sectoral and international mobility that eases the cross-fertilisation of ideas and learning, or by facilitating the transition from higher education and training to employment and *vice versa*. The acceleration of technological change has made lifelong learning a key means of preserving and upgrading the pool of human resources for science and technology (HRST). Demand for the highly skilled can also be boosted through support for job openings in academia or in the business sector, especially in small and medium-sized enterprises (SMEs). Mismatches between demand and supply can be addressed by promoting mobility and training and by building knowledge about current and future skills needs (see the policy profile Labour market policies for the highly skilled).

Innovation culture

It is increasingly recognised that innovation is influenced by the social and cultural values, norms, attitudes and behaviours that inform an innovation culture. Building an innovation culture implies raising public awareness of and interest in S&T, especially among youth, valuing the contribution of S&T to well-being and social welfare, fostering an entrepreneurial spirit through a positive attitude towards risk taking, nurturing a research culture while raising awareness of IPRs in the research community, etc. (see the policy profile *Building a science and innovation culture*).

Key figures
(Panel 1 of the country profiles)

The table provides an overview of the size of a country's national research system and the relative importance of the government's commitment to R&D through public funding. It also shows how these indicators have changed from 2009 to 2014. When data are not available for these years, the nearest years are used. Growth rates are compound annual growth rates[2] expressed in percentage.

Gross domestic expenditure on R&D (GERD) is total intramural expenditure on R&D performed on the national territory during a given period, i.e. it includes domestically performed R&D that is financed from abroad (i.e. from the "Rest of the world") but excludes funding for R&D performed abroad. (OECD, 2015b). GERD is one of the most widely used measures of innovation inputs. It reflects a country's R&D efforts and investments and its potential for generating new knowledge. GERD is expressed in current US dollars PPP. R&D expenditures are derived from harmonised national R&D surveys based on joint OECD/Eurostat efforts to collect internationally comparable data on resources for R&D. GERD data –including for the following indicators if not otherwise specified- are drawn from the OECD Main Science and Technology Indicators

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[2]   Compound annual growth rates are calculated based on values in constant prices, according to the following formula in which CAGR is the compound annual growth rate, I is the value considered over the period of time between t_0 and t_1:

$$CAGR\ ^{I}_{t_1,t_0} = \left[\ \left(I_{t_1} | I_{t_0}\right)^{(1|(t_1-t_0))}\ \right]\ - 1$$

(MSTI) Database which seeks to reflect the level and structure of efforts in the field of science and technology (www.oecd.org/sti/msti). Additional data for Lithuania are drawn from Eurostat Science, Technology and Innovation (STI) Databases and from the UNESCO Institute for Statistics (UIS) for Brazil, Colombia, Costa Rica, Egypt, India, Indonesia, Malaysia, Peru and Thailand.

Figure A.1. GERD as a percentage of GDP and researchers per thousand employment, 2015 or latest available year
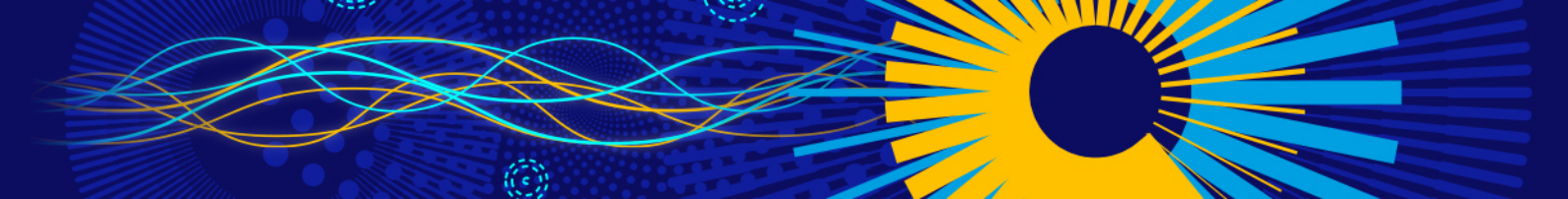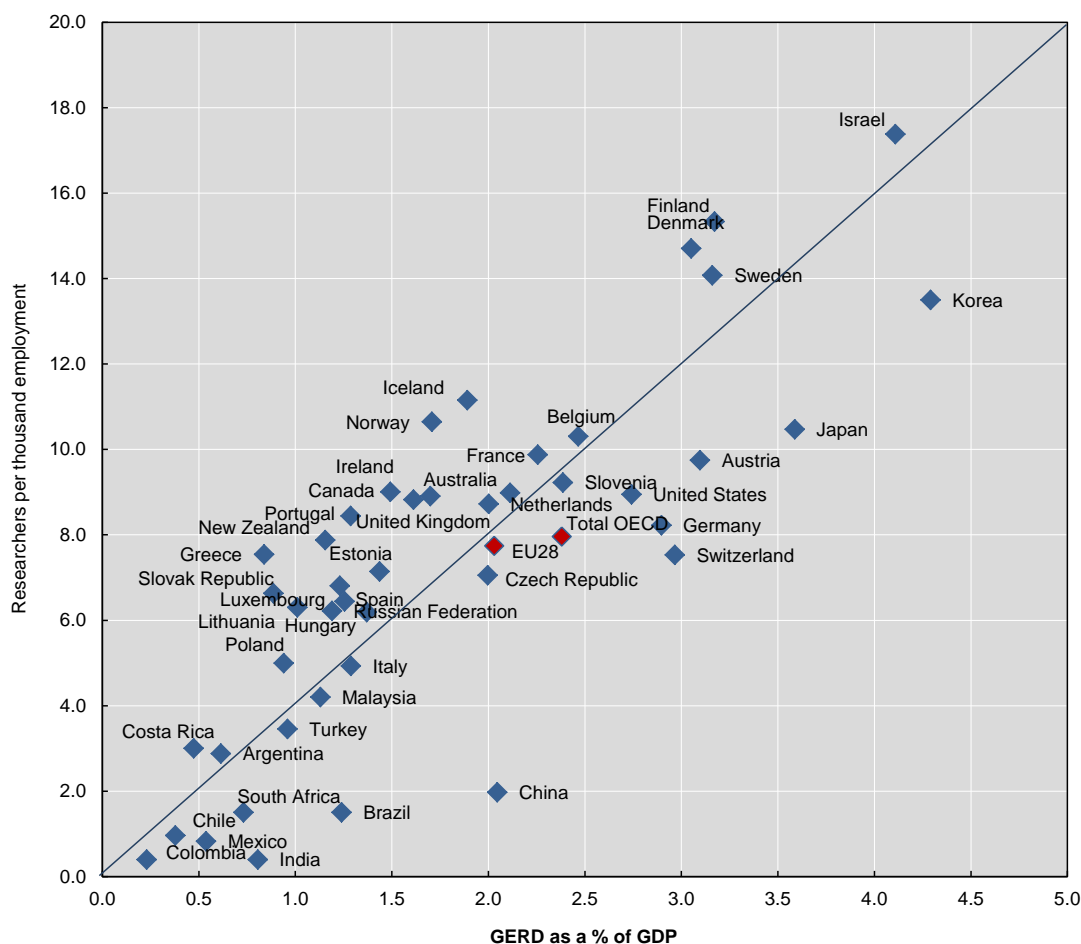

Note: For GERD, data refer to 2015 for Austria. Data refer to 2013 for Australia, Brazil, New Zealand, the United States. Data refer to 2012 for Colombia, Indonesia, South Africa, Switzerland. Data refer to 2011 for Costa Rica, India, and Malaysia. For other countries data refer to 2014.

For researchers, data refer to 2014 for Canada, Iceland, Lithuania, New Zealand, total OECD, the United States. Data refer to 2013 for Colombia, Israel, Malaysia, South Africa, and Switzerland. Data refer to 2012 for Costa Rica and Mexico. Data refer to 2011 for Australia, Brazil and India. For other countries, data refer to 2015.

Source: OECD MSTI Database, June 2016, www.oecd.org/sti/msti; Eurostat and UNESCO Institute for Statistics (UIS), June 2016. Data retrieved from IPP.Stat on 20 October 2016

GERD, intensity and annual growth. Many OECD and non-OECD countries "target" a certain level of GERD intensity to help focus policy decisions and public funding (see the policy profile *National strategies for STI*). The volume of GERD to be achieved is often expressed as a percentage of gross domestic product (GDP). Compound annual growth rates are calculated based on R&D expenditures at constant prices.

In many economies most R&D expenditures cover personnel costs, which include researcher salaries and compensation. GERD intensity as a percentage of GDP and researchers per thousand employment are therefore closely related. To avoid redundancy, data on researcher density are not presented in the country profiles. The researcher population in Figure A.1 is estimated in full-time equivalent (FTE).
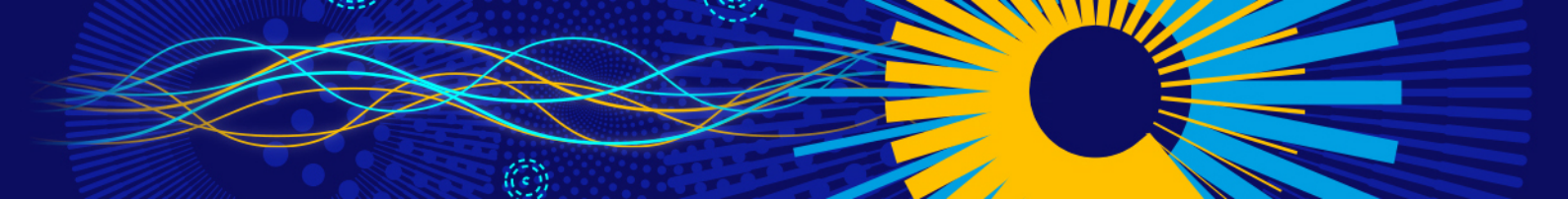
Publicly financed GERD, intensity and annual growth. GERD is financed by various *source*s: business enterprises (industry), government, higher education, private non-profit institutions (PNPs) and foreign funds (abroad). In the country profiles, public funding of GERD encompasses financing by the government and higher education sectors. It reflects public commitment to R&D relative to the size of the country. It is expressed as a percentage of GDP. Data are based on harmonised national R&D surveys and drawn from the OECD Research and Development Statistics (RDS) Database which provides detailed information on a range of R&D statistics (www.oecd.org/sti/rds), except for Lithuania for which data come from Eurostat STI Databases and for other countries for which data come from the UIS.

Major STI policy priorities
(Panel 2 of the country profiles)

Governments set priorities for public intervention, including for determining public investment in STI and the focus of their reforms. They also intend to mobilise STI actors around specific goals, such as energy, environmental issues or health issues, and policy action may help steer the investments of private actors and of increasingly autonomous universities and public research institutes towards priority areas or technologies.

National STI policy priorities in the STI Outlook are defined by a country's self-assessment of the following questions: "*1) What are the current major STI policy priorities in your country? Please select three (maximum five) STI policy priorities in the drop-down lists below.*" Responses are provided by country delegates to the OECD Committee for Scientific and Technological Policy (CSTP) and the European Research and Innovation Committee (ERAC). Respondents are provided with a standard list of "hot issues", i.e. most topical issues debated in STI policy circles at the time of the survey. The standard list of "hot" STI policy issues is provided below. Data come from the EC/OECD International STIP Survey (https://www.innovationpolicyplatform.org/sti-policy-database).

- Promoting structural adjustment and new approach to growth
- Fostering sustainable/green growth
- Addressing societal challenges (e.g. inclusiveness)
- Improving the governance of innovation system and policy
    - Improving coordination and participatory governance
    - Improving the design and implementation of STI policy (e.g. experimentation)
    - Improving STI policy evaluation and impact assessment
- Improving the framework conditions for innovation (e.g. competitiveness)
- Strengthening the public research system
    - Reforming public research (including university research)
    - Strengthening public R&D capacity and infrastructures
    - Improving transfers, returns and impact of science
- Encouraging business innovation and innovative entrepreneurship
    - Revising the policy mix for business innovation
    - Supporting R&D and innovation in firms
    - Targeting innovative entrepreneurship and SMEs
- Targeting priority areas/sectors (e.g. new industrial policy, clean tech)
- Improving direct and indirect knowledge transfers
- Addressing challenges of STI globalisation and increasing international cooperation

- Improving overall human resources and skills
  - Improving the education system (in general or focusing on tertiary education)
  - Improving the attractiveness of scientific and research careers
  - Building a broad innovation culture

Some key STI performance indicators (Panel 3 of the country profiles)

Innovation provides the foundation for new businesses, new jobs and productivity growth and is thus an important driver of economic growth and development. Innovation can help address pressing societal and global challenges, including demographic shifts, resource scarcity and the changing climate. Innovation can contribute to decoupling growth from natural capital depletion. Moreover, innovation can help address these challenges at the lowest cost (OECD, 2015b).

Economic performance: labour productivity growth

Innovation is widely acknowledged as a major driver of productivity and economic performance and is seen as a key way to create new business values while also benefiting people and the planet and addressing global challenges.

Welfare is traditionally gauged through the GDP per capita indicator. Changes in GDP per capita are explained by changes in labour productivity (GDP per hour worked) and labour utilisation (hours worked per person employed). Labour productivity is defined as the volume of output divided by the volume of labour input, namely GDP per hour worked, Labour productivity growth is expressed as an index (100=2005 value). Labour productivity is however a partial productivity measure and reflects the joint influence of a host of factors. It is easily misinterpreted as technical change or as the productivity of the individuals in the labour force. Data are drawn from the OECD Productivity Database which provides estimates of productivity growth and levels and allows for comparison of standards of living and underlying factors across countries (www.oecd.org/std/productivity-stats/).

Environmental performance

A first conceptual broadening of the framework of innovation analysis concerns the relationship between innovation and green (or sustainable) growth (OECD, 2015c). A central element of green growth is the efficiency with which environmental and natural resources are used in production and consumption. A declining asset base and climate change constitute risks for growth and sustainable development. Environmental outcomes are also important determinants of health and wellbeing. The main concerns relate to the effects of increasing atmospheric greenhouse gas (GHG) concentrations on global temperatures and the Earth's climate, and the consequences for ecosystems, human settlements, agriculture and other socioeconomic activities that can affect global economic output (OECD, 2011b). Carbon dioxide (CO_2) accounts for the largest share of GHG emissions. Fuel combustion in economic activities and by households is a main source of climate change and GHG emissions.

Green productivity growth. Green productivity, or environmental and resource productivity, is production-based CO_2 productivity, i.e. GDP generated per unit of CO_2 emitted through fuel consumption. Estimates are computed by the International Energy Agency (IEA) on the basis of the IEA energy balances and the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IEA, 2015). Environmental productivity growth is expressed as an index (100=2005 value).

Societal challenges

It has become increasingly clear that economic growth, as measured by GDP, can no longer be the overriding goal for government policy and can also not be an end in itself (OECD, 2015c). Innovation can make a substantial contribution to dealing with societal challenges such as poverty, ageing, social exclusion and health.

Ageing

Changing demographics are expected to significantly impact production activities in the future, because of both supply and demand factors (OECD, 2015c). An ageing population may lead to skill mismatches, and even skill shortages, and can change consumer preferences and demand (see chapter 1 on Megatrends affecting STI and the policy profile *Innovation in an ageing society*). At the same time, ageing societies could see slower economic growth. With a declining share of the population in work, ageing countries will face an uphill battle to maintain their living standards. The resulting fiscal pressures could draw public spending away from other areas, including STI.

More than 65-year old Internet users. Differences in Internet uptake are linked primarily to age and education, often intertwined with income levels (OECD, 2015a). Users include individuals who accessed the Internet within the last three months prior to surveying. Data are collected through ICT surveys and come from the OECD, ICT Database, Eurostat, Information Society Statistics Database and ITU, World Telecommunication/ICT Indicators Database.

Old-age dependency ratio. At current rates, there will be almost global parity between the number of over-60s and the number of children by 2050 (see chapter 1 on Megatrends affecting STI). The size of the working-age population (15-64) is currently at an historical peak and will very soon begin to diminish. This means the size of the dependent population (currently defined as younger than 15 and older than 64) relative to the working-age population that provides social and economic support will increase. The old-age dependency ratio is the number of more than 64-year old expressed as a percentage of total working-age population. Data come from the OECD Labour Force Statistics Database for OECD countries, Eurostat for Lithuania and the World Bank for other countries.

Public expenditures on pension. Public pensions are often the largest single item of social expenditure, accounting for 18% of total government spending on average (2011) (OECD, 2015d). And public spending on cash old-age pensions and survivors' benefits in the OECD increased 28% faster than domestic output between 1990 and 2011. Public expenditures on pension are expressed as a percentage of total government expenditures. Data come from the OECD Social Expenditures Database (www.oecd.org/social/expenditure.htm).
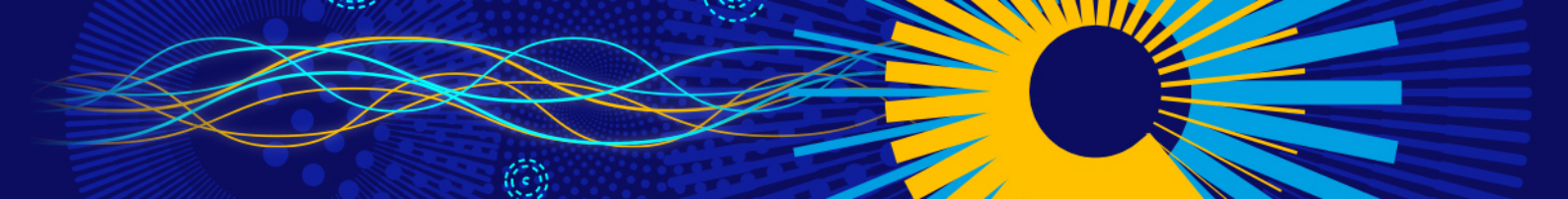
Unemployment

Unemployment has an impact on final demand, capital availability, tax revenues, economic growth and social climate. In addition high unemployment, among other factors, could feed a general belief that governments are not able to protect the best interests of their citizens (see chapter 1 on Megatrends affecting STI). Youth unemployment could have long-term effects on economic and fiscal sustainability, by encouraging informal economic activity, reducing tax revenues or increasing public health outlays. Historically, 15-24 year-olds are more likely to be unemployed than older employees. They have been hit particularly hard by the 2008 crisis (OECD, 2014a). Persons employed in vulnerable employment are less likely to have formal work arrangements and equal earnings as compared to other workers. They are also more likely to lack decent working conditions, social protection and fundamental rights. The share of workers in vulnerable employment is directly linked to the share of people living in poverty.

Unemployment rate and youth unemployment rate. Unemployment rate is the number of unemployed people as a percentage of the total labour force, and the youth unemployment rate is the number of unemployed 15-24 year-olds expressed as a percentage of the youth labour force. Data come from the OECD Labour Force Statistics Database.

Vulnerable employment rate. The share of vulnerable employment is calculated as the sum of contributing family workers and own-account workers as a percentage of total employment. Data come from the Key Indicators of the Labour Market database of the International Labour Organization.

Gender balance

Improving the gender balance in science and research careers is a long-standing policy issue. At the higher education level, gender equality is making significant inroads. In most OECD countries, women already account for at least 50% of tertiary education enrolments. However, the number of women drops significantly in science, technology, engineering and mathematics (STEM) fields; the proportion of female scientists tends to fall as seniority rises; there are more male than female entrepreneurs, and in many

countries, women still face a glass ceiling in the research profession (see chapter 3 on The future of research systems and the policy profile *Research careers*).

The share of women is expressed as a percentage of total populations of STEM university graduates, doctorate graduates and researchers (headcount). Data come from the OECD Education and Skills Database (graduates) and the OECD MSTI Database (researchers) for OECD countries and Eurostat Education and STI Databases for Lithuania.

Inequality

Governments are increasingly focusing on inclusive growth, aiming to improve living standards and share the benefits of increased prosperity more evenly across social groups. Income inequality remains at record-high levels in many countries despite declining unemployment and improving employment rates (OECD, 2016b). Beyond its impact on social cohesion, growing inequality is harmful for long-term economic growth (OECD, 2015e). A main transmission mechanism between inequality and growth is human-capital investment. While there is always a gap in education outcomes across individuals with different socio-economic backgrounds, the gap widens in high-inequality countries as people in disadvantaged households struggle to access quality education. This implies large amounts of wasted potential and lower social mobility (see the policy profile *Innovation for societal challenges*).
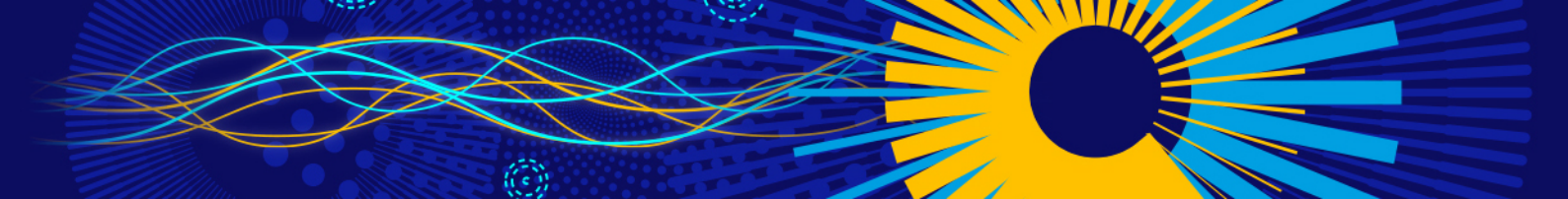
Income is defined as household disposable income in a particular year. It consists of earnings, self-employment and capital income and public cash transfers; income taxes and social security contributions paid by households are deducted. Income inequality is measured by five indicators, such as the Gini coefficient, S90/S10 and P90/10 among others. S90/S10 is the ratio of the average income of the 10% richest to the 10% poorest, real household net disposable income being ranked by ascending values of household disposable income per equivalent household member. P90/P10 is the ratio of the upper bound value of the ninth decile (i.e. the 10% of people with highest income) to that of the first decile. The indicator used here is P90/P10. Data come from the OECD Income Distribution Database.

Benchmarking national innovation performance (Panel 4 of the country profiles)

The performance of a country's national innovation systems as compared to all OECD countries is represented in Panel 4 of the country profiles. Panel 4 (double graph) reflects the country's strengths and weaknesses in several areas (see the conceptual framework discussed above). A standard set of indicators is used to: i) describe the competences and capacity of the science base and the business sector to innovate, as well as the framework conditions for entrepreneurship; ii) provide some insights on interactions between STI actors via the deployment and use of the Internet and their participation in domestic and international co-operation networks; and iii) depict the status of the human resources (HR) pool and prospects for increasing human capital further through inflows of new S&T talent.

Indicators are normalised (by GDP or population) to take account of the size of the country. Data for GDP are drawn from the OECD MSTI Database and are based on national accounts. Data for GDP for Lithuania are drawn from Eurostat Annual National Accounts (ANA) Databases and for Brazil, Colombia, Costa Rica, Egypt, India, Indonesia Malaysia, Peru and Thailand from the World Economic Outlook (WEO) Databases of the International Monetary Fund (IMF).

The country's values are compared to the median value observed in the OECD area, i.e. the middle position among OECD countries for which data are available. Non-OECD countries are also compared and may appear out of range (e.g. lower than the lowest OECD country). The use of the median avoids a statistical bias towards large players that skew the average, while still reflecting international rankings. The median has also the advantage over a simple ranking that it preserves the deviation between country values. The distance of the country's value from the median value will appear on the chart at a proportional distance from the median. This applies equally to all countries. In a simple ranking, the difference between two successive country values is 1 and the distance to the median is the rank. All indicators are presented in indices and reported on a common scale from 0 to 200 (0 being the lowest OECD value, 100 the median value and 200 the highest) to make them comparable. The benchmark charts also highlight the position and

dispersion of the top five and bottom five OECD values. When data are not available, the country's relative position does not figure on the graph (no dot).

Given X_t^c the indicator for country c at time t, and X_t^{Max}, X_t^{Med} and X_t^{Min} the respective OECD maximum, median and minimum values for this indicator, the country index I_t^c shown in Panel 1 is calculated as followed:

$$\text{If } X_t^c > X_t^{Med} \text{ then} \qquad I_t^c = 100 + (X_t^c - X_t^{Med})/(X_t^{Max} - X_t^{Med})*100$$

$$\text{If } X_t^c < X_t^{Med} \text{ then} \qquad I_t^c = 100 - (X_t^c - X_t^{Med})/(X_t^{Min} - X_t^{Med})*100$$

The standard set of indicators includes the following:

Universities and public research

(a) Public expenditure on R&D (per GDP). Higher education and government research institutions play a key role in the national STI system. Public expenditure on R&D (per GDP) measures the public sector's relative R&D performance. Public expenditure on R&D is the sum of higher education expenditure on R&D (HERD) and government expenditure on R&D (GOVERD) and is expressed as a percentage of GDP. Data are drawn from OECD MSTI Database and based on harmonised national R&D surveys and national accounts. Data for Lithuania are drawn from Eurostat STI Databases and data for other countries from the UIS.

(b) Top 500 universities (per GDP). Excellent research is often concentrated in a few higher education institutions with strong international impact. The Academic Ranking of World Universities (ARWU), also known as the Shanghai ranking, ranks the world's top universities and medium-high performing institutions according to a composite indicator based on number of alumni; staff winning Nobel Prizes and Fields Medals; number of highly cited researchers selected by Thomson Scientific; number of articles published in *Nature* and *Science*; number of articles indexed in the Science Citation Index Expanded and Social Sciences Citation Index; and per capita performance with respect to the size of the institution (Box 1). More than 1 200 universities have been ranked by the ARWU every year since 2003 and the list of the leading 500 are published on the web (www.shanghairanking.com). This indicator has certain limits however. The bibliometrics-based indicators skew the ARWU ranking towards English-speaking institutions and emphasise the natural sciences over the social sciences or humanities, as well as research excellence over the quality of teaching. However, this last is less an issue for benchmarking the performance of the science base, as this publication seeks to do. In addition, the ranking tends to focus on larger institutions and does not reflect research performance in PRIs; this may disadvantage countries in which the science base relies heavily on public labs. The top 500 universities are expressed per million US dollars of GDP PPP to take into account countries' size and relative wealth.

According to the ARWU data, most countries have a relatively constant share of world-class universities as measured at different performance thresholds (Figure A.2). This may reflect a homogeneous science base of institutions of different classes and of different visibility. The United States, Germany and China deserve further attention however (Panels 1 and 3). The United States has the world's best universities with 15 of the top 20 and 31 of the top 50, but its share drops rapidly when the performance threshold is lowered to include institutions below the top 50, i.e. high- and medium-high-performing institutions. The situation is different for Germany and China, which lack universities in the top 20 and top 50 but whose share in the world's top universities increases markedly from the top 50 to the top 200 for the former and from the top 100 to the top 500 for the latter. The selected benchmark threshold will therefore have an impact on these three countries' performance compared to other countries. With a higher benchmark threshold, the United States will perform better and Germany and China will perform less well. With a lower benchmark threshold, the reverse will be true.
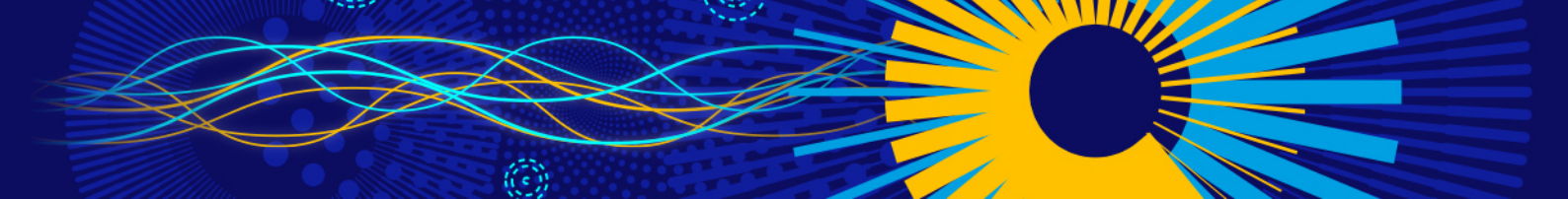
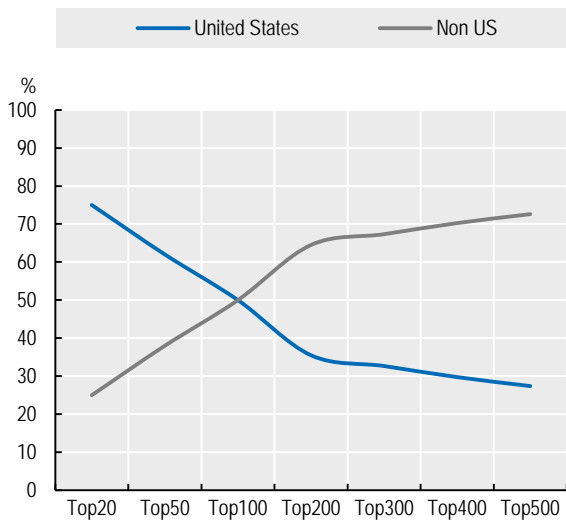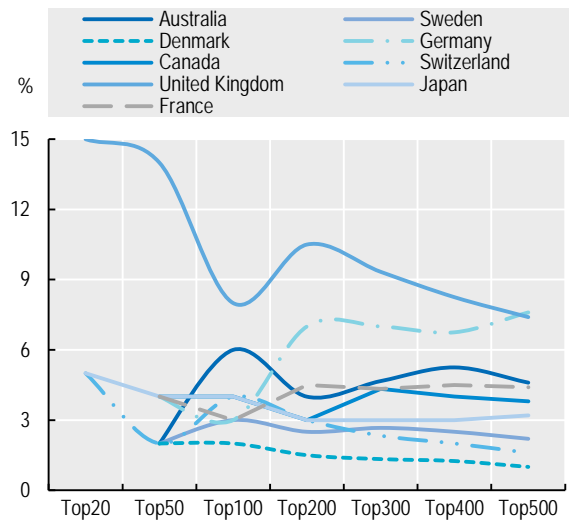**Figure A.2.** Impact of ranking thresholds on country's performance in ARWU ranking, 2016

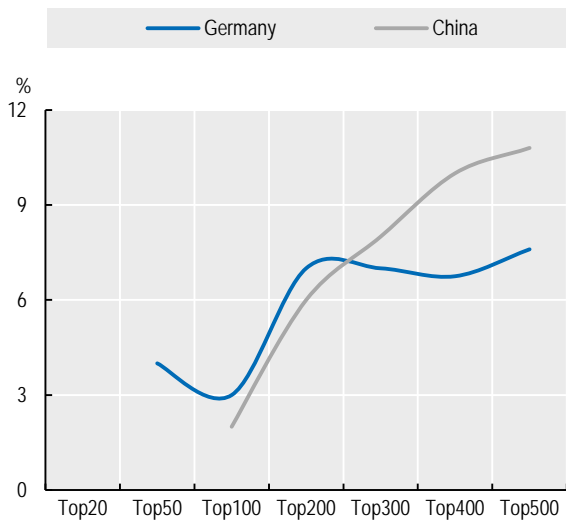Country share in ARWU ranking of universities
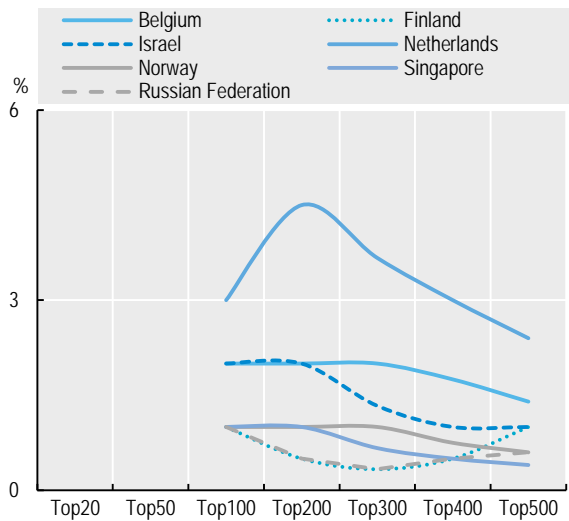
Panel 1. US versus non-US universities

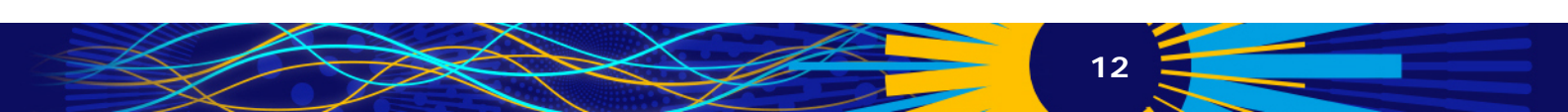Panel 2. Countries besides the United States with the largest share of top 50 universities

Panel 3. Germany and China

Panel 4. Other countries besides the United States

Source: OECD, based on ARWU ranking of universities 2016.

For the top 50, US universities lead eight other countries in 2016: the United Kingdom (7), Canada (2), France (2), Japan (2), Germany (2) and Australia, Denmark, Sweden and Switzerland (all at 1). A similar exercise was conducted for the *OECD STI Scoreboard 2015* on the basis of bibliometric data (OECD, 2015a). A new indicator reveals which institutions account for the largest number of highly cited publications within the higher education (HE) and government sectors. The results are not intended as league tables, but help illustrate the extent to which high impact publications are concentrated in a number of major institutions or countries. These results are presented in Table A.1 beside the top 50 ranking based on ARWU data. The ARWU ranking has little effect on US performance little or tends to increase slightly the number of US institutions in the top 50 as well as the impact of countries with larger institutions (see comments on the limitations of this indicator above).

Table A.1. The world's top 50 universities, according to the *OECD STI Scoreboard 2015* and ARWU ranking 2016, 2003-12

	STI Scoreboard 2015	ARWU ranking 2016									
	2003-2012	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
United States	31	35	35	37	37	37	36	37	35	34	36
United Kingdom	5	5	5	5	5	5	5	5	5	5	5
Canada	3	2	2	2	2	2	2	2	2	2	2
Switzerland	1	2	1	1	1	1	1	1	1	1	1
Japan	2	2	2	2	2	2	2	2	2	2	2
France	1	..	2	1	1	1	2	2	2	2	2
Sweden		1	1	1	1	..	..	..	1	1	1
Netherlands	2	1	1	1	1	1	1	..	1	1	
China	1										
Australia	2	1									
Belgium	1										
Germany		1	1							1	
Singapore	1										
Denmark						1	1	1	1	1	1
Total number of countries	**11**	9	9	8	8	8	8	7	9	10	8

Source: OECD (2015a) and ARWU Shanghai ranking (2016).

The STI Outlook presents one indicator to compare the performance of universities across countries. A more detailed approach would require considering a wider range of indicators to reflect other dimensions of performance (e.g. teaching quality, technology transfer, innovative and entrepreneurial activities etc.).

(c) Publications in top-quartile journals (per GDP). Publication is the main means of disseminating and validating research results. Publications in top journals provide a measure of "quality-adjusted" research output and serve as an indicator of the expected impact of institutions' scientific production. Publications in the top-quartile journals are defined as documents published in the most influential 25% of the world's scholarly journals (in their category, in the reference period, by authors' institutional affiliation, in a given country). This ranking is based on the Scientific Journal Ranking (SJR) an impact-factor normalised index that takes the prestige of the journals as a measure of quality. Scientific production is based on whole counts of documents by authors' institutional affiliation in the country. Bibliometric data are drawn from the Elsevier Research Intelligence database. However, although publications are commonly used as proxies for academic research output, it is worth mentioning that publishing institutions are not necessarily all public sector research institutions. Publications counts are expressed per million US dollars of GDP at PPP to take into account the size and the relative wealth of the country.

Box. 1. Indicators and weights used for the ARWU ranking of universities

CRITERIA	INDICATOR	DEFINITION	WEIGHT
Quality of education	Alumni of an institution winning Nobel Prizes and Fields Medals	Defined as those who obtain bachelor's, master's or doctoral degrees from the institution. Different weights are given according to the period of obtaining a degree. The weight is 100% for alumni obtaining degrees after 1991, 90% for alumni obtaining degrees in 1981-90, 80% in 1971-80, and so on, and finally 10% in 1901-10. If a person obtains more than one degree from an institution, the institution is only considered once.	10%
Quality of faculty	Staff of an institution winning Nobel Prizes and Fields Medals in Physics, Chemistry, Medicine and Economics and Fields Medal in Mathematics.	Defined as those who work at an institution at the time of winning the prize. Different weights are given according to the period of winning the prize. The weight is 100% for winners after 2001, 90% for winners in 1991-2000, 80% in 1981-90, 70% in 1971-80, and so on, and finally 10% in 1911-20. If a winner is affiliated with more than one institution, each institution is assigned the reciprocal of the number of institutions. For Nobel prizes, if a prize is shared by more than one person, weights are set for winners according to their share of the prize.	20%
	Highly cited researchers in 21 broad subject categories	These individuals are the most highly cited within each category. The definition of categories and detailed procedures can be found at the website of Thomson ISI (see *source*).	20%
Research output	Papers published in *Nature* and in *Science* in the four years preceding the publication of the ARWU ranking	To distinguish the order of author affiliation, a weight of 100% is assigned for corresponding author affiliation, 50% for first author affiliation (second author affiliation if the first author affiliation is the same as corresponding author affiliation), 25% for the next author affiliation, and 10% for other author affiliations. Only publications of "articles" and "proceedings papers" are considered. Institutions specialised in humanities and social sciences are not taken into account and weighting in the ARWU composite index is reallocated proportionally to other criteria.	20%
	Papers indexed in Science Citation Index-expanded and Social Science Citation Index in the year preceding the publication of the ARWU ranking	Only publications of "articles" and "proceedings papers" are considered. When calculating the total number of papers of an institution, a special weight of two was introduced for papers indexed in Social Science Citation Index.	20%
Per capita academic performance	Weighted scores of the above five indicators divided by the number of full-time equivalent (FTE) academic staff.	If the number of academic staff of a country's institutions cannot be obtained, a weighted score of the above five indicators is used. The data are obtained from national agencies such as the Ministry of Education, the Bureau of Statistics, the Association of Universities and Colleges, the Rector's Conference.	10%
Total			**100%**

Source: ARWU university ranking webpages accessed 02 December 2016 at < http://www.shanghairanking.com/ARWU-Methodology-2016.html#2 > based on the official website of the Nobel Prize <http://nobelprize.org/>, International Mathematical Union <http://www.mathunion.org/index.php?id=prizewinners> (list of Fields medalists), Thomson Reuters Research Analytics <www.highlycited.com> (highly cited researchers), Thomson Reuters Web of Science at <www.webofknowledge.com> (papers published in *Nature* and *Science* and articles indexed in Science Citation Index-Expanded and Social Science Citation Index), and national sources (number of FTE academic staff).

Business R&D and innovation

(d) Business R&D expenditure (per GDP). Business enterprise expenditure on R&D (BERD) accounts for the bulk of R&D activity in most OECD countries. It is frequently used to compare countries' private-sector efforts on innovation since industrial R&D is more closely linked to the creation of new products and production techniques and mirrors market-oriented innovation efforts. Data are drawn from the OECD MSTI Database and are based on harmonised national R&D surveys and national accounts, except for Lithuania for which data come from Eurostat STI Databases and for other countries for which data come from the UIS.

(e) Top 500 corporate R&D investors (per GDP). Big companies make an important contribution to R&D and innovation. Large firms tend to introduce innovations of larger scale and bigger impact than SMEs which more frequently tend to be "adopters" and "pioneers" (OECD, 2009a). In addition, large firms often drive collaboration, as they play a structuring role in innovation clusters that also include SMEs. Large firms also play the role of "innovation assemblers": by integrating innovations from SMEs in their own products, they bring SMEs' innovations to markets. The *2015 EU Industrial R&D Investment Scoreboard* (http://iri.jrc.ec.europa.eu/scoreboard15.html) presents economic and financial information about the world's 2 500 largest companies ranked according to the level of their own-funded R&D investments. The top 500 accounted in 2014 for 82% of the 2 500 firms' total R&D investments. Data are based on companies' publicly available audited accounts. The EU Scoreboard is intended to raise awareness of the importance of R&D for businesses and to encourage firms to disclose information about their R&D investments and other intangible assets. It gathers information about a sample of 608 European companies, and 829 companies based in the US, 360 in Japan and 703 from the rest of the world. that invested more than EUR 607.2 billion in R&D in 2014. For different reasons (changes in exchange rates, mergers and acquisitions, etc.), the composition of the sample may vary from year to year and data are not fully comparable from one edition of the EU Scoreboard to the next. It is worth noting that companies' accounts do not include information on where R&D is actually performed and that companies' total R&D investment is attributed to the country in which it is registered. The EU Scoreboard's approach to BERD is, therefore, different from that of statistical offices or the OECD which attribute data to a specific territory. The EU Scoreboard data are primarily of interest to those concerned with benchmarking company commitments and performance (e.g. companies, investors and policy makers), while BERD data are primarily used by economists, governments and international organisations interested in the R&D performance of territorial units defined by political boundaries (EC, 2015). The two approaches are complementary. The number of top 500 corporate R&D investors is expressed per million US dollars of GDP at PPP to take account of the size of the country.

(f) Triadic patents (per GDP). Patents provide a uniquely detailed source of information on the inventive activity of countries. Triadic patents are typically of relatively high value and eliminate biases arising from home advantage and the influence of geographical location. Triadic patent families are defined as patents applied for at the European Patent Office (EPO), the Japan Patent Office (JPO) and the US Patent and Trademark Office (USPTO) to protect a same invention. Counts are presented according to the priority date and the residence of the inventors. The number of triadic patent families applied for over the 2011-13 period is expressed per billion US dollars of GDP at PPP. Data for patents are drawn from the OECD Patent Database (http://www.oecd.org/sti/inno/oecdpatentdatabases.htm).

(g) Trademarks (per GDP). A trademark is a sign that distinguishes the goods and services of one undertaking from those of other undertakings. Firms use trademarks to launch new products on the market in order to signal novelty, promote their brand and appropriate the benefits of their innovations. Trademarks convey information not only on product innovations, but also on marketing innovations and innovations in the services sector. The number of trademark applications is highly correlated with other innovation indicators (OECD, 2011a). Because the data relating to trademark applications are publicly available immediately after filing, trademark-based indicators can provide timely information on the level of innovative activity. Trademark-based indicators are therefore a good predictor of economic downturns (OECD, 2010b). However, trademarks counts are subject to home bias as firms tend to file trademarks in their home country first. Trademarks abroad correspond to the number of applications filed at the USPTO (Graham, 2013), the Office for Harmonization in the Internal Market (OHIM), and the JPO, by application date and country of residence of the applicant. For the United States, EU members and Japan, counts exclude applications in their domestic market (USPTO, OHIM and JPO, respectively). Counts are rescaled by taking into account the relative average propensity of other countries to file in these three offices (OECD, 2013a). The number of trademarks applied for over the 2010-12 period is expressed per billion US dollars of GDP at PPP. Data for trademarks are drawn from OECD calculations based on USPTO Bulk Downloads: Trademark Application Text hosted by Reed Technology Information Services; OHIM Community Trademark Database CTM Download; JPO Annual Reports 2001-13.

Entrepreneurship

(h) Venture capital (per GDP). A financial and policy environment that fosters the start-up and growth of new firms is essential for innovation to flourish. Access to finance for new and innovative small firms is vital but banks may be reluctant to lend to risky ventures. For entrepreneurial firms, especially if they are young, technology-based and have high growth potential, venture capital is an important source of funding during the seed, start-up and growth phases. Venture capital (VC) is private equity provided by specialised firms acting as intermediaries between primary sources of finance (insurance, pension funds, banks, etc.) and private companies whose shares are not freely traded on any stock market. Data for VC investments are drawn from the OECD Entrepreneurship Financing Database (OECD, 2015).

(i) Patenting firms less than 5 years old (per GDP). The presence of young firms among patent applicants underlines the inventive dynamics of firms early in their development. Young firms are defined as firms less than five years old with an incorporation date in business registers (ORBIS©) between 2004 and 2011. Patenting firms are those filing patent applications at the European Patent Office (EPO), at the US Patent and Trademark Office (USPTO) or through the Patent Cooperation Treaty (PCT) between 2008 and 2011. It should be stressed that this experimental indicator is obtained by matching patent (EPO/USPTO/PCT patent filings) and business (listed in the ORBIS database) data: the names of applicants as they appear in the patent were linked with those of firms listed in business registers. Counts are limited to a set of patent applicants which have been successfully matched with business register data. In addition, only countries with average matching rates over 70% over the period are included. Counts of young patenting firms are expressed per billion USD GDP using PPPs. Data for young patenting firms are based on the OECD Patent Database and the ORBIS Database (Bureau Van Dijk Electronic Publishing).
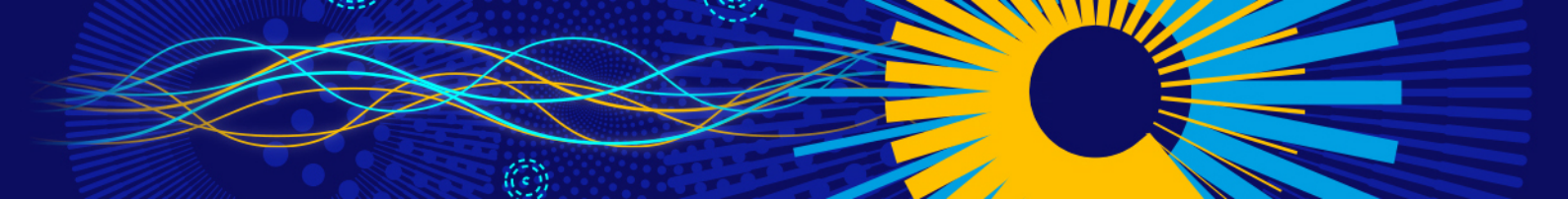
(j) Ease of entrepreneurship index. For businesses to enter the market and grow they need a suitable regulatory framework. Most OECD countries have lowered barriers to entrepreneurship during the last decade (OECD, 2010c). The "barriers to entrepreneurship" indicator is one of the OECD Indicators of Product Market Regulation (PMR) and measures regulations affecting entrepreneurship. The index uses a scale of zero to six to evaluate: i) complexity of regulatory procedures (e.g. licences and permits system, communication and simplification of rules and procedures); ii) administrative burdens on start-ups (e.g. administrative burdens for corporations and sole proprietor firms, barriers in services sector) and iii) regulatory protection of incumbents (e.g. legal barriers to entry, antitrust exemptions, barriers in network sectors). As lower values suggest lower barriers, the barriers to entrepreneurship index is reversed so as to be read in the same way as other indicators used in this international benchmark. The ease of entrepreneurship index is calculated as 6 minus the barriers to entrepreneurship index. Calculations are made with 2013 data drawn from the OECD Product Market Regulation Database (www.oecd.org/economy/pmr).

Internet for innovation

The Internet has become a critical infrastructure for businesses, consumers/users and the public sector (OECD, 2012). In terms of data transmission, traffic levels have increased exponentially and are expected to continue to do so. New network applications and the expected migration of mobile users to more advanced 3G networks place larger demands on existing infrastructures by generating more traffic flow.

(k) ICT investment (per GDP). Investment in ICT enables new technologies to enter the production process and is seen as an important driver of productivity growth. ICT investment is defined according to the 2008 System of National Accounts (SNA). It has three components: i) computers hardware); ii) telecommunications equipment; and iii) computer software and databases. In 2008 SNA, the software definition has change to include databases. ICT investment is expressed as a percentage of GDP. Data for ICT investment are taken from the OECD Digital Economy Outlook 2015 (OECD, 2015f).

(l) Fixed broadband subscriptions (per population). Broadband provides high-speed Internet access and enables the broader participation of customers, suppliers, competitors, government laboratories and universities in the innovation process. It makes outsourcing and off-shoring more efficient and has changed personal and business practices dramatically. OECD work also indicates a strong correlation between the penetration of broadband and the use of e-government services by citizens (OECD, 2009a). While mobile broadband is developing rapidly and has become the dominant broadband access channel in OECD countries, fixed wired broadband connections are still the foundation of high-speed data transport (OECD, 2012). Fixed broadband includes all subscriptions to DSL lines offering Internet connectivity (the DSL line is excluded if it is not used for Internet connectivity, e.g. leased lines), cable modem, fibre-to-the-premises

(e.g. house, apartment) and fibre-to-the-building (e.g. apartment LAN) and other broadband over power lines capable of download speeds of at least 256 kbit/s. It does not include 3G mobile technologies and Wi-Fi. The number of fixed broadband subscriptions includes business and residential connections and is expressed per 100 inhabitants. Data for fixed broadband subscriptions are drawn from the OECD Broadband Statistics portal (www.oecd.org/sti/ict/broadband) which are compiled from information collected directly from telecommunications firms and national regulators twice a year. For non-OECD countries, data come from the ITU World Telecommunication/ICT Indicators 2016 Database and population data come from Eurostat and the UIS.

(m) Wireless broadband subscriptions (per population). Wireless broadband includes subscriptions with advertised download speeds of at least 256 kbit/s through satellites, terrestrial fixed wireless, terrestrial mobile wireless (including standard mobile subscriptions and dedicated data subscriptions). It does not include Wi-Fi. The number of wireless broadband subscriptions includes business and residential connections, to the exclusion of satellite subscriptions that tend to be null, and is expressed per 100 inhabitants. Data for fixed broadband subscriptions are drawn from the OECD Broadband Statistics which are compiled from information collected directly from telecommunications firms and national regulators twice a year. For non-OECD countries, data come from the ITU World Telecommunication/ICT Indicators 2016. Database and population data come from Eurostat and the UIS.
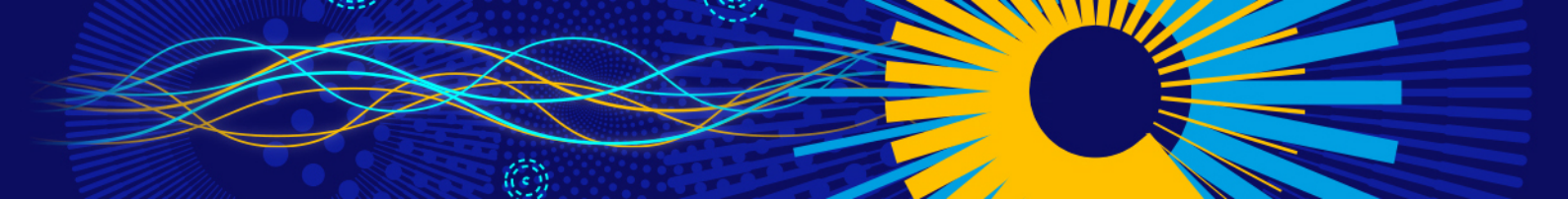
(n) E-government s index. Governments increasingly use the Internet to improve their interaction with citizens by making it easier for them to obtain information, fill out necessary forms and file taxes (OECD, 2012). ICTs support changes in public services delivery by allowing more personalised, better-quality services, changes in work organisation and management through greater back-office coherence and efficiency; this improves the transparency of government activities as well as citizen engagement. OECD countries are transforming government through the use of ICT and ICT-enabled governance structures, new collaboration models (i.e. sharing data, processes and portals), and networked or joined-up administrations. ICTs increasingly drive public-sector innovation. The e-government readiness index is a composite index which shows how prepared a country is to use ICT-enabled public administrations for greater efficiency and measures its capacity to develop and implement e-government services. The index ranges from 0 (low level of readiness) to 1 (high level). Data are drawn from the UN e-government survey 2014.

Knowledge flows and commercialisation

Public research is the source of significant scientific and technological breakthroughs. To optimise the economic and social benefits from public research and the return on public R&D investments, effective linkages are needed between academia and industry. Knowledge flows between public research institutions and industry are channelled through spin-offs, joint research projects, training, consultancy and contract work, the commercialisation of public research output, staff mobility between workplaces and informal co-operation by researchers.

(o) Industry-financed public R&D expenditures (per GDP). Direct funding of public research by industry takes the form of grants, donations and contracts and influences the scope and orientation of public research, generally steering it towards more applied and commercial activities. The share of public R&D expenditure financed by industry is the domestic business enterprise sector's contribution to the intramural R&D expenditures of the higher education (HERD) and government (GOVERD) sectors. Data are drawn from the OECD MSTI Database and are based on harmonised national R&D surveys and national accounts, except for Lithuania for which data come from Eurostat STI databases and for other countries for which data come from the UIS. .

(p) Patents filed by universities and public labs (per GDP): The pool of available public research output can be diffused and commercialised via patenting and licensing. Patents applications by universities and public research institutions cover the government sector, higher education and hospitals. Counts are based on IP5 patent families, i.e. patents filed at the five patent offices (the European Patent Office [EPO], the Japan Patent Office [JPO], the Korean Intellectual Property Office [KIPO], the State Intellectual Property Office of the People's Republic of China [SIPO], and the United States Patent and Trademark Office [USPTO]), according to the earliest filing date and applicant's residence, using fractional counts. Patent applicant names are allocated to institutional sectors using a dataset developed by Eurostat and Katholieke Universiteit Leuven (KUL). Because there are important variations in the names recorded in patent documents, misallocations to sectors may occur and thus introduce biases in the resulting indicator. Patents are allocated to institutions categories according to the data provided in the ECOOM-EUROSTAT-EPO PATSTAT Person Augmented Table (EEE-PPAT), October 2015. D. Distributions by type of institutions are only provided for economies with more

than 150 patent families in the period considered Patent counts by universities and PRIs are expressed per billion USD GDP PPP*.

(q) International co-authorship in total scientific articles (%). The growing specialisation of scientific disciplines and the increasing complexity of research encourage scientists to engage in collaborative research. Production of scientific knowledge is shifting from individuals to groups, from single to multiple institutions, and from a national to an international focus. Researchers increasingly network across national and organisational borders (OECD, 2009a). International co-authorship of research publications provides a direct measure of international collaboration in science. International co-authorship is measured as the share of scientific articles produced in collaboration   with at least author of foreign institutions (from a different country or economy) in total articles produced by domestic institutions, between 2003 and 2012. Data are drawn from the OECD STI Micro-data Lab: Intellectual Property Database (http://oe.cd/ipstats) and the OECD/SCImago Research Group (CSIC) Compendium of Bibliometric Science Indicators.

(r) International co-invention in IP5 patent families (%). International co-invention of patents is a measure of the internationalisation of research and illustrates formal R&D co-operation and knowledge exchange among inventors in different countries. International collaboration by researchers can take place either within a multinational corporation (with research facilities in several countries) or through a research joint venture among several firms or institutions (e.g. universities or public research institutions). International co-operation is less widespread for patented inventions than for scientific publications (OECD, 2011a). International co-inventions are measured as the share of patent applications with at least one co-inventor located in a different economy in total patents invented domestically. Data refer to IP5 patent families with members filed at the EPO or the USPTO, by first filing date and according to the inventor's residence using whole counts. between 2003 and 2012. Data are drawn from the OECD STI Micro-data Lab: Intellectual Property Database and the OECD/SCImago Research Group (CSIC) Compendium of Bibliometric Science Indicators.
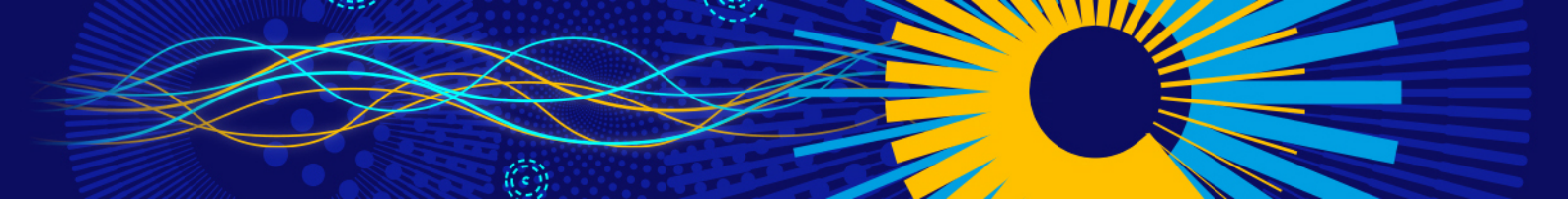
Human resources for innovation

Education systems play a broad role in supporting innovation because knowledge-based societies rely on a highly qualified and flexible labour force (OECD, 2015c). While basic competences are generally considered important for absorbing new technologies, high-level competences are essential for the creation of new knowledge and technologies.

(s) Tertiary education expenditure (per GDP). Education expenditure represent the total cost of services provided by all types of educational institutions (e.g. public institutions, government-dependent private institutions, and independent private institutions), without regard to sources of funds (whether they are public or private). Tertiary-level programmes include those delivering short-cycle tertiary degree, bachelor's or equivalent, master's or equivalent and doctoral or equivalent degree, at a minimum at Level 5 of the International Standard Classification of Education (ISCED) 2011. Education expenditure data are drawn from the OECD Education and Training Database, based on the UNESCO-OECD-Eurostat (UOE) data collection on education statistics, compiled from national administrative sources, reported by ministries of education or national statistical offices.

(t) Adult population at tertiary education level (%). The adult population with tertiary educational attainment is a measure of a country's pool of workers with advanced, specialised knowledge and skills. It indicates its potential to absorb, develop and diffuse knowledge and shows its capacity to upgrade continuously its high-end skills supply. Educational attainment affects all aspects of adult learning. Adults with higher levels of educational attainment are more likely to participate in formal and non-formal education during their working lives than adults with lower levels of attainment. Tertiary graduates are those with a short-cycle tertiary degree, bachelor's or equivalent, master's or equivalent and doctoral or equivalent degree, at a minimum at ISCED Level 5. The adult population is defined as those aged 25 to 64 years old. Data on population and educational attainment are compiled from national labour force surveys (LFS). Data come from *OECD Education at a Glance 2016* (OECD, 2016c).. For Argentina, Brazil, China, Colombia, Costa Rica, Indonesia, Peru, Russian Federation South Africa and Thailand, data are from the UIS Education Database.

(u) Top adult performers in technology problem solving (%). The Survey of Adult Skills defines problem solving in technology-rich environments as "using digital technology, communication tools and networks to acquire and evaluate information, communicate with others and perform practical tasks". It focuses on "the abilities to solve problems for personal, work and civic purposes by setting up appropriate goals and plans, and accessing and making use of information through computers and computer networks" (OECD, 2013d).

Problem solving in technology-rich environments represents the intersection of what are sometimes described as "computer literacy" skills (i.e. the capacity to use ICT tools and applications) and the cognitive skills required to solve problems. Data are drawn from the OECD (2016d) based on countries' results in the Programme for the International Assessment of Adult Competencies (PIAAC) (OECD, 2016).

(v) 15-year-old top performers in science (%). Demand for skills increasingly emphasises capabilities for adapting and combining multidisciplinary knowledge and solving complex problems. The acquisition of such skills starts at a very early age. The top performers in science are the students who reach the two highest levels of proficiency (levels 5 and 6) in the OECD Programme for International Student Assessment (PISA) 2013 science assessment (i.e. they have obtained scores of more than 633.33 points). The number of top performers is expressed as a percentage of 15-year-olds. Data are drawn from the OECD PISA 2013 Database (www.pisa.oecd.org).

(w) Graduation rate in science and engineering at doctoral level. Doctoral graduates are those with the highest educational level and are key players in research and innovation. They have been specifically trained to conduct research and are considered best qualified to create and diffuse knowledge (OECD, 2010c). They have attained the second stage of university education and obtain a degree at ISCED Level 8. They have successfully completed an advanced research programme and gained an advanced research qualification (e.g. Ph.D.). Graduation rates represent the estimated percentage of an age cohort that will complete the corresponding level of education during its lifetime (the number of graduates, regardless of their age, is divided by the population at the typical age of graduation). However, in some countries, graduation rates at the doctoral level are inflated by a high proportion of international students (e.g. Germany, Sweden and Switzerland). Science degrees include: life sciences; physical sciences; mathematics and statistics; and computing. Engineering degrees comprise: engineering and engineering trades; manufacturing and processing; and architecture and building. The rates presented combine graduation rates at doctoral level and the share of doctorate graduates by field of study. They constitute a good proxy of graduation rates in science and engineering at doctoral level. Data are drawn from *OECD Education at a Glance 2016* (OECD, 2016c) and the OECD Education Database (https://www.oecd.org/education/). For Lithuania data are drawn from Eurostat Education and Training databases. For other countries, data are from UIS.

Structural composition of BERD (Panel 5 of the country profiles)

A country's industrial structure determines the composition of its BERD and affects the growth prospects of its business research system.

Industrial structure

Industries and services are defined on the basis of the International Standard Industrial Classification (ISIC) Rev.4. The sectors are classified according to their R&D intensity (R&D expenditures relative to output). Data are drawn from the OECD ANBERD Database (www.oecd.org/sti/anberd). ANBERD has moved to the new sectoral classification, ISIC Rev.4, in line with the OECD STAN family of sectoral databases. Sectoral groupings may refer to years anterior to those for which industrial breakdown is available for countries in which recent data are available according to the new classification. For Lithuania data are drawn from Eurostat STI databases.

The sectoral groupings are defined as:

- *Industry* includes Mining (Section B), Manufacturing (Section C) utilities, i.e. Electricity, gas, steam and air conditioning supply (Section D) and Water supply, sewerage, waste management and remediation activities (Section E) and Construction (Section F). *Services* includes market-sector services (Sections G-N Divisions 45-82) and non-market-sector services (Sections O-T). Public-sector services encompass government (84), education (85), health (86-88), other community, social and personal services (90-96), and services to private households (97-98). However the distinction between market and public services on an industry-based definition is only approximate, as some services can be provided by public or private entities, or by a mix of the two (OECD, 2013a).

- *High-technology manufacturing* includes manufacture of basic pharmaceutical products and pharmaceutical preparations (Section C Division 21), manufacture of computer, electronic and optical products (26), manufacture of air and spacecraft and related machinery (30.3). *Medium-high-to low-technology industries* includes all other manufacturing industries. High- and medium-high-technology manufacturing is usually defined on the basis of industry R&D intensity, i.e. R&D expenditures relative to output. As countries are adopting the new ISIC revision and ISIC Rev.4 data are becoming available, technology aggregates are currently being redefined. In the meantime, an approximate correspondence from the ISIC Rev.3 definition has been adopted.

- *High-knowledge market services* refer to ISIC Rev.4 Section J: Information and communication (Divisions 58-63); K: Finance and insurance (64-66); and M: Professional, scientific and technical activities (69-75), including scientific research and development (72). *Low-knowledge services* include all other market services.

- *Primary-resource-based industries* are those that involve the harvesting, extraction and processing of natural resources. This aggregate includes Agriculture, forestry and fishing (Section A), Mining and quarrying (Section B), Food products, beverages and tobacco (Section C Divisions 10-12), Wood and products of wood and cork (16), Pulp, paper and paper products (17), Coke, refined petroleum products and nuclear fuel (19), Other non-metallic mineral products (23), Basic metals (24) and Electricity, gas and water supply (Sections D-E). Owing to their small contribution to total BERD and issues of data availability, Wearing apparel, dressing and dying of fur (14) and Leather, leather products and footwear (15) are not included. This sectoral grouping is not represented in the charts of countries in which these industries contribute marginally to business R&D expenditures.

Firm population

Firm size. SMEs play a key role in the R&D and innovation system. They are defined as firms with fewer than 250 employees; large firms have 250 employees and more. BERD data by firm size come from the OECD RDS Database.

Role of multinationals

Foreign affiliates contribute in many ways to a host country's international competitiveness by providing domestic firms with access to new markets, introducing new technologies and generating knowledge spillovers. In particular, foreign affiliates invest a higher share of their revenue in R&D than domestic firms (OECD, 2009). In addition, in the search for new technological competences, larger local market opportunities and lower R&D costs, companies are moving their research activities abroad. The geographical origin of a foreign affiliate is the country of residence of the ultimate controller. An investor (company or individual) is considered to be the investor of ultimate control if it is at the head of a chain of companies and controls directly or indirectly all the enterprises in the chain without itself being controlled by any other company or individual. The notion of control implies the ability to appoint a majority of administrators empowered to direct an enterprise, to guide its activities and determine its strategy. In most cases, this ability can be exercised by a single investor holding more than 50% of the shares with voting rights. Data come from the OECD AMNE Database.

Revealed technology advantage in selected fields (Panel 6 of the country profiles)

The revealed technology advantage (RTA) index provides an indication of the relative specialisation of a given country in selected technological domains and is based on IP5 patent families. It is defined as a country's share of patents in a particular technology field divided by the country's share in all patent fields. The index is equal to zero when the country holds no patents in a given sector; is equal to 1 when the country's share in the sector equals its share in all fields (no specialisation); and above 1 when a positive specialisation is observed. Only economies with more than 150 patents over the period reviewed are included. Data are drawn from the OECD STI Micro-data Lab: Intellectual Property Database.

Allocation of public funds to R&D (Panel 7 of the country profiles)

This figure shows several features of national research systems that are areas of direct or indirect public intervention.

Public research

Universities versus public research institutes (by sector of performance). Public research is traditionally performed by universities and PRIs (see the profile profile *Public research missions and orientation*). Although there is a general trend in the OECD area towards reinforcing the role of universities, PRIs still make a major contribution in several countries (e.g. China, Luxembourg, the Russian Federation). The figure shows the balance between R&D performed by universities and R&D performed by PRIs, as a percentage of total public expenditures on R&D. Public expenditure on R&D is the sum of HERD and GOVERD. Data are drawn from the OECD MSTI Database and are based on harmonised national R&D surveys. .
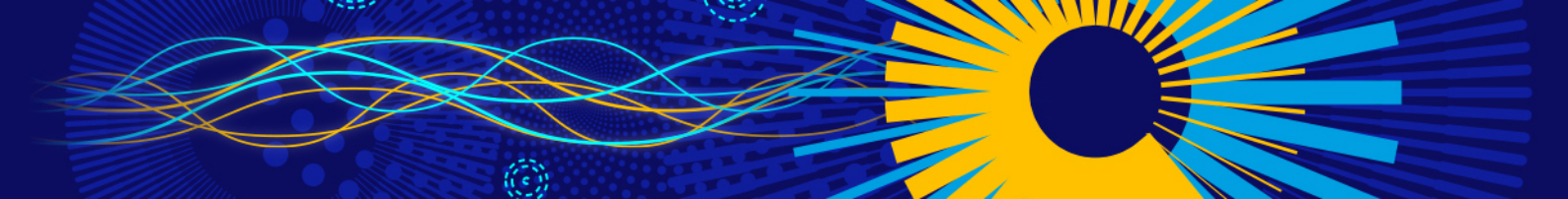
Basic research versus applied research/ development (by mission/orientation). Most basic research is performed by universities and PRIs (see the profile profile *Public research missions and orientation*). Basic research is essential for developing new scientific and technological knowledge and builds the long-term foundations of knowledge societies. It is experimental or theoretical work undertaken primarily to acquire new knowledge, without any particular application or use in view. The figure shows the balance between public expenditure on R&D for basic research and public expenditure on R&D for the purpose of applied research and experimental development. Total public expenditure on R&D is the sum of HERD and GOVERD. Data are drawn from the OECD RDS Database and are based on harmonised national R&D surveys.

Civil-oriented versus defence-oriented (by socioeconomic objective). Government budget appropriations or outlays for R&D (GBAORD) by socioeconomic objective indicate the relative importance of various socioeconomic objectives, such as defence, health and the environment, in public R&D spending. These are the funds committed by the federal/central government for R&D (GBAORD generally covers only the federal or central government). Programmes are allocated according to socioeconomic objectives on the basis of intentions when the funds are committed and may not reflect the actual content of the projects implemented. They reflect policies at a given moment in time. The classification used is the European Commission's Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets – NABS (see the OECD *Frascati Manual,* OECD, 2002). The GBAORD data are based on funders' reports; they are less accurate than "performer-reported" data, but they are more timely and can be linked back to policy issues by means of a classification by "objectives" or "goals".

Civil GBAORD includes total GBAORD less defence. Defence R&D financed by government, including military nuclear and space but excluding civilian R&D financed by ministries of defence (*e.g.* meteorology). Data are drawn from the OECD RDS Database and based on budget data assembled by national authorities using statistics collected for budgets.

Generic research versus thematic research (by socioeconomic objective). Generic public research includes: general university funds (GUF), a block grant which includes an estimated R&D content, granted by government to the higher education sector; and non-oriented GBAORD, which covers research programmes financed with a view to the advancement of knowledge. Thematic public research includes all other GBAORD. Data are drawn from the OECD RDS Database and based on budget data assembled by national authorities using statistics collected for budgets.

Institutional versus project-based funding (by funding mechanism). Governments support public research by means of institutional and project-based funding (see the policy profile on "Financing public research"). Institutional "block" grants provide stable long-run funding of research, while project-based funding can promote competition within the research system and target strategic areas. Project funding is defined as funding attributed on the basis of a project submission by a group or individuals for an R&D activity that is limited in scope, budget and time. Institutional funding is defined as the general funding of institutions with no direct selection of R&D projects or programmes (OECD, 2010b). The figure shows the balance between institutional funding and project funding for selected OECD countries. However it does not reflect the share of block funding allocated on performance criteria and the spread of new performance-based funding mechanisms, e.g. the research excellence initiatives. Data are based on an exploratory project carried out by

NESTI on public R&D funding and comparability may be limited (Van Steen, 2012; OECD, 2013b). Complementary data are drawn from Eurostat STI Databases.

Business R&D

Private investment in R&D and innovation may be below a socially optimal level, mainly because returns are uncertain or the innovator cannot appropriate all of the benefits. Governments therefore play an important role in fostering investment in R&D and innovation (see the policy profile Government financing business R&D and innovation). They can choose among various tools to leverage private-sector R&D. They can offer firms direct support via grants, loans or procurement or they can use fiscal incentives, such as R&D tax incentives (R&D tax credits, R&D allowances, reductions in R&D workers' wage taxes and social security contributions, and accelerated depreciation of R&D capital (see the policy profile Tax incentives for R&D and innovation).

Direct versus indirect funding (by funding mechanism). Direct R&D grants or subsidies target specific projects with high potential social returns. Tax credits reduce the marginal cost of R&D activities and allow private firms to choose which projects to fund. The optimal balance of direct and indirect R&D support varies from country to country, as each tool addresses different market failures and stimulates different types of R&D. For instance, tax credits mostly encourage short-term applied research, while direct subsidies foster more long-term research. Direct government funding of R&D is the amount of business R&D funded by the government as reported by firms. It is the sum of different components (contracts, loans, grants/subsidies) with different impacts on the cost of performing R&D. R&D grants and loans decrease the cost of performing R&D, but contracts (usually awarded through competitive bidding) do not directly affect the cost of performing R&D. Foregone revenues on R&D and innovation tax incentives are an estimated cost of the R&D tax concession. As the cost of tax incentives is estimated and reported in different ways across counties, these indicators are experimental. Eligible R&D expenditures can differ, and companies may use R&D tax incentives in some circumstances to fund intramural or extramural R&D, some of which may take place in other sectors. Tax incentives are excluded from the definition of government-funded BERD to minimise the risk of double counting. Data are drawn from the OECD RDS Database and from the OECD/NESTI data collection on R&D tax incentives (www.oecd.org/sti/rd-tax-stats.htm).

Balance

Business R&D versus public research. Governments support both public-sector research and business R&D and innovation but in different proportions. Most public money spent on R&D goes to universities and PRIs. However, public support to business R&D seems to have gained ground in many countries over the past five years. The figure shows the relative balance between government funding to universities and PRIs and government funding to business R&D. The former is defined as the sum of HERD and GOVERD funded by both government and higher education. The latter is defined as the sum of government-funded BERD and the estimated cost of R&D tax incentives, if any. The balance is expressed as a percentage of the sum of the two. Data are drawn from the OECD RDS Database and the NESTI data collection on R&D tax incentives (OECD, 2016).

Most relevant instruments of public funding of business R&D (Panel 8 of the country profiles)

Governments finance business R&D and innovation through a mix of complementary direct and indirect instruments (see the policy profiles *Government financing business R&D and innovation* and *Policy mix for business innovation*. Direct funding allows governments to target specific R&D activities and depends on discretionary decisions by governments and arm-length organisations (e.g. national funding agencies). Tax incentives reduce the marginal cost of R&D and innovation spending and are usually more neutral in terms of industry, region and firm characteristics. While direct subsidies tend to target long-term research, R&D tax schemes are more likely to encourage short-term applied research and boost incremental innovation rather than radical breakthroughs.

Direct funding. Governments may offer financial support to firms through a variety of competitive grants, repayable advances (e.g. subordinated to profit making by firms), debt financing and risk-sharing mechanisms (e.g. loans at preferential rate, credit guarantee schemes that reimburse a pre-defined share of
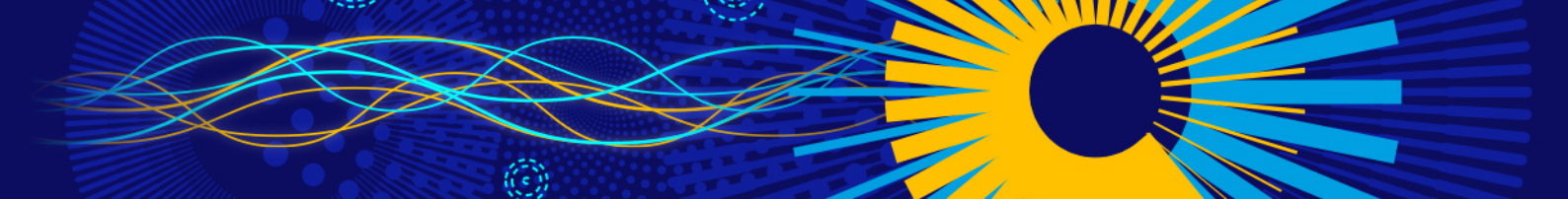
the outstanding loan to the lender in the event of a loan default, risk-sharing mechanisms such as guarantee funds and mutual guarantee associations that provide lenders with insurance against firms' risk of default, etc.). Many countries have schemes and funds to access early-stage finance, particularly for equity, and to support the venture capital industry, e.g. through public venture capital funds, co-investment funds with private investments and "funds of funds" (see the policy profile on *Start-ups and innovative entrepreneurship*). Technology consulting and extension programmes, albeit not a funding instrument per se, help firms access expertise, knowledge and technology at low or no cost. Innovation vouchers whose face value varies across countries are granted to firms for the purchase of knowledge services from universities and public research and education providers. Public procurement helps start-ups bridge the pre-commercialisation gap for their products and services by awarding contracts for pre-commercial innovations (i.e. first sales of technology). It also helps them achieve the critical mass needed to bring prices down and be competitive, and contribute to making access to private third-party funding easier (see the policy profile on *Stimulating demand for innovation*).

Indirect funding. Tax incentives applicable to different tax arrangements, including corporate and personal income taxes, are also widely used to encourage private investments in R&D and the exploitation of IP assets, to attract business angels and leverage early-stage finance, and to attract foreign talent or foreign multinationals (see the policy profiles *Tax incentives for R&D and innovation* and *Start-ups and innovative entrepreneurship*). In the figure, a distinction is made between tax breaks that are granted on the basis of expenditures incurred for R&D and innovation activities (expenditure-based) and tax breaks that are granted on gains from innovative activities (income-based).

Data are drawn from country responses to the EC/OECD *International Survey on STI Policies* 2016. Responses were provided by self-assessment by Delegates to the OECD Committee for Scientific and Technological Policy to the question: "*C.3) Which of the following are the principal instruments of public funding of business R&D and innovation in your country? How has the relative balance between these instruments changed recently, if at all? Please rate the relative relevance of the following financial instruments in your country's policy mix (high- medium- low - not used) and indicate whether their share in the total has increased/decreased or is remained unchanged.*" Responses have been aggregated as followed: 0= not used; 1= low and decreasing relevance; 2= low and stable relevance; 3= low and increasing relevance; 4= medium and decreasing relevance; 5= medium and stable relevance; 6= medium and increasing relevance; 7= high and decreasing relevance; 8= high and stable relevance; 9= high and increasing relevance.

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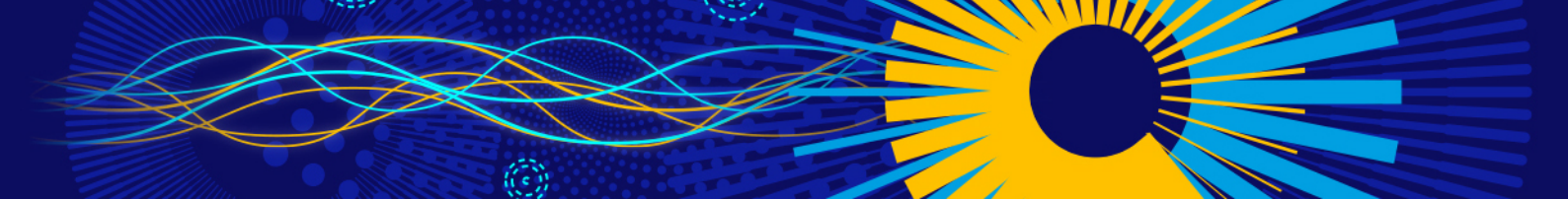
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