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Tracking country innovation performance: The Innovation Output Indicator 2022

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Contents

Abstract

This report presents the 2022 results of the Innovation Output Indicator (IOI), which is a composite indicator published by the European Commission since 2013 to offer an output-oriented measure of innovation performance at the country and EU levels and measure countries' capacity to derive economic benefits from innovation. This edition is based on a revised methodological framework and structure of the index, which aimed at improving the statistical properties of the index and aligning it with the new policy priorities set by the Commission.

The report presents the latest figures for the composite index and its underlying indicators for 44 countries, including European Union (EU) Member States (MSs) and selected EFTA, OECD and emerging economies. According to the IOI, Sweden and Germany are the best performers in the EU and are followed by Finland, Ireland and Belgium. Germany outperforms the other EU countries in the domestic value added content of its knowledge-intensive manufacturing exports, whereas Sweden is very strong in terms of IP applications. Conversely, Romania, Latvia and Bulgaria reported the lowest performance among EU countries. The EU, as a single block, leads New Zealand, China, Australia and Brazil, but it still lags behind its main competitors, including United States, South Korea and Japan.

IOI findings are complemented by an analysis of EU radical innovator and exporter companies, referred to as "global innovation champions" (GICs), and of innovative startups and scaleups, which is based on recent waves of the Eurostat Community Innovation Survey. The aim of this section of the report is to examine the characteristics of these types of firms, which are important drivers of innovation and economic growth, and contribute to understanding what sets them apart from other firms.

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1 Introduction

The Innovation Output Indicator (IOI) is a composite indicator, which has been used by the European Commission since 2013. Its objective is to support policy makers by offering an output-oriented measure of innovation performance at the country and EU levels and measure countries' capacity to derive economic benefits from innovation. It complements other benchmarking tools, as for example, the European Innovation Scoreboard. The IOI measurement framework was introduced in the 2013 Communication and Staff Working Document (European Commission, 2013) and further refined in 2014, 2016, 2017 and 2023.

This report, which illustrates the latest results of the IOI, is the first edition published using the 2023 methodological framework and structure of the index. The revision process included a number of virtual workshops attended by staff within the Commission and experts from other international organisations and academia, which aimed at improving the statistical properties of the IOI and aligning it with the new policy priorities set by the organisation. It resulted in improvements of existing components, including the identification of new indicators to better capture the technological capacity of countries, reflect innovation outside the manufacturing sector and take a step away from a high-tech view of innovation. This version also includes an extension of country coverage to 44 economies, including EU Member States and selected benchmark countries.

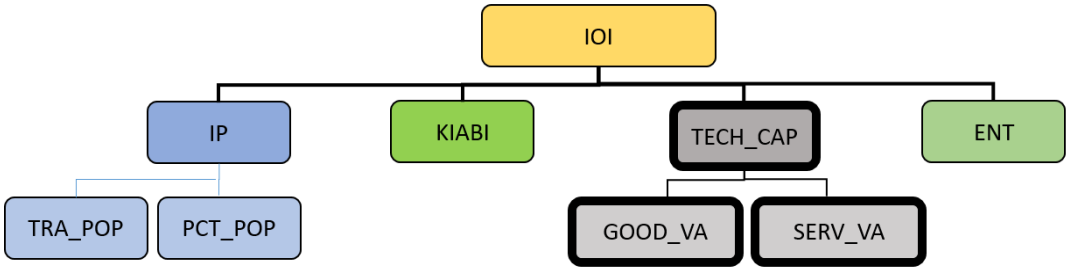
Besides the IOI, this report also contains information on the country context in the form of the Global innovation Champions and the Startup and Scaleup sections. These provide further data and analysis that compliments the IOI. Because most data in this report refers to 2020 or earlier, the initial impact of the Covid-19 pandemic is only partly captured and mainly for those countries that were affected first. The implications of the pandemic for country innovation performance will be more visible in future editions of this report when all components will cover data from 2021 and onwards.

The report is structured as follows. The next section presents the new structure of the IOI. Section 3 discusses country performance in terms of the composite score, both when comparing EU Member States with one another and when comparing the EU as a whole with other benchmark countries, and in relation to each IOI component. Section 4 includes a short description of contextual indicators to help understand performance differences across countries and the analysis of radical innovators and startup and scaleup enterprises in the EU. Section 5 concludes. The description of the dataset and the methods applied to compute the aggregate measures, alongside the description of a series of robustness and sensitivity tests of the IOI to the methodological choices are provided in Annex 1 and Annex 2.

2 Measuring country innovation performance: The IOI

The Innovation Output Index includes four components, which are depicted in **Figure 1** and are described in more detail in Annex 5.

Figure 1 The Innovation Output Indicator Framework



The IP component, namely Intellectual Property (*IP*), aims to capture the innovation outputs of a country. It consists of two sub-components receiving equal weights and include: the number of Patent Cooperation Treaty applications (*PCT_POP*) and the number of trademark classes in total resident trademark applications[1] (*TRA_POP*), each denominated by population (in millions)[2].

The first sub-component relies on patent data. The use of patent information as a proxy of innovation output is very common in the innovation literature (Maurseth & Verspagen, 2002; Barzotto et al., 2019; Corradini et al., 2021) as it can reflect the inventive performance of countries or firms. However, as known, patent data have a number of drawbacks and may not fully capture the whole set of innovation activities. Not all inventions, for instance, are patentable since they may not meet the patentability criteria (Choi et al., 2007, Dernis et al., 2001) or some organisations may prefer other mechanisms to protect their technologies (e.g., secrecy) (OECD, 2009). The limitations of patent data as a measure of innovation outputs are particularly evident in sectors with low propensities to patent, such as services (Scherer, 1983; Arundel and Kabla, 1998; Brouwer and Kleinknecht, 1999). With a view to bring another light on innovation, which is less focused on the technological side, the 2023 revision process of the IOI resulted in the inclusion of trademark data in the index. Trademarks have been shown to convey information on non-technological innovations (Mendonça et al., 2004; Millot 2009), such as innovation in services or marketing innovation, as well as to better capture innovation in SMEs than traditional innovation indicators (Mendonça et al., 2004).

The second component, *KIABI*, measures the number of persons employed in knowledge-intensive business industries within total employment. It aims to capture the structural orientation of the business economy towards knowledge intensive activities. This component has remained unchanged as compared to the previous edition of the IOI (Vertesy and Damioli, 2020).

The third component, *TECH_CAP*, aims to capture the contribution of domestic technology capacity to the production and trade of knowledge-intensive manufacturing and service sectors. It is composed of two sub-components: domestic value added content of medium-high and high-tech manufacturing exports as a share of total manufacturing exports (*GOOD_VA*), and domestic value added content of knowledge-intensive service exports as a share of total service exports (*SERV_VA*). This indicator replaces the component on the

[1] A trademark application is filed by an applicant who can be resident or non-resident in the country of application. For example, a Belgian resident may want to protect their trademark in Germany (non-resident application). Each trademark application can cover multiple goods and services which are categorized into classes. Trademark classes are designed for international comparison and therefore suitable for the IOI.

[2] Previous versions of the IOI used GDP to denominate PCT patents. During construction of the current IOI, the CC-COIN team found that dividing trademarks and PCT patents by GDP created highly skewed data and low correlations that would hamper the ability of the IOI to summarise information. Therefore it was decided to switch to denominating IP indicators by population which creates indicators with more desirable statistical properties.

competitiveness of knowledge-intensive goods and services (*COMP*)[3], used in previous editions of the IOI. The COMP indicator was adopted in the IOI to measure the technological competitiveness of countries, i.e. their ability to commercialize the results of research and development (R&D) and innovation in international markets. It also reflects specialization in medium- and high-technology products, which have been found to be positively associated with economic growth, productivity and welfare, as well as with high value-added and well-paid employment (e.g. Hausmann et al 2007, Yoo 2008, Falk 2009). The COMP indicator is based on data on gross exports. The increasing importance of global value chains, however, has highlighted the limitations of these traditional measures of trade, which record flows of good and services every time they cross borders and can lead to double counting and misguided policy decisions (OECD, 2013). In addition, it has been noted that gross trade figures often fail to differentiate between exports that entail the contribution of domestic technology capacity and those that are the results, for instance, of mere imported components assembling. On the contrary, the *TECHCAP* indicator makes use of trade in value added data[4], which measures flows related to the value that is added by a country in the production of any good or service that is exported (OECD, 2013). A higher value in *TECHCAP* indicates a more important contribution of the country to the exports of knowledge-intensive goods or services and a lower foreign content of the country's exports in these industries.

The fourth and last component of the IOI is *ENT,* which is the share of innovation-active firms on the total number of firms. The aim of this indicator is to capture both product and business process innovations (i.e., process, marketing and organisation innovation), as well as to reflect innovation activities in all sectors, including those that are less knowledge-intensive industries, which are not captured in the KIABI or TECH_CAP components.

[3] It consists of two sub-components, the share of medium and high-tech goods in total exports (GOOD) and the share of knowledge-intensive services in the total service exports (SERV).

[4] https://www.oecd.org/sti/ind/measuring-trade-in-value-added.htm

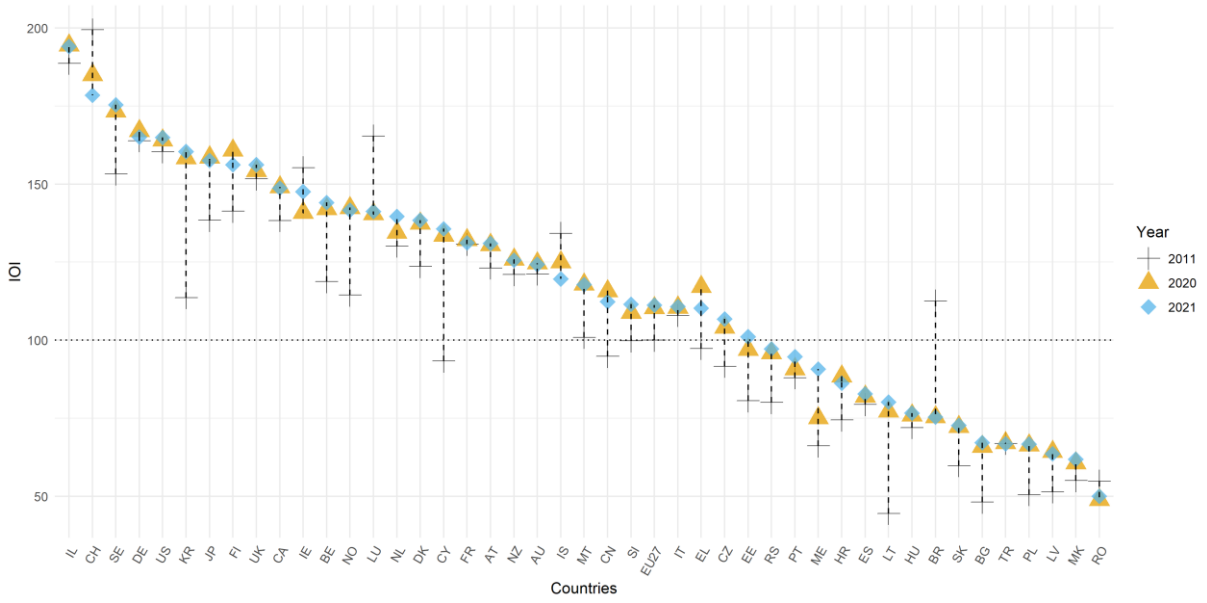
3 Results of the IOI 2022

3.1 Country performance in composite scores

This section describes the IOI 2022 scores obtained from the aggregation. Figure 2 shows IOI scores in 2011, 2020 and 2021 for EU MSs, the EU27 average and a selection of extra-EU countries. IOI scores are normalized as to benchmark the EU27 to 100 in 2011. Following an approach developed in previous IOI editions, **Figure 2** presents the EU27 aggregate constructed including both intra-EU and extra-EU trade (measured in the GOOD_VA and SERV_VA indicators). This measure is suitable to compare EU Member States with the EU average, while a different EU27 benchmark, which excludes intra-EU trade, will be used to compare scores of the EU as a single entity with non-EU countries.

Israel has the largest IOI score among the countries in the sample in 2021, followed by Switzerland. Among EU Member States, Sweden and Germany are the best performers. Finland, Ireland and Belgium are other EU good performers, though they rank after the United States, Korea and Japan. On the opposite side of the ranking, there are Romania, Latvia, Poland and Bulgaria, and, among non/EU countries, North Macedonia and Turkey.

Figure 2 IOI scores normalized to the EU27 Average in 2011.



Source: Authors' calculation.

The trends across the 2011-2021 decade[5] show some signs of convergence across low and high performing countries. In fact, the average IOI scores' increase is larger for countries below than for countries above the 2011 IOI median score. In particular, considering all 44 countries, the average 2011-2021 absolute (relative to the international EU 2011 score) IOI change is 4.3 (3.7%) for countries above the median 2011 IOI score, and 13.8 (19.2%) for countries below such threshold (the simple average of IOI change across countries is 9.7 in absolute terms and 12.5% in relative ones). Focusing on EU Member States, the average 2011-2021 absolute (relative) IOI change is 7.4 (6.5%) for Member States above the median 2011 IOI score (which is represented by Greece, showing an IOI absolute increase equal to 13 and a relative one equal to 13.4%), and 14.5 (22.3%) for Member States below the median, while the simple average of IOI change across EU member States is 11.4 in absolute terms and 15.4% in relative ones. The largest improvements are observed in South Korea, Cyprus and Lithuania, as well as, though to a lower extent, in Sweden, Japan, Finland, Belgium, Norway, China, Malta, Estonia, Serbia, Montenegro, Bulgaria and Poland. By contrast, IOI scores experienced a fall in a minority of

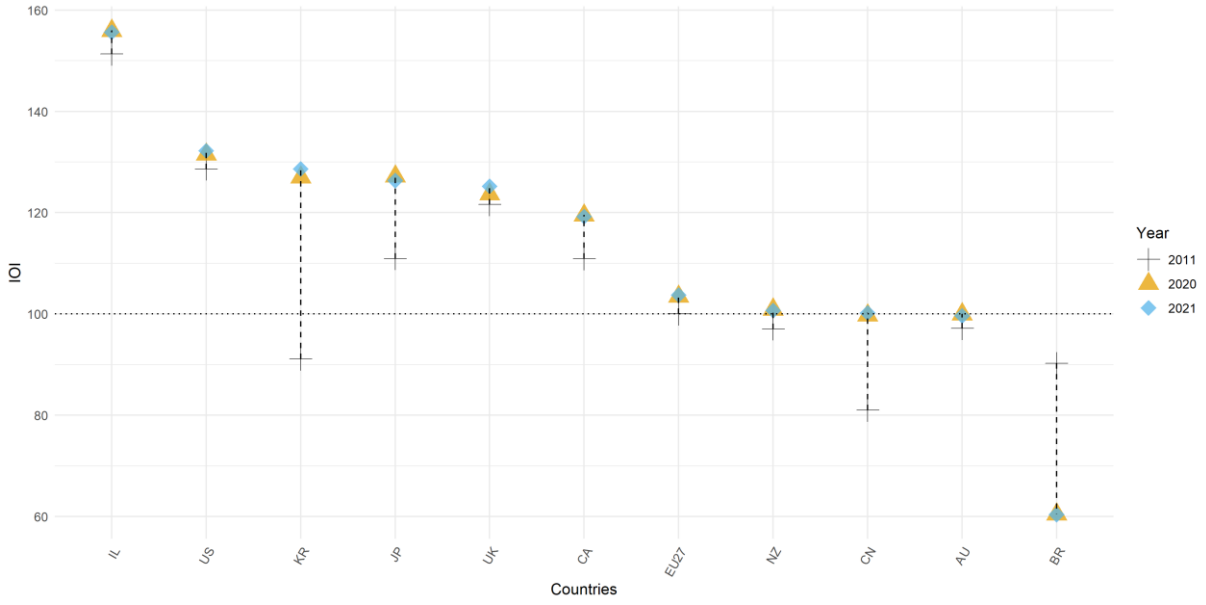
[5] Given the number of methodological changes performed across the different editions of the IOI (including the present one), the comparison of changes across years should be based on this version, which backdated IOI scores using the current methodology up to 2011, rather than using the current version of previous IOI editions.

countries, particularly marked in Switzerland, Luxembourg and Brazil, and more nuanced in Ireland, Iceland and Romania.

Figure 3 compares the EU aggregate performance with selected non-European countries using a slightly modified index, which uses GOOD_VA and SERV_VA figures that characterize the EU as a block by excluding intra-EU trade.[6] IOI scores are provided for 2011, 2020 and 2021. In 2021, Israel leads the international scene, followed by a group of countries with similar IOI scores including the United States, South Korea, Japan and the United Kingdom. The EU27 as a single block leads a group of following countries, which include New Zealand, China and Australia. Brazil is more distanced with the worse rank among selected countries. Looking at trends in the 2011-2021 period, South Korea shows the largest improvement, and the other considered Asian countries (Japan and China) smaller but significant improvements. By contrast, Brazil showed a marked decline, while the other countries, including the EU27, had limited changes in the same period.

It is important to keep in mind that performance scores for non-EU countries should be read with caution. Differences in industrial classification and coverage may imply that KIABI scores are not fully comparable. Moreover, the presence of missing indicators is more pronounced for non-European countries, in particular for Montenegro (with missing GOOD_VA, SERV_VA and ENT) and North Macedonia (TRA, GOOD_VA and SERV_VA). For comparisons across time, differences in data source (OECD, Eurostat and National Offices) within the same country are present in a few countries for ENT (Switzerland, Sweden, United Kingdom) and KIABI (South Korea, United Kingdom, United States).

Figure 3 Comparison with world / bench mark countries: IOI score normalized to the EU27 International score in 2011.



Source: Authors' calculation.

3.2 Analysis by indicator

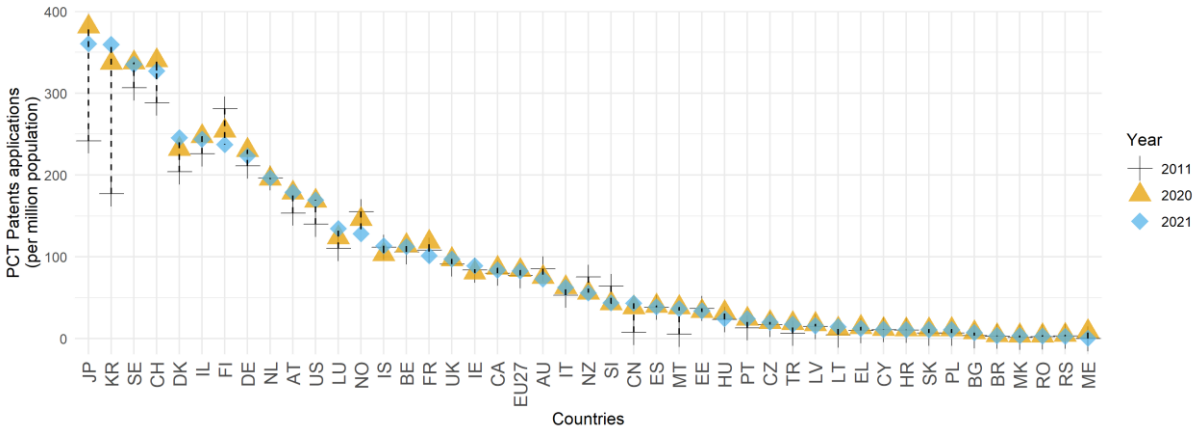
The IOI scores can serve as an entry point to examine the performance and trends at the level of indicators. This sub-section analyses countries' performance and changes over time for each IOI component.

Figure 4 shows per-capita PCT patent applications (PCT_POP) in 2011, 2020 and 2021 for all countries covered in the analysis. Japan, South Korea, Sweden and Switzerland are leading the 2021 ranking, while a large number of countries exhibits a particularly low performance, with Brazil, North Macedonia, Romania, Serbia and Montenegro being at the bottom of the distribution with nearly no PCT patent applications (per million in

[6] Following an approach developed in previous IOI editions, Figure 2 presents the EU27 aggregate constructed including both intra-EU and extra-EU trade (measured in the GOOD_VA and SERV_VA indicators), making it suitable to compare EU Member States with the EU average. Figure 3, by contrast, provides a different EU27 benchmark, which excludes intra-EU trade, making it suitable to compare scores of the EU as a single entity with non-EU countries.

population). As for changes, large improvements between 2011 and 2021 are observed in South Korea and Japan, and milder ones in Switzerland, Sweden, China and Malta. In the other countries, changes over time were very limited. Several countries experienced a decrease in PCT patent applications per capita including Finland, Norway, Austria, New Zealand and Slovenia.

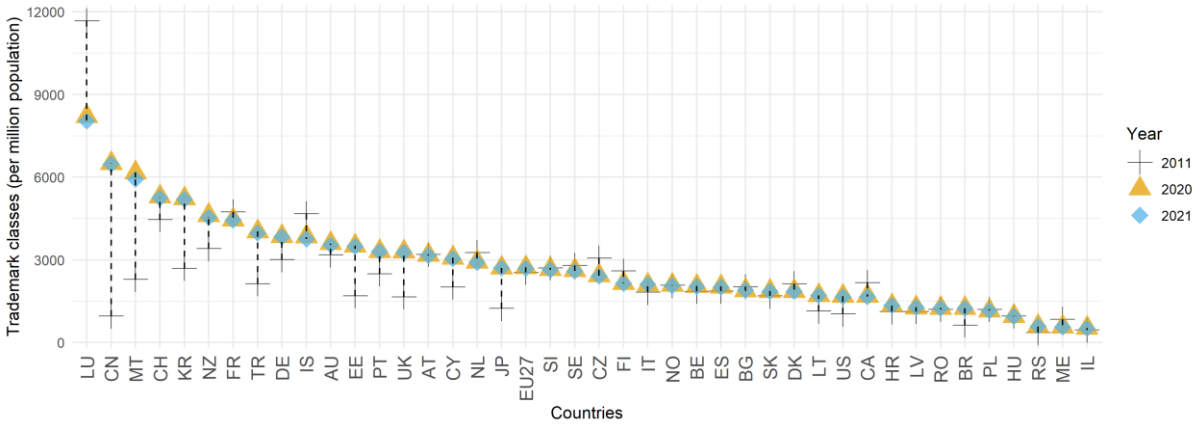
Figure 4 Number of patent applications filed under the Patent Cooperation Treaty per million in population (PCT_POP)



Source: See Annex 5. *Note:* Years refer to the IOI reference period and correspond to 2-year shift relative to patent priority years (See Annex 4 for more details)

Figure 5 shows the number of trademark classes[7] of resident applications per capita (TRA_POP) in 2011, 2020 and 2021 across countries, with the exception of Greece, Ireland and North Macedonia for which this indicator is not available[8]. Despite its marked fall since 2011, Luxembourg continues to lead the ranking in 2021, followed by China and Malta, which by contrast experienced the largest improvements in the 2010-2021 decade. These scores can indicate the top performance of these countries in less technological innovation, but can as well be linked to the presence of more favourable IPR-related regulations and procedures in these countries. At the opposite side of the 2021 ranking, Serbia, North Macedonia and Israel show the lowest performance. South Korea, Turkey, Estonia, the UK and Japan experienced marked improvements over time, though smaller than those observed in China and Malta.

Figure 5 Number of trademark classes of resident applications per million in population (TRA_POP)



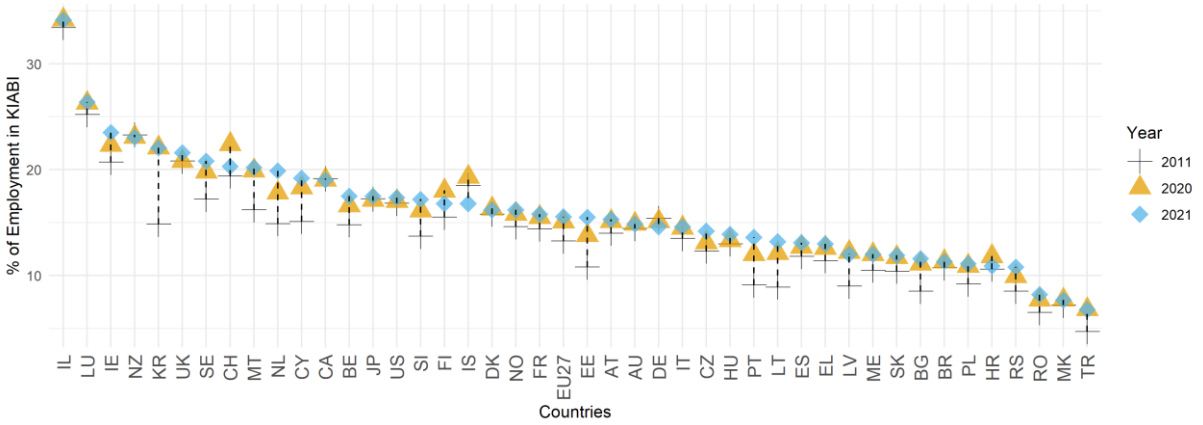
Source: See Annex 5. *Note:* Years refer to the IOI reference period and correspond to 1-year shift relative to the actual year (See Annex 4 for more details)

[7] Trademarks are registered with specific class codes – one for each type of product or service the trademark applies to. A single trademark application can cover many trademark classes.

[8] Annex 1 describes how data is imputed to build the final IOI for these countries.

Figure 6 shows the percentage of employment working in knowledge-intensive activities and business industries (KIABI) in 2011, 2020 and 2021 except for China for which this indicator is not available. Israel has the best performance in 2021 (as well as in 2011 and 2020), followed at a large distance by Luxembourg, Ireland and New Zealand, indicating the importance of knowledge-intensive sectors for these economies. Romania, North Macedonia and Turkey are, by contrast, the worst performers in 2021. As for changes, South Korea showed the strongest improvement since 2011, while a large number of countries exhibited more moderate ones, including: Sweden, Malta, the Netherlands, Cyprus, Belgium, Slovenia, Estonia, Portugal, Lithuania, Latvia, Bulgaria and Turkey. Iceland is the only country to show a worsening of the indicator since 2011.

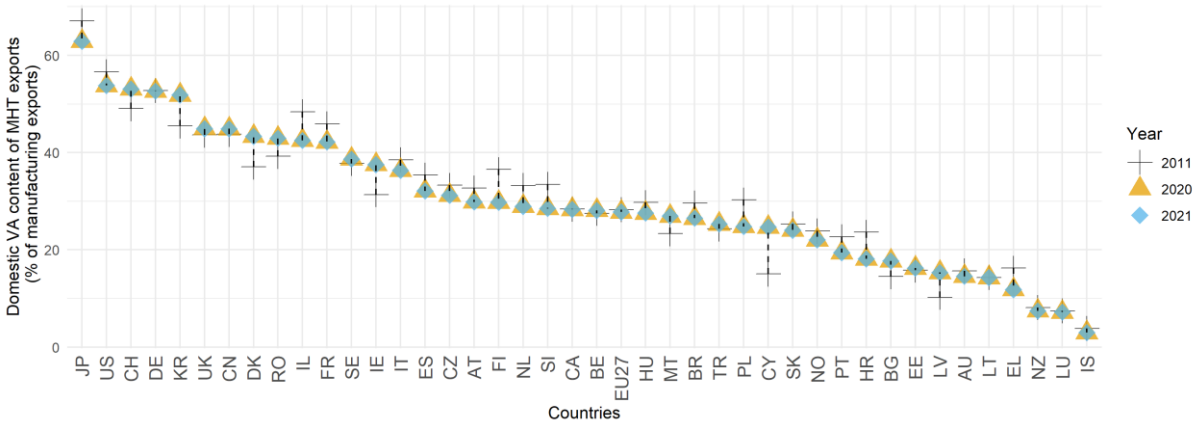
Figure 6 Employment in knowledge intensive activities and business industries (KIABI) as percentage of total employment



Source: See Annex 5. *Note:* Years refer to the IOI reference period, which corresponds to the indicator's actual year (See Annex 4 for more details)

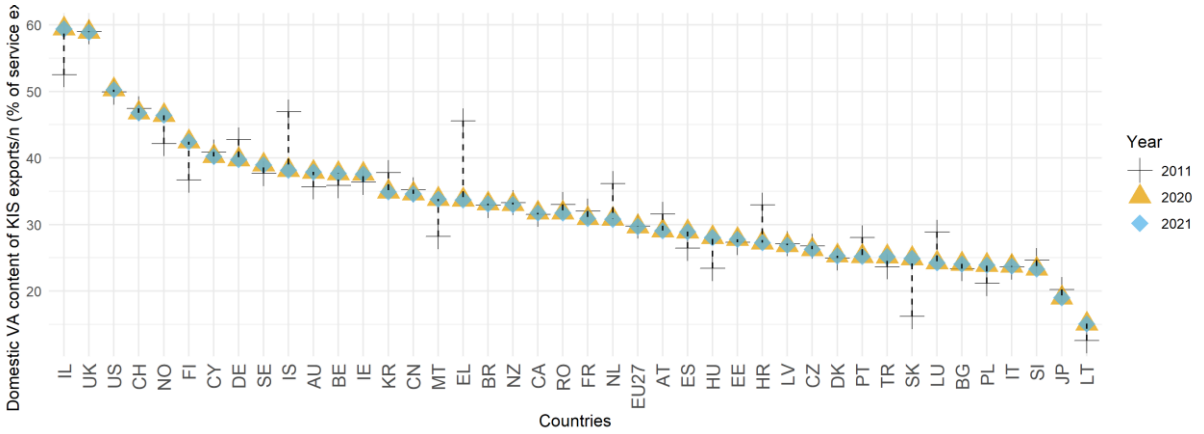
Figure 7 and **Figure 8** show the domestic value added content of exports in 2011, 2020 and 2021, respectively in high and medium-high technology manufacturing (as a percentage of total manufacturing exports) and knowledge-intensive service industries (as a percentage of total service exports). Data on these indicators are not available for Montenegro, North Macedonia and Serbia. The best 2021 performances in manufacturing are observed in Japan, followed by the United States, Switzerland, Germany and South Korea, while those in services are in Israel and the United Kingdom. This reveals the greater competitiveness of these countries and their lower dependency on foreign inputs in knowledge-intensive exports. On the opposite side of 2021 distribution, New Zealand, Luxembourg and Iceland are the worst performers in exports of manufacturing industries, Japan and Lithuania in those of services industries. Over time changes since 2011 are more marked in services than manufacturing industries, with Cyprus showing the strongest improvements in manufacturing industries, Slovakia, Israel, Malta and Finland in services ones. A marked worsening of the performance in services since 2011 is observed in Greece, Iceland, the Netherlands, Croatia and Luxembourg.

Figure 7 Domestic value added content of exports in high and medium-high technology manufacturing (MHT) industries as percentage of total manufacturing exports



Source: See Annex 5. *Note:* Years refer to the IOI reference period and correspond to 3-year shift relative to the actual year (See Annex 4 for more details)

Figure 8 Domestic value added content of exports in knowledge-intensive service industries as percentage of total service exports

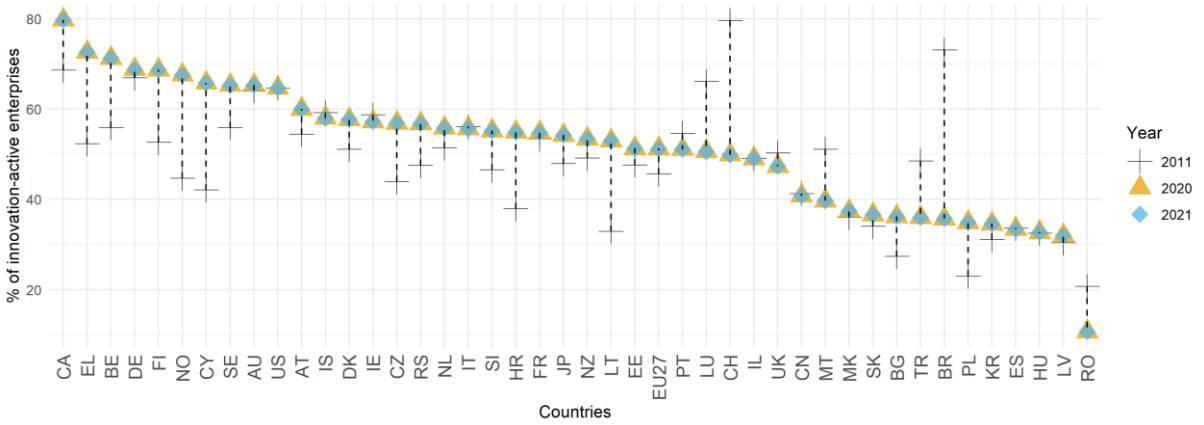


Source: See Annex 5. *Note:* Years refer to the IOI reference period and correspond to 3-year shift relative to the actual year (See Annex 4 for more details)

Figure 9 shows the percentage of innovative-active enterprises in 2011, 2020 and 2021, with the exception of Montenegro for which this indicator is not available. Canada exhibits the best performance in 2021, followed by Greece and Belgium, while Romania shows the worst performance. This indicator shows the largest time changes over the 2011-2021 as compared to other indicators, reflecting the large temporal volatility of business dynamism, but also possible methodological changes in national surveys. Large improvements are observed in Cyprus, Norway, Lithuania, Greece, Belgium, Finland, Croatia and Poland. The largest falls, by

contrast, are observed in Brazil and Switzerland[9], and less prominent though still marked changes in Luxembourg, Malta, Turkey and Romania.

Figure 9 Percentage of innovation-active enterprises as percentage of all enterprises



Source: See Annex 5. *Note:* Years refer to the IOI reference period and correspond to 1-year shift relative to the actual year (See Annex 4 for more details)

The analysis of performance and change over time of the different IOI components has shown the high heterogeneity in the contribution of the various dimensions of innovation to the overall ranking.

Within the EU, PCT patent applications drive the top performance of Sweden, the value added content of exports in high and medium-high tech manufacturing explains that of Germany, employment in knowledge-intensive activities and business industries drives the top performance of Ireland, the share of innovative enterprises drives that of Belgium, while a mix of good performances in exports in knowledge-intensive services and share of innovative enterprises explains the top performance of Finland.

A similar degree of variety is observed for extra-EU countries. A mix of good performances in employment in knowledge-intensive activities and business industries and value added content of exports in knowledge-intensive services is driving the ranking of Israel, which is the best IOI performer in 2021. A mix of good performances in PCT patent applications and value added content of exports in high and medium-high tech manufacturing drives the performance of Japan, South Korea and Switzerland. The value added content of exports in high and medium-high tech manufacturing explains the high ranks of the United States.

As for changes over time, PCT patent applications particularly contributed to the IOI improvement of Asian countries (China, Japan and South Korea), while employment in knowledge-intensive activities and business industries and/or the share of innovative enterprises contributed to the improvements of many EU Member States (Cyprus, Lithuania, Sweden, Finland, Belgium, Malta, Estonia, Bulgaria and Poland) as well as to the worsening of Ireland and Romania.

[9] Particular caution should be taken for the assessment of the time change Switzerland given the discontinuity of the used data source within the time series, with the indicator falling from 72% in 2016 to 50% in 2017 when moving from the OECD to the Eurostat data source.

4 Contextual Analysis

4.1 Macro-economic context

A set of contextual indicators is provided in Annex 6 to better understand differences across EU countries in relation to the IOI, as well as to its single components. The selected indicators refer to the following macro-economic dimensions: economic performance, structure of the economy, entrepreneurship and innovation.

The best performing countries in the IOI, namely Sweden, Germany, Finland, Ireland and Belgium, were also among the best performers in terms of GDP per capita (see **Table 10** in Annex 6) in 2021, confirming the positive link between innovation and economic performance. They, however, differ in terms of structural orientation of their economy. Manufacturing, for instance, is more important for the German economy than it is for the Swedish or Belgian economy, which are more service-oriented. Romania, which is at the bottom of the IOI ranking, is the EU country with the lowest share of employment generated in the service sector.

Enterprises' birth rates are also quite heterogeneous across EU countries. In 2020, they ranged from 4.6% in Greece, 5.4% in Austria and 6.5% in Italy to 14.1% in Malta and 18.1% in Lithuania. Among the four top innovators, as measured by the IOI, only Finland performed close to the EU average (nearly 9%), whereas the other three countries reported lower birth rates. Over the past years, there has been a steady decline in business dynamics in the EU, raising concerns about the implications for innovation. As shown in the Annex 6 (**Table 12**), birth rates have declined in 20 out of the 27 EU countries over the period 2011-2020. This decline is documented if enterprises' births are measured as a share of the total number of active firms or as a share of total employment. Several factors, including the demographic factors, the reduction in knowledge diffusion, the combination of increasing mark-ups and changes in market structure, and the Covid-19 pandemic in recent years, can explain this decline (European Commission, 2022).

Finally, fast-growing enterprises can also be a key driver of economic growth and knowledge creation. In this regard, the EU has been found to lag behind its main international competitors (European Commission, 2021). Fast-growing enterprises only represent 13% of EU total employment, although large differences exist across countries. The share of fast-growing enterprises ranged from nearly 3% in Cyprus to around 25% in Ireland and Greece in 2020. Section 4.3 discuss the characteristics of innovative startups and scaleups in the EU.

Box 1: Assessing the impact of the COVID-19 pandemic crisis on innovation

The COVID-19 pandemic crisis has largely disrupted the business environment, as well as the functioning of the science and innovation systems. R&D investment (PPS, in constant prices), which tends to be pro-cyclical, declined by 2% in 2020, whereas the share of R&D expenditure on GDP increased by nearly 3.6%, mainly due to a stronger drop in GDP (by nearly 4%) in the same year (Eurostat, accessed on 7th March 2023). The impact of the crisis on R&D, however, largely varied across sectors. R&D investments, for instance, increased in health and ICT while it decreased in the automotive industry (European Commission, 2022). Preliminary data also seems to point to a decline in the competitiveness of EU knowledge-intensive exports. The share of medium and high-tech products exports declined by 3.4% in 2021 (**Table 11** in Annex 6), which is the highest drop in the last 10 years. Similarly, the share of these sectors in total employment declined by nearly 2%.

Finally, the crisis also affected business dynamics in the EU with the employment share of enterprises' births and that of fast-growing enterprises declining by 15% and 19%, respectively, in 2020 (**Table 12** in Annex 6).

However, the effects of the pandemic crisis on countries' innovation performance is not yet captured in the IOI. Out of its six indicators, only two indicators, namely employment in knowledge intensive activities and business industries (KIABI) and number of trademark classes of resident applications (TRA_POP)[10], refer to the pandemic period. In 2021, the employment share of knowledge-intensive activities and business industries only declined in five EU countries, with the largest drop being recorded in Hungary (13%) and Finland (9%). In 2021 and 2020, the number of trademark classes of resident applications per million population declined in more than ten countries, compared to the previous year. As trademark figures tend to fluctuate, it is not yet possible to link these changes to the impact of COVID-19 pandemics.

[10] The impact of the pandemic is hard to measure by the ENT indicator as the reference period of the latter covers the years from 2018 to 2020.

4.2 Global Innovation Champions

This section presents evidence on European global innovation champions (GICs) to add contextual information to the IOI on the European innovation scene. The GICs, term first introduced in the IOI 2019 report, are defined as exporters that have introduced a 'world first' product innovation. Radical innovators are important for shaping the direction of technological change as well as for job creation (Pianta, 2003; Lucchese and Pianta, 2012). While there is a rich body of literature on the innovative and economic performance of large corporations that account for the bulk of business R&D expenditures (see e.g. Montresor and Vezzani 2015, Bogliacino 2014, Ortega-Argilés et al. 2009), evidence on the small- or medium-sized radical innovator enterprises in Europe is still limited. Yet, analysis of Community Innovation Survey 2014 data shows that about half of European GICs are small- or medium-sized enterprises (SMEs) that are not part of a corporate group (Vertesy and Damioli, 2019). This suggests a similarity with "hidden champions", a term introduced by Simon (1996) to describe highly-specialized SME world leaders in a niche market, which have been the object of substantial research (e.g. Audretsch et al. 2018, Witt and Carr 2013, Simon 2009, Fryges 2006). In particular, analogously to "hidden champions", GICs might have specific strategies and behaviours that may easily fall under the radar in spite of their relevance for policy.

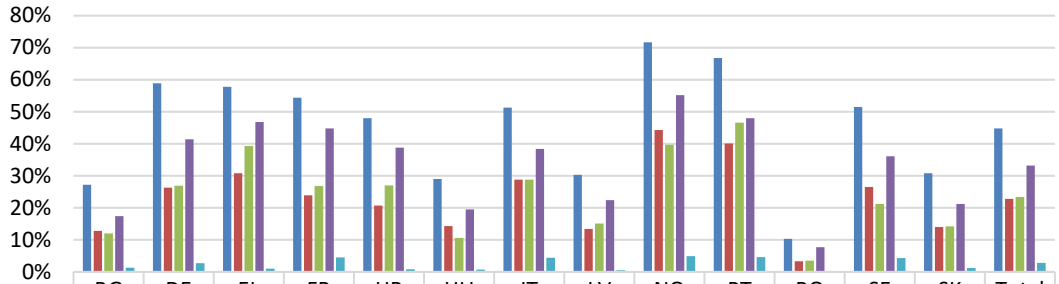
The analysis characterises the prevalence and features of GICs in the business economy of 12 EU Member States and Norway, for whom micro data was accessible , and describes their export performances and IPR-related behaviours using as a benchmark active innovator companies that had not introduced any 'world first' product innovations. It exploits company-level information from a recent wave of the Community Innovation Survey (CIS2016 microdata safe centre files[11]).

Figure 10 shows the percentage of enterprises that are innovation-active, product innovators, process innovators, market and or organizational innovators and/or global innovation champions. There is a large variety across countries in the percentage of firms that are active innovators, from 10% in Romania up to 72% in Norway. On average, just under half of enterprises (45%) in the CIS 2016 are innovation-active.

Organizational and marketing innovators are most common type of innovation, being reported by 33% of enterprises on average. Product and process innovations are reported less (23% on average) than other innovation activities. Only 23% of enterprises on average report product or process innovations. However, differences between countries are marked. In some countries, in particular in Greece, Italy, Norway, Portugal and Sweden, product innovators account for more than half of the innovative active enterprises. As one can expect given their definition, which aim to identify some of the most innovative among international active product innovators, the GICs are a tiny share of enterprises in all countries, ranging from less than 2% in Eastern European Member States and Greece to 5% in France, Portugal and Norway.

[11] Data from the Community Innovation Survey 2018 and 2020 could not be used for the analysis as the question on "world first" innovation is no longer included in the questionnaire.

Figure 10: Percentage of all enterprises reporting an innovation



	BG	DE	EL	FR	HR	HU	IT	LV	NO	PT	RO	SE	SK	Total
Active	27%	59%	58%	54%	48%	29%	51%	30%	72%	67%	10%	52%	31%	45%
Product	13%	26%	31%	24%	21%	14%	29%	13%	44%	40%	3%	27%	14%	23%
Process	12%	27%	39%	27%	27%	11%	29%	15%	40%	47%	4%	21%	14%	23%
Org./Mrkt.	17%	41%	47%	45%	39%	20%	38%	22%	55%	48%	8%	36%	21%	33%
GIC	1%	3%	1%	5%	1%	1%	4%	1%	5%	5%	0%	4%	1%	3%

Source: Eurostat's Community Innovation Survey 2016.

Table 1 shows the correlations between the indicators of global innovation championship and different indicators of innovation (product, process, marketing/organizational). These correlations show that most innovating firms are not global innovation champions. All in all, GICs seem to constitute a phenomenon relatively separate from other innovation activities, being their correlation with other types of innovation lower (raging between 0.18 and 0.34) than the correlations between the other types of innovation shown in Table 1 (ranging between 0.47 and 0.77).

Table 1. Correlations between Global Innovator Championships and innovation indicators.

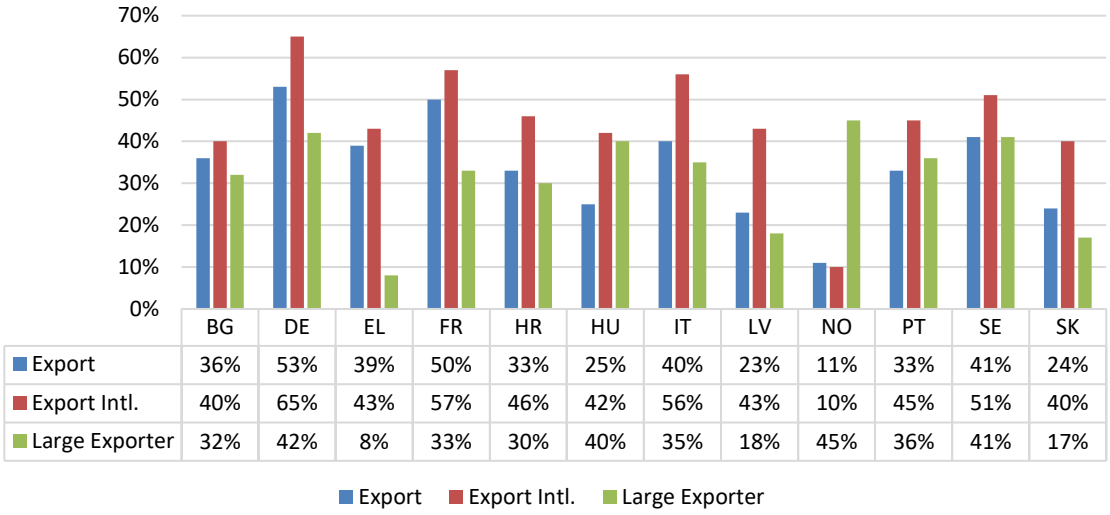
	1	2	3	4	5
GICs	1.00	0.21	0.34	0.21	0.18
Innovation-active		1.00	0.63	0.62	0.77
Product			1.00	0.54	0.47
Process				1.00	0.48
Marketing or Organisational					1.00

Note: all correlations are significant at $p < 0.001$

Figure 11 shows the percentage point difference between GICs and innovation-active-enterprises who export (within or outside the EU market), export internationally (outside the EU) and enterprises whose largest market share is outside the national borders. Thus, the higher the bar the lower the percentage of innovation active enterprises who export. For example, the share of Bulgarian innovation-active enterprises that export is lower than that of GICs by 36 percentage points, meaning 64% of innovative active enterprises export in Bulgaria. In Norway, innovation active enterprises are more similar to GICs in exporting and international exporting.

In all countries the share of GICs who export, export internationally and whose largest market share is outside the national borders is higher compared to other innovation active enterprises. Thus, the GICs are substantively more export oriented. The percentage point difference is largest in Germany, France, Italy and Sweden (at least 40%) and lower in Norway, Hungary, Latvia, and Slovakia (25% of less). As the definition of GICs includes exportation, these figures indicate that other innovation active enterprises in the high percentage point countries export relatively little compared to countries with a lower percentage point difference.

Figure 11: Percentage point difference between GICs and other innovation active enterprises in exporting



	BG	DE	EL	FR	HR	HU	IT	LV	NO	PT	SE	SK
Export	36%	53%	39%	50%	33%	25%	40%	23%	11%	33%	41%	24%
Export Intl.	40%	65%	43%	57%	46%	42%	56%	43%	10%	45%	51%	40%
Large Exporter	32%	42%	8%	33%	30%	40%	35%	18%	45%	36%	41%	17%

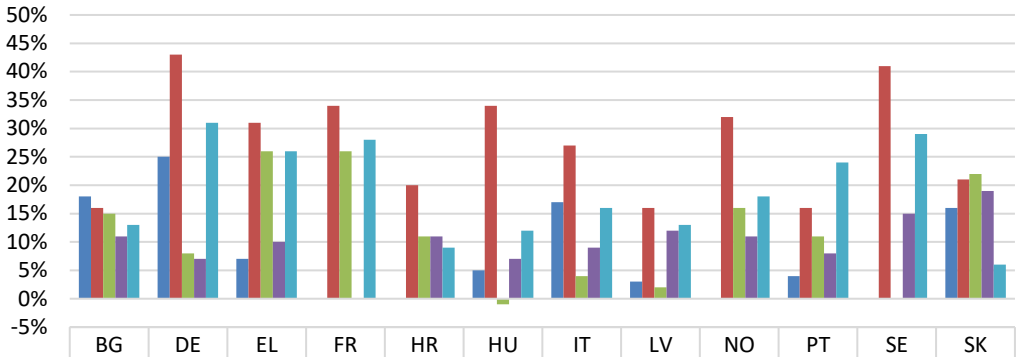
Source: Eurostat's Community Innovation Survey 2016.
Note: "Export" refers to the share of firms that export. "Export Intl." refers to the share of firms that export outside the EU. "Large Exporter" is the share of firms whose largest market share is outside the national borders.

Figure 12 shows the percentage point difference between GICs and other innovation active enterprises in claiming intellectual property rights (patent, European utility model, industrial design and copyright). A greater percentage of GICs claim IPR – regardless of the type - compared to other innovation active enterprises. The only exception are Hungarian GICs, which claim copyrights less than other innovation active enterprises. In all countries, the largest difference between GICs and other innovative active enterprises is in the percentage who claim patents with the exceptions of Bulgaria, where the highest difference is in utility models, and Portugal, where the greatest difference is in trademarks.

Figure 13 shows the percentage difference between GICs and other innovation active enterprises in the percentage who have cooperation agreements with other actors. A higher percentage of GICs have cooperation agreements with other enterprises in their group (internal), within the EU, outside the EU (Extra-EU), with other private enterprises (Market) or public and private research institutions (research) than other innovation active enterprises. Only in Norway do GICs engage less frequent in internal cooperation agreements than other innovative active enterprises.

There are also some marked country differences in the type of innovation cooperation activities that GICs perform compared to other innovative enterprises. For instance, in France and Greece GICs engage much more frequently than in other countries in cooperation activities of various types. In particular, French and Greek GICs are particularly engaged in internal cooperation agreements within their enterprise group, and, together with Hungarian GICs, in cooperation with research institutions. French GICS, in addition, are particularly active in EU cooperation agreements, and, together with Bulgarian GICs, in cooperation agreements with other private sector actors. Greek and Norwegian GICs, by contrast, stand out in extra-EU cooperation agreements,

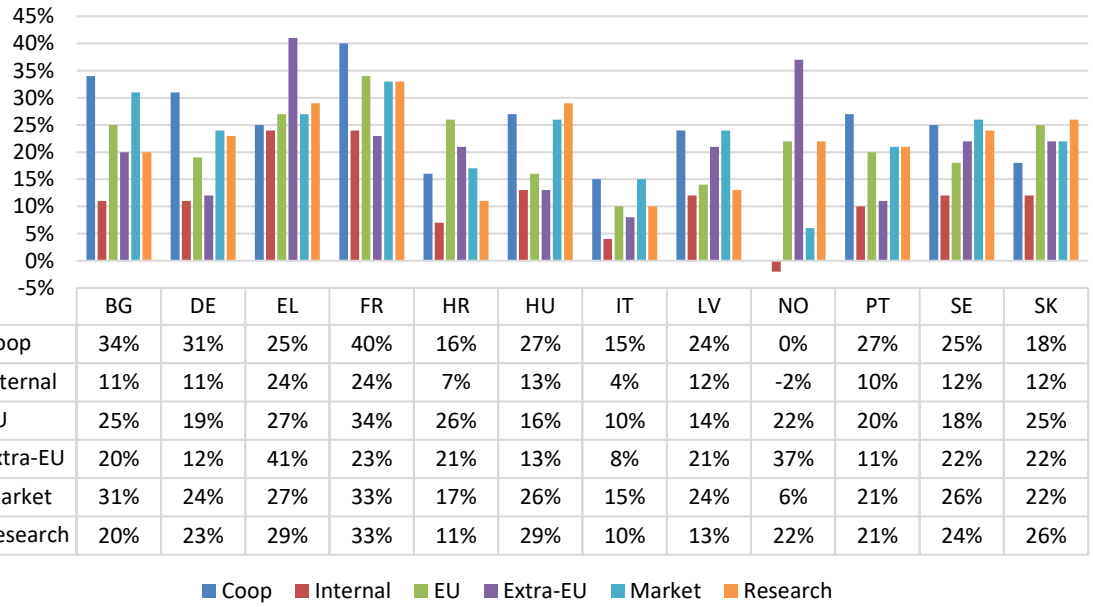
Figure 12. Percentage point difference between GICs and other innovation active enterprises in intellectual property claims



	BG	DE	EL	FR	HR	HU	IT	LV	NO	PT	SE	SK
Utility model	18%	25%	7%			5%	17%	3%		4%		16%
Patent	16%	43%	31%	34%	20%	34%	27%	16%	32%	16%	41%	21%
Copyright	15%	8%	26%	26%	11%	-1%	4%	2%	16%	11%		22%
Industrial design	11%	7%	10%		11%	7%	9%	12%	11%	8%	15%	19%
Trademark	13%	31%	26%	28%	9%	12%	16%	13%	18%	24%	29%	6%

Source: Eurostat's Community Innovation Survey 2016.
Note: empty cells indicate there was no data to estimate the percentages

Figure 13: Percentage point difference between GICs and other innovation active enterprises collaborating on innovation

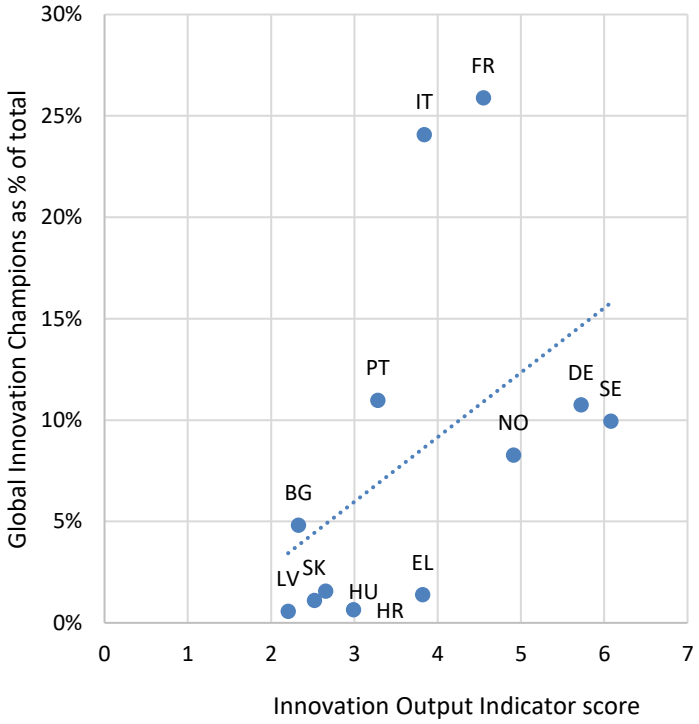


	BG	DE	EL	FR	HR	HU	IT	LV	NO	PT	SE	SK
Coop	34%	31%	25%	40%	16%	27%	15%	24%	0%	27%	25%	18%
Internal	11%	11%	24%	24%	7%	13%	4%	12%	-2%	10%	12%	12%
EU	25%	19%	27%	34%	26%	16%	10%	14%	22%	20%	18%	25%
Extra-EU	20%	12%	41%	23%	21%	13%	8%	21%	37%	11%	22%	22%
Market	31%	24%	27%	33%	17%	26%	15%	24%	6%	21%	26%	22%
Research	20%	23%	29%	33%	11%	29%	10%	13%	22%	21%	24%	26%

Source: Eurostat's Community Innovation Survey 2016.

Figure 14 shows a scatterplot between the IOI 2022 scores and the percentage of GICs in a country as the percentage of total GICs. The correlation between the two measures is moderate and positive (r = 0.66) but markedly larger than the correlations of GICs with the specific innovation activities shown in Table 1, indicating that the IOI 2022 gives some indication of how likely a country will generate a GIC. Italy and France are two outliers who have a considerably larger share of GICs than expected based on the trend line shown in the plot. This may indicate that some contextual factors encouraging GIC emergence in these countries are not covered by the IOI. It also reflects the broadness of the IOI, as some of its components, such as SERV_va and ENT have very low correlations with the percentage of GICs in a country, 0.08 and 0.33 respectively.

Figure 14. GICs percentage of total enterprises and IOI 2022 scores



Source: Eurostat's Community Innovation Survey 2016.

Table 1 shows the correlations between the indicators of global innovation championship and different indicators of innovation (product, process, marketing/organizational). These correlations show that most innovating firms are not global innovation champions. All in all, GICs seem to constitute a phenomenon relatively separate from other innovation activities, being their correlation with other types of innovation lower (raging between 0.18 and 0.34) than the correlations between the other types of innovation shown in Table 1 (ranging between 0.47 and 0.77).

Global innovation champions are distinct not only in view of having introduced a world first innovation and of their global export orientation, but also in their high levels of IRP production and cooperation with other private and public sector actors. The correlations in Source: Eurostat's Community Innovation Survey 2016.

Table 1 shows the correlations between the indicators of global innovation championship and different indicators of innovation (product, process, marketing/organizational). These correlations show that most innovating firms are not global innovation champions. All in all, GICs seem to constitute a phenomenon relatively separate from other innovation activities, being their correlation with other types of innovation lower (raging between 0.18 and 0.34) than the correlations between the other types of innovation shown in Table 1 (ranging between 0.47 and 0.77).

Table 1 show that indeed, GIC status is not highly correlated with any other categories of innovation activities. Yet, at the aggregate level, the percentage of GICs in a country is correlated with the IOI, indicating that the IOI

captures certain components that facilitate their emergence. In the future research, it could be interesting to further investigate the GICs and track them across the 2010-2016 waves of the CIS[12].

4.3 Startups and scaleups

Startups and scaleups are thought to be critical for employment growth, innovation and economic growth. This section examines some characteristics of these types of firms to add further contextual analysis to complement the IOI. The analysis is based on information from the Community Innovation Survey 2018 wave, which includes for the first time a question on the company age. CIS2018 microdata safe centre files include data from 16 EUMS and candidates (BE, BG, CZ, DE, EE, EL, ES, FR, HR, HU, IT, LT, LV, PT, RO, SK). However, not every country could provide the same information. For example, the turnover of enterprises is not available in FR. More information can be found on the Eurostat website.

Startups are defined as companies that were founded in the last 5 years at the time of the survey. Scaleups are defined in two ways. Turnover scaleups are companies that are within the top 10 percentile of growth in turnover within their country and 2-digit NACE sector over the period January 2016 to December 2018. Employment scaleups are enterprises, which are in the top 10 percentile in terms of employment growth in their country and 2-digit NACE sector. Firms can be categorized in all three categories at once. Firm size and innovation activity status are not considered in the definitions of startups and scaleups for the purpose of this technical report.

4.3.1 What startups do and where can they be found?

Most startups are SMEs (94%) and are not part of an enterprise group (72%). Startups are a larger percentage of firms in transport and storing, and information and communication sectors (NACE divisions H and J) (13-15%) and less prevalent in manufacturing, utilities, wholesale and retail (NACE divisions C, D, E, G) (7-9%), as well as in financial and insurance sector, and professional, scientific and technical activities (NACE divisions K and M) (~10%). On average, about 10% of enterprises are startups.

Startups are often hailed as drivers of innovation and disruption. However, the CIS data shows that only 25% of startups report a product innovation (good or service), about 5% points less than non-startups (30%). There is a similar gap between innovative startups and non-startups in product or process innovating firms (37% of startups and 44% of non-startups) and innovation active firms (40% of startups and 48% of non-startups). Startups also lag behind non-startups in terms of buying, selling and creating intellectual property rights in the form of patents, industrial designs, trademarks, and trade secrets. Within innovative startups, 62% are not part of an enterprise group. Thus, it seems that startups are not distinctive in terms of having innovated. Nevertheless, a significant proportion of startups does innovate and these are often SME's, in line with conventional wisdom on the topic.

Several statistics also show that startups still have to establish their network and diversify their funding strategy. In particular, a lower percentage of startups collaborate on innovation with public, private or international actors than non-startups; they have a lower percentage of funding from private and government sources and a lower percentage of startups exports to the EU and outside the EU. However, a higher percentage of startups (25%) say they will increase expenditure in innovation compared to non-startups (19%). Thus, many startups are looking toward the future.

A place where startups shine is in turnover and employment growth. Among firms with positive turnover growth, startups were responsible for 9% of total turnover. In some countries, startups were responsible for higher percentages. In Bulgaria, Spain, Croatia and Slovakia startup turnover growth was between 13-15% of the total while in RO it was 22%. Across sectors, startups contribute less to turnover growth in financial and insurance activities (NACE division K) (4%) than the average across industries (9%) and more in water supply and management activities (NACE division E) (11%), information and communication (NACE division J) (16%) and professional, scientific and technical activities (NACE division M (35%). Startups are responsible for a large part of employment growth. Startups were responsible for 15% of positive employment growth reported by all firms. Startups are responsible for at least 20% of growth in Croatia, (31%), Bulgaria (26%), Italy, Lithuania, Slovakia (~20%) and for less than 10% in Germany (3%), Belgium, and Czech Republic (8%).

[12] The GIC section uses data from CIS2016 as it is the latest available data where the question on "world first" innovations was asked.

4.3.2 Scaleup firms

Scaleup firms are generally defined as firms that grow very fast in terms of turnover or employment. What is remarkable about these firms, and piqued policy-maker's interest, is that they are responsible for a large part of turnover or employment growth while other firms are relatively stagnant (Monteiro, 2019). Because the employment and turnover definitions of scaleups identified mostly the same firms, this section report the results for turnover scaleups only.

Like startups, turnover scaleups are most often SME's (61%). Turn-over scaleup firms are almost equally split between single entities (43%) and those part of EU-EFTA headquartered (24.1%) or national group (22.8%), only 9% are headquartered in other countries. However, many EU-EFTA Enterprise groups (21.3%) and other Enterprise groups (21.9%) are scaleups, more than among National groups (11.8%) or as single entities (6.8%). Thus, scaleups are found equally between single entity and group enterprises but make up larger percentage of firms which are part of international enterprise groups than national groups or single entities.

Additionally, among very large enterprises[13] there are a considerable number of scaleups (45.4%), a much higher percentage than among large enterprises (29.9%) or SMEs (7.1%). Thus, there is some indication that being part of an enterprise group or being a large enterprise helps enterprises achieve scaleup. These figures may reflect that scaleups are often enabled through mergers and acquisitions that occur after a start-up managed to develop a viable business model and product innovation.

Unlike startups, scaleups are often doing process or product innovation (56%) compared to non-scale up firms (44%). A similar difference is observed among innovation active firms (61% for scaleups, 48% for non-scaleups). Additionally, the percentage of turnover scaleups creating, selling or buying intellectual property is 3-8% points higher than non-scaleups. They also more frequently report to collaborate on innovation with international, EU, private sector and public sector actors by margins from 4-9% points. Turnover scaleups also more frequently report planning to increase expenditure on innovation (27%) than non-scaleups (19%). Lastly, more than half of scaleups (67%) export within the EU while 43% also export outside the EU. Thus, it seems that many turnover scaleups are innovation oriented, have successfully entered a market and created a network of collaborators.

As expected, turnover scaleups account for a large percentage of total turnover and employment growth within a country. Turnover scaleup enterprises contribute 79% of total positive turnover growth from 2016-2018. The percentage is lowest in Greece, Estonia and Lithuania, between 50 and 59%, while it is above 80% in Belgium, Bulgaria, Czechia, Germany, Italia and Sweden. Turnover scaleups are a greater percentage of turnover growth in electricity, gas, steam and air conditioning supply, wholesale and retail trade, and professional, scientific and technical activities (NACE divisions D, G and M), while they contribute slightly less in manufacturing and water supply; sewerage; waste management and remediation activities (NACE divisions C and E).

As for employment growth, turnover scaleups contributed on average 57% of total positive employment growth reported by enterprises. The aggregate percentage masks marked differences across countries. Luxembourg, Estonia, Greece, and Latvia show particularly low percentages (22, 39, 35, and 39%, respectively) compared to Italy (64%) and Germany (74%). Turnover scaleups are responsible for more employment growth as a percentage of total positive growth reported in wholesale and retail trade, transporting and storage, information and communication, and financial and insurance activities (NACE divisions G, H, J and K).

[13] SME's are defined as having up to 250 employees, large enterprises have between 251 and 500 employees while very large enterprises are defined as having more than 500 employees.

5 Conclusions

This report presents the 2022 results of the IOI, an output-oriented measure of innovation performance at the country and EU levels and measures countries' capacity to derive economic benefits from innovation. This edition is based on the new methodological framework and structure of the index, which are the results of a revision process undertaken by the Commission between 2021 and 2022 to improve the statistical properties of the index and align it with the new policy priorities set by the organisation.

The report presents the latest figures for the composite index and its underlying indicators for 44 countries, including EU Member States and selected EFTA, OECD and emerging economies. According to the IOI, Sweden and Germany are the best performers in the EU and are followed by Finland, Ireland and Belgium. Germany mainly outperforms the other EU countries in the domestic value-added[14] content of its medium-high and high-tech manufacturing exports, whereas Sweden is very strong in terms of IP applications. Conversely, Romania, Latvia and Bulgaria reported the lowest performance among EU member states. The EU, as a single block, leads New Zealand, China, Australia and Brazil, but it still lags behind its main competitors, including United States, South Korea and Japan. These results are mainly due to its low performance in employment in knowledge-intensive activities and share of innovative firms, while it is strong in the domestic value added content of its medium-high and high-tech manufacturing exports.

IOI findings are complemented by an analysis of radical innovator and exporter companies, referred to as "global innovation champions", and a study of start-up and scaleup firms in the EU. This work is based on recent waves of the Eurostat Community Innovation Survey and selected countries, for which micro data could be accessed. The aim of this section of the report is to examine the characteristics of these types of firms that can make outsized contributions to innovation and job creation, and contribute to understanding what sets them apart from other firms. The analysis shows that the relatively small group of exporters that introduced a 'world first' product innovation distinguishes themselves also in terms of IRP production and cooperation with other private and public sector actors. The positive correlation between the share of GICs by country and the IOI indicates that the IOI allows to capture certain components that facilitate their emergence. Start-up and scaleup firms are also slowly becoming important actors of the European innovation landscape. In the selected countries, startups are mainly present in the transportation and information and communication sectors. While just over one third are product or process innovator, they are more likely to increase innovation expenditure in the future than other firms. Conversely, scaleup firms are for the most part product and process innovators and are more likely among large firms and among those that are part of a group.

While the IOI ranking and analysis are limited to its country coverage and temporal horizon, which does not allow to capture more recent phenomena such as that of the Covid-19 pandemics, they can provide important contributions to better capture the key and evolving features of the science and innovation systems, and improve the measurement systems of innovation. Results have, for instance, documented that countries with a more dynamic and diversified innovation system are performing the best, while they have pointed to a need to capture country innovation in a more comprehensive way and refrain from adopting a narrowed high-tech understanding of innovation. Timely, richer, and more granular data, however, is needed to better understand cross-country differences and inform European innovation policy on the complex range of factors influencing innovation and on the impact of the latter on economic growth, sustainability and inclusiveness.

[14] GOOD_VA component.

References

Acs, Z.J., Anselin, L. and Varga, A., 2002. 'Patents and innovation counts as measures of regional production of new knowledge.' *Research policy*, 31(7), pp.1069-1085.

Audretsch D.B., Lehmann E.E., Schenkenhofer J. (2018). 'Internationalization Strategies of Hidden Champions: Lessons from Germany', *Multinational Business Review*, 26(1): 2-24.

Becker, W., Saisana, M., Paruolo, P., & Vandecasteele, I., (2017). 'Weights and importance in composite indicators: Closing the gap.' *Ecological Indicators*, 80, 12-22. doi:10.1016/j.ecolind.2017.03.056

Bello, M., Caperna, G., Damioli, G. Mathevet, I. (2022), *The Innovation Output Indicator 2021*, EUR 31087 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-53056-5, doi:10.2760/802325, JRC129410.

Bogliacino, F. (2014). 'Innovation and employment: A firm level analysis with European R&D Scoreboard data'. *EconomiA*, 15(2), 141-154.

Castellani, D. and Koch, A., (2015). 'Mapping competitiveness with European Data'. *Bruegel Blueprint Series* Nr. 23.

European Commission, Directorate-General for Research and Innovation (2022), *Science, research and innovation performance of the EU 2022: building a sustainable future in uncertain times*, Publications Office of the European Union, 2022

European Commission, (2013). Communication from the Commission to the Institutions. Measuring innovation output in Europe: towards a new indicator COM(2013)624 and SWD(2013)325

European Commission, Directorate-General for Research and Innovation, Hollanders, H., Es-Sadki, N., Khalilova, A., *European Innovation Scoreboard 2022*, Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2777/309907

Falk, M. (2009). 'High-tech exports and economic growth in industrialized countries', *Applied Economics Letters*, 16(10), pp.1025-1028, DOI: 10.1080/13504850701222228

Fryges H. (2006). 'Hidden Champions – How Young and Small Technology-Oriented Firms Can Attain High Export-Sales Ratios'. *ZEW Discussion Paper* No. 06-045, Mannheim.

Galindo-Rueda, F. and Verger, F. (2016) 'OECD Taxonomy of Economic Activities Based on R&D Intensity', OECD Science, Technology and Industry Working Papers, 2016/04, OECD Publishing, Paris. http://dx.doi.org/10.1787/5jlv73sqqp8r-en

Griliches, Z., (1990). 'Patent statistics as economic indicators: a survey (No. w3301)'. *National Bureau of Economic Research*.

Griliches, Z., (1998). 'Patent statistics as economic indicators: a survey. In R&D and productivity: the econometric evidence', (pp. 287-343). *University of Chicago Press*.

Groeneveld, R. A. & Meeden, G. (1984). 'Measuring Skewness and Kurtosis'. *The Statistician* 33, 391–99.

Hall, B.H., Griliches, Z. and Hausman, J.A. (1986). 'Patents and R and D: Is there a lag?'. *International economic review*, 265-283.

Hausmann, R., Hwang, J. & Rodrik, D. (2007). 'What you export matters'. *Journal of Economic Growth,* 12, pp.1–25 (2007) doi:10.1007/s10887-006-9009-4

Honaker, J., King, G., & Blackwell, M. (2011). 'Amelia II: A Program for Missing Data'. *Journal of Statistical Software*, 45(7), 1–47. doi:10.18637/jss.v045.i07

JRC-OECD (2008), *Handbook on constructing composite indicators: Methodology and User guide*. Paris: OECD.

Lucchese, M., & Pianta, M. (2012). 'Innovation and employment in economic cycles'. *Comparative Economic Studies*, 54(2), 341-359.

Mendonça, S. & Santos Pereira, T. & Mira Godinho, M. (2004). "Trademarks as an Indicator of Innovation and Industrial Change," LEM Papers Series 2004/15, Laboratory of Economics and Management (LEM), Sant'Anna School of Advanced Studies, Pisa, Italy.

Miles, I., Kastrinos, N., Flanagan, K., Bilderbeek, R., Den Hertog, P. (1995). 'Knowledge-intensive business services: users, carriers and sources of innovation'. European Innovation Monitoring Systems. EIMS Publication No 15. Innovation Programme, DGXIII, Luxembourg.

Monteiro, G. F. A. (2018). 'High-growth firms and scale-ups: a review and research agenda'. *RAUSP Management Journal*, 54(1),96-111.

Montresor, S., & Vezzani, A. (2015). 'The production function of top R&D investors: Accounting for size and sector heterogeneity with quantile estimations'. *Research Policy*, 44(2), 381-393.

Muller, E., and Doloreux, D. (2009). 'What We Should Know about Knowledge-Intensive Business Services.' *Technology in Society* 31(1):64–72. doi: https://doi.org/10.1016/j.techsoc.2008.10.001.

OECD/Eurostat (2018), *Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation, 4th Edition*, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris/Eurostat, Luxembourg, https://doi.org/10.1787/9789264304604-en.

OECD (2013), *Interconnected Economies: Benefiting from Global Value Chains*, OECD Publishing, Paris, https://doi.org/10.1787/9789264189560-en.

OECD (2009). *OECD Patent Statistics Manual*, OECD Publishing, Paris. doi:10.1787/9789264056442-en

Ortega-Argilés, R. Potters L., Voigt P. (2009). 'R&D-intensive SMEs in Europe: what do we know about them?', IPTS Working Paper on corporate R&D and innovation NO 15/2009, *Office for Official Publication of the European Communities*, Luxembourg.

Paruolo P., Saisana M., Saltelli A., (2013). 'Ratings and Rankings: Voodoo or Science?', *Journal Royal Statistical Society*, A176(3), 609-634 doi:10.1111/j.1467-985X.2012.01059.x50

Pavitt, K., (1985). 'Patent statistics as indicators of innovative activities: possibilities and problems'. *Scientometrics*, 7(1-2), pp.77-99.

Pianta, M. (2003). 'The employment impact of product and process innovations'. In: Pianta, M. & Vivarelli, M. (eds). *The employment impact of innovation* (pp. 93-111). Routledge, London.

Seung-Hoo Yoo (2008). High-technology exports and economic output: an empirical investigation, *Applied Economics Letters*, 15(7) pp.523-525, DOI: 10.1080/13504850600721882.

Simon H. (2009). *Hidden Champions of the 21st Century: Success Strategies of Unknown World Market Leaders.* Springer, London.

Simon H. (1996). 'Hidden champions: lessons from 500 of the world's best unknown companies'. *Harvard Business School Press,* Boston.

Vértesy, D., Damioli, G. (2020). 'The Innovation Output Indicator 2019', EUR 30104 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16413-5, doi:10.2760/540233, JRC119969.

Vértesy, D. and Tarantola, S. (2014). 'The Innovation Output Indicator 2014. Methodology Report'. *JRC Technical Reports*, EUR 26936, Luxembourg: Publications Office of the European Union. doi: 10.2788/836690

Vértesy, D., (2017). 'The Innovation Output Indicator 2017. Methodology Update.' *JRC Technical Reports*, EUR 28876, Luxembourg: Publications Office of the European Union. doi: 10.2760/971852

Vértesy, D. and Deiss, R., (2016). 'The Innovation Output Indicator 2016. Methodology Update.' *JRC Technical Reports*, EUR 27880, Luxembourg: Publications Office of the European Union. doi: 10.2788/261409

World Intellectual Property Organization (WIPO) (2022). *Global Innovation Index 2022: What is the future of innovation-driven growth?* Geneva: WIPO. DOI 10.34667/tind.46596

List of abbreviations and definitions

Code	Country
AT	Austria
AU	Australia
BE	Belgium
BG	Bulgaria
BR	Brazil
CA	Canada
CH	Switzerland
CN	China
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
EL	Greece
ES	Spain
EU27_2020	EU27 aggregate (average of EU27 MS)
EU27_2020int	EU27 aggregate for international comparison
FI	Finland
FR	France
HR	Croatia
HU	Hungary
IE	Ireland
IL	Israel
IS	Iceland
IT	Italy
JP	Japan
KR	South Korea
LT	Lithuania
LU	Luxembourg
LV	Latvia
ME	Montenegro
MK	North Macedonia
MT	Malta
NL	Netherlands
NO	Norway
NZ	New Zealand
PL	Poland
PT	Portugal
RO	Romania
RS	Serbia
SE	Sweden
SI	Slovenia
SK	Slovakia
TR	Turkey
UK	United Kingdom
US	United States

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Annexes

Annex 1. The IOI methodology

The IOI 2022 dataset and index development

The IOI 2022 dataset includes 496 country-year observations covering the 27 European Union Member States, EFTA countries (Switzerland, Iceland, Norway), EU candidates (Montenegro, North Macedonia, Serbia, Türkiye), selected OECD countries (Australia, Canada, Israel, Japan, South Korea, New Zeeland, United Kingdom, United States of America) and two of the BRICS (Brazil and China) over the time period 2011 until 2021. It also includes observations for the 27 EU MS as an average (EU27) and as a single economic zone (EU27x) for international comparisons. The dataset includes six indicators: PCT_POP, TRA_POP, KIABI, GOOD_VA, SERV_VA and ENT.

Data availability: The majority of missing data is imputed using the last known value. That is, in case data was missing on one country-year, the last known value was imputed from a previous year. If data was missing between two non-missing data points, the average of those adjacent years was imputed. In case no last known values are available, the imputation was done using the Amelia II package in R (Honaker, King and Blackwell, 2011), which uses a bootstrapped EM algorithm. The JRC imputed the KIABI indicator for China and the trademark indicator for Greece, Ireland and North Macedonia using Amelia II. All descriptive statistics and correlations shown in section 3 exclude the Amelia II imputed data. Please refer to **Table 8** in annex 3 for statistics of the data including the Amelia II imputation. **Figure 23** up to **Figure 28** in annex 3 show the available data for each indicator by country and year.

Outlier treatment: No outliers were detected using the criteria set out in JRC/OECD (2008), according to which (absolute) skewness and (absolute) kurtosis are considered excessive when they simultaneously cross the threshold-values of 2 and 3.5, respectively. Descriptive statistics for the non-normalized IOI 2022 dataset are shown in **Table 2**. This table excludes data imputed with Amelia II.

Table 2 Descriptive Statistics of IOI indicators for the 2021 data [before treatment and normalisation]

Indicator	Min	Max	Mean	Median	Std	Skew	Kurt	N. non-missing	% non-missing
GOOD_VA	2.97	62.9	30	28.3	14.2	0.28	-0.43	41	93%
SERV_VA	15.1	59.4	33	31.7	9.69	0.96	1.1	41	93%
KIABI	6.8	34.1	16.1	15.5	5.21	1	2.26	43	98%
PCT_POP	0.54	361	98.2	49.9	108	1.21	0.39	44	100%
TRA_POP	519	8040	2790	2420	1680	1.12	1.32	41	93%
ENT	10.7	79.8	51.5	54.2	14.1	-0.45	0.29	43	98%

Standardization: After imputation, the data was standardized over the last ten years of all countries (country-year observations). The min-max standardization is applied across all years and ensures the maximum score of 10 corresponds to the maximum observed value over the 10 years while the minimum score, zero, corresponds to the lowest observed value over the 10 years. Descriptive statistics for the standardised indicators are provided in **Table 3**.

Weighting: All indicators of pillars and all pillars of the IOI are equally weighted within their aggregate. While unequal weights were used in previous editions of the IOI so that the IOI was statistically balanced in its underlying components, their use was not necessary for this edition given the new correlations among the IOI components (See the following section)

Aggregation: All indicators were added up using the arithmetic mean to form components. All components of the IOI were added up using the arithmetic mean using equal weights.

Table 3. Normalized descriptive statistics of the IOI 2022 indicators.

Indicator	Min	Max	Mean	Median	Std	Skew	Kurt	N. non-missing
GOOD_VA	0.02	9.35	4.23	3.96	2.21	0.28	-0.43	41
SERV_VA	0.96	9.95	4.58	4.34	1.96	0.96	1.1	41
KIABI	0.71	10	3.87	3.67	1.77	1	2.26	43
PCT_POP	0.01	9.46	2.58	1.31	2.82	1.21	0.39	44
TRA_POP	0.13	5.78	1.84	1.56	1.26	1.12	1.32	41
ENT	0.07	10	5.93	6.33	2.02	-0.45	0.29	43

Correlations between normalised indicators and the structural coherence of the IOI

The JRC/OECD guidelines on composite indicators (JRC/OECD, 2018) recommends correlations between 0.30 and 0.94 for any two indicators that share the same pillar. An adequate correlation ensures a minimum level of information transmitted from indicators to aggregates. **Figure 15** shows the indicators of the intellectual property pillar (TRA_POP and PCT_POP) do not meet these criteria and have a slightly weaker correlation. Nevertheless, both indicators are included to cover both goods and services innovations. By contrast, both GOOD_VA and SERV_VA meet the criteria set in the guidelines.

Figure 15. Pairwise Pearson correlations between indicators

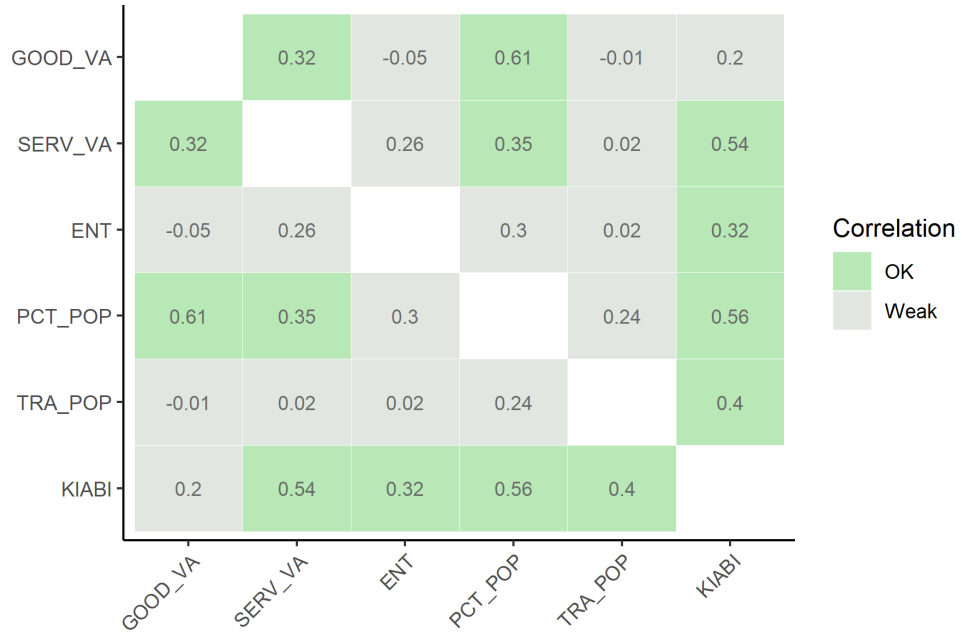
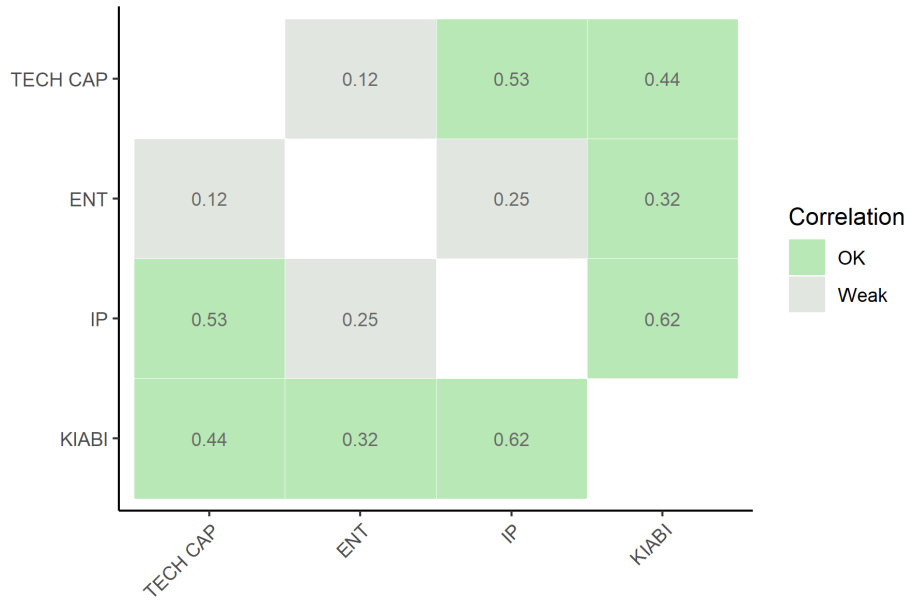


Figure 16 shows correlations between the pillars of the IOI. Overall, the correlation structure is adequate. Only the correlations between TECH_CAP and ENT and between IP and ENT are weak, suggesting a lower rate of information transmission from ENT to the IOI compared with other indicators.

Figure 16 Pairwise correlations between Pillars



The pairwise correlations between indicators with their respective pillars and the IOI are shown in **Figure 17**. The PCT_POP and TRA_POP indicators are correlated with the IP pillar while GOOD_VA and SERV_VA are correlated with TECH_CAP pillar in the left column. The right column shows indicator correlations with the IOI. The strength of the correlation between indicator and aggregates most directly reflects the amount of information an indicator transmits to the index. These correlations all fall within the recommended guideline, providing evidence that the IOI effectively summarises the information from its indicators and pillars. However, indicators' correlation with the IOI varies. The KIABI and PCT_POP indicators have the strongest correlation with the IOI while TRA_POP has the lowest. These correlations suggest that PCT_POP has a greater impact than TRA_POP on the IOI scores.

Figure 17 Pairwise correlations between indicators and their respective pillars and with the IOI

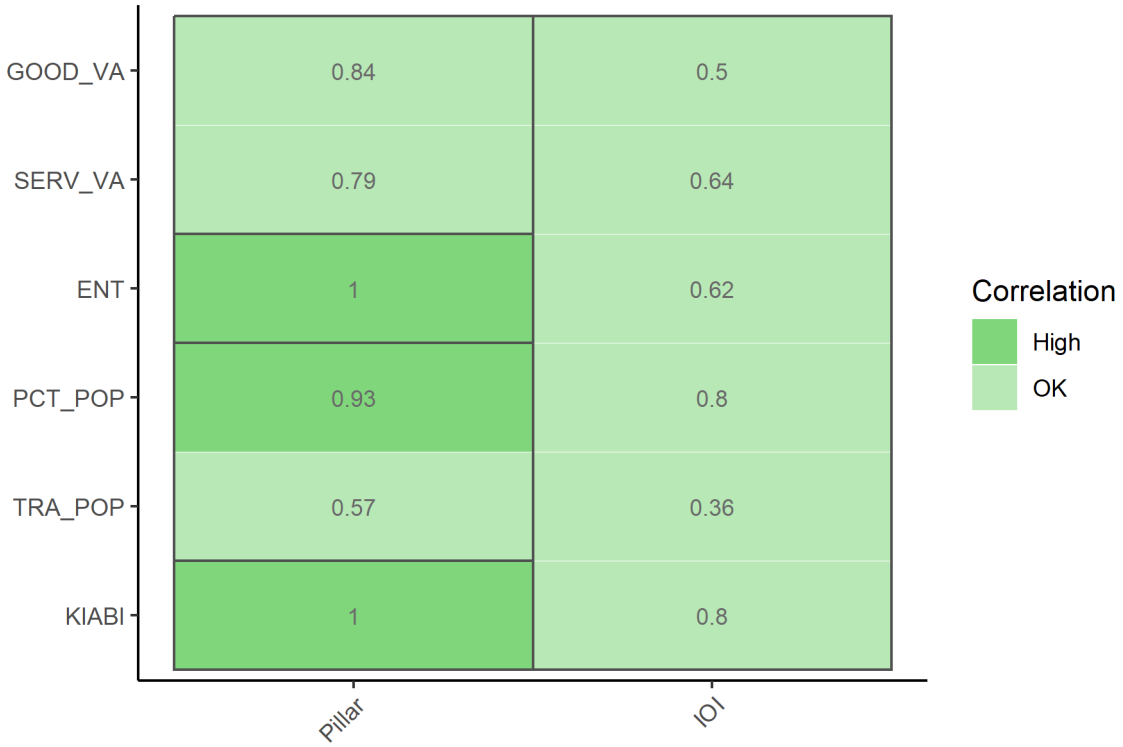
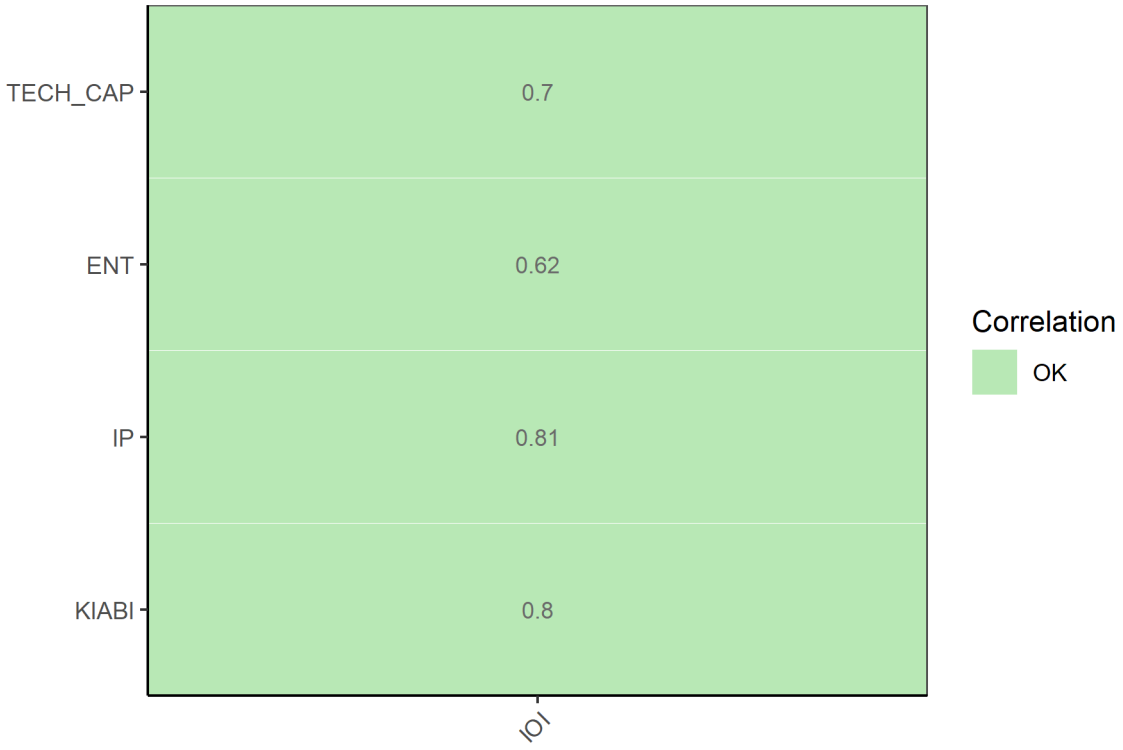


Figure 18 shows the correlations between pillars and the IOI. All pillars have an adequate correlation with the IOI. The similarity of correlations indicates each pillar contributes information to the IOI to a similar degree. The ENT pillar has a slightly lower correlation, as a result of its low correlation with the other pillars. Nevertheless, all correlations are adequate and similar, providing evidence that the IOI summarises the information well.

Figure 18 Pairwise correlations between pillars and the IOI.



Annex 2. Robustness of ranks and validation of results

Uncertainty analysis

Methodological choices are part of constructing a composite indicator. Developers make these choices using expert opinion, statistical theory or other practical considerations. However, there are often equally valid alternatives. Thus, these choices introduce some uncertainty, as users may ask whether rankings are robust to these alternative specifications. Indeed, it is desirable for any composite indicator not to have much uncertainty in ranking. This section investigates to what extent modelling choices influences the ranking of countries in the IOI.

The uncertainty analysis systematically changes four different modelling assumptions: the normalisation, imputation, the weights and aggregation. **Table 4** lists the current and alternative specifications in the IOI. Mean imputation is the alternative method to test for uncertainty in the treatment of missing data. Mean imputation is an often-used imputation method and provides a good benchmark. The standardization of indicators with mean of five and a standard deviation of 1.5 is the alternative normalisation method. Previous versions of the IOI used this standardization formula. The geometric mean is the alternative aggregation method. The geometric mean penalizes countries for having imbalanced profiles across indicators while the arithmetic mean implies full substitutability. Lastly, the weights are randomly varied by 20% from their original value.

Table 4 Uncertainty parameters: missing values, normalisation, aggregation and weights

Source of Uncertainty	**Original**	**Alternative**
I. Treatment of missing values	EM algorithm	Mean imputation
II. Normalisation of indicators	Min-max across last 10 years	Z-score (mean = 5, SD = 1.5) across last 10 years
III. Aggregation formula at pillar level	Arithmetic mean	Geometric mean
IV. Pillar weights	Equal weights	+/- 20%

The analysis proceeds by specifying all combinations (original and alternative) of the normalisation, imputation and aggregation steps. These are eight different versions of the IOI. The analysis consists of computing each of these versions 50 times using a randomly selected set of weights from a distribution of weights with random perturbation of up to 20% of their original value. This results in 400 versions of the IOI. The statistics of interest - plotted in **Figure 19** and shown in **Table 5** - are the median rank, the 5th and 95th percentile rank for each country across the 400 versions.

As **Figure 19** shows, the ranks of the IOI are robust against changes in methodology. The dots in **Figure 19** are the median rank across the simulations. These are ordered closely to the original ranking of the IOI as indicated by the country order on the x-axis. In fact, 79.5% (35/44) of countries median rank is less than two ranks away from the nominal ranking. These are cases like Japan, Finland and the UK, which do switch ranks, but only by a few places. There are seven countries, which change two or three positions. Lastly, Montenegro and North Macedonia are the only cases with large changes in positions. These gain 12 and 4 positions in the median ranking, respectively.

The confidence interval (CI) provides another indication of the uncertainty in the ranking due to modelling choices. The confidence interval reflects whether modelling alternatives result in a wide variety of rankings. In the uncertainty analysis, confidence intervals are computed as the 5th and 95th percentile of the observed distribution of ranks across simulations.

The CI indicates highly stable rankings for 19 out of 44 countries, which have a CI of zero to three. An additional, 19 countries have a CI range between four and six, indicating some uncertainty, but still allowing accurate inference. Lastly, only six (Montenegro, Luxembourg, China, Canada, Korea and North Macedonia) out of 44 countries have a CI of greater than six positions, which indicate some uncertainty in their ranking and their ranks have to be interpreted with caution. **Table 5** shows the median ranks, confidence intervals, and deviations from the nominal rank.

Figure 19. Median rank in the Innovation Output Indicator across simulations with alternative methods.

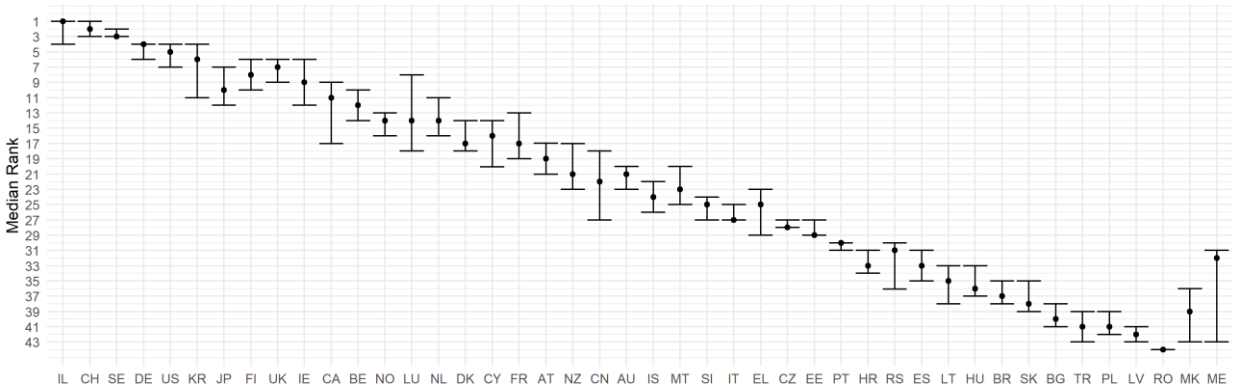


Table 5. Table of the Median rank, Q5 and Q95 across simulations and nominal rank.

Nominal IOI Rank	Country	Median Rank	Q5	Q95	CI Range	Deviation from Nominal
1	IL	1	1.00	4.00	3.00	0
2	CH	2	1.00	3.00	2.00	0
3	SE	3	2.00	3.00	1.00	0
4	DE	4	4.00	6.00	2.00	0
5	US	5	4.00	7.00	3.00	0
6	KR	6	4.00	11.00	7.00	0
7	JP	10	7.00	12.00	5.00	-3
8	FI	8	6.00	10.00	4.00	0
9	UK	7	6.00	9.00	3.00	2
10	IE	9	6.00	12.00	6.00	1
11	CA	11	9.00	17.00	8.00	0
12	BE	12	10.00	14.00	4.00	0
13	NO	14	13.00	16.00	3.00	-1
14	LU	14	8.00	18.00	10.00	0
15	NL	14	11.00	16.00	5.00	1
16	DK	17	14.00	18.00	4.00	-1
17	CY	16	14.00	20.05	6.05	1
18	FR	17	13.00	19.00	6.00	1
19	AT	19	16.95	21.00	4.05	0
20	NZ	21	17.00	23.00	6.00	-1
21	CN	22	18.00	27.00	9.00	-1
22	AU	21	20.00	23.00	3.00	1
23	IS	24	22.00	26.00	4.00	-1
24	MT	23	20.00	25.00	5.00	1
25	SI	25	24.00	27.00	3.00	0
26	IT	27	25.00	27.00	2.00	-1
27	EL	25	23.00	29.00	6.00	2
28	CZ	28	27.00	28.00	1.00	0
29	EE	29	27.00	29.00	2.00	0
30	PT	30	30.00	31.00	1.00	0
31	HR	33	31.00	34.00	3.00	-2
32	RS	31	30.00	36.05	6.05	1
33	ES	33	31.00	35.00	4.00	0
34	LT	35	33.00	38.00	5.00	-1
35	HU	36	33.00	37.00	4.00	-1
36	BR	37	35.00	38.00	3.00	-1
37	SK	38	35.00	39.00	4.00	-1
38	BG	40	38.00	41.00	3.00	-2
39	TR	41	39.00	43.00	4.00	-2
40	PL	41	39.00	42.00	3.00	-1

Nominal IOI Rank	Country	Median Rank	Q5	Q95	CI Range	Deviation from Nominal
41	LV	42	41.00	43.00	2.00	-1
42	RO	44	44.00	44.00	0.00	-2
43	MK	39	36.00	43.00	7.00	4
44	ME	32	31.00	43.00	12.00	12

Sensitivity Analysis

Sensitivity analysis builds on the results from an uncertainty analysis to investigate which modelling assumptions drive variation in the rankings of countries. **Table 6** shows descriptive statistics of the sensitivity analysis. It shows the median rank deviation from the nominal IOI ranks for each of the eight model specifications across 50 runs with random perturbations of the weights.

As seen from **Table 6**, the random perturbation of the weight alone has little impact, half of the countries median ranks are the same as the nominal rank. The median ranking of the other half of the countries is within two positions of the nominal ranks, the only exception being Montenegro. Changing one of the aggregation, imputation or normalisation functions in combination with the random weights has little impact on the ranking. For instance, model specifications with geometric aggregation only cause five countries' median rank to differ with three or more positions from the nominal ranking. Moreover, only six countries change three or more ranks in comparison to the nominal ranks when using all three alternative functions (normalisation, imputation, aggregation) and random perturbations of the weights.

The descriptive statistics of the sensitivity analysis are supplemented by a linear regression of the median rank deviation from the nominal rank on each modelling alternative and their interactions. The results show that the alternative imputation method in combination with the alternative geometric aggregation method causes the largest deviations in rank. The marginal effect of the interaction between alternative imputation and aggregation methods on rank deviations is estimated to be -1.77 ranks.

Overall, the sensitivity analysis shows that the model specifications in the IOI are robust to changes in the normalisation, imputation, weights and aggregation. However, Montenegro and North Macedonia are two outlying cases, whose rank fluctuates to a greater extent. These outlying cases are likely caused by their high percentage of missing data as any model specification with the alternative imputation strategy has the greatest impact on the median ranking in the descriptive statistics.

Table 6: Comparison of nominal rank to median rank of eight model specifications.

Nominal Rank	Country	Alternative Specification							
		Only Weights	Weights +						
			Agg	Imp	Norm	Agg+Imp	Agg+norm	Norm+Imp	All
1	IL	0	-2	0	0	-2	0	0	0
2	CH	0	1	0	0	1	0	0	0
3	SE	0	1	0	0	1	0	0	0
4	DE	-1	0	-1	-1	0	0	-1	0
5	US	0	-1	0	0	-1	0	0	0
6	KR	0	1	0	0	1	-3	0	-3
7	JP	-0.5	-2	0	-3	-3	-5	-3	-5
8	FI	0	0	0	-1	0	1	-1	1
9	UK	1	2	1	2	2	3	3	3
10	IE	-1	0	-1	1	1	2	1	2
11	CA	1	-3	0	0	-2	1.5	-1	1
12	BE	0	0	0	-1	0	1	-1	1
13	NO	0	-2	0	-1	-2	-1	-1	-1
14	LU	0	-1.5	0	3	-3.5	-2	3.5	-2
15	NL	0	4	0	-1	4	1	-1	2
16	DK	0	1	0	-2	1	-2	-1	-2
17	CY	0	-2	0	2	-3	2	2	2
18	FR	0	3	0	0	3	1	0	1
19	AT	0	1	0	-1	2	0	-1	0
20	NZ	-1	-2	0	1	-3	-1	1	-1
21	CN	-2.5	0	-1	-0.5	2	-2	0	-1
22	AU	1	1	1	0	0	1	0	1
23	IS	0	-1.5	0	-1	-3	-1	-1	-1
24	MT	0	3	0	1	3	2	1	1
25	SI	-1	0.5	-1	-1	0.5	0	-1	0
26	IT	-1	0	-1	-1	1	0	-1	-1
27	EL	2	-2	2	2	-2	1	2	1
28	CZ	0	0.5	0	0	1	0	0	0
29	EE	0	1	0	0	1	0	0	0
30	PT	0	0	-1	0	0	0	0	0
31	HR	-1	-2	-2	-1	-3	-1	-2	-2
32	RS	1	-1.5	2	1	0	1	1	1
33	ES	-0.5	2	-1	0	2	0	-1	-1
34	LT	0	-2	-1	0	-3	-1	-1	-1
35	HU	-1	2	-1	-1	0	-1	-1	-1
36	BR	-1	-1	-1	0	-2	0	-1	-1
37	SK	-1	2	-2	-1	1	-0.5	-2	-1
38	BG	-2	-0.5	-3	-2	-2	-1	-2.5	-2
39	TR	-1	-2	-3	-0.5	-4	-2	-1.5	-3
40	PL	-1	0	-1	-1	-1	0	-2	-1
41	LV	-1	0	-2	-1	-1	-1	-2	-2
42	RO	-2	-2	-2	-2	-2	-2	-2	-2
43	MK	0	0	5	0	4	0	5	4
44	ME	9.5	5	12	9	11	9.5	12	12

Note: *Agg* refers to alternative aggregation formula, namely the geometric mean. Imp refers to the alternative imputation formula, i.e. mean imputation. *Norm* refers to the alternative normalisation procedure, namely standardization (Mean = 5 , S.D. = 1.5).

Index validation analysis

A composite indicator aims to summarize a phenomenon that is not directly measurable. As such, composite indicators still require indicators of observable phenomena that are part of or closely related to the composite indicator's target concept. Given that the target concept is unobservable, it is useful to validate the measurement by comparing the composite indicator to other measures of the same or similar concepts. A strong relationship exists between independently created measures of the same concept provide evidence that they do indeed measure the same concept.

In this section, the IOI 2022 edition is plotted against the Global Innovation Index (GII), developed by WIPO and based on 81 indicators (WIPO, 2022), as well as the Summary Innovation Index (SII) developed by the European Commission (European Commission, 2022). The GII includes input and output sub-pillars. In this section, the IOI is plotted against the GII and its output sub-pillar. Each plot shows the subsample of countries that appear in both indexes.

Figure 20 is a scatterplot of the IOI 2022 score and the Global Innovation Output sub-index 2022 score. In the top left, readers can find the Pearson correlation coefficient. Overall, there is a strong correlation between the two measures of innovation output, indicating that both measure a similar phenomenon. There are also some difference, namely in the scores of top performers. A likely cause is the wider scope of the GII output sub-index, which tracks not only services, knowledge and technology outputs like the IOI but also creative outputs such as create goods and services and online creativity. For example, Israel scores highly and is ranked 7th in knowledge and technology outputs of the GII output sub-index. However it is ranked 36th in the creative outputs of the GII. Therefore, the overall score of Israel is much lower in the GII output sub-index compared to the IOI.

Figure 20. Score of the IOI and Global Innovation Output sub-index with correlation coefficient

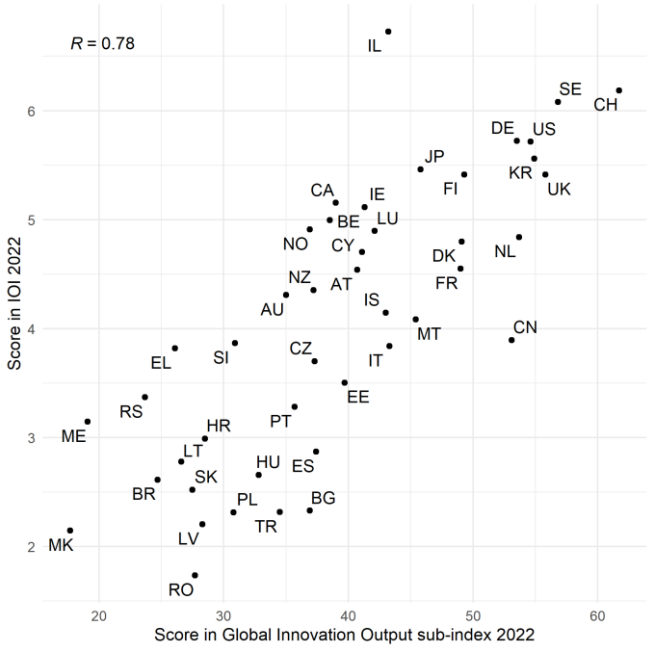


Figure 21 shows the scatterplot of the IOI 2022 and the Global Innovation Index 2022 scores. The correlation coefficient shows a strong relationship between the two indexes. The relationship between the IOI and the GII is stronger than that of the IOI with the GII output sub-index. A likely cause is the greater overlap in theme between the GII inputs and IOI. The GII input indicators focus on high-tech goods and services, weighing down the importance of the creative outputs, and aligning it further with the IOI. As a result, many countries in the GII and IOI have similar scores. Nevertheless, some countries scored differently. Israel scores lower in the GII compared to the IOI due to its score in institutions and infrastructure – which include rule of law and internet and electricity coverage. While Ireland performs less well due to its low scores on market sophistication in the GII. Estonia on the other hand, scores higher in the GII than the IOI because of its high scores on infrastructure, institutions and market sophistication inputs.

Figure 21. Score of the IOI and Global Innovation Index with correlation coefficient.

Figure 22 is a scatterplot of the IOI and SII scores. As with the GII there is a high correlation indicating substantial overlap in the phenomenon measured. Few countries deviate from the diagonal. Israel is one of these, an outlier in terms of its low score in the SII compared to the IOI. The cause is likely the inclusion of digitalisation (including internet access) and environmental sustainability in the SII, where Israel scores substantially lower than other top performers. Finally, it is also informative to consider for comparison the SII types of activities, i.e. investment, framework conditions, innovation activities and impacts. The latter includes three dimensions, namely employment impacts, sales impacts and environmental sustainability. As expected, the IOI correlates stronger with the impacts pillars (**Table 7**). This is mainly driven by the high correlation with the IOI and employment impacts sub-pillar, which includes the KIABI component in addition to a second component, which is close to the ENT indicator and corresponds to the share of innovative enterprises, measured in terms of employment.

Figure 22. Score of the IOI and Summary Innovation Index and correlation coefficient

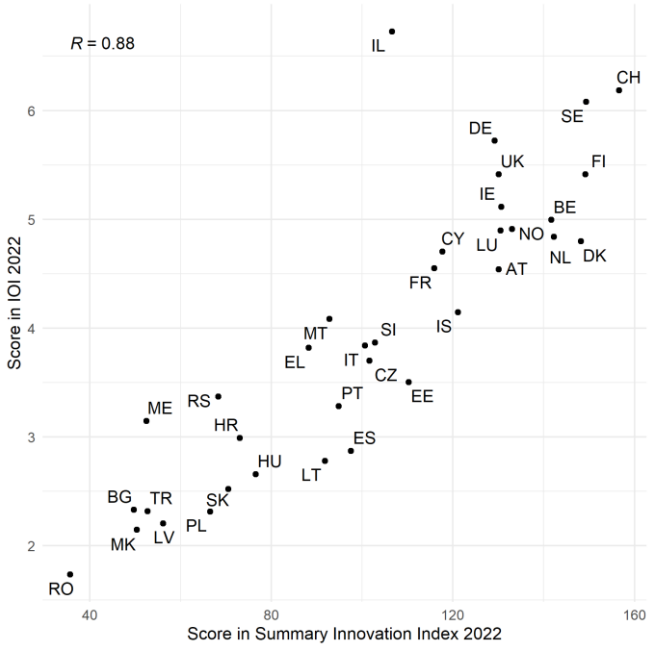


Table 7. Correlation table between EIS and IOI

	Investments	**Framework Conditions**	**Innovation Activities**	**Impacts**	**Impacts sub-pillars**		
					Employment Impacts	*Sales Impacts*	*Environmental Sustainability*
IOI	0.87	0.77	0.80	0.93	0.94	0.66	0.51

Note: all correlations are significant at p<0.001

Annex 3. Missing data patterns per IOI indicator

Figure 23. Missing data years per country on KIABI

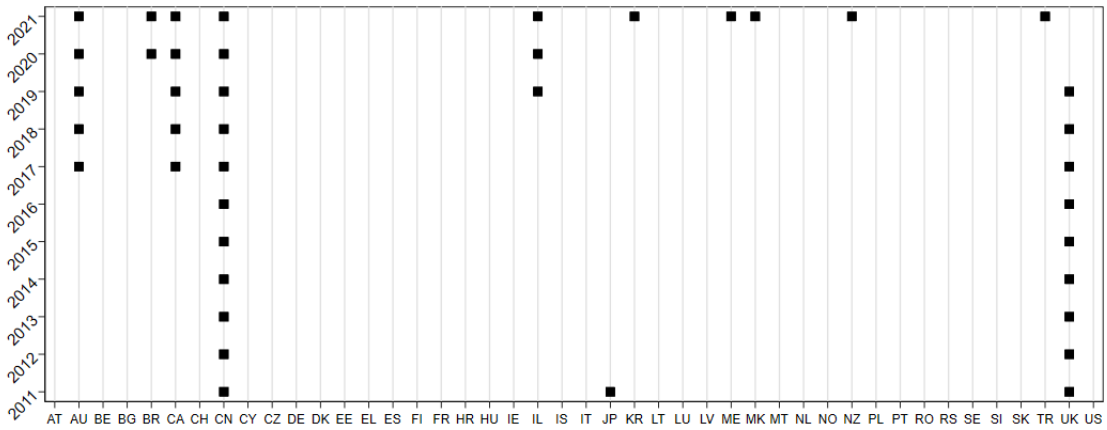


Figure 24. Missing data years per country on ENT

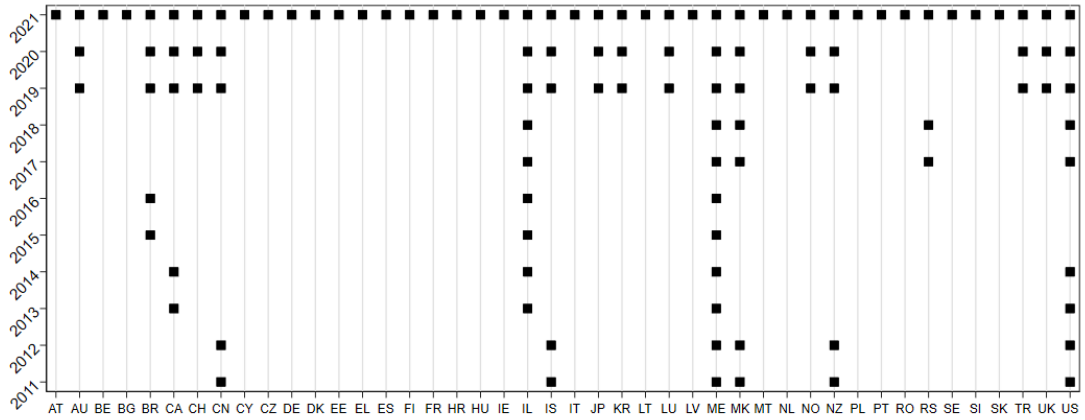


Figure 25. Missing data years per country on SERV_VA

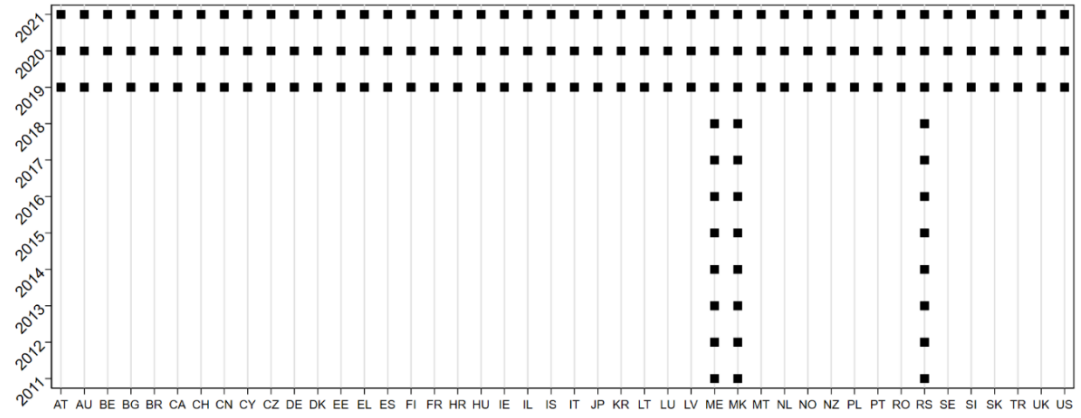


Figure 26. Missing data years per country on GOOD_VA

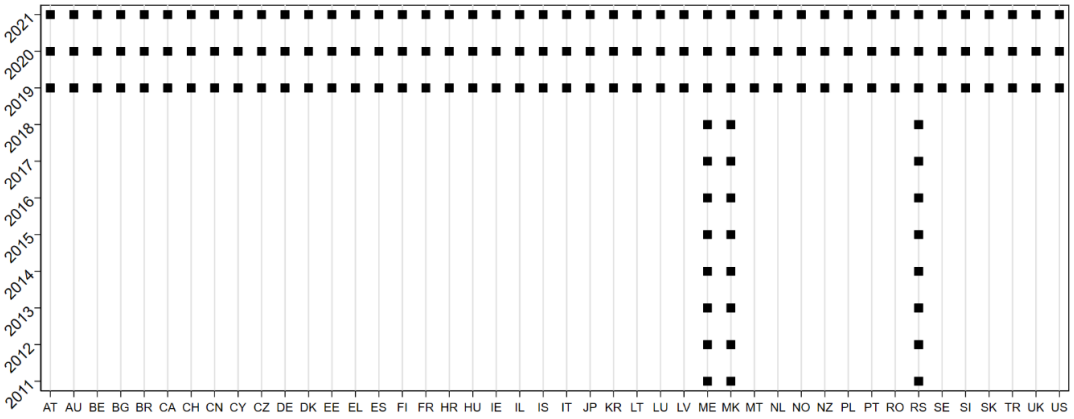


Figure 27. Missing data years per county on TRA_POP

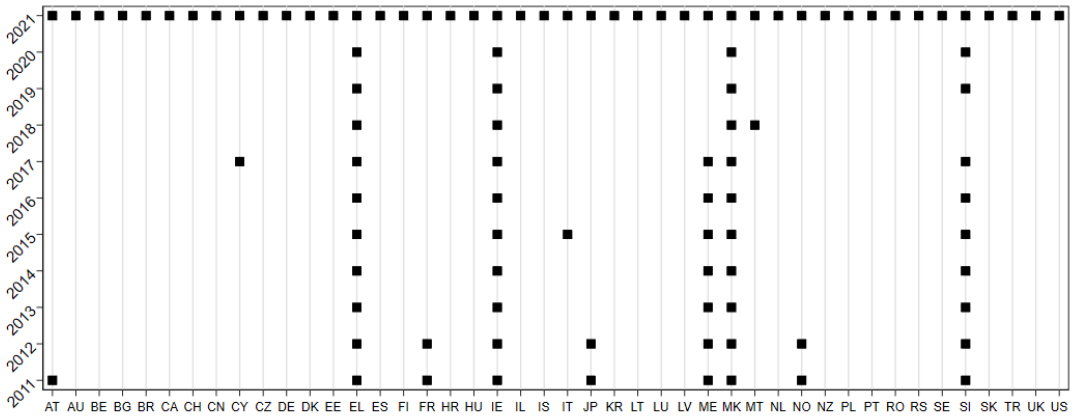


Figure 28. Missing data years per county on PCT_POP

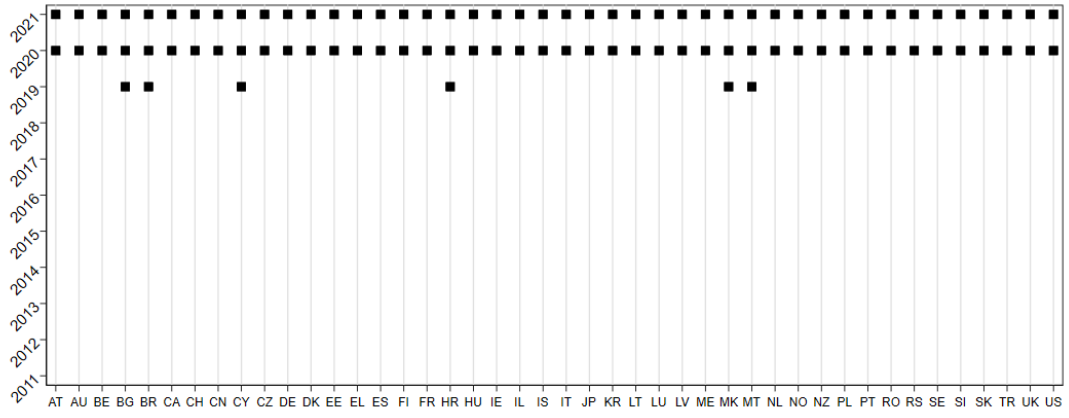


Table 8. Normalized and Imputed descriptive statistics of the IOI 2022 and data for the year 2021

Indicator	Min	Max	Mean	Median	Std	Skew	Kurt	N. non-missing
GOOD_VA	0.02	9.35	4.17	3.95	2.16	0.34	-0.31	44
SERV_VA	0.96	9.95	4.56	4.25	1.91	1	1.29	44

KIABI	0.71	10	3.84	3.63	1.76	1.03	2.32	44
PCT_POP	0.01	9.46	2.58	1.31	2.82	1.21	0.39	44
TRA_POP	0.08	5.78	1.76	1.37	1.26	1.15	1.41	44
ENT	0.07	10	5.96	6.37	2	-0.49	0.35	44

Annex 4. Country performance per IOI indicator

Table 9: Country performance per IOI indicator.

Country	Indicator	IOI	GOOD_va	SERV_va	Patents	Trademarks	TECH_CAP	ENT	IP	KIABI
AT	Rank 2021	18.5	18	28	10	16	25	12	10	24
AT	Value 2021	105	4.2	3.8	4.69	2.12	4	7.16	3.4	3.6
AT	% Change	5.71	-10.66	-13.25	14.06	-1.24	-11.89	11.24	9.31	12.26
AU	Rank 2021	22	41	11	22	11	31	9	22	26
AU	Value 2021	100	1.82	5.58	1.91	2.4	3.7	7.92	2.16	3.45
AU	% Change	3	-9.68	8.09	-17.23	11.36	3.72	2.16	-1.31	4.32
BE	Rank 2021	12	24	13	15	28	16	3	23	13
BE	Value 2021	116	3.93	5.54	2.95	1.27	4.74	8.78	2.11	4.35
BE	% Change	18.1	2.31	6.59	5.84	10.48	4.81	25.2	7.23	21.09
BG	Rank 2021	42	37	41	41	30	44	38	36	39
BG	Value 2021	54	2.32	2.78	0.19	1.17	2.55	3.74	0.68	2.34
BG	% Change	27.78	21.74	5.03	51.3	-7.87	12.62	33.85	0.56	44.93
BR	Rank 2021	39	29	20	42	39	23	40	41	40
BR	Value 2021	60	3.68	4.62	0.1	0.67	4.15	3.67	0.38	2.25
BR	% Change	-50	-13.31	1.03	23.68	67.69	-5.33	-146.43	62.11	8.98
CA	Rank 2021	11	23	23	20	35	22	1	26	12
CA	Value 2021	119	3.96	4.34	2.2	0.99	4.15	10	1.6	4.87
CA	% Change	6.72	-0.34	1.09	4.58	-38.88	0.41	16.05	-8.9	-0.8
CH	Rank 2021	2	3	4	4	4	4	31	2	8
CH	Value 2021	143	7.82	7.39	8.58	3.68	7.61	5.71	6.13	5.3
CH	% Change	-11.89	8.03	-1.74	11.89	16.02	3.28	-74.76	13.13	5.77
CN	Rank 2021	24	8	17	26	2	8	34	12	25
CN	Value 2021	95	6.54	4.92	1.14	4.6	5.73	4.39	2.87	3.45
CN	% Change	15.79	2.66	-2.58	82.37	90.02	0.41	-1.64	88.5	5.17
CY	Rank 2021	17	32	7	37	17	17	7	31	11

Country	Indicator	IOI	GOOD_va	SERV_va	Patents	Trademarks	TECH_CAP	ENT	IP	KIABI
CY	Value 2021	109	3.4	6.06	0.3	2.03	4.73	7.99	1.16	4.92
CY	% Change	31.19	44.24	-2.15	2.88	38.12	14.51	42.63	33.64	28.28
CZ	Rank 2021	30	17	35	32	24	28	16	33	30
CZ	Value 2021	86	4.41	3.23	0.53	1.56	3.82	6.71	1.04	3.23
CZ	% Change	15.12	-7.35	-3.09	14.81	-31.41	-5.55	27.84	-19.71	20
DE	Rank 2021	4.5	4	8	8	9	5	4	6	27.5
DE	Value 2021	132	7.75	5.97	5.86	2.63	6.86	8.42	4.24	3.36
DE	% Change	0.76	-0.22	-10.12	5.49	23.89	-4.53	3.24	11.19	-8.08
DK	Rank 2021	16	9	36	5	32	18	14	8	19.5
DK	Value 2021	111	6.3	3.03	6.44	1.14	4.67	6.83	3.79	3.91
DK	% Change	10.81	15.53	2.12	16.94	-18.27	11.17	13.89	11.67	3.48
EE	Rank 2021	31	39	31	29	12	40	26	25	23
EE	Value 2021	81	2.08	3.54	0.89	2.36	2.81	5.91	1.63	3.67
EE	% Change	19.75	3.02	2.81	-9.01	57.08	2.89	9	38.97	43.52
EL	Rank 2021	29	43	19	36	42	37	2	43	35
EL	Value 2021	88	1.4	4.74	0.33	0.43	3.07	8.97	0.38	2.82
EL	% Change	12.5	-49.47	-50.74	22.09	-19.68	-50.45	32.53	-1.72	19.28
ES	Rank 2021	36	16	29	27	29	21	43	32	34
ES	Value 2021	66	4.55	3.77	1.02	1.25	4.16	3.34	1.13	2.85
ES	% Change	3.03	-11.18	13.37	1.33	8.67	-0.07	-0.86	5.37	15.48
EU27_2020	Rank 2021	27	25	27	21	20	27	27	24	22
EU27_2020	Value 2021	89	3.88	3.92	2.17	1.74	3.9	5.9	1.96	3.69
EU27_2020	% Change	10.11	-1.95	-0.46	6.93	-2.62	-1.2	13.53	2.69	21.24
EU27_2020 int	Rank 2021	20	5	12	16	21	6	30	21	29
EU27_2020 int	Value 2021	104	7.73	5.55	2.68	1.73	6.64	5.76	2.2	3.33
EU27_2020 int	% Change	3.85	0.18	-7.96	6.45	7.71	-3.22	3.99	6.95	14.29
FI	Rank 2021	8.5	19	6	7	25	12	5	7	17.5
FI	Value 2021	125	4.19	6.51	6.23	1.35	5.35	8.41	3.79	4.11
FI	% Change	9.6	-25.11	17.92	-18.33	-24.81	1.07	27.52	-19.49	10.74
FR	Rank 2021	18.5	12	25	17	7	15	22	13	21

Country	Indicator	IOI	GOOD_va	SERV_va	Patents	Trademarks	TECH_CAP	ENT	IP	KIABI
FR	Value 2021	105	6.12	4.17	2.66	3.08	5.15	6.41	2.87	3.77
FR	% Change	0	-9.57	-5.35	-6.81	-7.36	-7.86	3.14	-7.11	12.61
HR	Rank 2021	35	36	32	38	36	38	21	39	42
HR	Value 2021	69	2.38	3.43	0.29	0.75	2.9	6.43	0.52	2.11
HR	% Change	13.04	-35.93	-33.46	7.18	22.69	-34.47	38.03	18.39	4.84
HU	Rank 2021	38	27	30	30	41	30	44	38	31
HU	Value 2021	61	3.85	3.59	0.64	0.45	3.72	3.23	0.55	3.12
HU	% Change	4.92	-8.84	26.31	4.67	-2.78	8.13	0.89	1.59	9.78
IE	Rank 2021	10	14	14	19	13	11	15	18	3
IE	Value 2021	121	5.4	5.53	2.34	2.35	5.46	6.76	2.34	6.38
IE	% Change	-2.48	17.84	4.6	5.84	-167.76	11.14	-3.19	-81.18	14.89
IL	Rank 2021	1	11	1	6	45	2	32	11	1
IL	Value 2021	156	6.17	9.95	6.4	0.13	8.06	5.58	3.26	10
IL	% Change	3.21	-14.8	14.05	7.38	36.95	3	0	7.97	2.45
IS	Rank 2021	23	46	10	14	10	39	13	14	17.5
IS	Value 2021	96	0.02	5.64	2.98	2.56	2.83	6.87	2.77	4.11
IS	% Change	-12.5	-699.36	-31.46	1.51	-26.77	-33.75	-2.51	-11.57	-14.05
IT	Rank 2021	27	15	43	23	26	26	19	28	27.5
IT	Value 2021	89	5.21	2.72	1.64	1.33	3.97	6.54	1.49	3.36
IT	% Change	2.25	-6.54	0.92	15.19	16.46	-3.98	-0.88	15.76	11.11
JP	Rank 2021	7	1	45	1	19	10	23	3	14
JP	Value 2021	126	9.35	1.76	9.46	1.77	5.55	6.33	5.62	4.35
JP	% Change	11.9	-6.99	-14.21	32.98	62.27	-8.13	14.38	37.6	2.07
KR	Rank 2021	6	6	16	2	5	7	42	1	5
KR	Value 2021	129	7.63	4.98	9.43	3.65	6.3	3.5	6.54	5.89
KR	% Change	29.46	12.95	-11.74	50.75	51.63	3.2	14.38	51	41.5
LT	Rank 2021	37	42	46	35	33	46	25	35	33
LT	Value 2021	64	1.78	0.96	0.38	1.03	1.37	6.15	0.7	2.89
LT	% Change	43.75	-0.4	53.24	68.78	41.49	18.38	46.96	48.88	50.59
LU	Rank 2021	14	45	40	12	1	45	29	5	2
LU	Value 2021	113	0.67	2.82	3.54	5.78	1.75	5.81	4.66	7.37

Country	Indicator	IOI	GOOD_va	SERV_va	Patents	Trademarks	TECH_CAP	ENT	IP	KIABI
LU	% Change	-17.7	-6.26	-33.01	18.24	-47.13	-27.85	-38.37	-22.32	5.53
LV	Rank 2021	44	40	34	34	37	43	45	37	36.5
LV	Value 2021	51	1.94	3.35	0.41	0.7	2.65	3.13	0.56	2.48
LV	% Change	19.61	40.64	-1.43	7.07	15.94	14.01	7.34	12.64	41.1
ME	Rank 2021	32.5	38	22	46	44	32	11	45	36.5
ME	Value 2021	78	2.26	4.54	0.01	0.17	3.4	7.49	0.09	2.48
ME	% Change	23.08	6.74	23.08	100	-122.74	17.65	28.06	-105.56	20.55
MK	Rank 2021	45	21	33	43	46	29	36	46	45
MK	Value 2021	47	4.04	3.41	0.09	-1.02	3.72	3.91	-0.46	1.02
MK	% Change	14.89	-9.22	49.93	59.04	-33.36	17.84	5.15	-42.73	16.67
MT	Rank 2021	25	28	18	28	3	20	35	16	9
MT	Value 2021	94	3.75	4.76	0.96	4.19	4.25	4.24	2.58	5.26
MT	% Change	13.83	14.92	23.91	85.23	65.19	19.95	-38.64	68.93	25.81
NL	Rank 2021	15	20	26	9	18	24	18	9	10
NL	Value 2021	112	4.06	4.15	5.15	1.93	4.1	6.56	3.54	5.16
NL	% Change	7.14	-16.46	-26.26	-0.06	-13.98	-21.41	9.65	-3.85	32.89
NO	Rank 2021	13	34	5	13	27	14	6	19	19.5
NO	Value 2021	114	2.99	7.31	3.37	1.29	5.15	8.25	2.33	3.91
NO	% Change	19.3	-9.52	11.8	-20.92	-0.66	5.62	39.9	-15.29	13.91
NZ	Rank 2021	21	44	21	24	6	42	24	20	4
NZ	Value 2021	101	0.72	4.6	1.47	3.15	2.66	6.21	2.31	6.23
NZ	% Change	3.96	-14.7	-1.25	-34.77	27.04	-3.07	9.94	7.41	-1.2
PL	Rank 2021	42	31	42	40	40	36	41	40	41
PL	Value 2021	54	3.42	2.75	0.28	0.61	3.08	3.55	0.45	2.17
PL	% Change	24.07	-24.93	20.23	37.74	-5.98	-4.8	48.18	7.89	29.69
PT	Rank 2021	34	35	37	31	14	41	28	30	32
PT	Value 2021	76	2.58	3.02	0.64	2.22	2.8	5.88	1.43	3.02
PT	% Change	6.58	-19.73	-18.92	45.9	27.25	-19.29	-8.56	31.43	50.56
RO	Rank 2021	46	10	24	44	38	13	46	42	44
RO	Value 2021	40	6.25	4.34	0.08	0.68	5.29	0.07	0.38	1.19
RO	% Change	-10	9.31	-6.03	32.05	4.85	3.02	-2000	7.79	48.57

Country	Indicator	IOI	GOOD_va	SERV_va	Patents	Trademarks	TECH_CAP	ENT	IP	KIABI
RS	Rank 2021	32.5	26	15	45	43	19	17	44	43
RS	Value 2021	78	3.88	5.39	0.08	0.19	4.63	6.7	0.13	2.07
RS	% Change	21.79	-8.46	32.18	-7.62	93.14	15.16	19.96	63.33	37.7
SE	Rank 2021	3	13	9	3	23	9	8	4	7
SE	Value 2021	141	5.58	5.8	8.8	1.69	5.69	7.92	5.24	5.47
SE	% Change	12.77	2.56	4.51	8.61	-9.12	3.55	17.06	5.75	22.36
SI	Rank 2021	27	22	44	25	22	33	20	29	16
SI	Value 2021	89	3.99	2.63	1.15	1.73	3.31	6.47	1.44	4.24
SI	% Change	10.11	-19.36	-10.11	-46.31	-2.75	-15.69	19.33	-20.15	28
SK	Rank 2021	40	33	39	39	31	35	37	34	38
SK	Value 2021	58	3.3	2.95	0.29	1.14	3.12	3.8	0.71	2.44
SK	% Change	17.24	-6.12	59.77	38.62	11.13	25.01	9.85	16.68	20.83
TR	Rank 2021	42	30	38	33	8	34	39	27	46
TR	Value 2021	54	3.49	3.01	0.46	2.72	3.25	3.71	1.59	0.71
TR	% Change	0	4.42	10.26	63.21	50.66	7.13	-48.45	52.49	100
UK	Rank 2021	8.5	7	2	18	15	1	33	17	6
UK	Value 2021	125	6.55	9.85	2.55	2.2	8.2	5.34	2.38	5.74
UK	% Change	2.4	3.13	-0.16	6.13	55.14	1.16	-7.99	28.83	4.82
US	Rank 2021	4.5	2	3	11	34	3	10	15	15
US	Value 2021	132	7.93	8.1	4.45	1	8.01	7.83	2.72	4.3
US	% Change	2.27	-5.58	0.92	17.55	47.56	-2.3	0	23.04	4.26

Annex 5. Definitions of IOI indicators

INDICATOR: PCT_POP		
	Numerator	**Denominator**
Definition	Number of PCT patent applications	Millions Population
Source	OECD MSTI (MSTI_PUB/P_PCT.) if available OECD PATSTAT otherwise. (PATS_IPC/PCT_A.INVENTORS..TOTAL.PRIORITY) OECD REGPAT Microdata used to compute missing countries (incl. RS, ME)	World Bank sp.pop.totl

Notes		
Most recent year used [Nr. Years lag vs. 2021]	2019 [2]	
Corresponding EIS indicator	NA	

INDICATOR: TRA_POP		
	Numerator	**Denominator**
Definition	Number of trademark classes in total trademark resident applications in direct and Madrid system by origin (equivalent count).	Millions of Population
Source	WIPO IP Statistics Data Center: https://www3.wipo.int/ipstats/index.htm?tab=trademark Indicator: "5 – Class count in total applications (direct and via the Madrid system)". Report type: "Total count by applicant's origin (equivalent count)". Type = "Resident".	World Bank sp.pop.totl
Notes	Missing time-series for Greece, Ireland, North Macedonia.	
Most recent year used [Nr. Years lag vs. 2021]	2020 [1]	
Corresponding EIS indicator	NA	

INDICATOR: KIABI		
	Numerator	**Denominator**
Definition	Employment in knowledge-intensive business industries	Total employment
Sources	Eurostat, htec_kia_emp2; Japan Statistical Office, LFS; US BLS CPB; UK BRES, OECD, SSIS_BSC_ISIC4, KOSIS	
Notes	US, JP: data reporting discontinued on Eurostat website; figures were re-computed using national sources, following methodology described by Eurostat htec_esms. UK: data not available from 2020 onward, figures were re-computed using national sources, following methodology described by Eurostat htec_esms.	

	KR: Korean Office Statistical Information Service (KOSIS) from 2016-2020 No data available for China.
Most recent year used [Nr. year lag vs 2021]	2021 [0]
Corresponding EIS indicator	4.1.1 Employment in knowledge-intensive activities as percentage of total employment

INDICATOR: GOOD_VA		
	Numerator	**Denominator**
Definition	Domestic value added content of medium-high and high-tech manufacturing exports. Medium-high and high tech industries: ISIC Rev 4 Divisions 20,21,26,27,28,29,30.	Total manufacturing exports Manufacturing sectors: ISIC Rev. 4 Division 10-33.
Sources	OECD TIVA_2021_C1, EXGR_DVASH	
Notes	Data is missing for Montenegro, North Macedonia and Serbia	
Most recent year used [Nr. year lag vs 2021]	2018 [3]	
Corresponding EIS indicator	NA	

INDICATOR: SERV_VA		
	Numerator	**Denominator**
Definition	Domestic value added content of knowledge-intensive service exports Knowledge intensive service sectors: ISIC Rev. 4 Divisions: 50,51, 58, 59, 60, 61, 62, 63, 64, 65, 66, 69, 70, 71, 72, 73,74,75, 84, 85, 86, 87, 88, 90, 91, 92, 93	Total service exports Service sectors: ISIC Rev. 4 Division 45-95.
Sources	OECD TIVA_2021_C1, EXGR_DVASH	
Notes	Sectors 78 and 80 are not considered as they are aggregated into group 77-82.	

	Data is missing for Montenegro, North Macedonia and Serbia
Most recent year used [Nr. year lag vs 2021]	2018 [3]
Corresponding EIS indicator	NA

INDICATOR: ENT		
	Numerator	**Denominator**
Definition	Number of Innovation-active enterprises Innovation-active firms include product and/or process innovative firs, as well as firms with only innovation activities	Total number of enterprises.
Sources	Eurostat Community Innovation Survey OECD Innovation Indicators database	
Notes	Figures are based on Eurostat CIS core industries (NACE Rev. 2 sections & divisions B-C-D-E-46-H-J-K-71-72-73).	
Most recent year used [Nr. year lag vs 2021]	2020 [1]	
Corresponding EIS indicator	NA	

Annex 6. Contextual indicators

Table 10: Country performance and structure of the economy

Country	GDP per capita (PPS)				FDI inflows (as % of GDP)				Employment in the manufacturing sector, as a percentage of total employment				Employment in the service sector, as a percentage of total employment			
	2021	2020-21 Growth rate	2019-21 Growth rate	2011-21 Growth rate	2021	2020-21 Growth rate	2019-21 Growth rate	2011-21 Growth rate	2021	2020-21 Growth rate	2019-21 Growth rate	2011-21 Growth rate	2021	2020-21 Growth rate	2019-21 Growth rate	2011-21 Growth rate
AT	39,753.8	6.0	0.9	20.0	2.6	-195.7	-192.1	-51.8	16.7	7.1	4.4	5.0	70.7	-0.6	-0.6	2.3
BE	38,993.7	9.1	5.9	27.8	4.0	-187.3	-201.4	-87.1	11.5	-6.5	-6.5	-19.0	79.7	1.3	1.8	5.6
BG	18,638.3	12.5	12.2	58.9	2.5	-50.7	-21.6	-30.7	18.6	0.5	-1.1	-7.0	62.9	-0.3	-0.6	1.8
CY	21,303.9	8.9	2.2	15.2	-117.4	12.8	-157.7	-180.2	7.2	-5.3	-1.4	-6.5	79.3	1.9	0.0	4.9
CZ	30,251.6	7.8	3.7	40.0	2.7	-22.0	-36.5	48.0	26.1	-2.6	-5.1	-1.5	60.5	0.7	0.8	3.4
DE	38,982.4	5.4	2.9	23.0	1.7	-52.9	-6.2	-33.5	20.0	0.0	5.8	0.5	70.9	-0.3	-1.0	1.1
DK	43,016.5	8.0	8.8	30.0	3.7	728.8	-436.6	-6.3	11.5	1.8	4.5	-9.4	78.3	-0.5	-0.9	1.0
EE	28,824.1	11.6	12.0	57.5	19.8	71.7	101.5	310.6	18.2	-1.1	-1.6	-7.6	68.3	1.6	1.5	8.2
EL	20,747.7	11.5	0.9	8.5	2.9	63.2	17.2	639.5	9.9	3.1	3.1	-2.0	73.4	-1.3	0.4	4.7
ES	26,957.9	8.3	-5.2	13.5	3.1	7.2	65.7	69.8	12.3	-3.1	-2.4	-3.9	75.8	0.4	0.4	2.3
FI	36,269.0	5.9	6.1	19.0	8.0	-977.5	38.1	-468.3	12.6	-3.1	-1.6	-13.1	74.1	-0.1	-0.4	2.2
FR	34,053.0	8.0	2.2	22.1	3.0	435.8	52.5	93.8	11.0	-4.3	-6.8	-16.7	75.8	-1.0	-0.3	1.6
HR	22,901.7	17.8	9.9	45.7	6.8	210.9	6.9	243.1	17.7	0.0	-0.6	1.7	64.3	-1.4	-2.7	11.4
HU	24,322.6	8.7	6.4	41.8	16.1	-84.9	-73.2	113.3	21.2	-1.9	-4.1	-0.5	64.1	1.3	1.4	-0.3
IE	70,653.9	14.8	19.4	110.3	16.1	96.7	-237.6	62.1	11.7	1.7	6.4	3.5	76.8	0.1	0.1	0.0
IT	30,964.3	9.6	2.5	13.6	0.9	-177.0	-42.1	-40.3	18.6	-1.1	0.5	-0.5	69.3	-0.6	-1.4	1.9
LT	29,049.4	10.5	10.2	70.4	4.4	-43.7	-29.3	2.6	16.6	5.1	4.4	6.4	68.4	-0.7	0.7	2.1
LU	87,188.9	10.9	10.5	23.9	-10.6	-107.7	-157.8	-173.9	3.2	-15.8	-13.5	-44.8	84.8	1.6	2.4	2.4
LV	23,216.4	7.3	6.9	61.9	9.3	244.4	187.7	68.8	12.6	-1.6	0.0	-5.3	69.4	0.6	0.7	1.8
MT	33,132.1	12.6	2.0	53.5	25.2	-12.0	-5.2	-68.9	10.5	-5.4	-5.4	-30.9	80.9	0.4	1.1	8.9
NL	42,055.5	7.3	5.9	21.1	-14.0	-41.8	797.5	-138.2	8.3	-7.8	-8.8	-9.8	82.1	11.9	11.5	15.0
PL	25,282.5	9.3	9.6	49.8	5.5	71.0	84.8	57.3	19.4	-2.5	-5.8	3.2	60.3	3.3	3.3	6.9
PT	24,290.1	6.1	-1.3	21.8	3.1	77.6	-28.0	-22.8	16.9	-1.7	-1.7	0.6	72.7	3.3	3.4	13.9
RO	24,051.0	10.1	10.2	71.7	4.1	188.3	40.8	235.8	19.7	8.8	4.2	8.8	55.4	11.2	13.8	31.3

Country	GDP per capita (PPS)				FDI inflows (as % of GDP)				Employment in the manufacturing sector, as a percentage of total employment				Employment in the service sector, as a percentage of total employment			
	2021	2020-21 Growth rate	2019-21 Growth rate	2011-21 Growth rate	2021	2020-21 Growth rate	2019-21 Growth rate	2011-21 Growth rate	2021	2020-21 Growth rate	2019-21 Growth rate	2011-21 Growth rate	2021	2020-21 Growth rate	2019-21 Growth rate	2011-21 Growth rate
SE	39,862.5	8.4	7.1	19.9	8.3	139.8	167.9	581.7	9.9	0.0	-1.0	-17.5	79.0	-0.5	-0.6	1.7
SI	29,153.8	8.9	5.0	35.2	3.5	269.1	-12.1	104.9	22.1	-12.6	-13.7	-5.2	65.7	6.5	7.0	9.9
SK	22,480.8	4.3	1.8	14.9	0.8	-177.9	-61.4	-84.7	24.9	-0.8	1.2	2.9	60.8	-0.2	-0.5	2.4
EU	**32,479.5**	**8.0**	**3.6**	**26.4**	**2.2**	**25.1**	**-2.5**	**-60.5**	**16.1**	**-1.8**	**-1.2**	**-3.0**	**70.9**	**1.1**	**1.1**	**4.3**

Source: Eurostat and World Bank's *World Development Indicators*, accessed on 7 March 2023.

Table 11: Orientation of the economy toward knowledge-intensive sectors

Country	Employment in the high and medium-high tech manufacturing sectors, as a share of total manufacturing employment				Employment in the knowledge-intensive service sector, as a share of total service employment				The share of medium- and high-tech products in total product exports (GOOD)				Knowledge-intensive services exports as share of total service (SERV) exports			
	2021	2020-21 Growth rate	2019-21 Growth rate	2011-21 Growth rate	2021	2020-21 Growth rate	2019-21 Growth rate	2019-21 Growth rate	2021	2020-21 Growth rate	2019-21 Growth rate	2011-21 Growth rate	2021	2020-21 Growth rate	2019-21 Growth rate	2019-21 Growth rate
AT	6.5	6.6	4.8	18.2	40.2	2.0	3.6	10.4	56.2	-2.5	-3.6	4.2	55.4	8.9	20.9	27.6
BE	4.4	0.0	-4.3	-15.4	51.4	2.8	7.3	11.3	52.7	-0.9	3.9	12.6	74.1	0.7	3.7	12.9
BG	4.5	4.7	7.1	32.4	31.8	1.3	3.6	8.2	36.6	0.3	3.5	42.5	59.2	2.9	31.3	96.2
CY	1.1	22.2	37.5	57.1	42.0	4.2	8.2	17.3	54.1	-6.0	-2.6	42.0	86.6	-7.1	12.8	21.1
CZ	11.3	-1.7	-1.7	14.1	35.9	4.1	7.2	13.6	65.7	-3.4	-3.5	3.9	55.0	6.4	22.7	37.6
DE	10.1	0.0	2.0	3.1	42.2	-0.7	2.7	4.7	66.0	-1.5	-2.2	1.6	79.0	1.5	5.9	3.5
DK	5.0	2.0	8.7	-9.1	49.4	0.4	1.4	-1.0	50.7	-4.6	-1.7	19.9	82.4	1.7	11.5	5.5
EE	4.3	0.0	2.4	-2.3	38.4	3.2	4.6	12.0	37.3	-7.6	-5.1	-3.1	68.7	12.0	31.4	48.4
EL	1.6	-5.9	0.0	14.3	39.1	2.1	6.8	12.7	25.0	-13.6	8.6	19.7	64.9	-12.9	26.3	14.3
ES	4.0	0.0	0.0	5.3	38.3	2.4	6.1	7.6	43.9	-4.3	-3.7	-5.7	48.2	-10.1	50.5	57.2
FI	4.7	-6.0	0.0	-11.3	45.7	-3.8	-1.1	3.6	44.5	-3.9	-3.2	7.5	85.0	2.6	11.2	32.6
FR	3.8	-7.3	-9.5	-20.8	46.6	-2.3	-0.2	5.4	54.2	-4.9	-7.4	-3.2	67.9	-2.8	7.8	8.0
HR	3.7	2.8	5.7	-2.6	34.5	-3.9	-4.7	16.9	35.8	-9.1	-11.8	-17.4	23.0	-25.8	6.1	13.3
HU	9.3	-3.1	-4.1	6.9	37.0	3.9	6.0	7.2	66.6	-4.1	-2.9	-0.9	53.5	-3.4	5.1	8.0
IE	4.6	9.5	27.8	-8.0	48.4	3.0	7.6	7.3	63.0	3.2	10.5	23.9	94.5	0.7	1.7	6.9
IT	6.4	0.0	1.6	10.3	35.4	0.0	1.7	3.8	49.9	-3.6	-2.3	-0.1	60.2	-3.8	24.4	15.2
LT	2.8	7.7	16.7	64.7	37.1	0.8	5.7	9.1	39.1	-2.0	3.6	21.7	31.8	19.6	38.8	75.2
LU	0.5	-28.6	-37.5	-28.6	57.4	1.8	3.6	2.9	41.6	-2.4	-13.3	-15.2	92.7	0.1	1.4	6.5
LV	2.0	-9.1	17.6	53.8	38.0	2.4	4.1	7.6	31.8	-6.0	-4.3	7.5	60.5	8.4	14.1	19.4
MT	2.8	-15.2	-17.6	-33.3	49.8	3.8	6.4	17.7	54.8	-10.3	5.2	11.0	47.8	-8.9	-4.9	-24.3
NL	2.9	3.6	3.6	16.0	52.1	11.6	13.0	15.0	50.9	-6.0	-0.1	21.0	79.4	-1.3	-0.6	27.8
PL	5.2	-3.7	-10.3	8.3	33.2	3.1	4.7	10.7	48.8	-1.1	-1.3	-1.6	48.6	-0.1	9.7	22.6
PT	3.5	6.1	6.1	20.7	41.7	10.0	13.6	31.1	41.0	-3.9	-3.7	11.3	47.4	-0.7	28.7	9.4
RO	6.8	7.9	4.6	44.7	25.2	9.6	12.0	22.3	55.2	-6.3	-3.9	10.2	52.3	-3.6	9.0	30.2

Country	Employment in the high and medium-high tech manufacturing sectors, as a share of total manufacturing employment				Employment in the knowledge-intensive service sector, as a share of total service employment				The share of medium- and high-tech products in total product exports (GOOD)				Knowledge-intensive services exports as share of total service (SERV) exports			
	2021	2020-21 Growth rate	2019-21 Growth rate	2011-21 Growth rate	2021	2020-21 Growth rate	2019-21 Growth rate	2019-21 Growth rate	2021	2020-21 Growth rate	2019-21 Growth rate	2011-21 Growth rate	2021	2020-21 Growth rate	2019-21 Growth rate	2019-21 Growth rate
SE	4.4	4.8	4.8	-4.3	55.6	1.8	3.0	8.6	53.1	-5.7	-5.4	-0.1	81.2	-3.3	3.9	10.2
SI	8.8	-15.4	-14.6	7.3	41.8	11.2	17.1	21.2	60.9	-3.1	2.1	12.1	42.5	1.8	23.9	23.8
SK	11.9	6.3	9.2	22.7	36.3	2.3	3.4	12.4	67.8	-4.2	-1.7	12.6	46.3	1.0	21.0	93.1
EU	**6.1**	**-1.6**	**-1.6**	**3.4**	**40.7**	**1.5**	**4.4**	**8.5**	**55.6**	**-3.4**	**-2.3**	**4.1**	**74.7**	**-0.3**	**10.8**	**12.9**

Source: Eurostat, accessed on 7 March 2023.

Table 12: Entrepreneurship

Country	Birth rate, number of enterprise births on the total number of active enterprises				Employment share of enterprise births				Employment in fast-growing enterprises, as a share of total employment (DYN_rev)			
	2020	2019-20 Growth rate	2018-20 Growth rate	2011-20 Growth rate	2020	2019-20 Growth rate	2018-20 Growth rate	2011-20 Growth rate	2020	2019-20 Growth rate	2018-20 Growth rate	2011-20 Growth rate
AT	5.4	-9.8	-13.2	-29.4	1.1	-16.8	-19.3	-46.3	7.0	0.0	-20.3	-26.5
BE	6.9	-3.8	3.8	-2.3	2.3	-2.1	14.2	11.0	5.7	-21.2	-4.5	-39.2
BG	9.1	-20.4	-20.2	-17.4	2.1	-21.1	-26.0	-27.8	14.2	0.0	-25.4	-22.4
CY	9.1	3.3	-12.7	100.4	2.0	6.4	-20.3	19.8	2.9	-63.9	-64.4	-75.5
CZ	8.2	-6.5	-13.8	-22.7	1.9	-7.8	-10.4	-41.7	10.9	-19.4	-28.9	-3.8
DE	7.2	-21.6	-10.5	-17.3	1.2	-24.1	-1.6	-16.3	12.3	-9.2	-10.0	-16.6
DK	11.0	0.5	0.2	-9.1	1.5	4.1	10.1	-12.1	11.8	0.0	0.0	14.5
EE	12.1	9.1	-0.7	1.9	3.5	21.5	9.4	21.5	12.7	-14.3	-20.0	10.8
EL	4.6	-3.8	-1.7	-10.7	2.7	-6.9	-2.2	-10.9	25.6	0.0	0.0	0.0
ES	7.4	-20.7	-23.7	-7.0	2.5	-22.1	-26.7	-19.6	15.4	-21.4	-27.8	53.5
FI	8.8	1.7	10.0	-9.8	1.5	6.9	-26.3	108.1	15.6	-25.7	-19.6	37.7
FR	11.3	-6.1	3.7	2.8	3.3	-4.9	9.3	32.3	7.3	-26.6	-25.9	-50.1
HR	9.4	-26.1	-4.8	14.5	2.4	-26.3	-20.5	-25.8	12.3	-14.6	-14.0	12.9
HU	10.7	-13.2	-18.3	7.6	2.7	-41.0	-39.4	-26.8	20.1	-1.5	-4.5	19.7
IE	6.7	0.0	25.6	7.2	1.7	0.0	50.9	97.7	23.7	-4.2	-4.9	69.2
IT	6.5	-11.9	-8.7	-2.4	1.9	-15.5	-15.5	-15.9	12.2	-20.0	-28.4	24.3
LT	18.1	-6.4	-4.6	-23.6	2.9	-8.3	-4.3	-47.5	16.1	-11.6	-5.8	-17.8
LU	7.8	-14.4	-13.1	-19.4	1.3	-25.4	-17.1	-25.9	11.9	-12.5	-15.2	31.9
LV	11.3	-2.8	-7.4	-40.9	2.4	-5.9	-23.6	-53.9	12.2	-7.5	-11.4	-27.0
MT	14.1	1.9	-5.1	305.7	4.4	9.0	34.7	130.2	19.4	-14.3	-14.3	31.2
NL	10.4	-3.0	5.5	-6.5	1.4	-2.2	7.9	-17.1	16.9	-27.4	-39.4	7.4
PL	10.4	-17.9	-21.4	-16.3	2.9	-17.8	-21.9	-28.0	18.2	-6.7	-6.7	17.5
PT	12.2	-22.6	-23.7	-2.8	3.8	-24.3	-24.6	-11.1	21.8	-5.7	10.9	73.2

Country	Birth rate, number of enterprise births on the total number of active enterprises				Employment share of enterprise births				Employment in fast-growing enterprises, as a share of total employment (DYN_rev)			
	2020	2019-20 Growth rate	2018-20 Growth rate	2011-20 Growth rate	2020	2019-20 Growth rate	2018-20 Growth rate	2011-20 Growth rate	2020	2019-20 Growth rate	2018-20 Growth rate	2011-20 Growth rate
RO	10.8	-7.5	-0.9	-17.2	3.3	-5.8	4.2	-19.8	5.2	-9.0	-24.3	-9.9
SE	6.8	9.3	7.3	-17.0	1.8	-0.6	-2.2	-27.0	19.2	13.6	8.1	15.1
SI	9.1	-12.2	-14.2	-10.5	2.2	-11.4	-14.6	-11.1	10.7	-36.5	-38.9	12.5
SK	10.4	-14.1	-17.2	-27.5	3.6	-16.7	-17.9	-24.1	10.2	0.0	-45.2	-52.6
EU	**8.9**	**-11.6**	**-8.7**	**-1.4**	**2.2**	**-14.7**	**-10.6**	**-10.6**	**12.5**	**-17.9**	**-21.3**	**8.4**

Source: Eurostat, accessed on 7 March 2023. Note: Data on employment in fast-growing enterprises refers to 2019 for Poland and to 2018 for Denmark, Greece, Hungary, Ireland and Portugal.

Table 13: Innovation

Country	R&D investment (PPS, 2005 constant prices)				R&D expenditure, as a percentage of GDP				Employment in innovation-active firms, as a share of total employment			Share of turnover from new-to-market products		
	2021	2020-21 Growth rate	2019-21 Growth rate	2011-21 Growth rate	2021	2020-21 Growth rate	2019-21 Growth rate	2011-21 Growth rate	2020	2018-20 Growth rate	2011-20 Growth rate	2020	2018-20 Growth rate	2011-20 Growth rate
AT	8,973.5	4.1	-0.4	29.8	3.2	-0.3	1.9	19.5	80.7	-0.1	5.8	5.7	-9.5	38.5
BE	11,306.6	1.7	2.3	67.0	3.2	-3.9	1.9	48.4	86.0	1.7	7.1	5.5	34.1	36.5
BG	739.0	-2.1	-4.0	78.5	0.8	-9.4	-7.2	45.3	59.9	3.6	25.1	2.8	0.0	54.0
CY	195.9	9.4	24.5	124.6	0.9	3.6	22.5	93.3	76.5	-0.9	26.7	4.9	53.1	12.3
CZ	5,087.7	4.1	1.3	55.0	2.0	0.5	3.6	29.9	76.3	13.5	9.8	6.1	-4.7	-7.5
DE	82,116.7	2.7	-2.2	23.7	3.1	0.0	-1.3	11.4	86.4	-0.1	0.1	3.4	-2.9	14.2
DK	5,186.2	-0.7	-1.8	13.5	2.8	-5.1	-4.1	-4.4	68.2	-0.4	-6.7	4.7	51.6	-42.1
EE	471.3	8.1	15.4	5.4	1.8	0.0	7.4	-24.2	77.0	-9.3	19.2	2.3	-68.3	-37.0
EL	2,755.2	4.3	12.3	98.0	1.5	-4.0	13.3	113.2	82.5	9.4	17.7	9.7	-6.7	72.4
ES	15,309.3	6.9	7.0	11.8	1.4	1.4	14.4	7.5	58.2	2.1	-6.3	6.4	-7.2	19.7
FI	4,710.5	5.4	7.0	-11.9	3.0	2.4	6.4	-17.7	81.8	1.0	8.8	5.0	-7.4	14.5
FR	40,434.5	2.6	-0.6	9.8	2.2	-3.9	0.9	0.9	82.0	3.9	5.7	3.6	-26.5	-42.7
HR	816.4	13.3	19.2	97.0	1.2	0.0	14.8	67.6	72.3	6.3	10.6	3.9	21.9	8.1
HU	3,081.1	10.6	14.3	82.6	1.7	3.8	12.2	39.8	53.5	2.7	-11.3	2.6	-36.6	-47.1
IE	3,136.8	-2.7	4.0	42.6	1.1	-13.8	-13.8	-31.6	76.0	42.3	0.0	18.4	166.7	-66.0
IT	20,558.0	5.4	-1.2	20.5	1.5	-1.3	2.1	24.2	71.7	-6.5	-3.4	4.3	-31.7	-15.3
LT	688.3	3.4	18.1	71.8	1.1	-2.6	12.1	23.3	76.2	7.2	39.3	4.3	19.4	105.9
LU	392.7	-1.5	-9.8	-9.2	1.0	-6.4	-13.6	-28.2	65.2	-2.2	-20.2	1.4	-41.7	-64.7
LV	233.5	4.3	10.2	27.8	0.7	0.0	7.8	-4.2	51.6	-7.0	-2.1	3.0	-6.3	28.9
MT	94.1	8.2	14.6	64.1	0.6	-3.1	12.5	-6.0	59.5	-5.1	-19.2	3.1	-13.9	18.8
NL	13,945.8	1.9	4.1	35.6	2.3	-2.6	3.2	19.7	70.6	7.8	-8.1	4.9	2.1	-29.9
PL	11,427.6	10.7	13.6	165.7	1.4	3.6	9.1	92.0	60.9	20.8	12.4	3.6	63.6	35.6
PT	3,460.7	8.6	15.2	20.0	1.7	3.1	18.6	13.7	70.4	17.3	-1.9	4.3	-10.4	-33.2
RO	1,306.1	7.5	1.2	36.6	0.5	0.0	-2.1	0.0	21.4	-13.7	-39.7	1.0	-54.5	10.0

Country	R&D investment (PPS, 2005 constant prices)				R&D expenditure, as a percentage of GDP				Employment in innovation-active firms, as a share of total employment			Share of turnover from new-to-market products		
	2021	2020-21 Growth rate	2019-21 Growth rate	2011-21 Growth rate	2021	2020-21 Growth rate	2019-21 Growth rate	2011-21 Growth rate	2020	2018-20 Growth rate	2011-20 Growth rate	2020	2018-20 Growth rate	2011-20 Growth rate
SE	11,569.7	1.1	1.9	27.2	3.4	-3.7	-0.9	5.3	81.1	0.9	9.0	6.3	16.7	66.2
SI	1,133.0	8.1	8.5	8.6	2.1	0.0	4.9	-11.2	75.7	9.2	5.6	3.6	38.5	-10.9
SK	1,100.9	6.9	12.8	75.2	0.9	3.3	13.4	43.1	61.7	13.4	5.8	11.9	58.7	-19.1
EU	**250,231.26**	**3.6**	**1.2**	**26.5**	**2.3**	**-1.7**	**1.8**	**11.9**	**73.2**	**3.4**	**2.7**	**4.6**	**-2.1**	**-3.2**

Source: Eurostat, accessed on 7 March 2023.

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