A critical assessment of the European Innovation Scoreboard

21. A critical assessment of the European Innovation Scoreboard

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21.1 INTRODUCTION

Most innovation scoreboards aim at measuring the performance of countries' national systems of innovation. The national innovation system approach has been used as a tool for analysing national specificities in the innovation process and as a guide for policy. Well-known examples are the Global Innovation Index (GII) and the European Innovation Scoreboard (EIS).

The GII was introduced in 2007 and covers more than 130 countries using data for more than 80 variables. The GII, however, has used very few variables that directly measure business innovation. Instead, it mainly uses indirect variables measuring framework conditions, knowledge creation and economic performance. The EIS was introduced in 2001 and covers a smaller number of countries, all in Europe, using data for more than 30 variables. This approach has been extended to the regional level, with well-known examples such as the Regional Innovation Scoreboard (RIS) and the Regional Innovation Index (RII).

Most of the available innovation scoreboards assume that four main actors, firms, government, academia and skilled individuals, are involved in national and regional innovation systems, in line with the quadruple innovation helix framework. Firms conduct innovation activities and interact and collaborate with academia, while the government coordinates and facilitates policy instruments to establish favourable framework conditions and the availability of skilled human resources. Innovation scoreboards also include variables that measure the results of these innovation activities on economies. Innovation scoreboards usually use many statistical variables to measure business innovation and can also summarize performance across all the variables in one or a small number of composite indexes.

There are also examples of focused innovation scoreboards such as the European Public Sector Innovation Scoreboard (EPSIS) and the Eco-Innovation Scoreboard. However, most of the established and annually published scoreboards have a national or regional perspective.

This chapter focuses on the EIS, its history, and the most recent 2021 revision of the conceptual framework, including a discussion of the different variables in the EIS, why they were selected, and the interpretation for policy. Examples of other innovation scoreboards are discussed in Hollanders and Janz (2013). This chapter also discusses the criticism that innovation scoreboards, and in particular the EIS, have received.

21.2 BUILDING AN INNOVATION SCOREBOARD

21.2.1 Selection of Variables

Arundel and Hollanders (2008) identified four criteria for the selection of variables to be included in an innovation scoreboard: '1) the variables should be of similar importance as measures of the drivers of innovative activity; 2) the variables should be based on reliable statistics; 3) the variables should hold their value over time; and 4) the variables should be of relevance to medium and long-term policy issues.'

In real life it is almost impossible to meet all four criteria. Variables will have differing importance as drivers and relevance over time and between countries. In more developed countries, variables capturing the development of new knowledge and new technologies will be more relevant, whereas in less developed countries variables are needed that capture the absorption and diffusion of already existing knowledge and technologies. In a one-size-fits-all scoreboard using the same measurement framework for all countries, the selected variables will favour some countries and disfavour others.

Variables can be built on data from different types of data sources. The preference is for 'hard' statistical data available from statistical offices such as the number of tertiary education graduates or patent applications, as these data are collected following international guidelines, including harmonization of data collection, ensuring comparability between countries. For many innovation activities hard data are not available. Instead, scoreboards use data from innovation surveys or even opinion surveys. Innovation survey data are from questions that ask firms about their innovation activities. A well-known example is the Community Innovation Survey (CIS) that is used in most European countries and based on the same standardized questions.

Innovation survey data are less reliable than hard data but should be included for two reasons (Arundel and Hollanders 2008). First, they can signal relevant areas for innovation and second, trigger policy support for future improvements in data quality. Due to a lack of hard data for many aspects of innovation, it might be better to include data perceived to be of lesser quality than no data at all, in particular for measuring the outputs of innovation.

The least reliable data are those collected in expert surveys where respondents are asked about their opinion on activities that take place outside their direct environment. A well-known example is the World Economic Forum's Executive Opinion Survey, used in many different scoreboards. Opinion survey-based data are less reliable for several reasons. First, respondents are asked to reflect on external activities in which they are not directly involved, making it more likely that their reflections are biased by personal opinions. Second, sample sizes are usually quite small, making it less likely that respondents' answers are representative for the country at large.

Another criterion that is difficult to meet is to identify variables that hold their value over time. For example, a variable that is increasing over time might decline in relevance if its value approaches a policy target. Most European countries have set targets for the share of GDP that should be spent on Research and Development (R&D), but the closer the expenditure share comes to the target value, the less relevant it will become to further increasing it. Hence, there is less interest to include such variables in scoreboards as tracking progress over time is one of the key objectives of innovation scoreboards. Another example is for variables related to the digital economy. The value of variables for the share of households with internet access or the share of firms with broadband access sharply declined as both access rates approached saturation. As internet speeds are continuously increasing, the definition of a fast-speed internet connection also needs to be revised.

Data timeliness issues add to the difficulty of finding variables that are relevant for current and future policy. Hard statistical and innovation survey data are the least timely, with a two-to-three-year delay before results become available, and opinion-survey data are usually very timely, with results available in the same year. Additionally, the change in a variable's value over time, and differences in the relevance of variables as drivers of innovation between countries, all add complexity. What is relevant today might no longer be relevant tomorrow and for new policy challenges none of the currently available variables might be relevant, requiring the collection of new data to construct new variables.

In reality, therefore, the selection of variables to be included in an innovation scoreboard is more based on ad hoc criteria such as data availability, both over time and across countries, sufficient differences in the value of variables to ensure that there are measurable differences in countries' performance, and the public availability of such data to ensure that results can be easily replicated, both to validate the results and to encourage additional analyses by users, including academics and policy makers. The European Innovation Scoreboard (EIS) from the European Commission has followed this practical approach.

21.2.2 European Innovation Scoreboard

The EIS is a well-established analytical tool providing a comparative assessment of the innovation performance of EU Member States and other European countries and regional neighbours, and the relative strengths and weaknesses of their research and innovation systems. The pilot EIS was published in 2000 and the first full EIS in 2001. In the 20 years since 2000, the EIS has evolved to adapt to changing economic realities and the expansion of the European Union from 15 to 28 Member States, followed by the recent retraction to 27 Member States with the withdrawal of the United Kingdom.

The EIS measurement framework distinguishes between broad innovation dimensions and specific innovation variables within each dimension. Average performance is captured in a composite Summary Innovation Index. The EIS has undergone several major revisions in its measurement framework. Most of the changes led to broadening the measurement framework by adding dimensions and indicators to better capture the intricacies of national innovation systems and the diffuse role innovation plays in all facets of an economy.

The first pilot EIS in 2000 covered the EU15 Member States,[1] four dimensions and 16 variables. The EIS 2001 increased the number of variables to 18, and from the EIS 2001 onwards average performance is captured through a composite indicator: the Summary Innovation Index. Country coverage increased to 31 European countries in the EIS 2002. In the EIS 2003 and EIS 2004 the number of variables increased further to 22.

The first major revision in the measurement framework was for the EIS 2005. The revision was partly a response to criticism of a perceived bias in the EIS towards measuring 'technological innovation' in manufacturing. The revised EIS included more variables capturing performance in services and 'non-technological change'.

The second major revision was for the EIS 2008, increasing the number of innovation dimensions and the number of variables. Some of the new variables included Exports of

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knowledge-intensive services, Non-R&D innovation expenditures, and Broadband access by firms.

The third major revision was introduced in the EIS 2010 following the publication of the Innovation Union, one of the flagship initiatives of the Europe 2020 strategy for smart, sustainable and inclusive growth.[2] The Innovation Union contained over 30 action points and aimed to do three things: turn Europe into a world-class science performer; remove obstacles to innovation like high patent costs, market fragmentation, slow standard-setting and skills shortages; and revolutionize the way public and private sectors work together, notably through Innovation Partnerships between European institutions, national and regional authorities, and businesses (EC 2010). In response to the Innovation Union, the EIS included three new variables measuring the openness, excellence and attractiveness of research systems (international scientific co-publications per million population, the share of publications in the top 10 per cent most cited publications worldwide, and the share of doctorate students from non-EU countries in the total number of doctorate students). Also, the name of the report was changed from EIS to Innovation Union Scoreboard. The most important change in the 2016 report was the addition of a forward-looking section to provide an analysis of EU innovation performance discussing more recent developments, trends and expected changes. Furthermore, the name was changed back to the European Innovation Scoreboard.

The fourth major revision took place for the EIS 2017, increasing the number of dimensions to ten and the number of variables to 27. Performance was no longer measured by comparing the scores on the Summary Innovation Index, but by comparing relative performance levels, where relative performance is calculated as a country's performance relative to that of the EU in a particular base year (2010 for the EIS 2017). This revision reflected the need for better aligning the EIS innovation dimensions with evolving policy priorities, improving the quality and timeliness of the indicators, better capturing new and emerging phenomena such as digitisation and entrepreneurship, and providing a toolbox with contextual data, which can be used to analyse structural differences between Member States (EC 2017b). In the EIS 2020, the withdrawal of the United Kingdom from the EU affected the composite indices as the EU average no longer captured 28 but 27 Member States.

The fifth major revision took place for the EIS 2021, following new policy developments and methodological issues with the existing measurement framework. The revision process included methodological improvements to existing variables, and the identification of additional innovation dimensions and variables to be included in the EIS. The new EIS 2021 framework has been revised based on the historical evolution of the EIS and on interactions with different stakeholders. The new framework includes indicators for several new topics: measuring digital skills, digitalization and environmental innovation. The 2021 EIS measurement framework distinguishes 12 innovation dimensions and 32 different variables (Table 21.1). Country coverage increased in the EIS 2022 to 39 countries by including more countries in the group of 12 'other European and neighbouring countries', which also includes the United Kingdom.

21.2.3 EIS Innovation Dimensions and Variables

The EIS measurement framework distinguishes between four main types of variables. 'Framework conditions' captures the main drivers of innovation performance external to the firm and includes three innovation dimensions: Human resources, Attractive research

Table 21.1 New measurement framework of the European Innovation Scoreboard

FRAMEWORK CONDITIONS
Human resources
● Doctorate graduates in science, technology, engineering, and mathematics (STEM) (per 1,000 population aged 25–34)
● Population aged 25–34 with completed tertiary education (%-share)
● Population aged 25–64 involved in lifelong learning (%-share)
Attractive research systems
● International scientific co-publications (per million population)
● Top 10% most cited scientific publications (%-share of all scientific publications)
● Foreign doctorate students (%-share of all doctorate students)
Digitalisation
● Broadband penetration (firms with a maximum contracted download speed of the fastest fixed internet connection of at least 100 Mb/s; %-share)
● Individuals who have above basic overall digital skills (%-share)
INVESTMENTS
Finance and support
● R&D expenditure in the public sector (% of GDP)
● Venture capital expenditure (% of GDP)
● Direct government funding and government tax support for business R&D (% of GDP)
Firm investments
● R&D expenditure in the business sector (% of GDP)
● Non-R&D innovation expenditure (% of turnover)
● Innovation expenditure per person employed in innovation-active firms
● Use of information technologies
● Firms providing training to develop or upgrade personnel's ICT skills (%-share)
● Employed ICT specialists (%-share)
INNOVATION ACTIVITIES
Innovators
● SMEs with product innovations (%-share)
● SMEs with business process innovations (%-share)
Linkages
● Innovative SMEs collaborating with others (%-share)
● Public-private co-publications (per million population)
● Job-to-job mobility of Human Resources in Science & Technology (%-share)
Intellectual assets
● PCT patent applications (per billion GDP)
● Trademark applications (per billion GDP)
● Design applications (per billion GDP)
IMPACTS
Employment impacts
● Employment in knowledge-intensive activities (%-share)
● Employment in innovative firms (%-share)

Sales impacts
● Medium and high-tech goods exports (%-share)
● Knowledge-intensive services exports (%-share)
● Sales of product innovations (% of turnover)
Environmental sustainability
● Resource productivity (GDP generated per unit of direct material consumed)
● Air emissions by fine particulates (PM 2.5) in Industry (in tonnes per value added)
● Development of environment-related technologies (%-share of all patents)

Source: EC (2021), European Innovation Scoreboard 2021.

systems and Digitalization. 'Investments' captures public and private investment in research and innovation and includes three dimensions: Finance and support, Firm investments and Use of information technologies. 'Innovation activities' captures relevant activities in the business sector and includes three dimensions: Innovators, Linkages, and Intellectual assets. Finally, 'Impacts' covers the effects of business innovation and includes three dimensions: Employment impacts, Sales impacts and Environmental sustainability.

In the following, the innovation dimensions and indicators are briefly discussed including a short summary of the main criticism received, by email or during meetings, from multiple stakeholder consultations as part of the 2021 revision process.

21.2.4 Framework Conditions

The human resources dimension measures the availability of a high-skilled and educated workforce and includes three variables.

1. *Doctorate graduates in science, technology, engineering and mathematics (STEM)* is a measure of the supply of new second-stage tertiary graduates. STEM doctorate graduates contribute to business innovation by taking up researcher and managerial positions in firms. Compared to previous versions of the EIS that covered doctorate graduates in all fields, the variable now focuses on STEM graduates following recommendations made for several years by policy makers. The revised variable has been criticized for not acknowledging a broader, non-technological concept of innovation and for not acknowledging the contribution to business innovation by personnel not directly employed by firms, for instance. consultants and employees of firms providing services and technical support to innovative firms.
2. *The share of the population aged 25–34 with completed tertiary education* is a variable of the supply of advanced skills. This variable is not limited to STEM fields because the adoption of innovations in many areas, in particular in the service sectors, depends on a wide range of skills. The variable focuses on a younger age cohort of the population to reflect recent changes in educational policies. This variable is commonly used in many reports. An alternative is to use a broader age range of 25–64-year-olds, but the narrower range used here has not received any major criticisms.
3. *The share of the population aged 25–64 years old involved in lifelong learning activities* captures all purposeful learning activity, whether formal, non-formal or informal, undertaken on an ongoing basis with the aim of improving knowledge, skills or competences. The variable complements the other two variables which focus on skills attained by formal education. This variable did not receive much criticism except for the fact that results

between countries might be biased due to differences in the four-week period in which responses are collected.

Data sources for all three variables are official statistics including Labour Force Survey data. Data are updated every year and common definitions across countries ensure that results are comparable.

The attractive research systems dimension includes three variables and measures the international competitiveness of the science base.

1. *International scientific co-publications* measures the quality of scientific research as collaboration increases scientific productivity. The variable has been introduced in the 2010 edition of the EIS and never received any criticism.
2. *Scientific publications among the top 10 per cent most cited publications worldwide as a percentage of total scientific publications* is a measure of the efficiency of the research system, as highly cited publications are mostly also of higher quality. For these two variables data are obtained from bibliometric data sources such as Scopus or Web of Science with annually updated data and a common methodology across countries to collect data. Access to these data might be restricted as they use proprietary private data sources. A possible point of criticism is a bias towards English-speaking and more developed countries, making it more difficult for countries in, for example, Eastern Europe to perform above average on this variable.
3. *The share of foreign doctorate students* reflects the inward mobility of students as an effective way of diffusing knowledge. Attracting high-skilled foreign doctorate students will add to a continuous supply of researchers. Data for this variable are available from official statistics and are usually updated every year. A possible drawback of this variable is that foreign graduates might return to their home country and not contribute to the supply of researchers in the country where they graduated.

The digitalization dimension measures the level of digital technologies and the availability of digital skills and includes two variables.

1. *Broadband penetration among firms*, defined as the share of firms with a maximum contracted download speed for a fixed internet connection of at least 100 Mb/s. This captures how well a country reaps the e-potential from electronic commerce. For this variable the minimum download speed has to be adjusted over time as download speeds are continuously increasing.
2. *Individuals who have above basic overall digital skills* measures the availability of digitally skilled employees. Above 'basic overall digital skills' is the highest level of Europe's digital skills variable, using selected activities performed by individuals aged 16–74 on the internet in four specific areas (information, communication, problem solving, content creation) during a period of three months.

Data sources for both variables are official statistics including data from two ICT surveys for firms and households.[3] Data are updated every year and common definitions and survey methodologies across countries ensure a high comparability of results.

21.2.5 Investments

The finance and support dimension measures the availability of public and private support and includes three variables.

1. *R&D expenditure in the public sector as a share of GDP* measures how much the government and higher education sector invest in R&D. R&D spending is essential for making the transition to a knowledge-based economy as well as for improving production technologies and stimulating growth. Data are obtained from official statistics, usually from national R&D surveys. Data are collected every year following the international recommendations in the *Frascati Manual* (OECD 2015a). The variable has not been criticized as these expenditures are seen as very relevant. The only point of criticism is that not all higher education institutes are publicly funded and that the name of the variable is therefore slightly misleading.
2. *Venture capital expenditure as a share of GDP* is a measure for new business creation resulting from innovation. For firms using or developing new and risky technologies, venture capital is often the only available means of financing their new or expanding business. Data are obtained from Invest Europe, which is the association of private capital providers in Europe. The variable has been criticized for capturing only a small share of the funding used for innovation activities. In several European countries a venture capital market is almost non-existent where firms in these countries could still access venture capital funding in foreign markets.
3. *Direct government funding and government tax support for business R&D* captures government support for business R&D. Public financing of R&D can take two forms: direct funding for R&D through instruments such as grants and public procurement, and indirect support through the tax system. Over time, more and more countries have introduced R&D tax incentives. The OECD started to collect such data systematically in 2017 and data are made available in the 'OECD R&D Tax Incentives database'. The OECD data are combined with data from official statistics on the direct funding of R&D, where these data are collected using R&D surveys. This variable has been criticized for combining data from two different sources, with data on direct business R&D funding being collected through the European Statistical System and using strict guidelines, whereas the data on indirect business R&D funding are collected on a voluntary basis using more generic guidelines. Nevertheless, given the growing use of tax credits, including these data is relevant to better capture the full spectrum of funding of business innovation.

The firm investments dimension includes three variables on R&D and Non-R&D investments that firms make to generate innovations.

1. *R&D expenditure in the business sector as a share of GDP* measures how much the business sector invests in R&D.
2. *Non-R&D innovation expenditures* is relevant to capture innovation activities that do not involve R&D activities. Several components of innovation expenditure, such as investment in equipment and machinery and the acquisition of patents and licences, measure the diffusion of new production technologies and ideas, and these innovation activities are more relevant for firms active in less technology-intensive industries and services.

3. *Innovation expenditures per person employed* measures the monetary input directly related to innovation activities, with higher expenditures per person employed signalling larger investments by firms. The indicator includes both R&D and non-R&D innovation expenditures. Innovation expenditures per person employed has been criticized for several reasons. The indicator is supposed to be biased in favour of less labour-intensive economies and therefore fails to fully capture investments in innovation across different countries. It also overlaps with the variable for non-R&D innovation expenditures, as it includes innovation expenditures in the numerator and the size of the business sector in the denominator.

For the first of these three variables, data are from official statistics, usually from national R&D surveys. Data are internationally comparable and updated every year. For the other two variables, the data are from the Community Innovation Survey (CIS), used by all EU Member States and most other European countries to measure innovation activities in the business sector (see the CIS section below for more details).

The 'Use of information technologies' dimension includes two variables.

1. *Firms actively increasing the ICT skills of their personnel* measures the share of firms actively promoting the development of such skills. ICT skills are particularly important for innovation in a digital economy.
2. *The share of employed ICT specialists* measures the availability of 'workers who have the ability to develop, operate and maintain ICT systems, and for whom ICT constitute the main part of their job' (OECD 2015b).[4]

Data for both variables are from official statistics, the Survey of ICT Usage and E-commerce in Enterprises and the Labour Force Survey. Data are collected annually and are highly comparable across countries. During the revision process of the EIS measurement framework, both variables were widely supported and not criticized.

21.2.6 Innovation Activities

The innovators dimension captures the presence of business innovation and includes two variables measuring the share of small and medium-sized enterprises (SMEs) that have introduced innovations on the market (products) or within their organizations (mostly business processes): (1) *the share of SMEs introducing product innovation*s and (2) *the share of SMEs introducing business process innovations*. Product innovations are a key ingredient to innovation as they can create new markets and improve competitiveness. Higher shares of product innovators reflect a higher level of innovation activities. Many firms also innovate by improving their business processes. Business process innovations include process, marketing and organizational innovations. Data are collected from the Community Innovation Survey with data being collected every two years. Both variables as such have received no criticism besides the general criticism on using innovation survey data as discussed below.

The linkages dimension includes three variables measuring cooperative innovation activities.

1. *The share of innovative SMEs collaborating with others* measures the degree to which SMEs are involved in innovation collaboration. Complex innovations often depend on the ability to draw on diverse sources of information and knowledge, or to collaborate in

the development of an innovation. Data are from the Community Innovation Survey and collected every two years.
2. *Public-private co-publications per million population* captures public-private research linkages and active collaboration activities between business sector researchers and public sector researchers that result in scientific publications. For this variable data are from bibliometric data sources such as Scopus or Web of Science. The variable has been criticized for capturing only a relatively small subset of all publications. For the EIS 2021, the definition was therefore revised to not only include publications assigned to the country in which the firm or other private sector organization is located, but by also including publications assigned to the country where the public sector organization is located.
3. *Job-to-job mobility of Human Resources in Science & Technology (HRST)* measures the mobility of highly skilled workers. The mobility of skilled personnel affects the degree of knowledge creation, which is one of the key drivers of innovation. HRST are people who either have successfully completed a tertiary level education or who are employed in a S&T occupation. Annual data are collected by national statistical offices in their Labour Force Surveys. The variable has been criticized for being biased due to differences between labour markets in how easily employees can leave jobs or be dismissed and for differences in business cycles with lower mobility when demand is higher than the supply of skilled workers.

The Intellectual assets dimension captures different forms of Intellectual Property Rights (IPR) including patents, trademarks and designs. The capacity of firms to develop new products will influence their competitive advantage.

1. *PCT patent applications per billion GDP* measures the rate of new discoveries of potential value for both product and business process innovations.
2. *Trademark applications per billion GDP* are an important innovation variable, especially for the service sector. Trademarks identify the origin of goods and services, guarantees consistent quality through evidence of the firm's commitment vis-à-vis the consumer, and are used for publicity and advertising.
3. *Design applications per billion GDP* measures the number of individual designs. 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.

Data on IPRs are collected from official statistics. Patent data are obtained from the OECD and data on trademarks and designs from the EU Intellectual Property Office (EUIPO). Data are collected annually and are internationally comparable. For EUIPO data the comparability is best between European countries, as non-European countries are less likely to apply for trademarks and designs. All three variables have been included in the EIS for many years and have not received criticism. The definitions have been changed several times, for example, including high-tech patents only, combining trademark applications from both EUIPO and the World Intellectual Property Office (WIPO) and using data on individual designs versus data on design applications. The last change, to use individual design applications, was introduced in the EIS 2016 following a recommendation from EUIPO as one design application can include multiple individual designs.

21.2.7 Impacts

The employment impacts dimension measures the impact on employment and includes two variables.

1. *Employment in knowledge-intensive activities as a percentage of total employment*. The data are from the Labour Force Survey.
2. *Employment in innovative firms as a percentage of total employment*. The data are from the Community Innovation Survey. The variable has been criticized for being biased towards the presence of large firms, as innovation rates are consistently higher amongst larger firms compared to SMEs.

Knowledge-intensive activities are important as they provide services directly to consumers, such as telecommunications, and provide inputs to the innovative activities of other firms in all sectors of the economy. Knowledge-intensive activities are defined, based on the EU Labour Force Survey data, as all NACE Rev. 2 industries at the 2-digit level where at least 33 per cent of employees have completed higher education. Innovation in firms has a profound impact on the employment of highly educated workers, but the impact varies across countries. Firm innovation proves to be specifically important for highly educated employees during a time of economic recession. Although high-skilled employees are less affected by a recession than low-skilled employees, a notable positive effect is observed for low-skilled employees in innovative firms as well.

The sales impacts dimension measures the economic impact of innovation and includes three variables.

1. *The share of exports of medium and high-tech goods*[5] measures the technological competitiveness of countries, the ability to commercialize the results of R&D and innovation in international markets. Medium and high-technology goods are key drivers for economic growth, productivity and welfare, and are generally a source of high value added. The variable has been criticized for including exports and re-exports as a significant share of exports are produced using imported parts. Instead, it would be better to use data on net exports, for example from the OECD database on trade in value added (TIVA), but such data are not available for all countries and are not very timely, with the most recent data being about five years old. The variable is from official data on goods and services exports and is updated annually.
2. *The share of exports of knowledge-intensive services*[6] measures the competitiveness of the knowledge-intensive services sector. It 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. The variable has been criticized for being biased against landlocked countries as these countries lack activities in sea transport, one of the services defined as knowledge intensive. The variable is from official data on goods and services exports and is updated annually.
3. *The share of sales resulting from innovative products* measures the turnover of new or significantly improved products and includes both products that are only new to the firm and products that are also new to the market. The variable captures both the creation of state-of-the-art technologies and the diffusion of these technologies. Data are from the Community Innovation Survey with data collected every two years.

The Environmental sustainability dimension captures the impact of business innovations that reduce negative impacts on the environment and includes three variables which have been introduced for the first time in the 2021 edition of the EIS.

1. *Resource productivity* is a measure of the total amount of materials directly used by an economy (measured as domestic material consumption (DMC)) in relation to GDP. It provides insights into whether decoupling between the use of natural resources and economic growth is taking place. DMC is defined as the annual quantity of raw materials extracted from the domestic territory, plus all physical imports minus all physical exports. Data are collected from official data sources from the economy-wide material flow accounts.
2. *Air emissions of fine particulate matter (PM2.5) in tonnes per million euros value added (Chain linked volumes (2010)) in industry* captures emissions of fine particulate matter by industry. Particles with a diameter of 2.5 micrometres or less which are considered by the World Health Organization (WHO) as the pollutant with the highest impact on human health. Air pollution may be human-induced or of natural origin. Air pollution has the potential to harm both human health and the environment: particulate matter (PM), nitrogen dioxide and ground-level ozone are known to pose health risks. Long-term and peak exposures to these pollutants may be associated with cardiovascular and respiratory diseases or an increased incidence of cancer. As data are collected for European countries only, this variable is less useful for international comparisons with non-European countries. Lower levels of air emissions over time are to a large extent the result of the introduction and use of more efficient and less polluting technologies. Data are collected from two sources, data on air emissions from the European Environmental Agency (EEA) and data on value added from national statistical offices. The variable is rather narrowly defined by only including air emissions by industry, not including air emissions from other industries that produce high levels of PM2.5, including agriculture, transportation and storage. The focus on industry is linked to the European Commission's ambition to raise the industrial share of EU GDP to 20 per cent (EC 2017a).
3. *The share of environment-related inventions* measures the share of patents or new technologies in a wide range of environment-related technological domains, including environmental management, water-related adaptation and climate change mitigation technologies. Data are obtained from the OECD Green Growth database and are updated annually. Data are also available for non-European countries. A possible criticism is that there is some double counting as these patents are already included in the variable measuring all patent applications.

21.2.8 Community Innovation Survey

Most European countries use a comparable questionnaire and methodology for collecting these data, following the *Oslo Manual* recommendations (OECD/Eurostat 2018). The innovation survey is referred to as the Community Innovation Survey or CIS and national statistical offices collect results once every two years and share a common set of data with Eurostat, the statistical office of the EU. Although there is a high degree of similarity in the structure of the CIS questionnaire in different countries, there are issues in the comparability of results between countries and over time. Sample sizes differ between countries, with most countries targeting all larger firms and using a random sample for smaller firms. Differences in translation of the harmonized questionnaire in national languages can also create differences in how firms respond to the questions. Furthermore, questions often require a subjective answer, for example, asking firms if something is significantly new, which leaves room for interpretation and thus differences in responses. Despite some of these drawbacks, innovation surveys are the most relevant source of information for measuring business innovation as they collect information from firms on specific innovation activities. No other data, either from official data or opinion surveys, can provide the same relevant information on business innovation.

21.2.9 Building a Composite Indicator

Scoreboards are used in different ways. One can analyse the results per variable or per group of variables as shown in the following section. One can also analyse overall results by summarizing all variable scores in one single number by using composite indicators. Composite indicators are calculated for each country as the unweighted average of rescaled scores of all variables included in a scoreboard's measurement framework. Rescaling includes normalization as well as transformation of skewed data. There are different steps involved in constructing a composite indicator (OECD/Eurostat 2008) of which the most important ones are the following:

- Build a theoretical framework that will help in selecting and combining variables relevant for measuring innovation.
- Select data based on measurability, country coverage, timeliness and analytical soundness.
- If there are missing values, these should be estimated or imputed to ensure a complete dataset.
- Normalize all data by recalculating all variables so they are measured on the same scale.
- Aggregate the different variables into one number, possibly by using weights for different variables that are perceived to be of more or less importance in the theoretical framework.

The composite indicator approach has received criticism, in particular on how it is calculated and its weighting scheme. Grupp and Mogee (2014) argue that countries' composite indicator scores and their rank position vary strongly depending on the choice of indicators and the calculation methodology. Grupp and Schubert (2010) specifically show that for the EIS changing the weights of the indicators has a profound impact on the results. On the other hand, it has clear advantages over a single indicator, for example, the number of patents or R&D expenditures, which only cover a small range of innovation activities. The composite indicator allows for a user-friendly statistic that is understood by the general public. On the other hand, tools such as the EIS focus much more on the underlying statistics and in recent editions have given less emphasis to country rankings.

Missing values are imputed in a simple and transparent way. Data are carried forward or backward if data are missing but available for at least one year. If no data are available for a particular variable and imputation is not possible, the variable is not included in the composite index of that country.

The measurement framework takes into account the policy relevance of the different variables. Correlation analyses are used to check if variables are highly correlated, but highly correlated variables are not excluded from calculating the composite indicator if the indicators are considered to have a high policy relevance and capture different although related innovation activities.

Composite indicators using the EIS data are normalized by first identifying and removing statistical outliers, by transforming highly skewed variables and then by applying the max-min transformation. Most of the variables are fractional variables with values between 0 per cent and 100 per cent, and some variables are unbound variables, where values are not limited by an upper threshold.

Several EIS variables have skewed data distributions where most countries show low performance levels, and a few countries show exceptionally high levels of performance. Not correcting for highly skewed distributions would result in only a few countries obtaining a high score in a normalized composite index, with most other countries taking on low scores with only a few countries in between. Outliers are the main cause of highly skewed distributions and removing them is a first step in creating a more equivalent distribution of normalized scores. Positive (negative) outliers are identified as country scores that are higher (smaller) than the mean across all countries plus (minus) twice the standard deviation. These outliers are replaced by the respective maximum and minimum values observed over all the years and all countries. Any variable where the degree of skewness across the full eight-year period is still higher than one after outliers have been replaced is transformed using a square root transformation.

Normalized scores (after correcting for outliers and a possible transformation of the data) are then calculated by first subtracting the lowest or minimum score over all countries and years and then dividing by the difference between the highest or maximum and minimum score over all countries and years. The maximum normalized score is equal to 1 and the minimum normalized score is equal to 0. The composite indicator is then calculated as the unweighted average of the normalized scores for all variables. To better monitor performance changes over time, performance scores relative to the EU weighted score are used in the EIS. For each year, the composite indicator of the respective country is divided by the composite indicator of the EU weighted score in the first year of the eight years covered in the EIS and multiplied by 100.

21.3 INTERPRETATION OF RESULTS

The EIS focuses on covering EU Member States and other European and neighbouring countries. Data for most variables are obtained from Eurostat, ensuring good country coverage and comparable results across countries. Data are not always very timely, for example, the data obtained from the Community Innovation Survey are usually released almost two years after the end of the survey's reference period. For example, the 2020 edition of the CIS asks respondents if they introduced a product or business process innovation during the three years 2016 to 2018. Data are then collected and processed by national statistical offices from early 2019 up to the second quarter of 2020 and submitted to Eurostat in June 2020. After a quality control, Eurostat then released the data for all countries in the fourth quarter of 2020. Data from other sources are usually timelier, for example, the data for the variables capturing performance in scientific publications become available with a delay of only year. Data coverage is near perfect for most EU Member States, but data coverage is poorer for several other countries that do not take part in the European Statistical System (ESS),[7] with data missing for several of the EIS variables. For these countries, the composite index needs to be interpreted with care.

21.3.1 Analysing Composite Indicator Results

How the composite innovation index is calculated in the EIS easily allows us to monitor performance change over time. Other scoreboards, such as the Global Innovation Index (GII), only calculate results for one year and due to changes in the methodology or the number of countries included, results are not 100 per cent comparable between different GII reports. The same also holds true if one would compare results between different EIS reports, and to avoid improper comparisons over time, each EIS report provides a consistent time series result for eight years, allowing us to compare results over these eight years as these have been calculated using the same methodology.

Results from the 2022 edition of the EIS are shown in Table 21.2 and compared for each of the seven years from 2015 onwards. For all countries, performance is expressed relative to that of the EU weighted score in 2015. For example, in 2022 the EU performed 9.9 per cent above its 2015 performance. In 2015 Belgium performed 24.9 per cent and in 2022 41.7 per cent above the performance of the EU in 2015, showing an increase of 16.8 percent points. These performance results relative to the EU directly show if a country was more innovative or less innovative than the EU average and whether its relative performance increased or decreased over time. A comparison of the scores in 2015 and 2022, as shown in the last column, reveals that national performance only declined for three countries over time: France, Turkey and Ukraine. But as the performance of the EU also increased over time, it is more interesting to compare countries' rates of change since 2015 with that of the EU average rate of change. For 17 countries, performance increased faster than the average improvement of 9.9 per cent-point for the EU, and most so for Cyprus (37.9 per cent-point), Estonia (24.4 per cent-point), Greece (24.1 per cent-point) and Norway (21.3 per cent-point). For 23 countries performance increased at a slower pace than that of the EU (or even decreased).

The results in Table 21.2 also allow a comparison between two or more countries to see which countries are more innovative and to assign countries to a limited number of performance groups. The EIS countries are classified into four different groups based on their performance relative to the EU in the most recent year (2021):

- The group of *Innovation Leaders* includes six countries where relative performance is above 125 per cent of the EU average: Belgium, Denmark, Finland, the Netherlands, Sweden and Switzerland.
- The group of *Strong Innovators* includes nine countries with a relative performance between 100 per cent and 125 per cnt of the EU average: Austria, Cyprus, France, Germany, Iceland, Ireland, Luxembourg, Norway and the United Kingdom.
- The group of *Moderate Innovators* includes ten countries with relative performance between 70 per cent and 100 per cent of the EU average: Czechia, Estonia, Greece, Israel, Italy, Lithuania, Malta, Portugal, Slovenia and Spain.
- The group of *Emerging Innovators* includes 14 countries that have a relative performance below 70 per cent of the EU average: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Hungary, Latvia, Poland, Montenegro, North Macedonia, Romania, Serbia, Slovakia, Turkey and Ukraine.

These performance groups were introduced in the EIS because users were focusing too much on year-to-year rank changes which, given the small differences in performance scores between countries close to each other in performance rankings, are not very relevant.

Table 21.2 European Innovation Scoreboard 2022: composite innovation index scores

	Performance scores relative to EU in 2015								Change over
	2015	2016	2017	2018	2019	2020	2021	2022	time
European Union	100.0	100.4	101.5	103.7	104.3	108.0	109.3	109.9	9.9
EU Member States									
Belgium	124.7	125.8	128.0	129.9	127.2	137.9	137.2	141.5	16.8
Bulgaria	48.2	49.5	48.4	48.8	48.5	46.5	46.7	49.7	1.5
Czechia	82.0	82.9	83.5	84.3	86.8	89.8	90.0	101.7	19.8
Denmark	136.8	137.4	139.3	137.6	138.5	145.5	147.7	148.1	11.3
Germany	121.8	121.0	121.9	123.0	123.2	130.0	130.9	129.2	7.4
Estonia	85.5	79.3	82.2	96.2	99.0	112.1	118.7	109.8	24.4
Ireland	123.6	125.5	127.2	126.1	125.6	122.0	123.0	130.7	7.1
Greece	64.1	64.6	67.6	73.5	74.7	81.0	84.5	88.2	24.1
Spain	88.9	89.9	91.6	94.0	95.5	93.2	92.1	97.5	8.6
France	116.8	117.1	118.2	117.5	117.1	115.8	116.8	115.9	-1.0
Croatia	57.5	58.9	58.9	60.8	62.1	69.0	71.1	73.0	15.5
Italy	83.2	83.7	85.1	89.7	90.9	102.1	103.6	100.7	17.4
Cyprus	79.5	80.0	83.4	87.2	84.1	108.8	111.5	117.4	37.9
Latvia	51.1	54.4	55.2	55.7	54.2	56.6	56.6	55.8	4.7
Lithuania	72.1	75.0	76.2	84.1	84.0	83.6	85.6	92.0	19.9
Luxembourg	128.9	130.3	132.7	132.6	133.0	132.6	130.8	130.4	1.4
Hungary	69.6	69.9	69.8	71.7	68.9	71.3	73.8	76.7	7.1
Malta	86.4	87.9	90.6	95.4	98.7	108.2	97.6	93.0	6.7
Netherlands	132.2	134.4	135.2	138.3	140.4	138.9	140.1	142.1	9.9
Austria	125.4	124.5	125.4	128.9	128.2	127.6	128.6	130.1	4.6
Poland	55.2	56.8	58.9	58.5	59.5	59.9	62.2	66.5	11.3
Portugal	88.0	87.9	87.6	95.2	97.2	89.0	92.2	94.3	6.4
Romania	35.7	35.5	34.4	32.2	33.6	38.4	38.7	35.9	0.2
Slovenia	100.8	99.8	100.3	96.6	93.4	96.0	99.7	102.7	2.0
Slovakia	66.1	64.6	68.1	67.3	67.6	66.0	66.1	70.7	4.6
Finland	129.4	130.6	129.8	135.3	136.2	138.6	141.4	148.9	19.5
Sweden	138.6	139.9	141.7	141.7	141.9	147.6	147.4	149.1	10.5
Other European and neighbouring countries									
Albania	40.8	43.4	39.4	40.5	48.0	45.4	45.9	45.8	5.0
Bosnia and Herzegovina	37.5	37.4	36.7	32.0	31.5	36.6	39.2	38.3	0.9
Iceland	106.5	109.6	108.2	106.7	108.9	110.8	112.3	114.5	8.0
Israel	101.7	102.4	104.1	104.3	105.3	105.8	106.6	106.0	4.3
North Macedonia	38.0	37.4	38.7	42.4	42.5	42.6	47.0	50.1	12.0
Montenegro	45.6	49.0	49.8	44.5	47.4	47.1	50.7	52.2	6.5
Norway	113.1	113.1	114.3	123.9	125.1	128.6	130.0	134.4	21.3
Serbia	52.3	50.8	55.0	58.9	63.1	69.7	71.6	67.9	15.6
Switzerland	152.5	153.4	153.2	151.5	153.2	154.1	154.9	156.5	4.0
Turkey	53.0	53.1	54.8	60.7	61.3	50.7	50.9	52.4	-0.5
Ukraine	34.5	33.2	31.4	30.7	30.1	31.0	32.5	34.1	-0.5
United Kingdom	126.0	126.6	130.6	132.8	132.9	129.0	129.7	129.5	3.4

Source: EC (2022), European Innovation Scoreboard 2022.

Countries have only rarely changed their performance group over time, underlining that it is more relevant to compare countries within the same group.

21.3.2 Analysing Countries' Strengths and Weaknesses

Innovation scoreboard results can be used to identify and analyse the strong and weak elements in countries' innovation systems. Foray and Hollanders (2015) used the 2011 edition of the EIS, then called Innovation Union Scoreboard, to analyse the strengths and weaknesses of Switzerland. The authors also argued that the EIS 'should not be applied in an isolated manner or without relying on other types of indicators and information'. For each of the 24 variables included in the EIS 2011, Switzerland was compared with the top-five best performing countries, showing performance gaps where Switzerland's performance was lower than the top-five for three variables measuring spending on innovation activities (the share of non-R&D innovation expenditures in turnover, the share of GDP for R&D expenditures in the public sector, and the share of GDP for venture capital expenditures), two variables on firms' innovation activities (the share of SMEs innovating in-house and the share of innovative SMEs collaborating with others), and one variable measuring the economic impact of innovation (the share of medium-high and high-tech goods exports). The authors also identified variables that could cause a decline in Swiss performance in the EIS. These included variables that were below the average of all variables and had declined over time, including the same two variables on firm innovation activities and one variable measuring the economic impact of innovation (the share of knowledge-intensive services exports). The EIS results could similarly be used to analyse other countries in more detail.

21.3.3 Policy Relevance and Use of an Innovation Scoreboard

Innovation scoreboards can be used to evaluate specific indicators to assess national innovation performance and to suggest national targets for several key indicators. EIS variables should also be of relevance for measuring the outcomes of specific innovation policies. Table 21.3 provides an updated version of the results in Arundel and Hollanders (2005) that linked individual EIS variables with one or more innovation policy themes. Table 21.3 also shows which indicators are direct (**) or indirect (*) measures of the success or failure of each policy. Most variables are of indirect relevance as many other variables, not used in the EIS, can influence specific policy themes. Conversely, most variables are relevant to only one specific policy theme, making it easier to use changes in these variables to evaluate if a policy has had an impact. For several policy themes the EIS offers multiple variables that could be used for policy evaluation.

A different approach is followed by Cvijanović and Reid (2018), who link the EIS variables to different policy instruments identified in the STIP Compass (EC-OECD 2020). The STIP Compass is a joint initiative of the European Commission and the OECD that collects quantitative and qualitative data on STI policies. The STIP Compass has identified 28 policy instruments grouped in five categories: governance, direct financial support, indirect financial support, collaborative infrastructures, and guidance, regulation and incentives. Table 21.4 follows the approach by Cvijanović and Reid (2018) by linking the EIS variables to STIP policy instruments, the expected scale of impact (from low to medium and high) and the expected timescale of impact (short term or three years or less, medium term or four to nine years, and long term or ten years or more).

Table 21.3 Relevance of EIS variables for policy themes

	Collaboration	Digitalization	Environment	Finance	Human resources	Promote IPR	Research	R&D & Innovation	Trade	General
Doctorate graduates in STEM					**		*			
Population with tertiary education					**					
Population involved in lifelong learning					*					
International scientific co-publications	*						*			
Top 10% most cited scientific publications							*			
Foreign doctorate students	*									
Broadband penetration										*
Individuals with above basic overall digital skills		**								
R&D expenditure in the public sector								**		
Venture capital expenditure				*						
Direct government funding and tax support for business R&D				*						
R&D expenditure in the business sector								*		
Non-R&D innovation expenditure								*		
Innovation expenditure per person employed								*		
Firms providing ICT training to personnel		*								
Employed ICT specialists		*								
SMEs with product innovations								*		
SMEs with business process innovations								*		
Innovative SMEs collaborating with others	*							*		
Public-private co-publications	*						*			
Job-to-job mobility of HRST	*				*			*		
PCT patent applications						*				

	Collaboration	Digitalization	Environment	Finance	Human resources	Promote IPR	Research	R&D & Innovation	Trade	General
Trademark applications						*				
Design applications						*				
Employment in knowledge-intensive activities										*
Employment in innovative firms										*
Medium and high-tech goods exports									*	
Knowledge-intensive services exports									*	
Sales of product innovations								*		
Resource productivity			**							
Air emissions by fine particulates			**							
Development of environment-related technologies			*			*				

Note: **/* Direct/indirect measures of the success or failure of each policy.
Source: Revised version of table 2 in Arundel and Hollanders (2005).

Table 21.4 Linking EIS variables to STIP Compass policy instruments

	STIP policy instrument	Scale of impact	Timescale
Doctorate graduates in STEM Population with tertiary education Population involved in lifelong learning	Institutional funding for public research Fellowships and postgraduate loans and scholarships	Medium to high	Medium to long term
International scientific co-publications Top 10% most cited scientific publications Foreign doctorate students	Institutional funding for public research Project grants for public research Centres of excellence grants Labour mobility regulation and incentives	Medium to high	Medium to long term
Broadband penetration Individuals with above basic overall digital skills	Technology extension and business advisory services	Low to medium	Short to medium term
R&D expenditure in the public sector Venture capital expenditure Direct government funding and tax support for business R&D	Institutional funding for public research Project grants for public research Dedicated support to research infrastructures Equity financing	Medium to high	Short to medium term
R&D expenditure in the business sector Non-R&D innovation expenditure Innovation expenditure per person employed	Grants for business R&D and innovation Corporate tax relief for R&D and innovation	Medium to high	Short to medium term
Firms providing ICT training to personnel Employed ICT specialists	Technology extension and business advisory services	Medium to high	Short to medium term
SMEs with product innovations SMEs with business process innovations	Loans and credits for innovation in firms Innovation vouchers Technology extension and business advisory services	Medium to high	Short to medium term
Innovative SMEs collaborating with others Public-private co-publications Job-to-job mobility of HRST	Centres of excellence grants Networking and collaborative platforms	Low to medium	Short to medium term
PCT patent applications Trademark applications Design applications	Intellectual property regulation and incentives	Low to medium	Short to medium term
Employment in knowledge-intensive activities Employment in innovative firms	Tax relief for individuals supporting R&D and innovation	Low to medium	Short to medium term
Medium and high-tech goods exports Knowledge-intensive services exports Sales of product innovations	Technology extension and business advisory services	Low to medium	Short to medium term
Resource productivity Air emissions by fine particulates Development of environment-related technologies	Loans and credits for innovation in firms Technology extension and business advisory services	Medium to high	Medium to long term

Source: Revised version of table 3 in Cvijanović and Reid (2018).

21.4 CONCLUSION

The EIS is a well-known example of many innovation scoreboards that try to measure the performance and development of national innovation systems. The history of the EIS dates back more than 20 years and over time the measurement framework has been revised several times, with the most recent revision in 2021. Each revision has benefited from increasing knowledge about the innovation process and inputs from stakeholders, both academics and policy makers. The latest 2021 edition of the EIS considers the important and increasing role of digitalization in businesses and societies at large. The EIS 2021 also pays special attention to the growing awareness of the role innovation could play in reducing environmental impacts. The aggregate and more detailed results in the EIS can be used to analyse national innovation systems and, to a lesser extent, to evaluate the impact of innovation policies. Despite the progress made since the first EIS in 2001, more and better data are needed, in particular to measure the impact of innovation on the economy and on people's wellbeing. Further revisions of the measurement framework are needed, and more emphasis should be placed on improving the timeliness of the available data.

NOTES

1. Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom.
2. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:EU_2020_Strategy. Accessed 25 October 2021.
3. Survey of ICT Usage and E-commerce in Enterprises, respectively, Survey on the ICT usage in households and by individuals.
4. The Eurostat-OECD statistical definition of ICT specialists is based on the International Standards Classification of Occupations (ISCO) 2008 and includes the following occupations: *ICT managers, professional and associate professional occupations*: 133 ICT Service managers, 251 Software and multimedia developers and analysts, 252 Database specialists and systems administrators, 351 ICT operations and user support technicians, 352 Communications technicians; *Other groups that are primarily involved in the production of ICT goods and services*: 2,152 Electronic engineers, 2,153 Telecommunication engineers, 2,166 Graphic and multimedia designers, 2,356 Information technology trainers, 2,434 ICT sales professionals, 3,114 Electronics engineering technicians, 7,421 Electronics mechanics and servicers, 7,422 ICT installers and servicers.
5. Exports of medium and high-tech goods are defined as the sum of exports in the following SITC Rev. 4 (Standard International Trade Classification) 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.
6. Exports of knowledge-intensive services are 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) and SK1 (Audio-visual and related services).
7. 'The European Statistical System (ESS) is the partnership between the Community statistical authority, which is the Commission (Eurostat), and the national statistical institutes (NSIs) and other national authorities responsible in each Member State for the development, production and dissemination of European statistics. This Partnership also includes the EEA and EFTA countries. Member States collect data and compile statistics for national and EU purposes.' See https://ec.europa.eu/eurostat/web/european-statistical-system. Accessed 25 October 2021.

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