European Innovation Scoreboard 2017

Methodology Report

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1. Introduction

The annual European Innovation Scoreboard (EIS) provides a comparative assessment of the research and innovation performance of the EU Member States and the relative strengths and weaknesses of their research and innovation systems. It helps Member States assess areas in which they need to concentrate their efforts in order to boost their innovation performance.

This Methodology Report will first discuss in Section 2 the need for the revision of the EIS measurement framework. Section 3 discusses in detail the changes made to the EIS measurement framework for the 2017 edition. Section 4 gives the definitions and rationale for the indicators. Section 5 provides a detailed discussion of the methodology used for calculating the Summary Innovation Index and performance relative to the EU. Section 6 discusses the impact of the different changes in the measurement framework on countries' performance scores. Section 7 provides the definitions for the contextual indicators included in the EIS 2017 Country profiles. Section 8 provides a sensitivity audit of the Summary Innovation Index of the revised EIS.

2. The need for a revised measurement framework

The EIS has gone a long way since its first introduction in 2001.[1] Since then, the EIS has been published annually and has well served its purpose as an analytical tool to help monitor, measure and benchmark the innovation performance of the European Union, individual Member States, as well as associated countries and selected global competitors.

Over time, the EIS methodology for measuring the performance of national research and innovation systems has not remained without criticism. Incremental changes to the methodology have been introduced almost every year, with more major revisions in 2005, 2008, 2010, and in 2017. The revision in 2008, for example, was a response to the following aspects of criticism[2]:

- The EIS supposedly lacked an underlying model of innovation that would justify the choice of innovation dimensions and indicators, and reflect causalities that could be influenced by policy;
- The use of a single composite indicator and ranking table would lead to "naming and shaming", while missing the complexity of the process behind one simple number;
- Too many indicators would measure innovation in high-tech industries. This would bias innovation performance in favour of those countries specialised in high-tech industries, in particular in high-tech manufacturing;
- Many of the indicators are (highly) correlated and these indicators may thus capture and measure the same aspect of the innovation process;
- For many indicators and countries, data are not available. Missing data would jeopardize a robust comparison of countries' performance. Differences in the timeliness of the data between indicators but also between countries for the same indicator would cause similar problems;

[1] The first pilot EIS was introduced in 2000.

[2] For more details, see the EIS 2008 Methodology Report.

Most of this criticism continued to be expressed after the revisions in 2008 and 2010 (the 2010 revision followed the publication of the Innovation Union initiative, with the revised methodology broadening the scope of the measurement framework from innovation to research and innovation).

At the 2016 OECD Blue Sky Forum in Ghent[3], the EIS was criticised for the following:

- There would be an unbalanced use of input and output indicators;
- Structural differences between countries are not taken into account when calculating performance scores;
- There is a lack of a conceptual and theoretical discussion;
- The information in the EIS report should be supplemented with additional contextual and qualitative information for policy-making.

In addition to the above, there has been a growing concern about the timeliness of the data used in the EIS, as using data two to three years older than the year in which the report is published might have a negative impact on the policy relevance of the EIS. In response to the latter, the EIS 2016 introduced a forward-looking analysis of EU innovation performance discussing more recent developments, trends, and expected changes.

One of the major criticisms has been the claim of a lack of a conceptual and theoretical model. The initial development of the EIS in the early 2000s was build on such a model, but due to smaller and larger changes over time – in particular the revision in 2010, which introduced indicators not well embedded in the existing framework at that time – the EIS measurement framework is considered to be less well connected to existing theoretical models of innovation.

The revision of the EIS 2017 does not seek to fully align the measurement framework with theory, but it intends to close this perceived gap by introducing new dimensions and indicators which have been of increasing importance for innovation, notably digitisation and entrepreneurship. Digitisation has a positive effect on productivity through innovations in management techniques, business models, work processes and human resource practices. Digitisation is said to change the way innovation itself is performed, by improving real-time measurement of business activities, by fostering faster and cheaper business experimentation, by making it more easy to share ideas, and by increasing the possibilities for imitating innovations more quickly and more accurately[4]. Given this positive impact of digitisation on innovation, two indicators have been introduced in the EIS 2017, which capture particular aspects of this process: broadband penetration by enterprises and the upgrading of ICT skills of employees.

The 2006 Aho report[5] already suggested "the need for Europe to provide an innovation friendly market for its businesses". Rather than stressing innovation inputs such as R&D, the Aho Report stresses innovation demand and the myriad of socio-cultural factors that encourage innovation, such as entrepreneurship, risk taking, flexibility and adaptability, and mobility. The 2013 Exploratory report on "New ways of measuring

[3] Every 10 years, the OECD engages the policy community, data users and providers into an open dialogue to review and develop its long-term agenda on science, technology and innovation (STI) data and indicators. This event is known as the "OECD Blue Sky Forum", an open and unconstrained discussion on evidence gaps in science and innovation and on initiatives the international community can take to address data needs in this area. Blue Sky has been held in Paris (1996), Ottawa (2006) and Ghent (2016): http://www.oecd.org/innovation/blue-sky.htm

[4] See e.g. the work by E. Brynjolfson: http://digital.mit.edu/erik/

[5] Creating an Innovative Europe, Report of the Independent Expert Group on R&D and Innovation appointed following the Hampton Court Summit and chaired by Mr. Esko Aho, http://ec.europa.eu/invest-in-research/action/2006_ahogroup_en.htm

innovation"[6] identified entrepreneurship as one of the indicators "that could capture the innovation-friendliness of the business environment". Entrepreneurship is strongly linked to innovation as it can turn inventions into innovations by successfully bringing them to the market, entrepreneurial activity being defined as "the enterprising human action in pursuit of the generation of value, through the creation or expansion of economic activity, by identifying and exploiting new products, processes or markets" (OECD, 2012)[7]. Entrepreneurship is sharply influenced by the overall business climate (in particular the regulatory burdens) and the personal attitudes towards risk-taking (shaped notably through education but not only), and it is a direct enabler of innovative activities. The EIS 2017 includes one new indicator that captures differences in the entrepreneurial capacity of countries. However, not all types of entrepreneurship are relevant. For instance, in times of economic hardship, there is an increase in the rate of entrepreneurship, with people who have lost their job becoming self-employed by necessity. What is relevant are those entrepreneurial activities trying to exploit new opportunities, including the commercialisation of goods and services innovations. The Global Entrepreneurship Monitor[8] has developed an Index, the Motivational Index, which captures the relative prevalence of improvement-driven opportunity entrepreneurs versus those motivated by necessity. By using GEM data, the EIS is introducing opinion survey data which, by many, are seen as being of lower quality than data supplied by National Statistical Offices. Official statistics on entrepreneurial activities, however, are limited to data on the number of business start-ups, without distinguishing between the reasons for starting a new enterprise (opportunity versus necessity). The Motivational Index is considered to best capture the link between entrepreneurship and innovation.

[6] Bruno, N., K. Izsak and H. Hollanders (2013), New ways of measuring innovation, IUS Exploratory reports. Brussels: European Commission, 2013. Available at: hollanders.unu-merit.nl/EIS/New%20ways%20of%20measuring%20innovation.pdf

[7] OECD (2012), Entrepreneurship at a Glance 2012, Paris: OECD.

[8] The Global Entrepreneurship Monitor (GEM) is a global study conducted by a consortium of universities, analysing the level of entrepreneurship in a large number of countries. GEM measures entrepreneurship through both surveys and interviews to field experts, conducted by teams in each country. http://www.gemconsortium.org/

3. EIS 2017 measurement framework

3.1 A revised framework

For the EIS 2017[9], the measurement framework has been significantly revised. The 2016 European Innovation Scoreboard (EIS) largely followed the methodology of previous editions. The last major revision of the measurement framework had been introduced in 2010 with the launch of the Innovation Union. Following new developments in policy priorities, economic theory and data availability, last year's measurement framework was in need of adjustment. The revision of the framework started in 2016 and benefited from discussions in various forums, including an expert workshop, various meetings of the Enterprise Policy Group (EPG)'s Subgroup on Innovation, a presentation at the European Research and Innovation Area Committee (ERAC)[10] plenary, and a workshop under ERAC auspices.

Notably, for the present 2017 edition, there was a need to: (1) better align the EIS dimensions with changing policy priorities; (2) continuously improve the quality, timeliness and analytical soundness of indicators; (3) ensure that the EIS better captures increasingly important phenomena, including in fields such as digitisation and entrepreneurship, and that it includes indicators on key areas such as human resources, skills and science-business links; and (4) provide a contextual analysis of the data presented, examining the effects of structural differences between Member States, in order to provide an enhanced evidence base for policy-making purposes.

Changes to the EIS measurement framework: regrouping and addition of dimensions

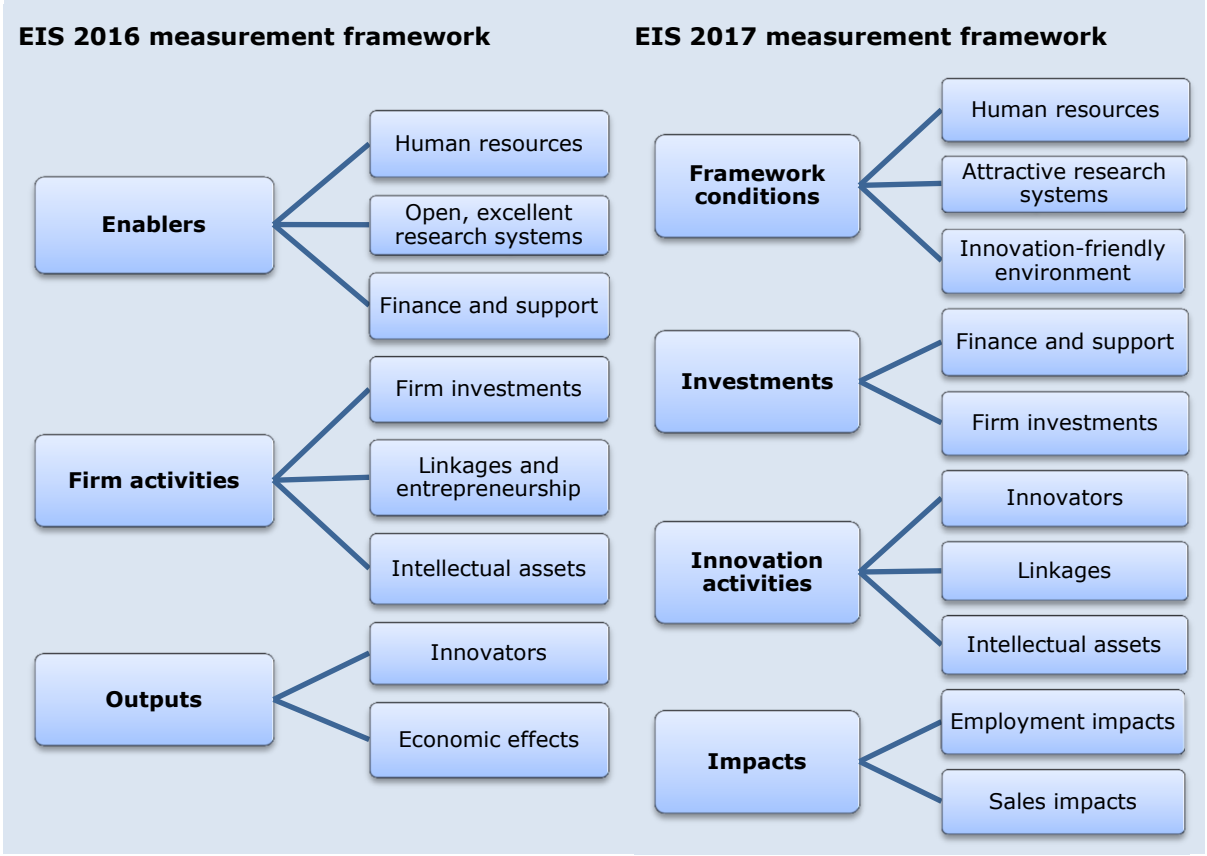
In the following, the changes to the EIS measurement framework will be discussed. The first change to the measurement framework involves a regrouping of the EIS 2016 innovation dimensions (Figure 1). The objective of this regrouping is to better distinguish between framework conditions and investments in innovation, enterprises' innovation activities, and the impact of these activities.

The second change has been to add one more dimension to better capture the environment in which enterprises operate. Enterprises innovate in response to changes in their environment, in particular to new opportunities to expand their business or to threats from either existing enterprises or new entrants. Results from the Community Innovation Survey (CIS) show that most enterprises innovate to improve the quality of goods or services, to increase the range of goods or services, or to increase their market share. A lack of internal funds, excessive innovation costs or a lack of external funds are for most enterprises the most important factors hampering their innovation activities. Also, a lack of qualified personnel, markets being dominated by established enterprises, and uncertain demand for innovative goods or services score high among the factors hindering innovation. An environment which is "innovation-friendly" will act as a catalyst, helping enterprises to innovate or innovate more.

[9] The EIS reports have been published under the name "European Innovation Scoreboard" until 2009, as "Innovation Union Scoreboard" between 2010 and 2015, and again as "European Innovation Scoreboard" from 2016 onwards.

[10] http://www.consilium.europa.eu/en/council-eu/preparatory-bodies/european-research-area-innovation-committee/

Figure 1: EIS measurement framework: main groups and dimensions



A third change involves splitting the EIS 2016 dimension measuring economic effects in two dimensions, one measuring employment impacts and the other one measuring sales impacts.

Changes to the EIS measurement framework: deleted, revised and new indicators

Within each of the dimensions, performance of the research and innovation system is captured by two or three indicators. Table 1 summarises the changes made, including the deletion of three indicators, minor revisions to six indicators, and the inclusion of five new indicators. All indicators have been carefully screened for their contribution to measuring the performance of Member States' research and innovation systems. Some indicators included in previous editions of the EIS have been deleted, not because these indicators would not be relevant, but to ensure that the total number of indicators would be comparable to that in the EIS 2016 (27 indicators now compared to 25 indicators in the EIS 2016).

Deleted indicators

Youth with at least upper secondary education has been removed for several reasons: first, education attainment is already captured by the indicator measuring the share of population with tertiary attainment; second, the indicator has reached saturation for many countries and as such no longer contributes to monitoring progress over time; and third, removing the indicator allowed for the inclusion of an indicator measuring the upgrading of skills during working life, i.e. the new indicator on lifelong learning.

PCT patent applications in societal challenges has been removed as it is already included in the indicator measuring all 'PCT patent applications', and including it would lead to a double-counting of patent applications in societal challenges.

License and patent revenues from abroad has been removed as these revenues can be considered as exports of knowledge-intensive services. Differences in taxation and regulation systems between Member States also created a perceived distortion in the relative performance scores favouring a few Member States. The revenues previously captured by this indicator are now included in the revised indicator on *Knowledge-intensive services exports* (see below).

Revised indicators

The share of *Population having completed tertiary education* has been revised by extending the age group from 30-34 to 25-34. Broadening the age group will reduce the confidence interval and improve the statistical significance of changes, while still capturing a relatively narrow age group, thereby allowing the indicator to respond faster to policy changes. The revised indicator uses the same age group as the indicator on *New doctorate graduates*.

Foreign doctorate students as percentage of total doctorate students has been revised by not only capturing students with a citizenship of non-EU Member States as in the EIS 2016, but including all students with a citizenship of any foreign country (thus also including other EU Member States). The revision follows the fact that there should be no difference in the value of foreign students to a country's education system based on their country of origin. Broadening the definition will also provide a better benchmark with non-EU Member States, as for these the EIS 2016 indicator already included all foreign students.

The indicator measuring *Trademark applications* has been revised and will aggregate data from the European Union Intellectual Property Office (EUIPO) on Community trademark applications, already used in the EIS 2016, with data from the World Intellectual Property Organization (WIPO) on trademark applications applied for under the Madrid Protocol. In the EU, there is a four-tier system for registering trademarks:

1) For protection in one EU Member State only, one can make a trademark application directly at the relevant national IP office. This is the national route.
2) For protection in Belgium, the Netherlands and/or Luxembourg, one can make an application to the Benelux Office of Intellectual Property (BOIP), the only regional-level IP office in the EU, for trademark protection in those three Member States. This is the regional route.
3) For protection in more Member States of the EU, one can apply for an EU trademark from EUIPO – this is the European route.
4) The fourth route to protection in the EU is the international route. One can use a national, regional or EU trademark application to expand protection internationally, to any country that is a signatory of the Madrid Protocol.

In the EIS 2016, only the first three tiers were covered by the indicator measuring Trademark applications. In the EIS 2017, all four tiers are included.

Employment in fast-growing enterprises of innovative sectors suffered from being excessively complex, making it difficult to explain year-on-year changes in country performance. The indicator originates from the European Commission's Innovation Output Indicator (IOI). The previous indicator was computed by weighting sectoral innovation coefficients with sectoral shares of employment in high-growth enterprises. The revised indicator instead measures more simply the share of employment in high-growth enterprises in the top 50% most innovative sectors within total employment.

The top 50% most innovative sectors are selected based on a ranking of innovation coefficients measuring the degree of innovation of each industry at EU level[11].

The indicator measuring *Knowledge-intensive services exports* has been revised and also includes license and patent revenues from abroad, which was a separate indicator in the EIS 2016.

New indicators

Lifelong learning (percentage of population aged 25 to 64 participating in education and training) captures the share of the adult population involved in training activities and measures the upgrading of skills during working life. Lifelong learning encompasses all purposeful learning activity, whether formal, non-formal or informal, undertaken on an ongoing basis with the aim of improving knowledge, skills and competence. Lifelong learning makes workers involved in innovative activities more knowledgeable and efficient. The 25-64 year age group refers to the majority of the labour force outside initial formal education. The indicator was also included in earlier versions of the EIS, but was removed from the 2010 report onwards.

Broadband penetration (share of enterprises with a maximum contracted download speed of the fastest fixed internet connection of at least 100 Mbps) captures the increasing digitisation of European economies. Digital innovations are reshaping Europe's economy and industries. Big data, the Internet of Things, and mobile and cloud technologies are expected to be strong drivers of economic growth, job creation and the quality of life. Realising Europe's full e-potential depends on creating the conditions for electronic commerce and the Internet to flourish. This indicator captures the relative use of this e-potential by the share of enterprises that have access to fast broadband.

Opportunity-driven entrepreneurship is measured by the Motivational Index from the Global Entrepreneurship Monitor (GEM) and captures the prevalence of opportunity-driven entrepreneurship. Opportunity-driven entrepreneurship is the result of individuals wanting to exploit new innovative products. This type of entrepreneurship is relevant for measuring the performance of innovation systems.

The share of enterprises that provide training to develop/upgrade ICT skills of their personnel captures the upgrading of ICT skills in the business sector. ICT skills are particularly important for innovation in an increasingly digital economy. The share of enterprises providing training in this respect is a proxy for the overall skills development of employees.

Private co-funding of public R&D (percentage of GDP) measures public-private co-operation. The share of university and government R&D financed by the business sector captures the importance of external R&D and the role of Public Research Organisations and higher education institutions in an enterprise's innovation activities. The indicator also captures the quality and market relevance of public research. A higher share of business funding going to public R&D is expected in economies with a high share of large firms with more linkages to public R&D. In addition, external R&D-industry links are more developed in science-intensive sectors such as semiconductors, computers, communications equipment, drugs, organic chemicals, plastics, petroleum refining, pulp and paper.

[11] Vertesy, D. and R. Deiss, "The Innovation Output Indicator 2016. Methodology Update", EUR 27880 EN, doi:10.2788/261409

Table 1: EIS measurement framework: indicators

EIS 2016 measurement framework	EIS 2017 measurement framework
ENABLERS	**FRAMEWORK CONDITIONS**
Human resources	*Human resources*
1.1.1 New doctorate graduates	1.1.1 New doctorate graduates
1.1.2 Population aged 30-34 with tertiary education - REVISED	1.1.2 Population aged 25-34 with tertiary education - REVISED
1.1.3 Youth with at least upper secondary education - DELETED	1.1.3 Lifelong learning - NEW
Open, excellent research systems	*Attractive research systems*
1.2.1 International scientific co-publications	1.2.1 International scientific co-publications
1.2.2 Top 10% most cited publications	1.2.2 Top 10% most cited publications
1.2.3 Non-EU doctorate students - REVISED	1.2.3 Foreign doctorate students - REVISED
Finance and support	*Innovation-friendly environment*
1.3.1 R&D expenditure in the public sector	1.3.1 Broadband penetration - NEW
1.3.2 Venture capital expenditures	1.3.2 Opportunity-driven entrepreneurship - NEW
FIRM ACTIVITIES	**INVESTMENTS**
Firm investments	*Finance and support*
2.1.1 R&D expenditure in the business sector	2.1.1 R&D expenditure in the public sector
2.1.2 Non-R&D innovation expenditures	2.1.2 Venture capital expenditures
Linkages and entrepreneurship	*Firm investments*
2.2.1 SMEs innovating in-house	2.2.1 R&D expenditure in the business sector
2.2.2 Innovative SMEs collaborating with others	2.2.2 Non-R&D innovation expenditures
2.2.3 Public-private co-publications	2.2.3 Enterprises providing training to develop or upgrade ICT skills of their personnel - NEW
Intellectual assets	**INNOVATION ACTIVITIES**
2.3.1 PCT patent applications	*Innovators*
2.3.2 PCT patent applications in societal challenges - DELETED	3.1.1 SMEs with product or process innovations
2.3.3 Trademark applications - REVISED	3.1.2 SMEs with marketing or organisational innovations
2.3.4 Design applications	3.1.3 SMEs innovating in-house
OUTPUTS	*Linkages*
Innovators	3.2.1 Innovative SMEs collaborating with others
3.1.1 SMEs with product or process innovations	3.2.2 Public-private co-publications
3.1.2 SMEs with marketing or organisational innovations	3.2.3 Private co-funding of public R&D expenditures - NEW
3.1.3 Employment fast-growing enterprises of innovative sectors - REVISED	*Intellectual assets*
Economic effects	3.3.1 PCT patent applications
3.2.1 Employment in knowledge-intensive activities	3.3.2 Trademark applications - REVISED
3.2.2 Medium and high tech product exports	3.3.3 Design applications
3.2.3 Knowledge-intensive services exports - REVISED	**IMPACTS**
3.2.4 Sales of new-to-market and new-to-firm product innovations	*Employment impacts*
3.2.5 License and patent revenues from abroad - DELETED	4.1.1 Employment in knowledge-intensive activities
	4.1.2 Employment fast-growing enterprises of innovative sectors - REVISED
	Sales impacts
	4.2.1 Medium and high tech product exports
	4.2.2 Knowledge-intensive services exports - REVISED
	4.2.3 Sales of new-to-market and new-to-firm product innovations

3.2 Definitions of EIS 2017 innovation indicators

Indicator	**1.1.1 New doctorate graduates per 1000 population aged 25-34**
Numerator	Number of doctorate graduates
Denominator	Population between and including 25 and 34 years
Interpretation	The indicator is a measure of the supply of new second-stage tertiary graduates in all fields of training (ISCED 8). For most countries, ISCED 8 captures PhD graduates.
Data source	Eurostat
Indicator	**1.1.2 Percentage population aged 25-34 having completed tertiary education**
Numerator	Number of persons in age class with some form of post-secondary education
Denominator	Population between and including 25 and 34 years
Interpretation	This is a general indicator of the supply of advanced skills. It is not limited to science and technical fields, because the adoption of innovations in many areas, in particular in the service sectors, depends on a wide range of skills. The indicator focuses on a relatively young age cohort of the population, aged 25 to 34, and will therefore easily and quickly reflect changes in educational policies leading to more tertiary graduates.
Data source	Eurostat
Indicator	**1.1.3 Percentage population aged 25-64 participating in lifelong learning**
Numerator	The target population for lifelong learning statistics refers to all persons in private households aged between 25 and 64 years. The information collected relates to all education or training, whether or not relevant to the respondent's current or possible future job. Data are collected through the EU Labour Force Survey. The reference period for the participation in education and training is the four weeks preceding the interview, as is usual in the Labour Force Survey.
Denominator	Total population of the same age group, excluding those who did not answer the question concerning participation in (formal and non-formal) education and training
Interpretation	Lifelong learning encompasses all purposeful learning activity, whether formal, non-formal or informal, undertaken on an ongoing basis with the aim of improving knowledge, skills and competence. The intention or aim to learn is the critical point that distinguishes these activities from non-learning activities, such as cultural or sporting activities.
Data source	Eurostat
Indicator	**1.2.1 International scientific co-publications per million population**
Numerator	Number of scientific publications with at least one co-author based abroad (where abroad is non-EU for the EU28)
Denominator	Total population
Interpretation	International scientific co-publications are a proxy for the quality of scientific research as collaboration increases scientific productivity.
Data source	Publication data provided by CWTS (Leiden University) as part of a contract to European Commission (DG Research and Innovation). Population data from Eurostat

Indicator	**1.2.2 Scientific publications among the top-10% most cited publications worldwide as percentage of total scientific publications of the country**
Numerator	Number of scientific publications among the top-10% most cited publications worldwide
Denominator	Total number of scientific publications
Interpretation	The indicator is a measure for the efficiency of the research system, as highly cited publications are assumed to be of higher quality. There could be a bias towards small or English-speaking countries given the coverage of Scopus' publication data.
Data source	Data provided by CWTS (Leiden University) as part of a contract to the European Commission (DG Research and Innovation).
Indicator	**1.2.3 Foreign doctorate students as a percentage of all doctorate students**
Numerator	Number of doctorate students from foreign countries
Denominator	Total number of doctorate students
Interpretation	The share of foreign doctorate students reflects the mobility of students as an effective way of diffusing knowledge. Attracting high-skilled foreign doctorate students will secure a continuous supply of researchers.
Data source	Eurostat
Indicator	**1.3.1 Broadband penetration**
Numerator	Number of enterprises with a maximum contracted download speed of the fastest fixed internet connection of at least 100 Mb/s
Denominator	Total number of enterprises
Interpretation	Realising Europe's full e-potential depends on creating the conditions for electronic commerce and the Internet to flourish. This indicator captures the relative use of this e-potential by the share of enterprises that have access to fast broadband.
Data source	Eurostat, Community Survey of ICT Usage and E-commerce in Enterprises
Indicator	**1.3.2 Opportunity-driven entrepreneurship (Motivational index)**
Definition	This index is calculated as the ratio between the share of persons involved in improvement-driven entrepreneurship and the share of persons involved in necessity-driven entrepreneurship.
Interpretation	Data from GEM distinguish between two types of entrepreneurship: 1) opportunity-driven entrepreneurship and 2) necessity-driven entrepreneurship. The first includes persons involved in TEA (Total Early-Stage Entrepreneurial Activity) who (i) claim to be driven by opportunity as opposed to finding no other option for work; and (ii) who indicate the main driver for being involved in this opportunity is being independent or increasing their income, rather than just maintaining their income; the second includes persons involved in TEA who are involved in entrepreneurship because they had no other option for work. GEM has constructed the Motivational index to measure the relative degree of improvement-driven entrepreneurship.
Comment	Three-year averages have been used for calculating the normalised scores for this indicator, which are used for calculating the Summary Innovation Index.
Data source	Global Entrepreneurship Monitor (GEM)

Indicator	**2.1.1 R&D expenditure in the public sector (percentage of GDP)**
Numerator	All R&D expenditures in the government sector (GOVERD) and the higher education sector (HERD)
Denominator	Gross Domestic Product
Interpretation	R&D expenditure represents one of the major drivers of economic growth in a knowledge-based economy. As such, trends in the R&D expenditure indicator provide key indications of the future competitiveness and wealth of the EU. Research and development spending is essential for making the transition to a knowledge-based economy as well as for improving production technologies and stimulating growth.
Data source	Eurostat
Indicator	**2.1.2 Venture capital (percentage of GDP)**
Numerator	Venture capital investment is defined as private equity being raised for investment in companies. Management buyouts, management buy-ins, and venture purchase of quoted shares are excluded. Venture capital includes early-stage (seed + start-up) and expansion and replacement capital.
Denominator	Gross Domestic Product
Interpretation	The amount of venture capital is a proxy for the relative dynamism of new business creation. In particular for enterprises using or developing new (risky) technologies, venture capital is often the only available means of financing their (expanding) business.
Comment	Three-year averages have been used for calculating the normalised scores for this indicator, which are used for calculating the Summary Innovation Index.
Data source	Venture capital data from Invest Europe. GDP data from Eurostat
Indicator	**2.2.1 R&D expenditure in the business sector (percentage of GDP)**
Numerator	All R&D expenditures in the business sector (BERD)
Denominator	Gross Domestic Product
Interpretation	The indicator captures the formal creation of new knowledge within firms. It is particularly important in the science-based sectors (pharmaceuticals, chemicals and some areas of electronics) where most new knowledge is created in or near R&D laboratories.
Data source	Eurostat
Indicator	**2.2.2 Non-R&D innovation expenditures (percentage of turnover)**
Numerator	Sum of total innovation expenditure for enterprises, excluding intramural and extramural R&D expenditures
Denominator	Total turnover for all enterprises
Interpretation	This indicator measures non-R&D innovation expenditure as a percentage of total turnover. Several of the components of innovation expenditure, such as investment in equipment and machinery and the acquisition of patents and licenses, measure the diffusion of new production technology and ideas.
Data source	Eurostat (Community Innovation Survey)

Indicator	**2.2.3 Enterprises providing training to develop or upgrade ICT skills of their personnel**
Numerator	Number of enterprises that provided any type of training to develop ICT related skills of their personnel
Denominator	Total number of enterprises
Interpretation	ICT skills are particularly important for innovation in an increasingly digital economy. The share of enterprises providing training in that respect is a proxy for the overall skills development of employees.
Data source	Eurostat, Community Survey of ICT Usage and E-commerce in Enterprises
Indicator	**3.1.1 SMEs introducing product or process innovations (percentage of SMEs)**
Numerator	Number of SMEs who introduced at least one new product or a new process to one of their markets
Denominator	Total number of SMEs
Interpretation	Technological innovation, as measured by the introduction of new products (goods or services) and processes, is a key ingredient to innovation in manufacturing activities. Higher shares of technological innovators should reflect a higher level of innovation activities.
Comment	SMEs are defined here as including all enterprises with 10 to 249 employees.
Data source	Eurostat (Community Innovation Survey)
Indicator	**3.1.2 SMEs introducing marketing or organisational innovations (percentage of SMEs)**
Numerator	Number of SMEs who introduced at least one new marketing innovation or organisational innovation to one of their markets
Denominator	Total number of SMEs
Interpretation	The Community Innovation Survey mainly asks firms about their technological innovation. Many firms, in particular in the services sectors, innovate through other non-technological forms of innovation. Examples of these are marketing and organisational innovations. This indicator captures the extent to which SMEs innovate through non-technological innovation.
Comment	SMEs are defined here as including all enterprises with 10 to 249 employees.
Data source	Eurostat (Community Innovation Survey)
Indicator	**3.1.3 SMEs innovating in-house (percentage of SMEs)**
Numerator	Number of SMEs with in-house innovation activities. Innovative enterprises are defined as enterprises which have introduced new products or processes either in-house or in combination with other firms.
Denominator	Total number of SMEs
Interpretation	This indicator measures the degree to which SMEs, that have introduced any new or significantly improved products or production processes, have innovated in-house. The indicator is limited to SMEs, because almost all large firms innovate and because countries with an industrial structure weighted towards larger firms tend to do better.
Comment	SMEs are defined here as including all enterprises with 10 to 249 employees.
Data source	Eurostat (Community Innovation Survey)

Indicator	**3.2.1 Innovative SMEs collaborating with others (percentage of SMEs)**
Numerator	Number of SMEs with innovation co-operation activities, i.e. those firms that had any co-operation agreements on innovation activities with other enterprises or institutions in the three years of the survey period
Denominator	Total number of SMEs
Interpretation	This indicator measures the degree to which SMEs are involved in innovation co-operation. Complex innovations, in particular in ICT, often depend on the ability to draw on diverse sources of information and knowledge, or to collaborate in the development of an innovation. This indicator measures the flow of knowledge between public research institutions and firms, and between firms and other firms. The indicator is limited to SMEs, because almost all large firms are involved in innovation co-operation.
Comment	SMEs are defined here as including all enterprises with 10 to 249 employees.
Data source	Eurostat (Community Innovation Survey)
Indicator	**3.2.2 Public-private co-publications per million population**
Numerator	Number of public-private co-authored research publications. The definition of the "private sector" excludes the private medical and health sector. Publications are assigned to the country/countries in which the business companies or other private sector organisations are located.
Denominator	Total population
Interpretation	This indicator captures public-private research linkages and active collaboration activities between business sector researchers and public sector researchers resulting in academic publications.
Data source	Publication data provided by CWTS (Leiden University) as part of a contract to European Commission (DG Research and Innovation). Population data from Eurostat
Indicator	**3.2.3 Private co-funding of public R&D expenditures (percentage of GDP)**
Numerator	All R&D expenditures in the government sector (GOVERD) and the higher education sector (HERD) financed by the business sector
Denominator	Gross Domestic Product
Interpretation	This indicator measures public-private co-operation. University and government R&D financed by the business sector are expected to explicitly serve the more short-term research needs of the business sector.
Data source	Eurostat
Indicator	**3.3.1 PCT patent applications per billion GDP (in PPS)**
Numerator	Number of patent applications filed under the PCT, at international phase, designating the European Patent Office (EPO). Patent counts are based on the priority date, the inventor's country of residence and fractional counts.
Denominator	Gross Domestic Product in Purchasing Power Standard
Interpretation	The capacity of firms to develop new products will determine their competitive advantage. One indicator of the rate of new product innovation is the number of patents. This indicator measures the number of PCT patent applications.
Data source	Patent data from the OECD. Population data from Eurostat

Indicator	**3.3.2 Trademark applications per billion GDP (in PPS)**
Numerator	Number of trademark applications applied for at European Union Intellectual Property Office (EUIPO) plus number of trademark applications applied for at World Intellectual Property Office (WIPO) ("yearly Madrid applications by origin")
Denominator	Gross Domestic Product in Purchasing Power Standard
Interpretation	Trademarks are an important innovation indicator, especially for the service sector. The Community trademark gives its proprietor a uniform right applicable in all Member States of the European Union through a single procedure which simplifies trademark policies at European level. It fulfils the three essential functions of a trademark: it identifies the origin of goods and services, guarantees consistent quality through evidence of the company's commitment vis-à-vis the consumer, and it is a form of communication, a basis for publicity and advertising.
Comment	Two-year averages have been used for calculating the normalised scores for this indicator, which are used for calculating the Summary Innovation Index.
Data source	Trademark data from European Union Intellectual Property Office (EUIPO) and World Intellectual Property Office (WIPO). Population data from Eurostat
Indicator	**3.3.3 Design applications per billion GDP (in PPS)**
Numerator	Number of individual designs applied for at European Union Intellectual Property Office (EUIPO)
Denominator	Gross Domestic Product in Purchasing Power Standard
Interpretation	A design is the outward appearance of a product or part of it resulting from the lines, contours, colours, shape, texture, materials and/or its ornamentation. A product can be any industrial or handicraft item including packaging, graphic symbols and typographic typefaces but excluding computer programmes. It also includes products that are composed of multiple components, which may be disassembled and reassembled. Community design protection is directly enforceable in each Member State and it provides both the option of an unregistered and a registered Community design right for one area encompassing all Member States.
Comment	Two-year averages have been used for calculating the normalised scores for this indicator, which are used for calculating the Summary Innovation Index.
Data source	Design data from European Union Intellectual Property Office (EUIPO). Population data from Eurostat
Indicator	**4.1.1 Employment in knowledge-intensive activities (percentage of total employment)**
Numerator	Number of employed persons in knowledge-intensive activities in business industries. Knowledge-intensive activities are defined, based on EU Labour Force Survey data, as all NACE Rev.2 industries at 2-digit level where at least 33% of employment has a tertiary education degree (ISCED 5-8).
Denominator	Gross Domestic Product in Purchasing Power Standard
Interpretation	Knowledge-intensive activities provide services directly to consumers, such as telecommunications, and provide inputs to the innovative activities of other firms in all sectors of the economy.
Data source	Eurostat

Indicator	4.1.2 Employment in fast-growing enterprises (percentage of total employment)
Numerator	Number of employees in high-growth enterprises in 50% 'most innovative' industries, defined as: • B06 (Extraction of crude petroleum and natural gas) • B09 (Mining support service activities) • C11 (Manufacture of beverages) • C12 (Manufacture of tobacco products) • C19 (Manufacture of coke and refined petroleum product) • C20 (Manufacture of chemicals and chemical products) • C21 (Manufacture of basic pharmaceutical products and pharmaceutical preparations) • C26 (Manufacture of computer, electronic and optical products) • C27 (Manufacture of electrical equipment) • C28 (Manufacture of machinery and equipment not elsewhere classified) • C29 (Manufacture of motor vehicles, trailers and semi-trailers) • C30 (Manufacture of other transport equipment) • C32 (Other manufacturing) • D35 (Electricity, gas, steam and air conditioning supply) • E39 (Remediation activities and other waste management services) • G46 (Wholesale trade, except of motor vehicles and motorcycle) • H51 (Air transport) • J58 (Publishing activities) • J59 (Motion picture, video and television programme production, sound recording and music publishing activities) • J60 (Programming and broadcasting activities) • J61 (Telecommunications) • J62 (Computer programming, consultancy and related activities) • J63 (Information service activities) • K64 (Financial service activities, except insurance and pension funding) • K65 (Insurance, reinsurance and pension funding, except compulsory social security) • K66 (Activities auxiliary to financial services and insurance activities) • L68 (Real estate activities) • M69 (Legal and accounting activities) • M70 (Activities of head offices; management consultancy activities) • M71 (Architectural and engineering activities; technical testing and analysis) • M72 (Scientific research and development) • M73 (Advertising and market research) • M74 (Other professional, scientific and technical activities) • M75 (Veterinary activities) • N79 (Travel agency, tour operator and other reservation service and related activities)
Denominator	Total employment for enterprises with 10 or more employees
Interpretation	This indicator provides an indication of the dynamism of fast-growing firms in innovative sectors as compared to all fast-growing business activities. It captures the capacity of a country to rapidly transform its economy to respond to new needs and to take advantage of emerging demand.
Data source	Calculations by European Commission (Joint Research Centre)

Indicator	**4.2.1 Exports of medium and high technology products as a share of total product exports**
Numerator	Value of medium and high tech exports, in national currency and current prices, including exports of the following SITC Rev.3 products: 266, 267, 512, 513, 525, 533, 54, 553, 554, 562, 57, 58, 591, 593, 597, 598, 629, 653, 671, 672, 679, 71, 72, 731, 733, 737, 74, 751, 752, 759, 76, 77, 78, 79, 812, 87, 88 and 891
Denominator	Value of total product exports
Interpretation	The indicator measures the technological competitiveness of the EU, i.e. the ability to commercialise the results of research and development (R&D) and innovation in international markets. It also reflects product specialisation by country. Creating, exploiting and commercialising new technologies are vital for the competitiveness of a country in the modern economy. Medium and high technology products are key drivers for economic growth, productivity and welfare, and are generally a source of high value added and well-paid employment.
Data source	Eurostat (ComExt) for Member States, UN ComTrade for non-EU countries
Indicator	**4.2.2 Knowledge-intensive services exports as percentage of total services exports**
Numerator	Exports of knowledge-intensive services is defined as the sum of credits in EBOPS 2010 (Extended Balance of Payments Services Classification) items: • SC1 (Sea transport) • SC2 (Air transport) • SC3A (Space transport) • SF (Insurance and pension services) • SG (Financial services) • SH (Charges for the use of intellectual property) • SI (Telecommunications, computer, and information services) • SJ (Other business services) • SK1 (Audio-visual and related services)
Denominator	Total value of services exports
Interpretation	The indicator measures the competitiveness of the knowledge-intensive services sector. Competitiveness-enhancing measures and innovation strategies can be mutually reinforcing for the growth of employment, export shares, and turnover at the firm level. The indicator reflects the ability of an economy, notably resulting from innovation, to export services with high levels of value added, and successfully take part in knowledge-intensive global value chains.
Data source	Calculations by European Commission (Joint Research Centre)
Indicator	**4.2.3 Sales of new-to-market and new-to-firm innovations as percentage of turnover**
Numerator	Sum of total turnover of new or significantly improved products, either new-to-the-firm or new-to-the-market, for all enterprises
Denominator	Total turnover for all enterprises
Interpretation	This indicator measures the turnover of new or significantly improved products and includes both products which are only new to the firm and products which are also new to the market. The indicator thus captures both the creation of state-of-the-art technologies (new-to-market products) and the diffusion of these technologies (new-to-firm products).
Data source	Eurostat (Community Innovation Survey)

4. Methodology for calculating composite scores

The overall performance of each country's innovation system has been summarised in a composite indicator, the Summary Innovation Index. Section 4.1 provides details on data availability per country and per indicator. Section 4.2 explains the methodology used for calculating the SII and performance relative to the EU.

4.1 Data availability in the EIS 2017

The EIS uses the most recent statistics from Eurostat and other internationally recognised sources as available at the time of analysis. International sources have been used wherever possible in order to ensure comparability between countries.

For the calculation of normalised scores, data have been used for an eight-year period.[12] The availability of data by indicator for this eight-year period covered in the EIS 2017 is shown in Table 2. Data availability is below 60% for several indicators. However, for the indicators highlighted with an '*', full eight-year time series are not available. Data availability for shorter time series is shown between brackets.

For the six indicators using CIS data, data are available for at most four years, as CIS data are collected only once every two years (CIS 2008, CIS 2010, CIS 2012 and CIS 2014). For *Broadband penetration*, data are available for three years (2014-2016) only; for *Venture capital*, data are available for seven years (2009-2015); for *Enterprises providing ICT skills*, data are available for four years (2012 and 2014-2016); for *Employment in fast-growing enterprises*, data are available for at most three years (2012-2014); and for *Exports of knowledge-intensive services*, data are available for at most six years (2010-2015).

For several indicators, there are also breaks in series for several countries, where the data before the break are not directly comparable with the data after the break. In most cases, data from before the break are excluded from the database and are thus counted as not available, even if Eurostat published data for these years. All missing data have been imputed as explained in step 3 in Section 5.2.

Table 2: Data availability by indicator

Innovation dimension / Indicator	**EU Member States**	**Other European and neighbouring countries**
Human resources		
1.1.1 New doctorate graduates	93%	81%
1.1.2 Percentage population aged 25-34 having completed tertiary education	100%	63%
1.1.3 Percentage population aged 25-64 participating in lifelong learning	79%	55%
Attractive research systems		
1.2.1 International scientific co-publications per million population	100%	100%
1.2.2 Top 10% most cited publications	100%	100%
1.2.3 Foreign doctorate students	91%	64%
Innovation-friendly environment		
1.3.1 Broadband penetration *	38% (100%)	14% (38%)
1.3.2 Opportunity-driven entrepreneurship	83%	73%

[12] To ensure consistency with previous EIS reports, data have been used for an eight-year period in the normalisation process, resulting in Summary Innovation Index scores for 2009 to 2016. Performance relative to the EU is, however, measured by comparing the SII in 2016 to the SII in 2010.

Innovation dimension / Indicator	**EU Member States**	**Other European and neighbouring countries**
Finance and support		
2.1.1 R&D expenditure in the public sector	90%	63%
2.1.2 Venture capital investment	100%	54%
Firm investments		
2.2.1 R&D expenditure in the business sector	92%	59%
2.2.2 Non-R&D innovation expenditures *	47% (95%)	25% (50%)
2.2.3 Enterprises providing training to develop or upgrade ICT skills of their personnel *	50% (100%)	17% (34%)
Innovators		
3.1.1 SMEs introducing product or process innovations *	49% (97%)	33% (66%)
3.1.2 SMEs introducing marketing or organisational innovations *	49% (98%)	30% (5%)
3.1.3 SMEs innovating in-house *	41% (82%)	28% (56%)
Linkages		
3.2.1 Innovative SMEs collaborating with others *	49% (98%)	31% (63%)
3.2.2 Public-private co-publications	99%	98%
3.2.3 Private co-funding of public R&D expenditures	84%	34%
Intellectual assets		
3.3.1 PCT patent applications	100%	88%
3.3.2 Trademark applications	100%	91%
3.3.3 Design applications	100%	100%
Employment impacts		
4.1.1 Employment in knowledge-intensive activities	87%	72%
4.1.2 Employment in fast-growing enterprises in innovative sectors *	35% (93%)	6% (17%)
Sales impacts		
4.2.1 Medium and high technology product exports	100%	95%
4.2.2 Knowledge-intensive services exports *	53% (71%)	33% (44%)
4.2.3 Sales of new-to-market and new-to-firm innovations *	49% (97%)	31% (63%)

The availability of data by country for this eight-year period covered in the EIS 2017 is shown in Table 3. For almost all Member States, data availability is between 70% and 80%, but for Greece and Luxembourg, it is below 67%. For non-EU countries, data availability is relatively high for Norway and low for Serbia and Ukraine. However, if one takes into account the fact that for several indicators eight-year time series are not available, data availability is much better, as shown by the percentages between brackets. For most Member States, data availability is above 90%, only for Belgium, Greece, France, Luxembourg, Malta, the Netherlands and Portugal it is between 80% and 90%. For non-EU countries, data availability is above 90% for Norway, between 70% and 80% for Former Yugoslav Republic of Macedonia, Switzerland, and Turkey, and below 70% for the other non-EU countries.

Table 3: Data availability by country

	Data availability		Data availability
BE Belgium	72% (87%)	NL Netherlands	72% (87%)
BG Bulgaria	77% (93%)	AT Austria	77% (93%)
CZ Czech Republic	78% (92%)	PL Poland	77% (93%)
DK Denmark	75% (91%)	PT Portugal	74% (89%)
DE Germany	77% (93%)	RO Romania	75% (90%)
EE Estonia	78% (94%)	SI Slovenia	78% (92%)
IE Ireland	75% (91%)	SK Slovakia	77% (93%)
EL Greece	68% (82%)	FI Finland	79% (95%)
ES Spain	78% (92%)	SE Sweden	78% (94%)
FR France	74% (89%)	UK United Kingdom	75% (91%)
HR Croatia	79% (96%)	IS Iceland	55% (68%)
IT Italy	79% (96%)	IL Israel	51% (61%)
CY Cyprus	75% (91%)	MK Macedonia	59% (71%)
LV Latvia	80% (96%)	NO Norway	78% (92%)
LT Lithuania	79% (96%)	RS Serbia	49% (59%)
LU Luxembourg	67% (80%)	CH Switzerland	63% (75%)
HU Hungary	78% (94%)	TR Turkey	61% (74%)
MT Malta	73% (88%)	UA Ukraine	40% (49%)

4.2 Methodology for calculating the Summary Innovation Index

Step 1: Identifying and replacing outliers

Positive outliers are identified as those country scores which are higher than the mean across all countries plus twice the standard deviation. Negative outliers are identified as those country scores which are lower than the mean across all countries minus twice the standard deviation. These outliers are replaced by the respective maximum and minimum values observed over all the years and all countries. Table 4 summarises the outliers per indicator and year (negative outliers are shown in italics).

Table 4: Overview of positive and negative outliers

	Positive / *Negative* outlier
Human resources	
1.1.1 New doctorate graduates	SI: 2013-2015; CH: 2008-2015
1.1.2 Percentage population aged 25-34 having completed tertiary education	CY: 2016 *TR: 2009, 2010*
1.1.3 Population aged 25-64 participating in lifelong learning	SE: 2013-2016; CH: 2010-2016
Attractive research systems	
1.2.1 International scientific co-publications per million population	DK: 2016, 2016; IS: 2010, 2012-2016; CH: 2011-2016
1.2.2 Top 10% most cited publications	CH: 2011, 2013
1.2.3 Foreign doctorate students	LU: 2011-2015
Innovation-friendly environment	
1.3.1 Broadband penetration	DK: 2016-2016; FI: 2016; SE: 2015, 2016

	Positive / *Negative* outlier
1.3.2 Opportunity-driven entrepreneurship *(years shown refer to three-yearly averages)*	DK: 2009, 2015, 2016; LU: 2013; IS: 2012; NO: 2009, 2012-2016
Finance and support	
2.1.1 R&D expenditure in the public sector	DK: 2013-2015; FI: 2010
2.1.2 Venture capital investment *(years shown refer to three-yearly averages)*	IE: 2010, 2011; LU: 2009-2011
Firm investments	
2.2.1 R&D expenditure in the business sector	FI: 2008-2010; SE: 2008; IL: 2008-2014
2.2.2 Non-R&D innovation expenditures *(years shown refer to year of CIS survey)*	EE: 2006; CY: 2006; LT: 2014; TR: 2012, 2014; CH: 2010; RS: 2012
2.2.3 Enterprises providing training to develop or upgrade ICT skills of their personnel	FI: 2012, 2014; NO: 2012, 2014-2016
Innovators	
3.1.1 SMEs introducing product or process innovations *(years shown refer to year of CIS survey)*	CH: 2008 *RO: 2012, 2014; UA: 2010, 2012*
3.1.2 SMEs introducing marketing or organisational innovations *(years shown refer to year of CIS survey)*	DE: 2006, 2008; IL: 2008 *RO: 2014; UA: 2012*
3.1.3 SMEs innovating in-house *(years shown refer to year of CIS survey)*	*RO: 2014*
Linkages	
3.2.1 Innovative SMEs collaborating with others *(years shown refer to year of CIS survey)*	BE: 2014; CY: 2006; FI: 2006; UK: 2008, 2010, 2014
3.2.2 Public-private co-publications	DK: 2010-2014; IS: 2008-2015; CH: 2008-2015
3.2.3 Private co-funding of public R&D expenditures	DE: 2008-2014; LT: 2009, 2013, 2014; NL: 2009
Intellectual assets	
3.3.1 PCT patent applications	FI: 2007, 2009-2013; SE: 2007-2010, 2012-2014; IL: 2007-2014
3.3.2 Trademark applications *(years shown refer to two-yearly averages)*	CY: 2013-2016; LU: 2009-2016; MT: 2013-2016
3.3.3 Design applications *(years shown refer to two-yearly averages)*	BG: 2014; LU: 2012-2016; MT: 2013-2016
Employment impacts	
4.1.1 Employment in knowledge-intensive activities	IL: 2011-2014
4.1.2 Employment in fast-growing enterprises in innovative sectors	IE: 2014; SK: 2012, 2013
Sales impacts	
4.2.1 Medium and high technology product exports	*EL: 2013; IS: 2008-2014;* *NO: 2008-2014*
4.2.2 Knowledge-intensive services exports	IE: 2012 - 2015
4.2.3 Sales of new-to-market and new-to-firm innovations *(years shown refer to year of CIS survey)*	EL: 2006; MT: 2006; SK: 2010; TR: 2012; CH: 2008

Step 2: Setting reference years

For each indicator, a reference year is identified for all countries based on data availability for all those countries for which data availability is at least 75%. For most indicators, this reference year will be lagging one or two years behind the year to which the EIS refers.

Step 3: Imputing for missing values

Reference year data are then used for "2016", etc. If data for a year-in-between are not available, missing values are replaced with the value for the previous year. If data are not available at the beginning of the time series, missing values are replaced with the next available year. The following examples clarify this step and show how 'missing' data are imputed. If data are missing for all years, no data will be imputed (the indicator will not contribute to the Summary Innovation Index).

Latest year missing	"2016"	"2015"	"2014"	"2013"	"2012"
Available data	N/A	45	40	35	30
Use most recent year	**45**	45	40	35	30
Year-in-between missing	"2016"	"2015"	"2014"	"2013"	"2012"
Available data	50	N/A	40	35	30
Substitute with previous year	50	**40**	40	35	30
Beginning-of-period missing	"2016"	"2015"	"2014"	"2013"	"2012"
Available data	50	45	40	35	N/A
Substitute with next available year	50	45	40	35	**35**

Step 4: Determining Maximum and Minimum scores

The Maximum score is the highest score found for the whole time period within all countries excluding positive outliers. Similarly, the Minimum score is the lowest score found for the whole time period within all countries excluding negative outliers.

Step 5: Transforming data that have highly skewed distributions across countries

Most of the indicators are fractional indicators with values between 0% and 100%. Some indicators are unbound indicators, where values are not limited to an upper threshold. These indicators can be highly volatile and can have skewed data distributions (where most countries show low performance levels and a few countries show exceptionally high performance levels). For these indicators where the degree of skewness across the full eight-year period is above one, data have been transformed using a square root transformation, i.e. using the square root of the indicator value instead of the original value. For the following indicators, data have been transformed: *Opportunity-driven entrepreneurship*, *Public-private co-publications*, *PCT patent applications*, and *Trademark applications* (Table 5).

Table 5: Degree of skewness and data transformations

Innovation dimension / Indicator	**Skewness**	**Skewness after trans-formation**
Human resources		
1.1.1 New doctorate graduates	0.465*	--
1.1.2 Population aged 25-34 having completed tertiary education	-0.152*	--
1.1.3 Population aged 25-64 participating in lifelong learning	0.757*	--
Attractive research systems		
1.2.1 International scientific co-publications	0.756*	--
1.2.2 Top 10% most cited publications	0.053*	--
1.2.3 Foreign doctorate students	0.870*	--
Innovation-friendly environment		
1.3.1 Broadband penetration	0.358*	--
1.3.2 Opportunity-driven entrepreneurship	1.138	0.683
Finance and support		
2.1.1 R&D expenditure in the public sector	0.074*	--
2.1.2 Venture capital investment	0.780*	--
Firm investments		
2.2.1 R&D expenditure in the business sector	0.716*	--
2.2.2 Non-R&D innovation expenditures	0.906*	--
2.2.3 Enterprises providing training to develop or upgrade ICT skills of their personnel	-0.034*	--
Innovators		
3.1.1 SMEs introducing product or process innovations	-0.078*	--
3.1.2 SMEs introducing marketing or organisational innovations	0.025*	--
3.1.3 SMEs innovating in-house	0.029*	--
Linkages		
3.2.1 Innovative SMEs collaborating with others	0.341*	
3.2.2 Public-private co-publications	1.175	0.466
3.2.3 Private co-funding of public R&D expenditures	0.653*	--
Intellectual assets		
3.3.1 PCT patent applications	1.080	0.539
3.3.2 Trademark applications	1.535	0.787
3.3.3 Design applications	0.761*	--
Employment impacts		
4.1.1 Employment in knowledge-intensive activities	0.227*	--
4.1.2 Employment in fast-growing enterprises in innovative sectors	0.114*	--
Sales impacts		
4.2.1 Medium and high technology product exports	-0.353*	--
4.2.2 Knowledge-intensive services exports	0.090*	--
4.2.3 Sales of new-to-market and new-to-firm innovations	0.250*	--

* No transformation as skewness is below 1.

Step 6: Calculating re-scaled scores

Re-scaled scores of the country scores (after correcting for outliers and a possible transformation of the data) for all years are calculated by first subtracting the Minimum score and then dividing by the difference between the Maximum and Minimum score. The maximum re-scaled score is thus equal to 1, and the minimum re-scaled score is equal to 0. For positive and negative outliers, the re-scaled score is equal to 1 or 0, respectively.

Step 7: Calculating composite innovation indexes

For each year, a composite Summary Innovation Index is calculated as the unweighted average of the re-scaled scores for all indicators where all indicators receive the same weight (1/27 if data are available for all 27 indicators).

Step 8: Calculating relative-to-EU performance scores

Performance scores relative to the EU are then calculated as the SII of the respective country divided by the SII of the EU multiplied by 100. Relative performance scores are calculated for the full eight-year period compared to the performance of the EU in 2010 and for the latest year also compared to that of the EU in 2016. For the definition of the performance groups, only the performance scores relative to the EU in 2016 have been used.

5. Revised methodology: impact on performance scores

This chapter discusses the impact of the changes in the measurement framework on the relative performance scores. The following pages will show the impact of the changes to 13 indicators providing detailed results in individual tables per indicator.

Revised: Population aged 25-34 having completed tertiary education

This indicator has been revised by broadening the age group captured in the numerator from the age group 30-34 years old to the group 25-34 years old. Using data for 2015 – the EIS 2017 uses data for 2016, but the most recent data in the EIS 2016 were for 2015 – for both indicators, the impact of broadening the age group is positive for 16 Member States and three other European countries, most notably for Greece. The impact is negative for 12 Member States and five other European countries. For Israel and Ukraine, there are no data for the age group 25-34 years old, and the negative impact reflects the effect of having had above-average performance on this indicator in the EIS 2016.

Table 6: Population aged 25-34 having completed tertiary education

	Tertiary education **aged 25-34** (2015)	Summary Innovation Index including Tertiary education **aged 25-34**	Performance relative to EU	Tertiary education **aged 30-34** (2015)	Summary Innovation Index including Tertiary education **aged 30-34**	Performance relative to EU	Difference in performance
EU	37.9	0.503	100.0	38.5	0.504	100.0	
BE	43.1	0.595	118.4	43.1	0.595	118.2	0.2
BG	31.8	0.233	46.4	32.0	0.234	46.6	-0.1
CZ	31.0	0.415	82.5	29.5	0.414	82.3	0.2
DK	44.5	0.674	134.0	46.7	0.675	134.1	-0.1
DE	29.6	0.608	120.9	31.8	0.611	121.4	-0.4
EE	40.6	0.393	78.2	45.2	0.397	78.9	-0.7
IE	52.0	0.571	113.6	52.3	0.570	113.3	0.4
EL	40.1	0.336	66.8	39.4	0.312	61.9	4.9
ES	41.0	0.386	76.8	41.1	0.386	76.7	0.1
FR	44.7	0.539	107.3	44.9	0.539	107.1	0.2
HR	30.8	0.267	53.2	31.7	0.269	53.5	-0.3
IT	25.2	0.370	73.7	24.9	0.372	73.8	-0.1
CY	54.7	0.369	73.3	54.2	0.367	72.8	0.5
LV	39.9	0.284	56.6	41.0	0.286	56.7	-0.1
LT	54.8	0.391	77.9	56.4	0.391	77.7	0.1
LU	50.3	0.598	118.9	50.5	0.597	118.6	0.4
HU	32.1	0.334	66.5	34.9	0.338	67.0	-0.6
MT	31.0	0.374	74.5	27.0	0.372	73.8	0.7
NL	45.1	0.639	127.1	46.4	0.640	127.1	0.1
AT	38.6	0.598	119.0	39.1	0.599	118.9	0.1
PL	43.2	0.270	53.7	43.2	0.270	53.6	0.1
PT	33.1	0.408	81.1	31.3	0.407	80.8	0.3
RO	25.5	0.167	33.3	25.5	0.169	33.6	-0.3
SI	40.8	0.480	95.5	42.6	0.482	95.7	-0.2
SK	31.3	0.343	68.3	27.9	0.341	67.7	0.5
FI	40.2	0.645	128.4	45.3	0.650	129.1	-0.7
SE	46.5	0.708	140.8	50.0	0.710	141.1	-0.3
UK	47.0	0.618	122.9	47.7	0.618	122.7	0.2
TR	26.5	0.291	57.9	23.0	0.289	57.5	0.5
IS	40.2	0.596	118.6	47.5	0.605	120.1	-1.4
NO	49.0	0.571	113.6	51.6	0.573	113.7	-0.1
CH	48.6	0.810	161.1	51.5	0.812	161.2	-0.1
MK	30.6	0.216	43.0	28.5	0.215	42.8	0.3
UA	n/a	0.142	28.3	50.3 (2013)	0.178	35.3	-7.0
IL	n/a	0.548	109.0	51.0 (2012)	0.563	111.8	-2.8
RS	n/a	0.297	59.1	24.7 (2012)	0.297	59.0	0.1

Revised: Foreign doctorate students

This indicator has been revised for the EU Member States by not only including students from outside the EU but also students from other Member States. Using data for 2014 for both indicators – a compromise between the EIS 2017 using data for foreign doctorate students in 2015 and the EIS 2016 using data for non-EU doctorate students for 2013 –, the impact of also including students from other Member States is positive for 21 Member States and four other European countries, in particular for Austria, Denmark, Luxembourg, and the Netherlands. The impact is negative for seven Member States and four other European countries, in particular for Norway.

Table 7: Foreign doctorate students

	Foreign doctorate students (2014)	Summary Innovation Index including **Foreign** doctorate students	Performance relative to EU	**Non-EU** doctorate students (2014)	Summary Innovation Index including **Non-EU** doctorate students	Performance relative to EU	Difference in performance
EU	25.01	0.503	100.0	17.77	0.505	100.0	
BE	36.64	0.593	117.9	25.01	0.595	117.8	0.1
BG	4.16	0.234	46.5	2.97	0.234	46.4	0.1
CZ	13.93	0.416	82.7	5.21	0.412	81.6	1.1
DK	30.48	0.673	134.0	15.16	0.669	132.6	1.4
DE	7.41	0.608	120.9	7.41	0.611	121.0	-0.1
EE	8.08	0.393	78.3	4.43	0.393	77.8	0.5
IE	23.10	0.571	113.6	14.30	0.571	113.1	0.5
EL	n/a	0.337	67.0	n/a	0.337	66.7	0.3
ES	11.92	0.389	77.3	11.95	0.391	77.5	-0.1
FR	40.05	0.539	107.2	33.64	0.548	108.5	-1.4
HR	3.16	0.270	53.7	3.01	0.271	53.7	0.0
IT	13.16	0.371	73.8	10.08	0.373	73.8	-0.1
CY	11.36	0.366	72.8	2.15	0.363	72.0	0.8
LV	8.82	0.285	56.7	2.91	0.284	56.2	0.5
LT	3.91	0.391	77.8	1.41	0.390	77.4	0.4
LU	86.99	0.599	119.2	23.53 (2013)	0.587	116.3	2.8
HU	7.17	0.333	66.3	3.84	0.332	65.7	0.6
MT	12.39	0.374	74.4	2.11	0.371	73.6	0.9
NL	36.62	0.639	127.2	19.30	0.635	125.8	1.4
AT	27.03	0.598	119.0	9.32	0.591	117.1	1.9
PL	1.92	0.270	53.8	1.32	0.270	53.6	0.2
PT	21.23	0.406	80.7	13.86	0.410	81.2	-0.5
RO	2.29	0.167	33.2	2.11	0.168	33.2	0.0
SI	8.51	0.482	96.0	5.67	0.483	95.7	0.3
SK	9.13	0.345	68.7	1.85	0.341	67.6	1.1
FI	19.88	0.645	128.4	12.84	0.646	128.0	0.3
SE	32.69	0.709	141.0	24.47	0.713	141.2	-0.2
UK	42.95	0.618	122.9	30.03	0.621	123.1	-0.2
TR	4.30	0.295	58.7	5.01	0.297	58.9	-0.2
IS	33.40	0.588	117.0	19.79 (2013)	0.599	118.6	-1.6
NO	20.53	0.571	113.6	33.51 (2012)	0.593	117.6	-4.0
CH	54.25	0.812	161.5	52.15 (2013)	0.812	160.9	0.6
MK	4.44	0.222	44.2	3.94 (2012)	0.220	43.5	0.7
UA	n/a	0.142	28.3	n/a	0.142	28.2	0.1
IL	n/a	0.548	109.0	n/a	0.548	108.5	0.5
RS	6.51	0.316	62.8	7.14 (2011)	0.320	63.5	-0.7

New: Population aged 25-64 participating in lifelong learning

This is a new indicator included in the EIS 2017. Compared to the average performance on the other 26 indicators, including 'Population aged 25-64 participating in lifelong learning' has a positive impact on relative-to-EU performance for 14 Member States and six other European countries, in particular for Denmark, Finland, Sweden, Iceland, and Switzerland. Including 'Population aged 25-64 participating in lifelong learning' has a negative impact for 14 Member States and two other European countries, in particular for Belgium, Ireland, and Slovakia.

Table 8: Population aged 25-64 participating in lifelong learning

	Lifelong learning (2016)	Summary Innovation Index **including** Lifelong learning	Performance relative to EU	Summary Innovation Index **excluding** Lifelong learning	Performance relative to EU	Difference in performance
EU	10.8	0.503	100.0	0.509	100.0	
BE	7.0	0.597	118.6	0.611	120.2	-1.6
BG	2.2	0.234	46.6	0.242	47.6	-1.0
CZ	8.8	0.416	82.7	0.421	82.8	-0.1
DK	27.7	0.675	134.1	0.663	130.3	3.8
DE	8.5	0.609	121.0	0.622	122.3	-1.2
EE	15.7	0.393	78.2	0.388	76.3	2.0
IE	6.4	0.571	113.5	0.586	115.1	-1.6
EL	4.0	0.337	66.9	0.346	68.1	-1.2
ES	9.4	0.386	76.8	0.389	76.5	0.2
FR	18.8	0.539	107.1	0.534	105.1	2.1
HR	3.0	0.270	53.6	0.277	54.6	-0.9
IT	8.3	0.371	73.7	0.375	73.7	0.0
CY	6.9	0.369	73.3	0.375	73.7	-0.4
LV	7.3	0.287	57.0	0.289	56.8	0.2
LT	6.0	0.391	77.8	0.400	78.6	-0.8
LU	16.8	0.599	119.1	0.600	117.9	1.2
HU	6.3	0.332	66.1	0.338	66.4	-0.3
MT	7.5	0.378	75.1	0.383	75.4	-0.3
NL	18.8	0.639	127.1	0.638	125.5	1.5
AT	14.9	0.599	119.1	0.603	118.5	0.6
PL	3.7	0.270	53.7	0.277	54.5	-0.7
PT	9.6	0.409	81.4	0.413	81.2	0.2
RO	1.2	0.167	33.1	0.173	34.0	-0.9
SI	11.6	0.482	95.9	0.486	95.6	0.3
SK	2.9	0.345	68.6	0.356	70.0	-1.4
FI	26.4	0.646	128.4	0.635	124.8	3.6
SE	29.6	0.708	140.9	0.697	137.1	3.8
UK	14.4	0.618	122.9	0.623	122.5	0.4
TR	5.8	0.294	58.5	0.300	59.0	-0.4
IS	24.7	0.600	119.3	0.587	115.5	3.9
NO	19.6	0.571	113.6	0.567	111.5	2.1
CH	32.9	0.812	161.5	0.804	158.2	3.3
MK	2.9	0.218	43.4	0.225	44.2	-0.8
UA	n/a	0.142	28.3	0.142	28.0	0.3
IL	n/a	0.548	108.9	0.548	107.7	1.2
RS	n/a	0.317	62.9	0.317	62.2	0.7

New: Broadband penetration

This is a new indicator included in the EIS 2017. Compared to the average performance on the other 26 indicators, including 'Broadband penetration' has a positive impact on relative-to-EU performance for 19 Member States and three other European countries, in particular for Latvia, Lithuania, Portugal, Spain, and Turkey. Including 'Broadband penetration' has a negative impact for nine Member States and five other European countries, in particular for Cyprus, Greece, the United Kingdom, and Serbia.

Table 9: Broadband penetration

	Broadband penetration (2016)	Summary Innovation Index **including** Broadband penetration	Performance relative to EU	Summary Innovation Index **excluding** Broadband penetration	Performance relative to EU	Difference in performance
EU	13.0	0.503	100.0	0.502	100.0	
BE	23.0	0.597	118.6	0.584	116.3	2.3
BG	10.0	0.234	46.6	0.228	45.4	1.2
CZ	10.0	0.416	82.7	0.417	83.0	-0.2
DK	31.0	0.675	134.1	0.662	131.8	2.3
DE	12.0	0.609	121.0	0.614	122.2	-1.1
EE	12.0	0.393	78.2	0.390	77.7	0.6
IE	15.0	0.571	113.5	0.570	113.5	0.1
EL	2.0	0.337	66.9	0.347	69.1	-2.2
ES	20.0	0.386	76.8	0.370	73.7	3.1
FR	9.0	0.539	107.1	0.546	108.6	-1.5
HR	6.0	0.270	53.6	0.271	53.9	-0.3
IT	5.0	0.371	73.7	0.377	75.1	-1.4
CY	3.0	0.369	73.3	0.378	75.3	-2.0
LV	22.0	0.287	57.0	0.264	52.5	4.5
LT	21.0	0.391	77.8	0.374	74.5	3.3
LU	21.0	0.599	119.1	0.590	117.4	1.7
HU	12.0	0.332	66.1	0.327	65.0	1.0
MT	12.0	0.378	75.1	0.374	74.4	0.7
NL	22.0	0.639	127.1	0.630	125.4	1.7
AT	12.0	0.599	119.1	0.604	120.2	-1.1
PL	11.0	0.270	53.7	0.264	52.5	1.2
PT	25.0	0.409	81.4	0.387	77.0	4.4
RO	13.0	0.167	33.1	0.153	30.5	2.7
SI	16.0	0.482	95.9	0.476	94.8	1.1
SK	9.0	0.345	68.6	0.345	68.6	0.0
FI	26.0	0.646	128.4	0.632	125.9	2.5
SE	32.0	0.708	140.9	0.697	138.8	2.0
UK	10.0	0.618	122.9	0.626	124.7	-1.8
TR	16.0	0.294	58.5	0.279	55.6	2.9
IS	n/a	0.600	119.3	0.600	119.5	-0.2
NO	19.0	0.571	113.6	0.564	112.3	1.3
CH	n/a	0.812	161.5	0.812	161.7	-0.2
MK	11.0	0.218	43.4	0.209	41.6	1.8
UA	n/a	0.142	28.3	0.142	28.4	0.0
IL	n/a	0.548	108.9	0.548	109.0	-0.1
RS	n/a	0.317	62.9	0.325	64.8	-1.9

New: Opportunity-driven entrepreneurship

This is a new indicator included in the EIS 2017. Compared to the average performance on the other 26 indicators, including 'Opportunity-driven entrepreneurship' has a positive impact on relative-to-EU performance for 13 Member States and four other European countries, in particular for Denmark, Iceland, and Norway. Including 'Opportunity-driven entrepreneurship' has a negative impact for 15 Member States and four other European countries, in particular for Belgium and Ireland.

Table 10: Opportunity-driven entrepreneurship

	Opportunity-driven entrepreneurship (2016) (three-year average)	Summary Innovation Index **including** Opportunity-driven entrepreneur-ship	Performance relative to EU	Summary Innovation Index **excluding** Opportunity-driven entrepreneur-ship	Performance relative to EU	Difference in performance
EU	3.14	0.503	100.0	0.504	100.0	
BE	1.51	0.597	118.6	0.609	120.9	-2.2
BG	0.99	0.234	46.6	0.236	46.9	-0.3
CZ	2.65 (2015)	0.416	82.7	0.416	82.5	0.2
DK	11.09	0.675	134.1	0.662	131.3	2.8
DE	2.92	0.609	121.0	0.615	122.0	-0.9
EE	3.40	0.393	78.2	0.389	77.2	1.0
IE	2.28	0.571	113.5	0.579	114.8	-1.3
EL	1.17	0.337	66.9	0.342	67.8	-0.9
ES	1.61	0.386	76.8	0.390	77.4	-0.6
FR	5.31	0.539	107.1	0.533	105.8	1.3
HR	0.98	0.270	53.6	0.273	54.2	-0.6
IT	2.72	0.371	73.7	0.369	73.1	0.6
CY	2.00	0.369	73.3	0.370	73.4	-0.1
LV	3.51	0.287	57.0	0.278	55.1	1.8
LT	2.23	0.391	77.8	0.392	77.8	0.0
LU	5.15	0.599	119.1	0.596	118.3	0.8
HU	1.96	0.332	66.1	0.332	65.9	0.1
MT	n/a	0.378	75.1	0.378	74.9	0.2
NL	3.89	0.639	127.1	0.642	127.5	-0.4
AT	3.21	0.599	119.1	0.604	119.8	-0.6
PL	1.64	0.270	53.7	0.270	53.5	0.3
PT	1.99	0.409	81.4	0.412	81.8	-0.4
RO	1.47	0.167	33.1	0.163	32.4	0.8
SI	2.12	0.482	95.9	0.487	96.7	-0.8
SK	1.41	0.345	68.6	0.349	69.2	-0.6
FI	5.98	0.646	128.4	0.643	127.5	0.9
SE	8.20	0.708	140.9	0.702	139.2	1.7
UK	3.34	0.618	122.9	0.623	123.5	-0.7
TR	1.90	0.294	58.5	0.293	58.2	0.4
IS	10.00 (2012)	0.600	119.3	0.581	115.3	4.0
NO	12.88	0.571	113.6	0.555	110.0	3.5
CH	5.23	0.812	161.5	0.818	162.3	-0.8
MK	0.61	0.218	43.4	0.223	44.3	-0.9
UA	n/a	0.142	28.3	0.142	28.3	0.1
IL	2.95	0.548	108.9	0.553	109.6	-0.7
RS	1.11 (2011)	0.317	62.9	0.322	63.8	-0.9

New: Enterprises that provide training to develop/upgrade ICT skills of their personnel

This is a new indicator included in the EIS 2017. Compared to the average performance on the other 26 indicators, including 'Enterprises that provide training to develop/upgrade ICT skills of their personnel' has a positive impact on relative-to-EU performance for 16 Member States and three other European countries, in particular for Austria, Belgium, Croatia, Finland, and Serbia. Including 'Enterprises that provide training to develop/upgrade ICT skills' of their personnel has a negative impact for 12 Member States and five other European countries, in particular for Bulgaria, Estonia, Italy, Lithuania, the Netherlands and Romania.

Table 11: Enterprises that provide training to develop/upgrade ICT skills of their personnel

	Training ICT skills (2016)	Summary Innovation Index **including** Training ICT skills	Performance relative to EU	Summary Innovation Index **excluding** Training ICT skills	Performance relative to EU	Difference in performance
EU	22.0	0.503	100.0	0.502	100.0	
BE	34.0	0.597	118.6	0.585	116.5	2.1
BG	8.0	0.234	46.6	0.240	47.8	-1.2
CZ	22.0	0.416	82.7	0.412	82.0	0.7
DK	28.0	0.675	134.1	0.673	134.1	0.0
DE	29.0	0.609	121.0	0.603	120.2	0.8
EE	13.0	0.393	78.2	0.399	79.5	-1.3
IE	30.0	0.571	113.5	0.563	112.2	1.4
EL	15.0	0.337	66.9	0.338	67.3	-0.3
ES	23.0	0.386	76.8	0.379	75.6	1.2
FR	20.0	0.539	107.1	0.541	107.9	-0.8
HR	22.0	0.270	53.6	0.260	51.7	1.9
IT	12.0	0.371	73.7	0.377	75.0	-1.3
CY	22.0	0.369	73.3	0.363	72.2	1.1
LV	12.0	0.287	57.0	0.289	57.6	-0.6
LT	10.0	0.391	77.8	0.401	79.8	-2.0
LU	29.0	0.599	119.1	0.593	118.2	0.9
HU	16.0	0.332	66.1	0.332	66.1	-0.1
MT	23.0	0.378	75.1	0.370	73.8	1.3
NL	22.0	0.639	127.1	0.643	128.2	-1.1
AT	37.0	0.599	119.1	0.584	116.3	2.8
PL	12.0	0.270	53.7	0.272	54.2	-0.5
PT	23.0	0.409	81.4	0.404	80.4	1.0
RO	5.0	0.167	33.1	0.173	34.5	-1.3
SI	27.0	0.482	95.9	0.475	94.6	1.4
SK	20.0	0.345	68.6	0.340	67.8	0.8
FI	34.0	0.646	128.4	0.636	126.7	1.7
SE	25.0	0.708	140.9	0.712	141.8	-0.9
UK	28.0	0.618	122.9	0.614	122.4	0.5
TR	n/a	0.294	58.5	0.294	58.7	-0.1
IS	25.0 (2014)	0.600	119.3	0.599	119.4	0.0
NO	42.0	0.571	113.6	0.555	110.5	3.0
CH	n/a	0.812	161.5	0.812	161.8	-0.4
MK	17.0	0.218	43.4	0.212	42.2	1.2
UA	n/a	0.142	28.3	0.142	28.4	-0.1
IL	n/a	0.548	108.9	0.548	109.1	-0.2
RS	22.0 (2014)	0.317	62.9	0.307	61.1	1.8

New: Private co-funding of public R&D

This is a new indicator included in the EIS 2017. Compared to the average performance on the other 26 indicators, including 'Private co-funding of public R&D' has a positive impact on relative-to-EU performance for nine Member States and two other European countries, in particular for Germany, Lithuania, and Turkey. Including 'Private co-funding of public R&D' has a negative impact for 19 Member States and six other European countries, in particular for Denmark, Ireland, and Luxembourg.

Table 12: Private co-funding of public R&D

	Private co-funding public R&D (2015)	Summary Innovation Index **including** Private co-funding public R&D	Performance relative to EU	Summary Innovation Index **excluding** Private co-funding public R&D	Performance relative to EU	Difference in performance
EU	0.052 (2014)	0.503	100.0	0.501	100.0	
BE	0.073 (2013)	0.597	118.6	0.590	117.7	0.9
BG	0.015 (2014)	0.234	46.6	0.238	47.4	-0.9
CZ	0.030	0.416	82.7	0.420	83.8	-1.1
DK	0.020	0.675	134.1	0.693	138.3	-4.1
DE	0.120 (2014)	0.609	121.0	0.594	118.5	2.5
EE	0.036	0.393	78.2	0.394	78.7	-0.4
IE	0.008 (2014)	0.571	113.5	0.590	117.8	-4.3
EL	0.040	0.337	66.9	0.333	66.5	0.5
ES	0.034 (2014)	0.386	76.8	0.387	77.3	-0.5
FR	0.036 (2014)	0.539	107.1	0.545	108.8	-1.7
HR	0.034	0.270	53.6	0.266	53.2	0.4
IT	0.013 (2014)	0.371	73.7	0.380	75.9	-2.2
CY	0.001 (2014)	0.369	73.3	0.383	76.5	-3.1
LV	0.052	0.287	57.0	0.277	55.2	1.8
LT	0.091	0.391	77.8	0.369	73.6	4.2
LU	0.010 (2013)	0.599	119.1	0.618	123.4	-4.4
HU	0.030	0.332	66.1	0.333	66.5	-0.4
MT	0.002	0.378	75.1	0.392	78.3	-3.2
NL	0.084	0.639	127.1	0.629	125.5	1.5
AT	0.042 (2013)	0.599	119.1	0.605	120.8	-1.6
PL	0.018	0.270	53.7	0.273	54.6	-0.9
PT	0.011 (2014)	0.409	81.4	0.421	84.1	-2.7
RO	0.033	0.167	33.1	0.160	31.9	1.2
SI	0.050	0.482	95.9	0.481	96.0	0.0
SK	0.037	0.345	68.6	0.344	68.6	0.0
FI	0.047	0.646	128.4	0.652	130.1	-1.7
SE	0.038 (2013)	0.708	140.9	0.720	143.8	-2.9
UK	0.032	0.618	122.9	0.629	125.5	-2.6
TR	0.063 (2014)	0.294	58.5	0.278	55.5	3.1
IS	0.030	0.600	119.3	0.614	122.6	-3.2
NO	0.045 (2013)	0.571	113.6	0.575	114.8	-1.2
CH	0.091 (2012)	0.812	161.5	0.805	160.7	0.8
MK	n/a	0.218	43.4	0.218	43.5	-0.2
UA	n/a	0.142	28.3	0.142	28.4	-0.1
IL	0.051 (2013)	0.548	108.9	0.548	109.4	-0.6
RS	0.018 (2014)	0.317	62.9	0.323	64.4	-1.5

Revised: Trademark applications

This indicator has been revised by not only including trademark applications at the European Union Intellectual Property Office (EUIPO) but also those at the World Intellectual Property Organization (WIPO). The impact of also including trademark applications at WIPO is positive for 16 Member States and all other European countries, in particular for Greece, Iceland, Israel, and Switzerland. The impact is negative for 12 Member States, in particular for Poland, Romania, and Spain.

Table 13: Trademark applications

	Trademark applications to **both EUIPO and WIPO** (2016) (two-year average)	Summary Innovation Index including Trademark applications to **both EUIPO and WIPO**	Performance relative to EU	Trademark applications to **only EUIPO** (2016) (two-year average)	Summary Innovation Index including Trademark applications to **only EUIPO**	Performance relative to EU	Difference in performance
EU	7.60	0.503	100.0	5.81	0.507	100.0	
BE	7.75	0.597	118.6	5.83	0.600	118.4	0.2
BG	9.49	0.234	46.6	6.81	0.237	46.8	-0.2
CZ	5.14	0.416	82.7	3.93	0.421	82.9	-0.2
DK	11.60	0.675	134.1	8.73	0.678	133.7	0.4
DE	9.34	0.609	121.0	6.91	0.612	120.8	0.3
EE	14.97	0.393	78.2	12.69	0.398	78.6	-0.3
IE	5.40	0.571	113.5	4.65	0.577	113.7	-0.2
EL	4.58	0.337	66.9	4.09	0.326	64.4	2.5
ES	9.13	0.386	76.8	8.04	0.392	77.3	-0.5
FR	5.85	0.539	107.1	3.84	0.542	106.8	0.3
HR	4.22	0.270	53.6	2.07	0.271	53.4	0.2
IT	8.14	0.371	73.7	6.45	0.375	74.0	-0.3
CY	41.39	0.369	73.3	32.62	0.369	72.7	0.6
LV	7.01	0.287	57.0	4.29	0.289	56.9	0.1
LT	6.24	0.391	77.8	4.59	0.395	78.0	-0.1
LU	38.51	0.599	119.1	28.42	0.599	118.1	1.0
HU	3.91	0.332	66.1	2.87	0.337	66.4	-0.3
MT	40.00	0.378	75.1	36.25	0.378	74.5	0.6
NL	9.58	0.639	127.1	7.35	0.643	126.8	0.3
AT	12.91	0.599	119.1	9.48	0.602	118.8	0.4
PL	5.25	0.270	53.7	4.69	0.276	54.5	-0.7
PT	7.21	0.409	81.4	6.21	0.415	81.8	-0.4
RO	2.37	0.167	33.1	2.08	0.173	34.0	-0.9
SI	10.21	0.482	95.9	6.72	0.484	95.5	0.4
SK	4.30	0.345	68.6	3.32	0.350	69.0	-0.4
FI	11.44	0.646	128.4	8.65	0.649	128.1	0.3
SE	10.75	0.708	140.9	8.72	0.713	140.6	0.2
UK	7.32	0.618	122.9	5.91	0.623	122.8	0.1
TR	1.11	0.294	58.5	0.30	0.297	58.5	0.1
IS	9.32	0.600	119.3	4.60	0.599	118.2	1.2
NO	2.93	0.571	113.6	1.74	0.574	113.3	0.3
CH	17.76	0.812	161.5	9.82	0.810	159.8	1.7
MK	2.29	0.218	43.4	0.70	0.219	43.1	0.2
UA	1.75	0.142	28.3	0.36	0.142	28.1	0.2
IL	18.72	0.548	108.9	2.55	0.525	103.5	5.4
RS	3.90	0.317	62.9	0.88	0.314	61.8	1.1

Revised: Employment in fast-growing enterprises of innovative sectors

This indicator has been revised and now measures the share of employment in high-growth enterprises in the top 50% most innovative sectors within total employment. Using data for 2013 – the EIS 2017 uses data for 2014, but the most recent data in the EIS 2016 was for 2013 – for both the revised and previous definition, the impact of the revised definition is positive for 14 Member States and six other European countries, in particular for Latvia and Lithuania. The impact is negative for 14 Member States and two other European countries, in particular for Cyprus, France, and Switzerland.

Table 14: Employment in fast-growing enterprises of innovative sectors

	High-growth enterprises (2013) - EIS 2017 definition	Summary Innovation Index using **revised definition** for high-growth enterprises	Performance relative to EU	High-growth enterprises (2013) - EIS 2016 definition	Summary Innovation Index using **previous definition** for high-growth enterprises	Performance relative to EU	Difference in performance
EU	5.31	0.505	100.0	18.80	0.506	100.0	
BE	2.62	0.596	118.0	16.93	0.604	119.4	-1.5
BG	6.26	0.234	46.3	16.52	0.221	43.8	2.5
CZ	7.30	0.427	84.4	18.41	0.415	82.1	2.3
DK	4.47	0.675	133.5	20.13	0.684	135.2	-1.7
DE	5.72	0.614	121.5	21.02	0.620	122.6	-1.1
EE	4.00	0.398	78.7	15.97	0.395	78.2	0.6
IE	6.56 (2012)	0.565	111.8	23.45	0.571	113.0	-1.2
EL	n/a	0.336	66.4	15.21	0.336	66.4	0.0
ES	3.10	0.384	76.0	16.19	0.387	76.5	-0.5
FR	4.34	0.540	106.8	21.66	0.555	109.7	-2.9
HR	3.02	0.268	53.1	11.56	0.256	50.6	2.5
IT	3.16	0.373	73.8	16.35	0.376	74.3	-0.6
CY	0.57	0.368	72.7	23.55	0.405	80.0	-7.3
LV	4.41	0.282	55.8	12.34	0.265	52.4	3.4
LT	4.45 (2012)	0.394	77.9	11.61	0.374	73.9	4.0
LU	3.91	0.596	117.9	17.65	0.599	118.6	-0.7
HU	7.72	0.335	66.2	19.24	0.324	64.1	2.2
MT	5.76	0.366	72.4	19.99	0.368	72.8	-0.4
NL	5.70	0.640	126.6	16.90	0.632	125.0	1.7
AT	3.08	0.599	118.5	19.45	0.613	121.2	-2.7
PL	5.23	0.268	53.1	18.23	0.267	52.8	0.3
PT	3.40	0.406	80.3	14.85	0.402	79.6	0.7
RO	2.19	0.164	32.5	16.87	0.174	34.4	-1.9
SI	2.70	0.479	94.8	15.95	0.483	95.5	-0.8
SK	9.29	0.345	68.2	20.91	0.340	67.2	1.0
FI	3.41	0.648	128.3	18.39	0.657	129.9	-1.7
SE	7.23	0.714	141.3	19.61	0.707	139.9	1.4
UK	7.38	0.620	122.7	18.65	0.609	120.5	2.2
TR	n/a	0.291	57.6	13.98	0.288	57.1	0.6
IS	n/a	0.596	118.0	16.66	0.591	116.9	1.1
NO	5.05	0.572	113.2	17.51	0.569	112.6	0.6
CH	3.25 (2014)	0.810	160.2	19.64	0.825	163.1	-2.9
MK	n/a	0.216	42.8	n/a	0.216	42.8	0.0
UA	n/a	0.142	28.2	n/a	0.142	28.2	0.0
IL	n/a	0.548	108.4	19.26	0.555	109.8	-1.5
RS	n/a	0.317	62.6	n/a	0.317	62.6	0.0

Revised: Knowledge-intensive services exports

The indicator measuring Knowledge-intensive services (KIS) exports has been revised and also includes 'License and patent revenues from abroad', which was a separate indicator in the EIS 2016. The impact of combining both indicators into one is measured by comparing the EIS 2017 results with the results if the definition of the EIS 2016 had been used, using data for 2013 as these data were used in the EIS 2016. The impact of including 'License and patent revenues from abroad' in 'Knowledge-intensive services exports' is positive for 10 Member States and five other European countries, in particular for Cyprus, Greece, and Norway. The impact is negative for 18 Member States and three other European countries, in particular for Finland, Hungary, Malta, the Netherlands, and Switzerland.

Table 15: Knowledge-intensive services exports

	Knowledge-intensive services exports (2013) - EIS 2017 definition	Summary Innovation Index using **EIS 2017 definition** for KIS exports	Performance relative to EU	Knowledge-intensive services exports (2013) - EIS 2016 definition	Summary Innovation Index using **EIS 2016 definition** for KIS exports	Performance relative to EU	Difference in performance
EU	67.4	0.502	100.0	63.1	0.494	100.0	
BE	67.7	0.597	118.8	64.6	0.590	119.4	-0.5
BG	31.9	0.230	45.7	27.1	0.228	46.1	-0.4
CZ	42.7	0.417	83.0	41.1	0.415	84.0	-1.1
DK	78.2	0.676	134.7	75.1	0.666	134.7	0.0
DE	74.9	0.609	121.3	69.6	0.594	120.2	1.1
EE	44.0	0.393	78.2	43.9	0.385	77.8	0.5
IE	93.2	0.571	113.7	88.5	0.571	115.5	-1.8
EL	52.0	0.341	67.9	51.8	0.327	66.2	1.6
ES	43.3	0.386	76.9	42.2	0.381	77.0	-0.1
FR	63.8	0.537	107.0	58.6	0.531	107.3	-0.3
HR	17.9	0.269	53.6	17.8	0.274	55.4	-1.8
IT	51.4	0.371	73.9	48.5	0.364	73.6	0.4
CY	69.0	0.369	73.5	69.0	0.345	69.8	3.7
LV	50.1	0.285	56.8	49.8	0.272	55.0	1.8
LT	18.8	0.390	77.8	18.3	0.395	80.0	-2.2
LU	89.3	0.598	119.1	88.4	0.592	119.8	-0.7
HU	47.8	0.333	66.2	38.3	0.347	70.1	-3.8
MT	28.8	0.378	75.2	25.9	0.410	83.0	-7.8
NL	75.3	0.638	127.1	65.3	0.645	130.4	-3.3
AT	44.8	0.599	119.4	43.2	0.598	120.9	-1.5
PL	37.4	0.269	53.6	36.7	0.265	53.6	0.0
PT	43.3	0.409	81.5	43.2	0.401	81.0	0.4
RO	45.3	0.167	33.3	44.7	0.159	32.2	1.0
SI	33.7	0.482	96.0	32.9	0.483	97.7	-1.7
SK	35.4	0.345	68.8	35.3	0.341	68.9	-0.1
FI	62.4	0.646	128.7	50.6	0.651	131.7	-3.0
SE	75.4	0.709	141.2	65.0	0.709	143.5	-2.3
UK	83.0	0.618	123.1	77.9	0.604	122.1	1.0
TR	27.7	0.294	58.5	27.7	0.301	60.8	-2.3
IS	65.2	0.599	119.4	62.9	0.592	119.8	-0.4
NO	74.6	0.570	113.6	75.8	0.548	110.8	2.7
CH	65.7	0.812	161.8	50.4	0.826	167.0	-5.3
MK	38.6	0.219	43.6	n/a	0.215	43.5	0.1
UA	48.8	0.141	28.1	38.9	0.129	26.0	2.0
IL	70.5	0.547	109.1	68.3	0.532	107.7	1.4
RS	44.4	0.317	63.1	n/a	0.310	62.7	0.5

Deleted: Youth with at least upper secondary education

This indicator was included in the EIS 2016 but has been removed from the EIS 2017. The impact of deleting this indicator is measured by comparing the EIS 2017 results with those of using data for the 27 indicators included in the EIS 2017 plus 'Youth with at least upper secondary education'. The impact of excluding 'Youth with at least upper secondary education ' is positive for 11 Member States and five other European countries, in particular for Denmark, Greece, Luxembourg, and Iceland. The impact is negative for 17 Member States and three other European countries, in particular for Croatia, Cyprus, Poland, Slovakia, and Former Yugoslav Republic of Macedonia.

Table 16: Youth with at least upper secondary education

	SII 2017	Performance relative to EU	Youth with at least upper secondary education (2015)	SII 2017 **plus Youth with at least upper secondary education**	Performance relative to EU	Difference in performance
EU	0.503	100.0	82.6	0.507	100.0	
BE	0.597	118.6	84.3	0.599	118.2	0.5
BG	0.234	46.6	85.2	0.250	49.4	-2.8
CZ	0.416	82.7	90.7	0.431	85.1	-2.4
DK	0.675	134.1	73.4	0.663	130.8	3.3
DE	0.609	121.0	77.4	0.604	119.1	1.9
EE	0.393	78.2	82.6	0.401	79.2	-0.9
IE	0.571	113.5	92.8	0.583	115.0	-1.5
EL	0.337	66.9	89.5	0.324	63.9	3.1
ES	0.386	76.8	67.9	0.379	74.8	2.0
FR	0.539	107.1	87.3	0.546	107.7	-0.6
HR	0.270	53.6	95.5	0.295	58.2	-4.6
IT	0.371	73.7	80.0	0.377	74.3	-0.6
CY	0.369	73.3	94.2	0.389	76.8	-3.5
LV	0.287	57.0	86.2	0.302	59.6	-2.6
LT	0.391	77.8	91.3	0.408	80.5	-2.7
LU	0.599	119.1	68.6	0.585	115.4	3.6
HU	0.332	66.1	84.3	0.344	67.9	-1.8
MT	0.378	75.1	77.4	0.381	75.1	0.0
NL	0.639	127.1	79.8	0.635	125.3	1.7
AT	0.599	119.1	88.7	0.606	119.5	-0.4
PL	0.270	53.7	90.9	0.291	57.4	-3.7
PT	0.409	81.4	75.9	0.410	80.9	0.5
RO	0.167	33.1	79.9	0.180	35.5	-2.3
SI	0.482	95.9	90.1	0.495	97.6	-1.7
SK	0.345	68.6	91.2	0.363	71.7	-3.1
FI	0.646	128.4	86.6	0.649	128.0	0.4
SE	0.708	140.9	87.7	0.710	140.1	0.7
UK	0.618	122.9	85.4	0.621	122.5	0.4
TR	0.294	58.5	53.7	0.283	55.8	2.8
IS	0.600	119.3	61.4	0.574	113.4	6.0
NO	0.571	113.6	79.1	0.569	112.3	1.3
CH	0.812	161.5	86.0	0.808	159.5	2.0
MK	0.218	43.4	87.1	0.238	47.0	-3.6
UA	0.142	28.3	61.7 (2013)	0.136	26.8	1.5
IL	0.548	108.9	91.4 (2014)	0.563	111.0	-2.1
RS	0.317	62.9	83.4 (2012)	0.330	65.1	-2.1

Deleted: PCT patent applications in societal challenges

This indicator was included in the EIS 2016 but has been removed from the EIS 2017. The impact of deleting this indicator is measured by comparing the EIS 2017 results with those of using data for the 27 indicators included in the EIS 2017 plus 'PCT patent applications in societal challenges'. The impact of excluding 'PCT patent applications in societal challenges' is positive for 26 Member States and six other European countries, in particular for Cyprus, Greece, Lithuania, and the Former Yugoslav Republic of Macedonia. The impact is negative for two Member States (Denmark and the Netherlands) and two other European countries (Iceland and Israel).

Table 17: PCT patent applications in societal challenges

	SII 2017	Performance relative to EU	PCT patent applications in societal challenges (2012)	SII 2017 **plus PCT patent applications in societal challenges**	Performance relative to EU	Difference in performance
EU	0.503	100.0	1.01	0.506	100.0	
BE	0.597	118.6	0.77	0.594	117.3	1.3
BG	0.234	46.6	0.08	0.232	45.8	0.8
CZ	0.416	82.7	0.24	0.412	81.3	1.4
DK	0.675	134.1	2.05	0.681	134.5	-0.4
DE	0.609	121.0	1.47	0.613	121.0	0.0
EE	0.393	78.2	0.20	0.389	76.8	1.4
IE	0.571	113.5	0.65	0.568	112.1	1.4
EL	0.337	66.9	0.13	0.324	63.9	3.0
ES	0.386	76.8	0.47	0.387	76.4	0.4
FR	0.539	107.1	0.92	0.540	106.6	0.5
HR	0.270	53.6	0.20	0.270	53.2	0.4
IT	0.371	73.7	0.47	0.372	73.5	0.2
CY	0.369	73.3	0.06	0.361	71.3	2.0
LV	0.287	57.0	0.28	0.288	56.8	0.2
LT	0.391	77.8	0.12	0.385	76.0	1.8
LU	0.599	119.1	0.68	0.595	117.5	1.6
HU	0.332	66.1	0.29	0.332	65.5	0.5
MT	0.378	75.1	0.28	0.375	74.1	0.9
NL	0.639	127.1	1.68	0.644	127.1	-0.1
AT	0.599	119.1	1.07	0.600	118.5	0.7
PL	0.270	53.7	0.17	0.269	53.2	0.6
PT	0.409	81.4	0.23	0.405	80.0	1.4
RO	0.167	33.1	0.04	0.165	32.6	0.6
SI	0.482	95.9	0.59	0.482	95.1	0.8
SK	0.345	68.6	0.09	0.339	67.0	1.6
FI	0.646	128.4	1.61	0.650	128.3	0.1
SE	0.708	140.9	1.88	0.712	140.7	0.2
UK	0.618	122.9	0.80	0.615	121.4	1.4
TR	0.294	58.5	0.19	0.293	57.9	0.6
IS	0.600	119.3	1.76	0.609	120.2	-0.8
NO	0.571	113.6	0.56	0.567	111.9	1.7
CH	0.812	161.5	1.94	0.813	160.5	0.9
MK	0.218	43.4	0.00	0.210	41.4	1.9
UA	0.142	28.3	n/a	0.142	28.1	0.2
IL	0.548	108.9	4.53	0.569	112.4	-3.5
RS	0.317	62.9	n/a	0.317	62.5	0.4

Deleted: License and patent revenues from abroad

This indicator was included in the EIS 2016 but has been removed as a separate indicator from the EIS 2017. In the EIS 2017, it is incorporated into the indicator measuring 'Knowledge-intensive services exports'. The impact of deleting this indicator is measured by comparing the EIS 2017 results with those of using data for the 27 indicators included in the EIS 2017 plus 'License and patent revenues from abroad'. The impact of excluding 'License and patent revenues from abroad' is positive for 20 Member States and five other European countries, in particular for Austria, Cyprus, Estonia, and Norway. The impact is negative for eight Member States and three other European countries, in particular for Hungary, Ireland, Malta, and the Netherlands.

Table 18: License and patent revenues from abroad

	SII 2017	Performance relative to EU	License and patent revenues from abroad (2014)	SII 2017 **plus License and patent revenues from abroad**	Performance relative to EU	Difference in performance
EU	0.503	100.0	0.543	0.502	100.0	
BE	0.597	118.6	0.628	0.593	118.2	0.4
BG	0.234	46.6	0.058	0.231	46.1	0.5
CZ	0.416	82.7	0.236	0.412	82.2	0.6
DK	0.675	134.1	0.713	0.670	133.5	0.7
DE	0.609	121.0	0.357	0.601	119.7	1.3
EE	0.393	78.2	0.044	0.384	76.6	1.7
IE	0.571	113.5	2.526	0.586	116.8	-3.3
EL	0.337	66.9	0.045	0.329	65.5	1.4
ES	0.386	76.8	0.104	0.380	75.7	1.1
FR	0.539	107.1	0.497	0.536	106.7	0.4
HR	0.270	53.6	0.042 (2013)	0.265	52.7	0.9
IT	0.371	73.7	0.158	0.367	73.0	0.7
CY	0.369	73.3	0.006	0.357	71.2	2.1
LV	0.287	57.0	0.017	0.279	55.7	1.3
LT	0.391	77.8	0.054	0.383	76.3	1.5
LU	0.599	119.1	1.663	0.607	121.0	-1.9
HU	0.332	66.1	1.506	0.348	69.4	-3.4
MT	0.378	75.1	3.096	0.401	79.8	-4.8
NL	0.639	127.1	2.240	0.650	129.6	-2.6
AT	0.599	119.1	0.247	0.589	117.4	1.7
PL	0.270	53.7	0.063	0.266	53.1	0.7
PT	0.409	81.4	0.036	0.399	79.6	1.9
RO	0.167	33.1	0.070	0.167	33.2	-0.1
SI	0.482	95.9	0.145	0.474	94.4	1.5
SK	0.345	68.6	0.029	0.337	67.1	1.5
FI	0.646	128.4	1.378 (2013)	0.650	129.5	-1.0
SE	0.708	140.9	1.593	0.712	141.9	-1.0
UK	0.618	122.9	0.602	0.614	122.3	0.6
TR	0.294	58.5	n/a	0.294	58.7	-0.1
IS	0.600	119.3	0.590 (2013)	0.596	118.7	0.7
NO	0.571	113.6	0.075 (2013)	0.557	111.0	2.6
CH	0.812	161.5	3.076 (2012)	0.819	163.3	-1.8
MK	0.218	43.4	0.085 (2013)	0.217	43.2	0.1
UA	0.142	28.3	0.090	0.145	28.9	-0.6
IL	0.548	108.9	0.419	0.541	107.9	1.0
RS	0.317	62.9	0.098 (2013)	0.312	62.1	0.8

6. Indicators measuring structural differences

In addition to changes to the main measurement framework, a need has emerged for additional contextual analyses explaining the impact of structural differences on observed scores. The analysis of structural differences by country is performed in the country profiles. The following sections discuss the importance of these structural aspects for a better understanding of differences between countries in the performance on particular indicators.

6.1 Structure of the economy

Of particular importance are differences in economic structures, with differences in the share of industry in GDP and so-called high-tech activities in manufacturing and services being important factors that explain why countries can performance better or worse on indicators like business R&D expenditures, PCT patents, and innovative enterprises.

Medium-high and high-tech industries have higher technological intensities than other industries. These industries, on average, will have higher R&D expenditures, patent applications, and shares of innovating enterprises. Countries with above-average shares of these industries are expected to perform better on several EIS indicators. For example, for the EU28 on average, 85% of R&D expenditures in manufacturing are accounted for by medium-high and high-technology manufacturing industries[13]. Also, the share of enterprises that introduced a product and/or process innovation is higher (53%) in medium-high and high-technology manufacturing industries compared to all core industries (31%) covered in the Community Innovation Survey[14].

[13] Based on NACE Rev. 2, manufacturing industries can be classified as follows :

- High-technology (HT): Basic pharmaceutical products and pharmaceutical preparations (NACE 21); Computer, electronic and optical products (NACE 26); Air and spacecraft and related machinery (NACE 30.3*).
- Medium-high-technology (MHT): Chemicals and chemical products (NACE 20); Weapons and ammunition (NACE 25.4**); Electrical equipment (NACE 27); Machinery and equipment not elsewhere classified (NACE 28); Motor vehicles, trailers and semi-trailers (NACE 29); Other transport equipment (NACE 30) excluding Building of ships and boats (NACE 30.1) and excluding Air and spacecraft and related machinery (NACE 30.3); Medical and dental instruments and supplies (NACE 32.5***).
- Medium-low-technology (MLT): Reproduction of recorded media (NACE 18.2***); Coke and refined petroleum products (NACE 19); Rubber and plastic products (NACE 22); Other non-metallic mineral products (NACE 23); Basic metals (NACE 24); Fabricated metal products, except machinery and equipment (NACE 25) excluding Manufacture of weapons and ammunition (NACE 25.4); Building of ships and boats (NACE 30.1*); Repair and installation of machinery and equipment (NACE 33).
- Low-technology (LT): Food products (NACE 10); Beverages (NACE 11); Tobacco products (NACE 12); Textiles (NACE 13); Wearing apparel (NACE 14); Leather and related products (NACE 15); Wood and products of wood and cork, except furniture; articles of straw and plaiting materials (NACE 16); Paper and paper products (NACE 17); Printing and reproduction of recorded media (NACE 18) excluding Reproduction of recorded media (NACE 18.2); Furniture (NACE 31); Other manufacturing (NACE 32) excluding Medical and dental instruments and supplies (NACE 32.5).

If data are only available at the NACE Rev. 2 2-digit level, industries identified with an * are classified as medium-high-technology, industries identified with an ** are classified as medium-low-technology, and industries identified with an *** are classified as low-technology (Source: http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:High-tech_classification_of_manufacturing_industries)

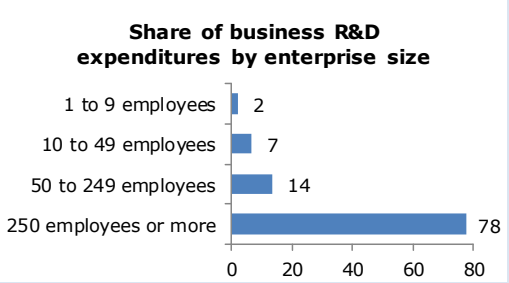
[14] In accordance with Commission Regulation No 995/2012, the following industries and services are included in the Core target population to be covered in the CIS:

- Core Industry (excluding construction): Mining and quarrying (NACE B), Manufacturing (NACE C) (NACE 10-12: Manufacture of food products, beverages and tobacco; NACE 13-15: Manufacture of textiles, wearing apparel, leather and related products; NACE 16-18: Manufacture of wood, paper, printing and reproduction; NACE 20: Manufacture of chemicals and chemical products; NACE 21: Manufacture of basic pharmaceutical products and pharmaceutical preparations; NACE 19-22 Manufacture of petroleum, chemical, pharmaceutical, rubber and plastic products; NACE 23: Manufacture of other non-metallic mineral products; NACE 24: Manufacture of basic metals; NACE

6.2 Business indicators

Enterprise characteristics are important for explaining differences in R&D spending and innovation activities. Large enterprises, defined as enterprises with 250 or more employees, account for almost four-fifths of EU business R&D expenditures (Figure 2), whereas SMEs, defined as enterprises with 10 to 249 employees, account for only one-fifth. The presence of large R&D-spending enterprises is captured by the *EU Industrial R&D Investment Scoreboard*, which provides economic and financial data and analysis of the top corporate R&D investors from the EU and abroad[15].

Figure 2: Enterprise size and business R&D expenditures



Average 2011-2014 data for EU28

Foreign ownership, including ownership from both other EU Member States and non-Member States, is important as about 40% of business R&D expenditures in EU Member States are by foreign affiliates, which is significantly higher compared to major international competitors[16]. The indicator measuring the **share of foreign-controlled enterprises** serves as a proxy for differences in foreign ownership rates between countries.

Opportunity-driven entrepreneurship is one of the new indicators in the EIS and provides a measure of opportunities for engaging in new business. The EIS indicator is complemented by a contextual indicator measuring the **share of new enterprise births in the economy**.

Institutional and legal differences between countries may make it more or less difficult to engage in business activities. The World Bank's Doing Business provides an index, **Ease of starting a business**, which measures the distance of each economy to the "frontier" economy providing the most lenient regulatory framework for doing business. Countries with more favourable regulatory environments will obtain scores closer to the maximum score of 100. This indicator complements the EIS indicators covering real new business activities or perceived possibilities for new business activities: *Employment of fast-growing firms in innovative sectors* and *Opportunity-driven entrepreneurship*.

25: Manufacture of fabricated metal products, except machinery and equipment; NACE 26: Manufacture of computer, electronic and optical products; NACE 25- NACE 30: Manufacture of fabricated metal products (except machinery and equipment), computer, electronic and optical products, electrical equipment, motor vehicles and other transport equipment; NACE 31-33: Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment, Electricity, gas, steam and air conditioning supply (NACE D), Water supply, sewerage, waste management and remediation activities (NACE E) (NACE 36: Water collection, treatment and supply; NACE 37-39: Sewerage, waste management, remediation activities).

- Core Services: Wholesale trade, except of motor vehicles and motorcycles (NACE 46), Transport and storage (NACE H) (NACE 49-51: Land transport and transport via pipelines, water transport and air transport; NACE 52-53: Warehousing and support activities for transportation and postal and courier activities); Information and communication (NACE J) (NACE 58: Publishing activities; NACE 61: Telecommunications; NACE 62: Computer programming, consultancy and related activities; NACE 63: Information service activities), Financial and insurance activities (NACE K) (NACE 64: Financial service activities, except insurance and pension funding; NACE 65: Insurance, reinsurance and pension funding, except compulsory social security; NACE 66: Activities auxiliary to financial services and insurance activities), Professional, scientific and technical activities (NACE M) (NACE 71-73: Architectural and engineering activities; technical testing and analysis; Scientific research and development; Advertising and market research).

[15] http://iri.jrc.ec.europa.eu/scoreboard.html

[16] Average shares for 2011-2015 are 40.8% for the EU (a weighted average of 15 Member States for which data are available), 29.4% for Australia, 35.6% for Canada, 16.1% for the United States, and 5.5% for Japan (own calculation using data from OECD Main Science and Technology Indicators).

Demand is an important driver of innovation. According to the Oslo Manual (2005)[17], demand factors shape innovation activity in two major ways: for the development of new products, as firms modify and differentiate products to increase sales and market share; and for the improvement of the production and supply processes in order to reduce costs and lower prices. A robust indicator measuring the demand for innovation is currently not available. The Executive Opinion Survey of the World Economic Forum includes an indicator that provides a measure of the preferences of individual consumers for innovative products. The **degree of Buyer sophistication** measures, on a scale from 1 (low) to 7 (high), whether buyers focus more on price or quality of products and services. Higher degrees of Buyer sophistication could explain higher shares of innovative sales as measured by the EIS indicator *Sales of new-to-market and new-to-firm product innovations*.

6.3 Socio-demographic indicators

Densely populated areas are more likely to be more innovative for several reasons. First, knowledge diffuses more easily when people and enterprises are located closer to each other. Second, in urbanised areas there tends to be a concentration of government and educational services. These provide better training opportunities and also employ above-average shares of highly educated people. Data on **the degree of urbanisation** distinguish between the share of households located in rural areas, towns and suburbs, and cities. For the EU28, higher shares of highly educated people and people involved in lifelong learning are found in more highly urbanised areas. At the regional level, differences in **population density** and in the degree of urbanisation are even more relevant. Regional data for 220 regions in Europe are available in the Regional Innovation Scoreboard 2017.

Structural data also include **population size** and **GDP per capita** in purchasing power standards[18], which is a measure for interpreting real income differences between countries. Other indicators include the **share of population aged 15-64** as a proxy for the share of the labour force, and two indicators measuring the **change between 2010 and 2015 in GDP and population**. In economies that grow faster, expanding markets may provide more favourable conditions for enterprises to sell their goods and services.

6.4 Indicator definitions

The indicators that are used in the country profiles in the European and international benchmarking in the EIS 2017 are shown in Table 19. Full definitions are presented after Table 19.

[17] The Oslo Manual is the foremost international source of guidelines for the collection and use of data on innovation activities in industry. OECD/Eurostat (2005), Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data, 3rd Edition, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789264013100-en

[18] The purchasing power standard, abbreviated as PPS, is an artificial currency unit. Theoretically, one PPS can buy the same amount of goods and services in each country. However, price differences across borders mean that different amounts of national currency units are needed for the same goods and services depending on the country. PPS are derived by dividing any economic aggregate of a country in national currency by its respective purchasing power parities. PPS is the technical term used by Eurostat for the common currency in which national accounts aggregates are expressed when adjusted for price level differences using PPPs. Thus, PPPs can be interpreted as the exchange rate of the PPS against the Euro.

Table 19: Structural indicators in the EIS 2017

European benchmark	International benchmark
Structure of the economy	
- Composition of employment, %-shares, average 2011-2015 - Agriculture & Mining (NACE A-B) - Manufacturing (NACE C) *Of which High and Medium high-tech (%)* - Utilities and Construction (NACE D-F) - Services (NACE G-N) *Of which Knowledge-intensive services (%)* - Public administration (NACE O-U)	- Composition of employment, %-shares, average 2011-2015 - Agriculture - Industry - Services - Share of manufacturing in total value added (%), 2015
Business indicators	
- Composition of turnover, %-shares, average 2011-2014 - Micro enterprises (0-9 employees) - SMEs (10-249 employees) - Large enterprises (250+ employees) - Share of foreign controlled enterprises (%), 2014 - Top R&D spending enterprises - Average number per 10 mln population, 2011-2015 - Average R&D spending (mln Euros), 2011-2015 - Enterprise births (10+ employees) (%), average 2012-2014 - Buyer sophistication (1, worst - 7, best), 2013-2014 - Ease of starting a business, Doing Business 2017 (report published in 2016)	- Top R&D spending firms per 10 mln population, 2011-2015 - Average R&D spending (mln Euros), 2011-2015 - Number of Unicorns, May 2017 - Buyer sophistication 1-7 (best), 2013-2014 - Ease of starting a business, Doing Business 2017 (report published in 2016)
Socio-demographic indicators	
- GDP per capita, PPS, average 2011-2013 - Change in GDP between 2010 and 2015 (%) - Population size (millions), average 2011-2015 - Change in population between 2010 and 2015 (%) - Population aged 15-64 (%), average 2011-2015 - Population density, average 2011-2015 - Degree of urbanisation (%), average 2011-2015	- GDP per capita, PPP (current international $), average 2011-2015 - Change in GDP between 2010 and 2015 (%) - Population size (millions), average 2011-2015 - Change in population between 2010 and 2015 (%) - Share of population aged 15-64 (%), average 2011-2015

Definitions European benchmarking

Composition of employment, %-shares, average 2011-2015	
	Agriculture & Mining (NACE Rev. 2 A-B)
Numerator	Employment in the respective industries
Denominator	Total employment
Calculated as	Average percentage for the years 2011 to 2015
Data source	Eurostat: Employment in technology and knowledge-intensive sectors at the national level, by type of occupation
	Manufacturing (NACE Rev. 2 C)
Numerator	Employment in the respective industry
Denominator	Total employment
Calculated as	Average percentage for the years 2011 to 2015
Data source	Eurostat: Employment in technology and knowledge-intensive sectors at the national level, by type of occupation
	Of which High and Medium high-tech (%)
Numerator	Aggregate of employment in the following industries: High-technology: • Basic pharmaceutical products and pharmaceutical preparations (NACE Rev. 2 21) • Computer, electronic and optical products (NACE Rev. 2 26) • Air and spacecraft and related machinery (NACE Rev. 2 30.3) Medium-high-technology: • Chemicals and chemical products (NACE Rev. 2 20) • Weapons and ammunition (NACE Rev. 2 25.4) • Electrical equipment (NACE Rev. 2 27) • Machinery and equipment not elsewhere classified (NACE Rev. 2 28) • Motor vehicles, trailers and semi-trailers (NACE Rev. 2 29) • Other transport equipment (NACE Rev. 2 30) excluding Building of ships and boats (NACE Rev. 2 30.1) and excluding Air and spacecraft and related machinery (NACE Rev. 2 30.3) • Medical and dental instruments and supplies (NACE Rev. 2 32.5)
Denominator	Employment in Manufacturing (NACE Rev. 2 C)
Calculated as	Average percentage for the years 2011 to 2015
Data source	Eurostat: Employment in technology and knowledge-intensive sectors at the national level, by type of occupation
	Utilities and Construction (NACE Rev. 2 D-F)
Numerator	Employment in the respective industries
Denominator	Total employment
Data source	Eurostat
	Services (NACE Rev. 2 G-N)
Numerator	Employment in the respective industries
Calculated as	Average percentage for the years 2011 to 2015
Denominator	Total employment

Data source	Eurostat: Employment in technology and knowledge-intensive sectors at the national level, by type of occupation
	Of which Knowledge-intensive services (%)
Numerator	Aggregate of employment in the following industries: • Water transport; Air transport (NACE Rev. 2 50-51) • Publishing activities; Motion picture, video and television programme production, sound recording and music publishing activities; Programming and broadcasting activities; Telecommunications; computer programming, consultancy and related activities; Information service activities (NACE Rev. 2 58-63) • Financial and insurance activities (NACE Rev. 2 64-66) • Legal and accounting activities; Activities of head offices, management consultancy activities; Architectural and engineering activities, technical testing and analysis; Scientific research and development; Advertising and market research; Other professional, scientific and technical activities; Veterinary activities (NACE Rev. 2 69-75) • Employment activities (NACE Rev. 2 78) • Security and investigation activities (NACE Rev. 2 80)
Denominator	Employment in Services (NACE Rev. 2 G-N)
Calculated as	Average percentage for the years 2011 to 2015
Data source	Eurostat: Employment in technology and knowledge-intensive sectors at the national level, by type of occupation
	Public administration (NACE Rev. 2 O-U)
Numerator	Employment in the respective industries
Denominator	Total employment
Calculated as	Average percentage for the years 2011 to 2015
Data source	Eurostat: Employment in technology and knowledge-intensive sectors at the national level, by type of occupation
Composition of turnover, %-shares, average 2011-2014	
	Micro enterprises (0-9 employees)
Numerator	Turnover in enterprises with 0 to 9 persons employed
Denominator	Turnover in Total business economy; repair of computers, personal and household goods; except financial and insurance activities
Calculated as	Average percentage for the years 2011 to 2014
Data source	Eurostat: Annual enterprise statistics by size class for special aggregates of activities
	SMEs (10-249 employees)
Numerator	Turnover in enterprises with 10 to 249 persons employed
Denominator	Turnover in Total business economy; repair of computers, personal and household goods; except financial and insurance activities
Calculated as	Average percentage for the years 2011 to 2014
Data source	Eurostat: Annual enterprise statistics by size class for special aggregates of activities

	Large enterprises (250+ employees)
Numerator	Turnover in enterprises with 250 persons employed or more
Denominator	Turnover in Total business economy; repair of computers, personal and household goods; except financial and insurance activities
Calculated as	Average percentage for the years 2011 to 2014
Data source	Eurostat: Annual enterprise statistics by size class for special aggregates of activities
Share of foreign controlled enterprises (%), average 2011-2014	
Numerator	Number of enterprises controlled by other than reporting country
Denominator	Number of enterprises controlled by all countries of the world
Calculated as	Average percentage for the years 2011 to 2014
Definition of foreign affiliate	"Foreign affiliate in the framework of inward FATS shall mean an enterprise resident in the compiling country over which an institutional unit not resident in the compiling country has control. Control shall mean the ability to determine the general policy of an enterprise by choosing appropriate directors, if necessary. Enterprise A is deemed to be controlled by an institutional unit B when B controls - directly or indirectly - more than half of the shareholders' voting power or more than half of the shares. Foreign control shall mean that the controlling institutional unit is resident in a different country from the one where the institutional unit over which it has control is resident." http://ec.europa.eu/eurostat/cache/metadata/en/fats_esms.htm
Data source	Eurostat: Foreign Affiliates Statistics (FATS)
Top R&D spending enterprises	
	Average number per 10 mln population, 2011-2015
Numerator	Number of enterprises in the top 2500 enterprises investing the largest sums in R&D in the world
Data source	European Commission (IPTS) - The EU Industrial R&D Investment Scoreboard
Calculated as	Average number for the years 2011 to 2015
Denominator	Population
Data source	Eurostat
	Average R&D spending (mln Euros), 2011-2015
Numerator	Aggregate R&D spending of the enterprises in the top 2500 enterprises investing the largest sums in R&D in the world
Calculated as	Average spending for the years 2011 to 2015
Data source	European Commission (IPTS) - The EU Industrial R&D Investment Scoreboard

Enterprise births (10+ employees) (%), average 2012-2014	
Numerator	Number of births of enterprises in year t
Size class	10 employees or more
Industries	Business economy except activities of holding companies
Denominator	Population of active enterprises in year t
Size class	10 employees or more
Industries	Business economy except activities of holding companies
Calculated as	Average percentage for the years 2012 to 2014
Data source	Eurostat: Business demography data
Buyer sophistication (1, worst - 7, best), 2013-2014	
Indicator	Average response to the following question: In your country, on what basis do buyers make purchasing decisions? [1 = based solely on the lowest price; 7 = based on sophisticated performance attributes]
Data source	World Economic Forum, Global Competitiveness Report
Ease of starting a business, Doing Business 2017	
Indicator	The "Starting a Business" indicator records all procedures, time, cost and paid-in minimum capital that are officially required for an entrepreneur to start up and formally operate an industrial or commercial business. These include obtaining all necessary licenses and permits and completing any required notifications, verifications or inscriptions for the company and employees with relevant authorities.
Data source	World Bank - Doing Business
GDP per capita, PPS, average 2011-2013	
Indicator	Nominal Gross Domestic Product per capita
Unit	Purchasing power standard (PPS) per inhabitant
Calculated as	Average value for the years 2011 to 2013
Data source	Eurostat: Annual national accounts data
Change in GDP between 2010 and 2015 (%)	
Indicator	Gross Domestic Product at market prices
Unit	Chain linked volumes, index 2010=100
Calculated as	Value in 2015 - 100
Data source	Eurostat: Annual national accounts data
Population size (millions), average 2011-2015	
Indicator	Population on 1 January
Calculated as	Average value for the years 2011 to 2015
Data source	Eurostat: Population data

Change in population between 2010 and 2015 (%)	
Data	Population on 1 January
Calculated as	100 * Value in 2015 / Value in 2010 - 100
Data source	Eurostat: Population data
Population aged 15-64 (%), average 2011-2015	
Data	Population from 15 to 64 years
Denominator	Population on 1 January
Calculated as	Average percentage for the years 2011 to 2015
Data source	Eurostat: Population data
Population density, average 2011-2015	
Numerator	Inhabitants per km2
Calculated as	Average value for the years 2011 to 2015
Data source	Eurostat
Degree of urbanisation (%), average 2011-2015	
Indicator	Share of households living in densely populated areas and intermediate density areas
Definition of urbanisation	"The degree of urbanisation (DEGURBA) creates a classification of all LAU2s (Local Administrative Units - Level 2/municipalities) into the following three categories: (1) Cities (densely populated areas) (Code 1) (2) Towns and suburbs (intermediate density areas) (Code 2) (3) Rural areas (thinly populated areas) (Code 3)" For more details: http://ec.europa.eu/eurostat/ramon/miscellaneous/index.cfm?TargetUrl=DSP_DEGURBA
Calculated as	Average percentage for the years 2011 to 2015
Data source	Eurostat: Labour Market statistics

Definitions International benchmarking

Composition of employment, %-shares, average 2011-2015	
	Agriculture
Indicator	Employment in agriculture (% of total employment). The agriculture sector consists of activities in agriculture, hunting, forestry and fishing, in accordance with division 1 (ISIC 2) or categories A-B (ISIC 3) or category A (ISIC 4).
Calculated as	Average percentage for the years 2011 to 2015
Data source	World Bank (World Development Indicators) Series name: SL.AGR.EMPL.ZS
	Industry
Indicator	Employment in industry (% of total employment). The industry sector consists of mining and quarrying, manufacturing, construction, and public utilities (electricity, gas, and water), in accordance with divisions 2-5 (ISIC 2) or categories C-F (ISIC 3) or categories B-F (ISIC 4).
Calculated as	Average percentage for the years 2011 to 2015
Data source	World Bank (World Development Indicators) Series name: SL.IND.EMPL.ZS
	Services
Indicator	Employment in services (% of total employment). The services sector consists of wholesale and retail trade and restaurant and hotels; transport, storage, and communications; financing, insurance, real estate, and business services; and community, social, and personal services, in accordance with divisions 6-9 (ISIC 2) or categories G-Q (ISIC 3) or categories G-U (ISIC 4).
Calculated as	Average percentage for the years 2011 to 2015
Data source	World Bank (World Development Indicators) Series name: SL.SRV.EMPL.ZS
Share of manufacturing in total value added (%), 2015	
Numerator	Value added in Manufacturing (in constant 2010 US$)
Denominator	Gross Domestic Product (in constant 2010 US$)
Data source	UNIDO - MVA - Manufacturing Value Added Database
Top R&D spending enterprises	
	Average R&D spending (mln Euros), 2011-2015
Numerator	Aggregate R&D spending of the enterprises in the top 2500 enterprises investing the largest sums in R&D in the world
Calculated as	Average spending for the years 2011 to 2015
Data source	European Commission (IPTS) - The EU Industrial R&D Investment Scoreboard
Number of Unicorns	
Indicator	Number of Unicorns
Description	A unicorn is a start-up company valued at over $1 billion
Data source	CB INSIGHTS https://www.cbinsights.com/research-unicorn-companies (data extracted May 2017)

Buyer sophistication (1, worst - 7, best), 2013-2014	
Indicator	Average response to the following question: In your country, on what basis do buyers make purchasing decisions? [1 = based solely on the lowest price; 7 = based on sophisticated performance attributes]
Data source	World Economic Forum, Global Competitiveness Report
Ease of starting a business, Doing Business 2017	
Indicator	The Starting a Business indicator records all procedures, time, cost and paid-in minimum capital that are officially required for an entrepreneur to start up and formally operate an industrial or commercial business. These include obtaining all necessary licenses and permits and completing any required notifications, verifications or inscriptions for the company and employees with relevant authorities.
Data source	World Bank - Doing Business
GDP per capita, PPP (current international $), average 2011-2015	
Indicator	GDP per capita, PPP (current international $)
Calculated as	Average for the years 2011 to 2015
Data source	World Bank (World Development Indicators) Series name: NY.GDP.PCAP.PP.CD
Change in GDP between 2010 and 2015 (%)	
Data	GDP (constant 2010 US$)
Calculated as	100 * Value in 2015 / Value in 2010 - 100
Data source	World Bank (World Development Indicators) Series name: NY.GDP.MKTP.KD
Population size (millions), average 2011-2015	
Data	Population, total
Calculated as	Average for the years 2011 to 2015
Data source	World Bank (World Development Indicators) Series name: SP.POP.TOTL
Change in population between 2010 and 2015 (%)	
Data	Population, total
Calculated as	100 * Value in 2015 / Value in 2010 - 100
Data source	World Bank (World Development Indicators) Series name: SP.POP.TOTL
Share of population aged 15-64 (%), average 2011-2015	
Indicator	Population aged 15-64 (% of total)
Calculated as	Average percentage for the years 2011 to 2015
Data source	World Bank (World Development Indicators) Series name: SP.POP.1564.TO.ZS

7. Sensitivity and robustness analysis of the Summary Innovation Index of the revised EIS

Sections 7.1 and 7.2 have been written by Dániel Vértesy and Giacomo Damioli

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This section describes the outcomes of the sensitivity and robustness analyses we performed in order to test the statistical soundness of the calculations and assumptions made to arrive at the Summary Innovation Index (SII) scores and country rankings. One of the main purposes of the analyses is to provide greater transparency about the statistical reasons for country performance in terms of the SII. Another important purpose is to shed light on the complex relationship between the various indicators monitored in the European Innovation Scoreboard (EIS) framework. This is instrumental to support an ongoing conceptual and statistical debate to further refine the measurement of innovation (see i.e. Freeman and Soete, 2009)[19].

We first carried out sensitivity analyses to better understand the contribution of each indicator to the overall Summary Innovation Index and the composite scores for each of the ten dimensions. We next conducted a similar, hypothetical test at the level of the four groups of indicators to shed further light on the EIS framework. We subsequently carried out a joint and simultaneous analysis of the impact of key modelling choices on the 2017 aggregate SII scores, in order to obtain error estimates and confidence intervals for the country rankings. The main findings of the tests show that while the SII scores are rather robust to modelling assumptions, the scores do not provide for a balanced summary of its 27 components. In order to fully utilise the wealth of information contained in the 27 indicators of the EIS, it is important to dedicate due attention to the dimension-level composite scores as well as to a few stand-alone indicators.

7.1 Statistical coherence of the SII and the dimension composite scores

The 27 indicators of the revised EIS framework were grouped on a conceptual basis to ten dimensions (i.e., human resources, attractive research systems, etc.), consisting of two to three indicators each. Each dimension is part of one of the four groups of indicators (framework conditions, investments, innovation activities and impacts). The main report presents composite scores for the SII, which is the arithmetic average of the 27 indicators, as well as for the 10 dimensions. We note that no composite scores were computed for the four groups, and that the dimension scores were not used in the aggregation process to obtain the SII. We therefore performed multivariate analyses to better understand the contribution of each indicator to the overall SII scores as well as to the ten dimension scores within the EIS framework.

7.1.1 Measuring the contribution of each indicator to the SII

The left part of Table 20 ("Indicators vs. SII scores" column) presents correlations and r^2 statistics between the overall SII (defined as the unweighted average of 27 individual indicators) and each indicator. Correlations and r^2 signal the contribution of an indicator to the overall composite score. The "Interpretation" column in the table offers a rough interpretation of the observed statistics.

[19] Freeman, C. and Soete, L. (2009) "Developing science, technology and innovation indicators: What we can learn from the past". *Research Policy* 38(4): 583-589.

Table 20 Sensitivity of the Summary Innovation Index (left) and Dimension composite index scores (right) to changes in the underlying indicators

	Indicators vs. SII scores			Indicators vs. Dimension scores		
		Sensitivity			Sensitivity	
	Corr. r	Indices (r^2)	Interpretation	Corr. r	Indices (r^2)	Interpretation
FRAMEWORK CONDITIONS						
Human resources				Dimension 1.1		
1.1.1 New doctorate graduates	0.691	0.477	driver	0.786	0.618	
1.1.2 Population completed tertiary education	0.561	0.315	weak driver	0.670	0.449	
1.1.3 Lifelong learning	0.844	0.713	Main driver	0.880	0.774	
Attractive research systems				Dimension 1.2		
1.2.1 International scientific co-publications	0.889	0.791	Main driver	0.931	0.867	
1.2.2 Scientific publications among top 10% most cited	0.898	0.806	Main driver	0.942	0.887	
1.2.3 Foreign doctorate students	0.831	0.691	driver	0.925	0.855	
Innovation-friendly environment				Dimension 1.3		
1.3.1 Broadband penetration	0.508	0.258	weak driver	0.901	0.812	
1.3.2 Opportunity-driven entrepreneurship	0.732	0.535	driver	0.870	0.757	
INVESTMENTS						
Finance and support				Dimension 2.1		
2.1.1 R&D expenditure in the public sector	0.731	0.534	driver	0.876	0.767	
2.1.2 Venture capital investments	0.507	0.257	weak driver	0.769	0.591	
Firm investments				Dimension 2.2		
2.2.1 R&D expenditure in the business sector	0.809	0.655	driver	0.833	0.694	
2.2.2 Non-R&D innovation expenditure	-0.065	0.004	silent	0.482	0.232	weak driver
2.2.3 Enterprises providing ICT training	0.777	0.603	driver	0.755	0.570	
INNOVATION ACTIVITIES						
Innovators				Dimension 3.1		
3.1.1 SMEs with product or process innovations	0.740	0.548	driver	0.959	0.920	
3.1.2 SMEs with marketing or organisational innovations	0.768	0.590	driver	0.923	0.851	
3.1.3 SMEs innovating in-house	0.763	0.582	driver	0.942	0.887	
Linkages				Dimension 3.2		
3.2.1 Innovative SMEs collaborating with others	0.696	0.484	driver	0.825	0.681	
3.2.2 Public-private co-publications	0.871	0.758	Main driver	0.842	0.709	
3.2.3 Private co-funding of public R&D expenditures	0.355	0.126	silent	0.682	0.465	
Intellectual assets				Dimension 3.3		
3.3.1 PCT patent applications	0.879	0.773	Main driver	0.708	0.501	
3.3.2 Trademark applications	0.464	0.216	weak driver	0.863	0.744	
3.3.3 Design applications	0.374	0.140	silent	0.857	0.734	
IMPACTS						
Employment impacts				Dimension 4.1		
4.1.1 Employment in knowledge-intensive activities	0.757	0.573	driver	0.822	0.676	
4.1.2 Employment fast-growing firms innovative sectors	-0.009	0.000	silent	0.783	0.613	
Economic effects				Dimension 4.2		
4.2.1 Medium & high tech product exports	0.185	0.034	silent	0.728	0.530	
4.2.2 Knowledge-intensive services exports	0.700	0.490	driver	0.606	0.367	weak driver
4.2.3 Sales of new-to-market and new-to-firm innovations	0.347	0.121	silent	0.791	0.625	
SII (arithmetic average of 27)	1.000					

Source: JRC calculations

We observe that the SII scores are most strongly influenced by five component indicators: '1.1.3 Population participating in lifelong learning', '1.2.1 International scientific co-publications', '1.2.2 Scientific publications among top 10% most cited', '3.2.2 Public-private co-publications', and '3.3.1 PCT patent applications'. At the same time, six indicators are not reflected at all in the composite scores (referred to as "silent" ones). These are indicators '2.2.2 Non-R&D innovation expenditure', '3.2.3 Private co-funding of public R&D expenditures', '3.3.3 Design applications', '4.1.2 Employment fast-growing firms innovative sectors', '4.2.1 Medium & high tech product exports', and '4.2.3 Sales of new-to-market and new-to-firm innovations'. Consequently, if the SII is defined as the unweighted arithmetic average of the 27 indicators, it does not provide for a balanced summary of its components. Unless adjustments are introduced, the aggregation entails a significant loss of the information contained in the individual indicators.

These findings are also confirmed in a principal component analysis (PCA) carried out on the entire set of indicators. PCA results reveal the presence of five latent dimensions, where the first one captures only about 45% of variance in data.

7.1.2 Measuring the contribution of each indicator to the respective dimension composite

The right part of Table 20 ("Indicators vs. Dimension Scores" column) presents similar statistics as discussed above, but here correlation and r2 statistics refer to their respective dimension, a more restricted aggregation of indicators. Here we see a rather different picture: most of the dimensions composite scores are strongly and positively correlated with the underlying indicators, implying that these underlying indicators can effectively influence performance in the dimension composites. We see two exceptions: indicator '2.2.2 Non-R&D innovation expenditure' has a weak influence on the 2.2 *Firm investments* dimension, and indicator '4.2.2 Knowledge-intensive services exports' has limited impact on the 4.2 *Economic effects* dimension.

We conducted PCA at the dimension level in order to understand the number of relevant underlying dimensions, and the contribution of the selected set of indicators to the first principal component. A desirable outcome is to find a single latent dimension underlying each component, with a balanced contribution of each indicator. PCA confirmed for eight out of the 10 dimensions the presence of a single latent dimension (one component with an eigenvalue greater than 1.0) that captures between 61% (dimensions 1.1 *Human resources* and 3.2 *Linkages*) to 89% (dimension 3.1 *Innovators*) of the total variance in the respective set of indicators. Indicators in the other two dimensions (2.2 *Firm investments* and 4.2 *Economic effects*) were associated with two, rather than one single latent dimension, calling for caution when aggregating indicators in this dimension. Both factor loadings obtained in the PCA and the sensitivity indices reported in the table show some "imbalance" in some of the dimensions, where some indicators have a stronger impact on composite scores than others. This is the case notably for dimensions 3.2 *Linkages* or 3.3 *Intellectual assets*, where indicators '3.2.3 Private co-funding of public R&D expenditures' and '3.3.1 PCT patent applications' have weaker impact on composite scores, respectively. This may be rebalanced by applying weights as scaling coefficients (see Paruolo et al, 2013 or Becker et al, 2017)[20].

In sum, the analyses of the statistical properties of composite scores at the dimension and overall SII levels showed that in general, dimension composite indices are better able to summarise the information contained in the respective set of indicators. Users of the EIS should therefore dedicate attention in the Main Report to sections that discuss country performance at the dimension level (with the caveats mentioned for dimensions 2.2 *Firm investments* and 4.2 *Economic effects*). The SII is strongest in capturing what may be referred to as science and R&D-based innovation efforts and performance, which may well be justified by EU policy priorities. Should one look for a more balanced representation of all indicators, it may be advisable for future refinements of the SII to make use of a hierarchical structure in which indicators are first aggregated in dimension composites and subsequently, into group or overall averages (such a hierarchical method is applied for instance in the Global Innovation Index). An alternative, which may be justified by strong and positive

[20] Becker, W., Saisana, M., Paruolo, P., Vandecasteele, I. (2017) "Weights and importance in composite indicators: Closing the gap", *Ecological Indicators* 80: 12–22.

Paruolo, P., M. Saisana, and A. Saltelli. (2013). "Ratings and Rankings: Voodoo or Science?" *Journal of the Royal Statistical Society* A 176 (3): 609–34.

correlations observed between the various dimensions, is to first introduce composites indices for the four groups (and eventually aggregate them to overall averages). In the next section, we look at the statistical properties of such hypothetical group (or pillar) level composite scores with respect to their underlying indicators.

7.1.3 Introducing Pillar-level composite indices

Given the findings on the overall SII and the dimension composites, we further investigated the possibility to improve the representation of single indicators by computing scores for separate groups, or pillars. As a preliminary test, we base the definition of each pillar on the four groups considered in the conceptual framework (Framework conditions, Investments, Innovation activities and Impacts) – without taking into consideration the dimensions.

We ran principal component analyses (PCA) on every pillar to understand a) the number of relevant underlying dimensions, and b) the contribution of the selected set of indicators to the first principal component. A desirable outcome is to find a single latent dimension underlying each component, with a balanced contribution of each indicator.

Table 21 summarises the key results and findings of this pillar-by-pillar analysis. In particular:

- Pillar 1 reflects one underlying dimension and individual indicators are relatively balanced;
- Pillars 2 and 3 reflect two underlying dimensions, so adjustments are needed to increase transparency;
- Pillar 4 reflects multiple underlying dimensions, highlighting the diversity of innovation impacts. A simple average of the five components results in a balanced composite, however, at the cost of losing information.

The pillar-level statistical analysis of the indicator framework shows that aggregating EIS indicators into multiple composite indices helps increase transparency and policy traction. However, since all but the first group or pillar (Framework conditions) was associated with more than one underlying dimension, there is added value in more fine-grained composite scores. One should pay particular attention to the presence of "stand alone" indicators that do not correlate with the majority of EIS indicators.

Table 21 Pillar by pillar PCA results and implications

Indicators	Principal component analysis results	Implication
Framework conditions pillar (1):	One latent dimension identified; captures about 62% of variance	Indicators can be aggregated without adjustments (strongest drivers are indicators 1.1.3, 1.2.1 and 1.2.2)
Investments pillar (2):	Two clear latent dimensions identified: • the first captures 48% of variance in data; • the second captures an additional 21% of variance in data (strongly associated with 2.2.2 Non-R&D innovation expenditures)	Country performance in 2.2.2 Non-R&D innovation expenditure is not reflected in pillar scores. Two possible ways to increase transparency could be: • Make adjustments by assigning *effectively equal* weights to each indicator within pillar (i.e., increase weight of indicator 2.2.2 and reduce weights of the other indicators accordingly). Given the lower stability over time of indicator 2.2.2, country ranks are likely to be more volatile over time. Or, • Do not include indicator 2.2.2 in the aggregation (= assign a nominal weight of 0, i.e. keep it as a contextual indicator): in such a case, all indicators are well represented in the pillar. (PCA results in this case show 1 latent dimensions capturing about 62% of variance.)
Innovation Activities Pillar (3):	Two clear latent dimensions identified; • the first captures 52% of variance; [minor issue: 3.2.3 is weakly, but still captured by this component] • the second captures 21% of variance in data [capturing trademark (*3.3.2*) and design (*3.3.3*) applications indicators]	Country performance in *Trademark and Design applications 3.3.2, 3.3.3* are not reflected in pillar scores. A possible way to increase transparency is to introduce a separate pillar for 3.3.2 and 3.3.3; To make it more coherent, these indicators could be combined with var331 (PCT patent applications), [slight rebalancing may be advisable to fully reflect the contribution of PCT patents]
Impacts Pillar (4):	Multiple latent dimensions identified; • the first captures 42% of variance; but correlates positively and in a balanced way with all five indicators; • subsequent components also capture relatively high shares of variance (28%, 15%, etc.), reflecting the weak correlations of indicators within pillar	At the cost of losing a relatively high degree of information contained in individual indicators, a simple average of the five indicators provides a pillar score that correlates with its components in a balanced way. The only way to *fully reflect* the diversity of information contained in the five indicators is to report them separately (without aggregation).

Source: JRC calculations

7.2 Robustness and uncertainty analysis

As described in Section 4.2, the computation of the SII scores and country ranks involved a number of modelling choices (i.e., establishing a framework and selecting individual indicators, deciding how to treat missing data and outliers, selecting the normalisation method, weights, and aggregation method). Each of these choices was selected from among a set of alternatives, amidst a certain degree of uncertainty. In our uncertainty analysis, we aim to assess the impact of modelling assumptions in a joint and simultaneous approach. This allows us to obtain error estimates and confidence intervals for the 2017 SII country rankings.

Missing data: Where possible, the developers of the SII used the nearest available year to impute missing data. In a few cases where no applicable data was available,

for the sake of transparency and replicability, the developers chose not to estimate missing data. This rather commonly applied 'no imputation' method in fact replaces missing values with the average of the other available figures in the aggregation, adding a potential over- or underestimation. To test the impact of the 'no imputation' choice, in the uncertainty analysis, we estimated missing data using the Expectation Maximization (EM) algorithm.[21]

Outlier treatment: The developers of the SII chose to replace outliers for each indicator that were higher (or lower) than the mean plus (or minus) two standard deviations. While this choice following the 'Chauvenet criterion' is often used, in a few cases, it may result in a still very highly skewed distribution and intervention at the lower tail. To test the impact of this choice, we opted for an alternative, also frequently used method (in positively skewed data), which is winsorizing the higher outliers based on skewness and kurtosis thresholds (i.e., treating outliers if absolute kurtosis and skewness is greater than 3.5 and 2, respectively).

Normalisation: In order to transform each of the 27 indicators to a common scale ranging between 0 and 1, the SII developers applied the most commonly used min-max method. Two alternative methods of normalization often used by composite indicator developers include the 'z-score' or standardisation method (for each indicator, subtracting the mean and dividing by standard deviation, resulting in a 0-centered scale [which could be shifted by a constant in order to avoid 0's]) or the division of each value by the maximum (resulting in a scale of [0;1]). As there is little conceptual difference between these three methods, we opted for testing each of them in our uncertainty analysis.

Aggregation: The SII scores were calculated as the unweighted arithmetic average of the 27 re-scaled indicators. The main property of the arithmetic average is that it is fully compensatory, implying that a country can fully compensate or substitute weak performance in one indicator with strength in another. Should decision makers aim to put more emphasis on addressing bottlenecks than rewarding top outcomes, it is advisable to apply a partially compensatory method, such as the geometric average. This method rewards countries with more balanced profiles and motivates them to improve in the dimensions in which they perform poorly. To address uncertainty in the aggregation formula, we considered in our tests the geometric average as an alternative.

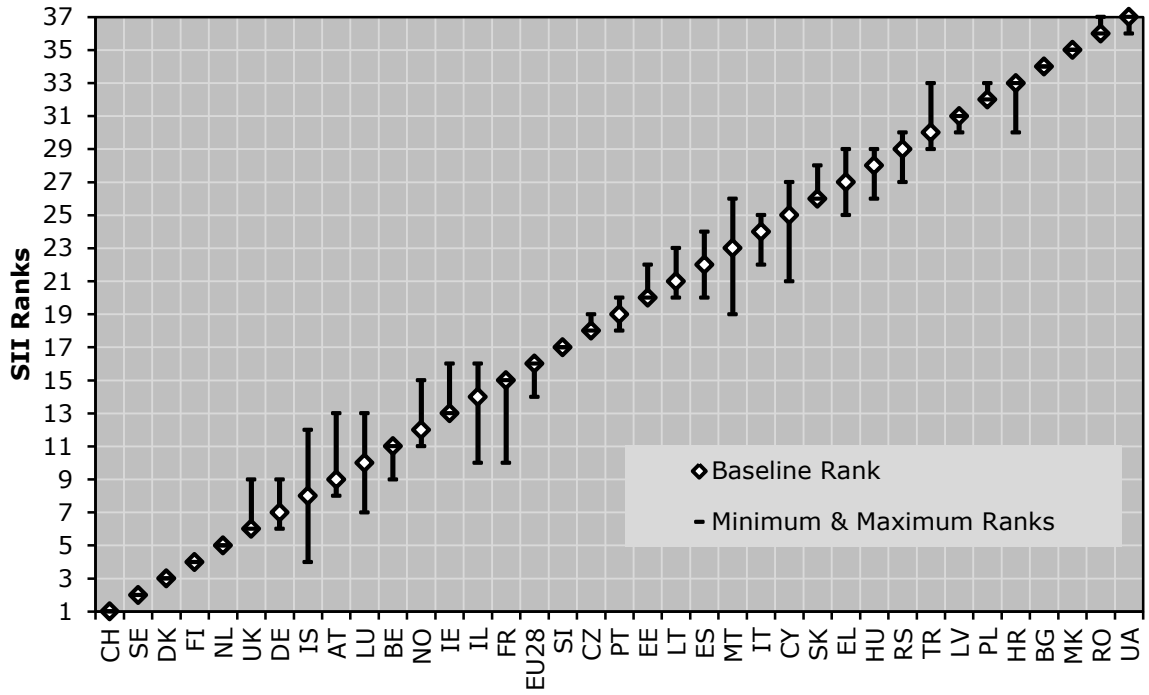
In our simulations, we computed composite scores and rankings applying jointly the full set of combinations of these four selected modelling choices. While uncertainty analyses often compute scores with a set of simulated weights, in this analysis we chose to follow a different strategy. Rather than introducing random weights and address uncertainty in what we could call as nominal weights, we address the difference between nominal weights and effective weights. This way, we do not consider weights as a source of uncertainty, but as a choice between nominally or effectively equal we assessed the direct impact of adjusting the weights on the obtained ranking. This is discussed below.

Figure 3 shows the range of country ranks obtained from the simulations. The figure orders countries based on their reference SII rank (diamond), the whiskers extend to the minimum and maximum ranks obtained in the simulations. We observe that the ranks in general are rather robust to the selected modelling assumptions, eight

[21] The Expectation-Maximization (EM) algorithm (Little and Rubin, 2002; Schneider, 2001) is an iterative procedure that finds the maximum likelihood estimates of the parameter vector by repeating two steps: (1) The expectation E-step: Given a set of parameter estimates, such as a mean vector and covariance matrix for a multivariate normal distribution, the E-step calculates the conditional expectation of the complete-data log likelihood given the observed data and the parameter estimates. (2) The maximization M-step: Given a complete-data log likelihood, the M-step finds the parameter estimates to maximize the complete-data log likelihood from the E-step. The two steps are iterated until the iterations converge.

countries, typically at the top and bottom of the ranking, do not shift their ranks at all, whereas the ranks of 18 countries shift by two positions or less. Nevertheless, one should exercise caution and avoid interpreting the ranks of Iceland, Israel, Luxembourg or Malta at face value, as these rankings may vary significantly (by at least six positions) when adjusting the modelling choices.

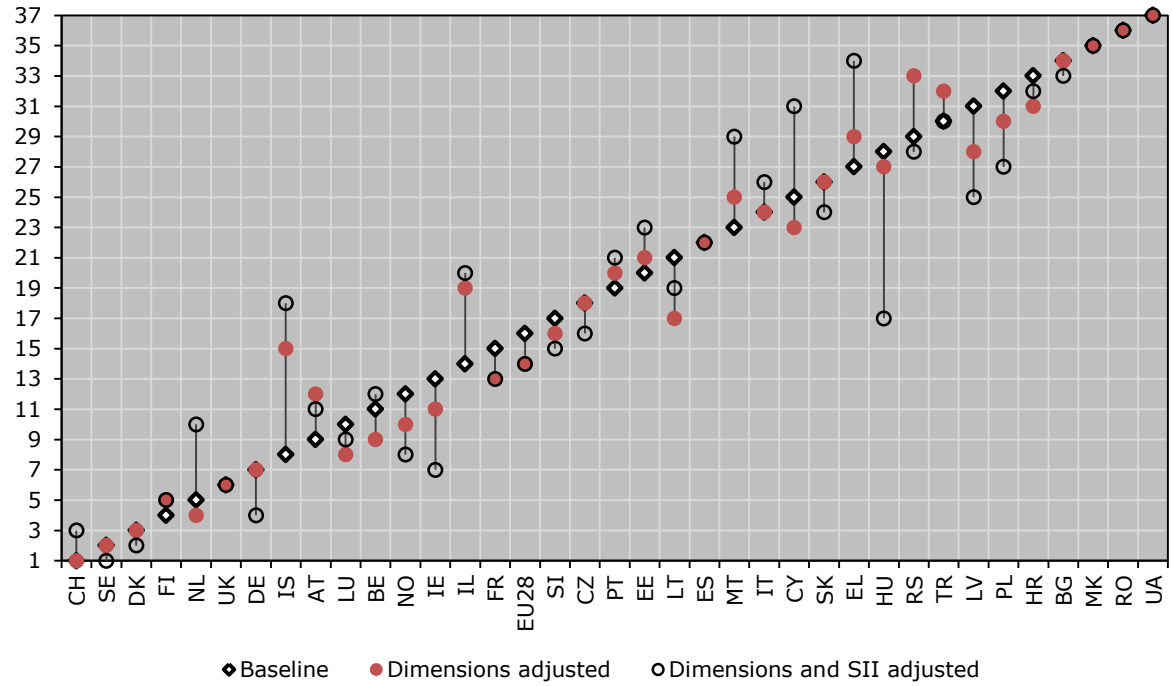
Figure 3 Robustness analysis: rank shifts due to alternative modelling assumptions



Notes: The figure shows the range of country rankings obtained from 24 simulated scenarios which combine imputed versus missing values, two types of outlier treatment, min-max, z-scores and x/Max normalization, and geometric versus arithmetic average aggregation methods.

Finally, we dedicated special attention to the choice of weights. Rather than considering it as a source of uncertainty, we assessed the direct impact of adjusting the weights in a special, two-step aggregation. We first assigned weights as scaling coefficients in a way to ensure that the correlation between each dimension and its underlying indicators are equal. We next computed modified SII scores both as the unweighted average of these adjusted dimensions, as well as a weighted average of these dimensions to ensure a more balanced representation of each dimension (although it was not possible to obtain a weight-combination for a fully balanced solution). The resulting ranks are shown in Figure 4. We observe that the average shifts in ranks in the two versions are 1.5 and 2.9 positions, respectively. This analysis highlights the need to treat the ranks of a few countries, notably Greece, Hungary and Iceland with care, due to the volatility observed. At the same time, it is important to note that despite the rank shifts, we only find two and seven countries changing performance groups due to these adjustments.

Figure 4 Robustness of SII ranks due to the use of adjusted dimension-level composite scores



7.3 Reflection on the sensitivity analysis[22]

The sensitivity analysis in Sections 7.1 and 7.2 has revealed some *perceived statistical shortcomings* of the EIS Summary Innovation Index. Cross-country variations in the SII scores would depend mostly on performance variations in only five indicators, and performance variations in six indicators would not be reflected in the variations in the SII scores. The SII would not provide a balanced summary of the 27 innovation indicators.

The objective of the EIS, however, is not to produce the best composite innovation index from a statistical point of view. The objective of the EIS is to supply users of the report with a toolbox of information. This toolbox is not limited to the SII, but rather provides a rich set of data capturing different aspects of countries' research and innovation systems. The detailed analysis of specific indicators and dimensions is what creates the added value of the EIS, not the 'simple' ranking of countries. The results of the sensitivity analysis show above all that readers of the EIS report should only use the ranking of countries as an introduction, and that the real wealth of the report is all the country specific information, including the newly introduced data on structural differences in the EIS 2017.

[22] Section 7.3 has been written by Hugo Hollanders from MERIT.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