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The Innovation Output Indicator 2016

Methodology Update

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Abstract / Executive Summary

This technical report presents the 2016 update of the Innovation Output Indicator (IOI), the latest scores for the composite index and for the underlying indicators. It also discusses in details how changes in the statistical definition of some of the underlying indicators affect the methodology and results.

We recall that the IOI was developed by the European Commission at the request of the European Council in order to benchmark national innovation policies and to monitor the EU's performance against its main trading partners. The IOI measures the extent to which ideas stemming from innovative sectors are capable of reaching the market, providing better jobs and making Europe more competitive. It covers technological innovation, skills in knowledge-intensive activities, the competitiveness of knowledge-intensive goods and services, and the innovativeness of fast-growing enterprises. It complements the R&D intensity indicator by focusing on innovation output. It aims to support policy-makers in establishing new or reinforced actions to remove bottlenecks preventing innovators from translating ideas into successful goods and services.

The IOI is a composite of four components, chosen for their policy relevance, data quality, international availability, cross-country comparability and robustness. Its four components are:

- technological innovation as measured by patents (PCT);
- Employment in knowledge-intensive activities in the business industries as a percentage of total employment (KIABI);
- the average of the share of medium and high-tech goods and services in a countries export (COMP); and
- employment dynamism of fast-growing enterprises in innovative sectors (DYN).

This 2016 edition of the IOI offers a number of novelties. It expands international coverage to Israel, New Zealand and Brazil (altogether 38 countries are now compared over a 4-year time frame). It implements changes in statistical definitions in national accounts (ESA2010) and international service trade statistics (BPM6), affecting PCT and SERV components, and uses updated innovation coefficients (CIS2010 as opposed to CIS2008) for the DYN scores, and updates scaling coefficients fitting the larger, updated dataset. The report addresses the issue of improving timeliness by using most recent data available for KIABI, GOOD and SERV. Sensitivity analysis highlights that the revision of SERV has the largest impact on outcomes.

1 Introduction

The purpose of this report is to report on the key issues addressed at the 2016 update of the Innovation Output Indicator (IOI). It follows the structure and methodology first presented in the 2013 Communication and Staff Working Document (European Commission, 2013) and further refined in the 2014 Methodology Report (Vertesy and Tarantola, 2014). The report also shows the most recent data available for each underlying indicator and the resulting composite scores.

1.1 About the Innovation Output Indicator

The IOI was designed to be **output-oriented**, measure the innovation performance of a country and its capacity to derive economic benefits from it, capture the dynamism of innovative entrepreneurial activities, and be useful for policy-makers at EU and national level. The component indicators aim to quantify the extent to which ideas for new products and services, carry an economic added value and are capable of reaching the market. Therefore, it can be captured by more than one measure. The IOI has four components called PCT, KIABI, COMP and DYN, one of which (COMP) is in turn composed by two sub-indicators, GOOD and SERV.

The PCT component measures **technological innovation** by patents, which account for the ability of the economy to transform knowledge into technology. The number of patent applications per billion GDP is used as a measure of the marketability of innovations.[1] The KIABI component focuses on how a highly skilled labour force feeds into the **economic structure** of a country. Investing in people is one of the main challenges for Europe in the years ahead, as education and training provide workers with the skills for generating innovations. This component captures the structural orientation of the economy towards knowledge-intensive business activities, as measured by the number of persons employed in those activities in business industries over total employment. The COMP component aims to capture the **competitiveness of knowledge-intensive goods and services**. This is a fundamental dimension of a well-functioning economy, given the close link between growth, innovation and internationalisation. Competitiveness-enhancing measures and innovation strategies can be mutually reinforcing for the growth of employment, export shares and turnover at the firm level. This component is built integrating in equal weights the share of high-tech and medium-tech product exports to the total product exports (GOOD), and knowledge-intensive service exports as a share of the total services exports of a country (SERV). It reflects the ability of an economy, notably resulting from innovation, to export goods and services with high levels of value added, and successfully take part in knowledge-intensive global value chains. The DYN component measures the **employment in high-growth [2] enterprises in innovative sectors**. Sector-specific innovation coefficients, reflecting the level of innovativeness of each sector, serve here as a proxy for distinguishing innovative enterprises. The component reflects the degree of innovativeness of successful entrepreneurial activities. The specific target of fostering the development of high-growth enterprises in innovative sectors is an integral part of modern R&D and innovation policy.

The IOI is closely related to the Innovation Union Scoreboard, as all of its indicators are part of the Scoreboard. The set of indicators used for the IOI is, however, more narrowly focused than the IUS's output pillar. Further differences arise from the fact that data used for the two reports are frozen at different points in time, from differences in the treatment of missing

[1] Despite the fact that these data might fail to capture innovation which occurs in industries where investors rely on alternative mechanisms to protect intellectual property such as secrecy or lead-time. (see i.e. Moser, 2013)

[2] High-growth is defined by a growth rate of 10% over a three-year period.

values, and from the differences in the normalization, weighting and aggregation procedures applied to obtain composite scores.

1.2 The 2016 update

Calculating the latest scores for the Innovation Output Indicator involved more than a simple update of the component scores, given the statistical constraints due to methodological revisions and the aim to expand coverage and to improve the timeliness of component indicators.

Thus, the main challenges for the 2016 edition were:

- Accommodating revisions in statistical definitions of underlying indicators
- Expanding international coverage where possible
- Improving timeliness of component indicators

These challenges and their implications are addressed in the following three sections. Subsequently, we present country performance scores by the component indicators, and present the 2016 updates for the composite. How these challenges may impact composite scores are addressed in the sensitivity analyses in section **Error! Reference source not found.**.

2 Refinements in the 2016 indicator

2.1 Changes in statistical definitions

2.1.1 Changes in the measurement of GDP

PCT scores may be affected by changes in GDP levels due to the revised accounting methodology.

Since September 2014, national accounts and GDP of EU countries is measured according to the European System of National and Regional Accounts (ESA 2010). This is the latest internationally compatible EU accounting framework for a systematic and detailed description of the economy, which follows the 2008 System of National Accounts (2008 SNA) methodology adopted by the United Nations Statistical Commission. Other countries, including the US, have also introduced the new accounting system. Apart from a general improvement in data production, the two main methodological changes that had an impact on GDP levels were (1) counting research and development expenditure as investment – which increased the level of EU GDP in 2010 by 1.9% – and (2) counting expenditure on weapon systems also as investment (this increased the level of EU GDP in 2010 by 0.2%). As Eurostat reported, the impact of the changes on the GDP level varied significantly across Member States. In 2010, they were largest in Cyprus (+9.5%) and in the Netherlands (+7.6%), while relatively small or even negative changes were observed in Luxembourg (+0.2%) and Latvia (-0.1%). While these changes give rise to shifts in the GDP levels of most Member States, growth rates have been almost unaffected.[3]

If the aim is to render the indicator independent of the business cycle, it is a question whether GDP may be replaced by population levels for the scale-normalization of the indicator. Such a change would have a positive impact on PCT scores for countries with above-average GDP per capita levels, and vice versa, negative impact for countries below the average.

2.1.2 Changes in the international trade in services statistics

The production of statistics on international trade in services follows as reference the International Monetary Fund (IMF)'s Balance Of Payments and International Investment Position Manual (BPM) and the United Nations' Manual on Statistics of International Trade in Services (MSITS). The 6th edition of the (BPM6) has recently replaced the 5th edition (BPM5) in order to reflect changes that have occurred in the global economy since 1993, and accordingly, the MSITS 2010 has replaced the MSITS 2002. As a result of these revisions, the Extended Balance of Payments Services (EBOPS) classification has been revised, rendering the classification of knowledge-intensive services used in previous editions of the Innovation Union Scoreboard and the Innovation Output Indicator incompatible. This turned out to be a particularly pressing issue given that fresh data was no longer produced according to the BPM5 methodology.

As work is still ongoing at the United Nations Statistics Division on the concordance tables that would allow an 'automatic' selection of knowledge-intensive services, a task-force involving experts from various European Commission services (DG-RTD, DG-GROW, DG-JRC, supported by DG-ESTAT) decided to select a list of services that – given the details in BPM6 – are potentially associated with knowledge-intensive business activities (taking into consideration a high /above 33%/ sectoral share of tertiary graduates). The selected list is presented in Table 1. It includes air, space and maritime transport services (but excludes other modes of

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[3] See Eurostat News Release 157/2014 (17 Oct 2014) "First estimation of European aggregates based on ESA 2010". See also "European system of national and regional accounts - ESA 2010" at Eurostat Statistics Explained: [http://ec.europa.eu/eurostat/statistics-explained/index.php/European_system_of_national_and_regional_accounts_-_ESA_2010]

transport, such as road or rail), includes insurance and pension financial, telecommunications, computer and information services, other business services (including R&D and Professional and management consulting services), as well as audio-visual and related services. The classification does not include "Charges for the use of intellectual property n.i.e." (class SH). Although this class refers to a highly knowledge-intensive activity, the Task Force decided to exclude it on the ground that it did not form part of the previous KIS classification (and that it also refers to a distinct indicator in the IUS framework). Tests for 22 EU MSs where sectoral data was available showed that the inclusion or exclusion of IP charges has a negligible effect on KIS shares and ranks.

Table 1 Selected international accounting items for the KIS classification

BPM6 "int_acc_item"		***Note***
SC1	Sea transport	
SC2	Air transport	
SC3A	Space transport	*Data mostly unavailable*
SF	INSURANCE AND PENSION SERVICES	
SG	FINANCIAL SERVICES	
SI	TELECOMMUNICATIONS, COMPUTER, AND INFORMATION SERVICES	
SJ	OTHER BUSINESS SERVICES	
SK1	Audio-visual and related services	
S	SERVICES (Total)	

2.2 Expanding international coverage

Previous editions of the IOI have focused on measuring the innovation output of the 28 EU Member States and a few benchmark countries, including 3 EFTA countries (CH, IS, NO), Turkey, the United States and Japan. Our aim is to further expand the set of countries to improve global comparison, by including other members of OECD and emerging economies from the so-called 'BRIC' group of countries.

The two main limitations of widening the geographic scope are generally the *availability of data* and *differences in the definitions* of some of our innovation indicators. In general, the more diverse set of countries are included in the coverage, the greater impact differences in the nature of economic activities, in statistical classification systems, or breaks in trends due to changes in methodology will play on cross-country comparability.

Expanding coverage poses less of a challenge for some of the component indicators that rely on a limited number of administrative sources (as in the case of patents) or where there is a high degree of harmonization in data definition and modes of provision (typically trade data). For instance, PCT and GOOD offer a nearly global coverage.

However, computing SERV scores for a larger set of countries is hampered on the one hand by the transition to a new accounting methodology and on the other hand by issues of confidentiality of data sources. In other words, even if all countries migrate from the BPM5 to the BPM6 reporting standard, data might not be available for all of the relevant KISBI sectors. The two main limitations with respect to data availability for KIABI are the differences in sectoral classifications (a problem affecting some OECD countries and BRIC countries) and limitations in the coverage of the service sectors (i.e., not all services or not all types of companies are covered in statistics, a problem typically affecting BRIC countries). Missing data, most notably for the DYN component which requires, fine-grained sectoral data (at the 3-digit level) on high-growth enterprises from structural business statistics, has already posed a problem for non-EU countries necessitating the use of imputation techniques. Given that much of the data is confidential and requires special calculations by national statistical institutes (NSIs) and by Eurostat, only the active participation of more NSIs can make DYN more broadly available. Since initial efforts have rendered no response, it will remain the main bottleneck for expanding coverage.

It is important to mention in this respect the OECD Entrepreneurship Indicators Project (EIP) in which framework indicators on high-growth enterprises (HGE) are produced for OECD countries and . However, OECD's growth threshold of 20% for HGE differs from the definition applied for the IOI, which is 10%. Some nevertheless provide employment data for what the EIP refers to as 'medium-growth enterprises' – which allowed us to make test calculations for DYN for 3 countries: Israel, New Zealand and Brazil.

Other OECD countries such as Australia, Canada and South Korea could provide for interesting comparison with the EU as a whole and with member states. However, due to missing indicators for more than one dimension (missing DYN and typically incomparable KIABI figures), we decided not to include them. Key emerging economies from the BRIC group were excluded for similar reason, with the exception of Brazil, where test DYN scores could be computed.

With the above considerations, the 2016 edition of the Innovation Output Indicator ranks 38 countries, which is an increase by 3 from previous editions – newly including, as Table 3 shows, Israel, New Zealand and Brazil. The expansion is particularly useful, as Israel's top scores in many of the components may provide examples for many of the leading European countries.

Table 2 Country coverage

Group	Countries	Notes
EU:	EU Member States & EU28 Total	See limitations and missing data in table above
EFTA:	CH, IS, NO	SERV uses ITC estimates; DYN imputed for CH, IS;
OECD:	US, JP, IL, NZ, TR	Differences in KIA methodology due to differences in national sectoral classification; DYN imputed for US, JP and TR
BRIC:	BR	different methodology for KIA, DYN, SERV

2.3 Improving timeliness

There is a trade-off between aligning indicators to the same year and timeliness. If indicators are aligned to the most recent year when data is available for all the indicators (but PCT[4]), the most recent data that could be used is lagged by two years with respect to the point of data freezing for the report, which was December 2015. This was the practice used in previous editions. In this 2016 edition, we could improve timeliness for PCT, KIABI, GOOD and SERV by two years with respect to the previous edition, while by one year for DYN. By choosing not to align all the indicators (all but PCT) to the same year, we could use 2014 data instead of 2013, offering more timely results. In order to see the impact of this timeliness – alignment trade-off, in the sensitivity analyses we considered an alternative dataset consisting of all indicators (but PCT) aligned to 2013.

This updates also decided improves timeliness of the DYN component by updating the CIS*KIA-based innovation coefficients. While previously these were computed on CIS2008 microdata, this latest update makes use of the subsequent CIS2010 wave in order to better reflect any structural changes in the innovativeness of European firms.

Table 3 provides a summary overview of the refinements, methodology change and data availability that concerns the 2016 edition of the innovation output indicator.

[4] In the case of PCT, we opted to use non-nowcast hard data, rather than projection data, in order to avoid misleading drop in most countries in the performance for the recent year.

Table 3 Overview of data availability and methodology changes by component indicator, as of December 2015

Component	Definition: Numerator	Definition: Denominator	Data notes	2016 edition: Data Years (lag v. 2015[a])	2016 edition: Change v. 2014 ed.	2016 edition: Missing Countries[b]	2016 edition: Change in Methodology
PCT	PCT Patent applications (OECD)	billion GDP (PPS) (ESTAT, OECD, National)	• Using new non-nowcast data from the OECD 2015 Main S&T Indicators & 2015 09 REGPAT data • EU MSs with unreliable figures: MT: 2009-2011; CY: 2008, 2010	2010-2013 (2 years lag)	+2 year	Nil	GDP: Switch to ESA2010 accounting method
KIABI[c]	Number of employed persons in knowledge-intensive activities (KIA) in business industries.	Total employment	• For IL, KR, NZ, BR: differences in sectoral classification may result in some bias; 1 year lag vs EU MSs (data available from 2010 to 2013)	2011-2014 (1 year lag)	+2 years	Nil	Nil;
GOOD	Sum of product exports in Standard International Trade Classification (SITC) Rev.3 classes: 266, 267, 512, 513, 525, 533, 54, 553, 554, 562, 57, 58, 591, 593, 597, 598, 629, 653, 671, 672, 679, 71, 72, 731, 733, 737, 74, 751, 752, 759, 76, 77, 78, 79, 812, 87, 88 and 891	Value of total product exports	• 2 sources: EU MSs: Comext; others: Comtrade • CH break in series in 2011 in Comext • 2014 edition of IOI used 2010-2012 data;	2011-2014 (1 year lag)	+2 years	Nil	Nil;
SERV	Sum of credits in bop items SC1, SC2, SC3A, SF, SG, SI, SJ, SK1	Total services exports (S)	• Special calculation using revised KIS(BI) classification according to BPM6 • EU MSs with limited coverage: FI, RO, CY: 2012 missing; HR: 2013 missing; + ES, NL, SK, MT missing (could impute BPM5-based 2012 figures) • EFTA, OECD, BRIC: figures based on International Trade Center (ITC) estimates matching the new KIS definition according to BPM6	2011-2014 (1 year lag)	+2 year	(see data notes)	New sectoral classification due to the incompatibility between BPM5 and the new BPM6 accounting method
DYN	The sum of sectoral results for the employment in high-growth enterprises by sector multiplied by the innovativeness coefficients of these sectors. (high growth = firms with average annualised growth in employees of 10%+ a year, over a 3-year period, and with 10+ employees at the beginning of the observation period.)	Total employment in high-growth enterprises in the business economy	• Using final 2013 data for EU28 and NO; • EU MSs with limited coverage: DE: 2010 missing; EL: no data; HR: 2013 only; MT: 2010-11 missing; IT, PL, SI: 2011 missing; OECD/BRIC with limited coverage: NZ: 2010-2012; IL: 2011-2013; BR: 2010, 2011, but missing sectors; • Others: no data	2010-2013 (2013: prelim.) (2 years lag)	+1 year	CH, IS, US, JP	Innovativeness coefficients updated from (CIS*KIA)2008 to (CIS*KIA)2010

Notes: a) Data collection was frozen in Mar 2015; b) Countries missing with respect to the coverage outlined in Table 2; c) The KIABI indicator was labelled as KIA in previous publications. While its definition remains the same, we changed the label to KIABI to more clearly reflect that the indicator focuses on the business industry.

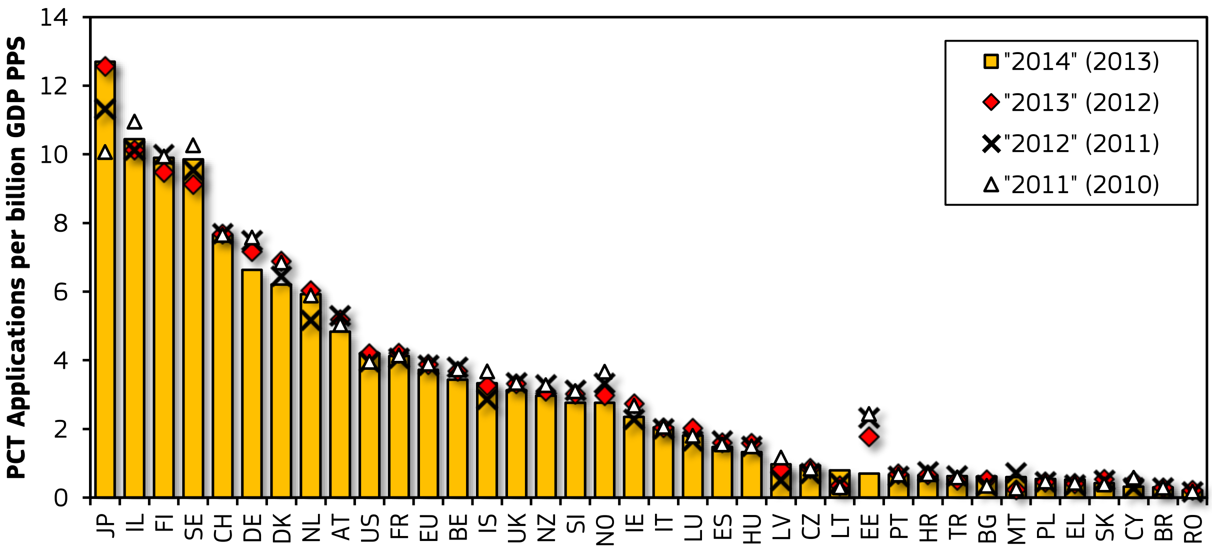
3 Country performance in the four components

This section presents the definition and country performance for each of the component indicators of the IOI. Composite scores for each country are reported in Section 4.

3.1 The PCT Component

The purpose of the PCT component is to measure the ability of the economy to transform knowledge into marketable innovations. Although it is understood that patents are better indicators of successful inventions than innovations as they say little about how novelties will perform on the market, we consider patents filed under the Patent Cooperation Treaty (PCT)[5] to carry the information that its filing company expects it to have a higher market impact. The PCT component of the IOI is identical to indicator 2.3.1 of the Innovation Union Scoreboard and counts the number of patent applications per billion GDP (PPP). The numerator is defined as the number of patent applications filed, in international phase, which name the European Patent Office (EPO) as designated office under the PCT. Patent counts are based on the priority date, the inventor's country of residence and fractional counts to account for patents with multiple attributions. The denominator is the GDP in Euro-based purchasing power parities, according to ESA2010.

Figure 1 PCT Patent applications per billion GDP (PPS)



Source: OECD Patent Statistics (PCT), Eurostat, OECD (GDP).
Notes: Data is reported for more countries than what were used in the final aggregation sample. Years in quotation marks indicate 1-year shift relative to patent priority years (i.e., "2014" refers to data from 2013).

3.2 The KIABI Component

The KIABI component aims at measuring how the supply of skills feeds into the economic structure. It is identical to indicator 3.2.1 of the Innovation Union Scoreboard and measures

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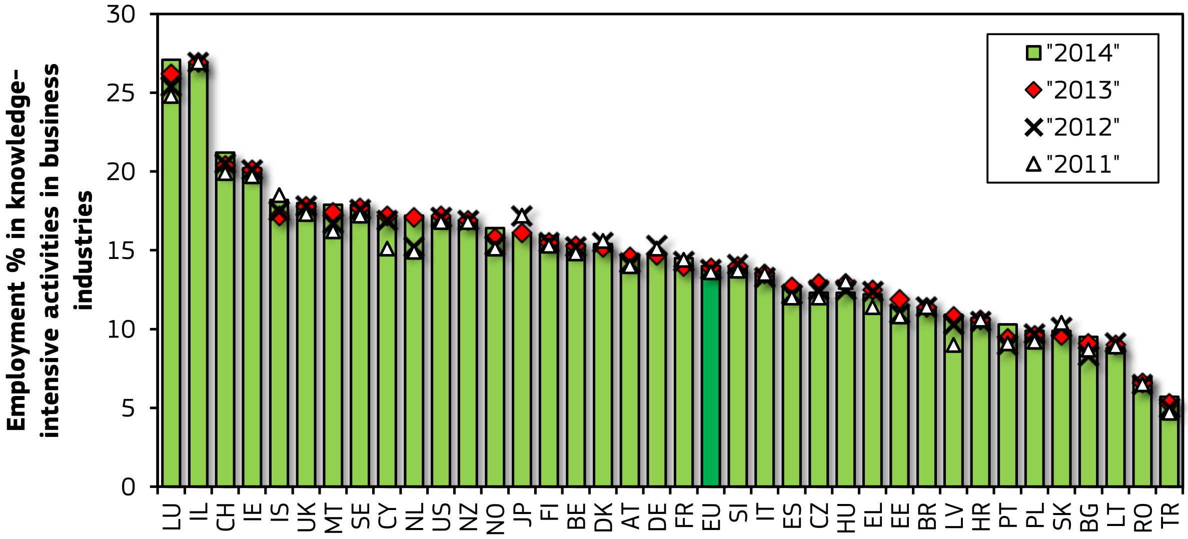
[5] PCT is an international patent law treaty concluded in 1970, unifying procedures for filing patent applications. An application filed under PCT is called an "international application". An international patent is subject to two phases. The first one is the "international phase" (protection pends under a single application filed with the patent office of a contracting state of the PCT). The second one is the "national and regional phase" in which rights are continued by filing documents with the patent offices of the various PCT states.

the number of employed persons in knowledge-intensive activities (KIA) in business industries [KIABI] as a percentage of total employment. The KIABI component is calculated from EU Labour Force Survey data, as all NACE Rev.2 industries at 2-digit level,[6] where at least 33% of employment has a tertiary degree.

Figure 2 Employment in knowledge-intensive activities in business industries as % of total employment



Sources: Eurostat; OECD (NZ, IL); IBGE (BR)
Notes: Years in brackets are identical to actual year of data.

3.3 The COMP Component

The COMP component aims to capture competitiveness in knowledge-intensive sectors, and is defined as the arithmetic average (with equal weights) of two indicators: GOOD and SERV. GOOD measures the share of high-tech and medium-tech products in a country's exports and is identical to indicator 3.2.2 of the Innovation Union Scoreboard. SERV, similar to indicator 3.2.3 of the Innovation Union Scoreboard measures the share of knowledge-intensive services exports to the total services exports of a country.

3.3.1 GOOD

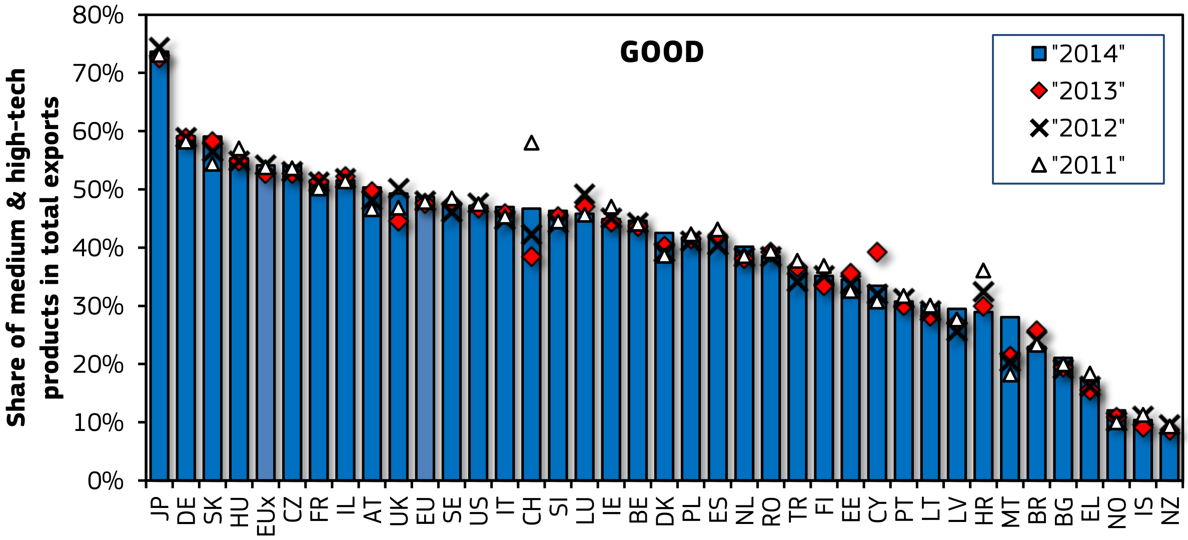
The numerator of GOOD is the total value of exports of a country in Standard International Trade Classification (SITC) Rev.4 classes: 266, 267, 512, 513, 525, 533, 54, 553, 554, 562, 57, 58, 591, 593, 597, 598, 629, 653, 671, 672, 679, 71, 72, 731, 733, 737, 74, 751, 752, 759, 76, 77, 78, 79, 812, 87, 88 and 891.[7] The denominator is the total value of product

[6] NACE (*Nomenclature statistique des activités économiques)* is the statistical classification of economic activities in the European Union and the subject of legislation at the EU level, which guarantees the use of the classification uniformly within all the Member States. It is a basic element of the international integrated system of economic classifications, based on classifications of the UN Statistical Commission, Eurostat as well as national classifications; all of them strongly related each to the others, allowing the comparability of economic statistics produced worldwide by different institutions.
[7] This product composition is similar to that of indicator 3.2.2 of the Innovation Union Scoreboard and is based on the product classification of Annex 8 of UNIDO (2011) *Industrial Development Report 2011, Industrial energy efficiency for sustainable wealth creation. Capturing environmental, economic and social dividends*, which is derived from the SITC Rev.2 classification proposed by S. Lall (2000) "The Technological Structure and Performance of Developing Country Manufactured Exports, 1985–98", *Oxford Development Studies*, 28 (3), pp 337-369. We note that the classes were selected for SITC Rev.3 and one-on-one applied for data reported according to SITC Rev.4, causing some discrepancies.

exports of a country. The data source for GOOD is the Eurostat COMEXT database for EU Member States and EFTA countries, and UN Comtrade for all others (OECD and BRIC countries).

For the EU28, two different GOOD scores were computed. In order to compare the EU as a single entity in global trade with other countries (i.e. the US), only extra-EU trade should be considered, as partners are considered as single entities (i.e., interstate trade is not considered for the US). However, in order to compare the EU performance against that of the Member States, intra-European trade (or dispatches) has to be considered in the computation of GOOD. Therefore, to allow both European and global comparisons, two different GOOD scores were computed for the EU28 aggregate. For global comparison, only extra-EU product exports were considered, resulting in the score for 'EUx'. For a European comparison, the 'EU' score was computed by including both intra- and extra-EU product exports.

Figure 3 The share of medium- and high-tech products in total exports



Sources: Eurostat Comext (EU MSs, EFTA); UN Comtrade (others).
Notes: The EU28 aggregate is represented by two values: EU refers to intra- plus extra-EU trade; EUx refers to Extra-EU trade only. For MS both intra and extra-EU trade are included. Years in brackets indicate actual year of data.

3.3.2 SERV

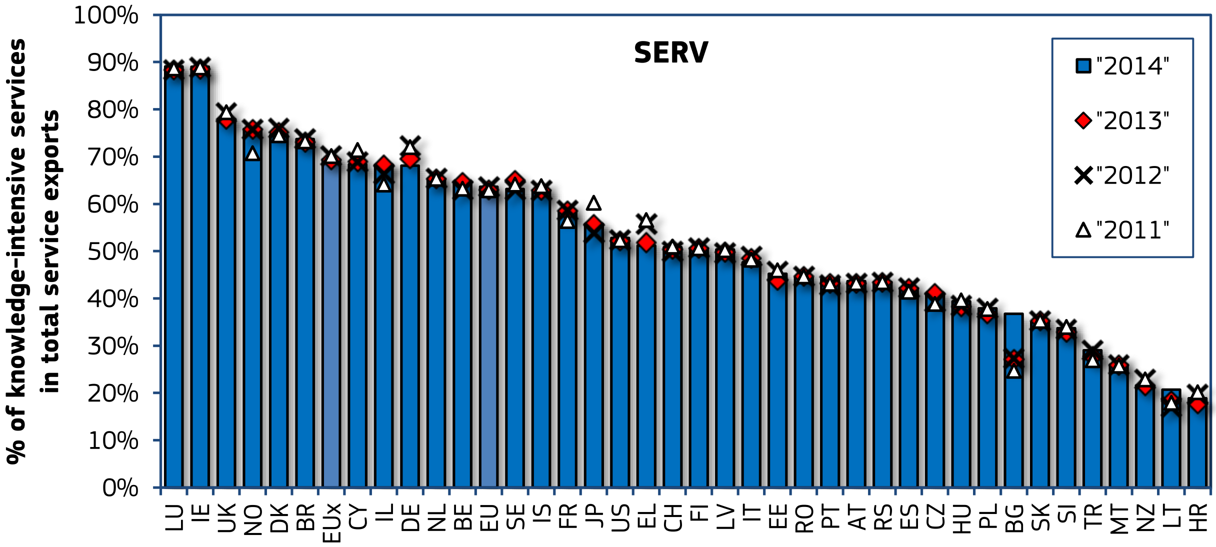
SERV is the second component of COMP and measures the share of knowledge-intensive services in total services exports. Taking into consideration the latest BPM revision (see discussion in section 2.1.2), it is defined as the sum of credits in EBOPS 2010 (Extended Balance of Payments Services Classification) items SC1, SC2, SC3A, SF, SG, SI, SJ and SK1. The denominator is the total value of services exports (S).

As an effect of the change in methodology and due to confidentiality reasons, many EBOPS service posts are missing in data published by Eurostat or OECD in some or all years. In a few cases, we relied on Eurostat special tabulations. In most other cases, we referred to estimates reported by the International Trade Centre (ITC),[8] in particularly for the following countries: CH, ES, IS, MT, NO, TR and BR. In cases where data was missing for a certain year, following the practice of the Innovation Union Scoreboards, figures were taken from the nearest available year. In some cases, this significantly limited the comparability over time: we opted to use only the officially published data for NL, which was only available for 2014.

[8] See URL: [http://www.trademap.org, data retrieved: Oct 2015]

As for GOOD, two different SERV scores were computed for the EU28 aggregate to accommodate both European and global comparisons. For the global comparison, only extra-EU service exports were considered, resulting in the score for 'EUx'. For a European comparison, the 'EU' weighted average score was computed by including both intra- and extra-EU service exports.

Figure 4 Knowledge-intensive services exports as % of total service exports

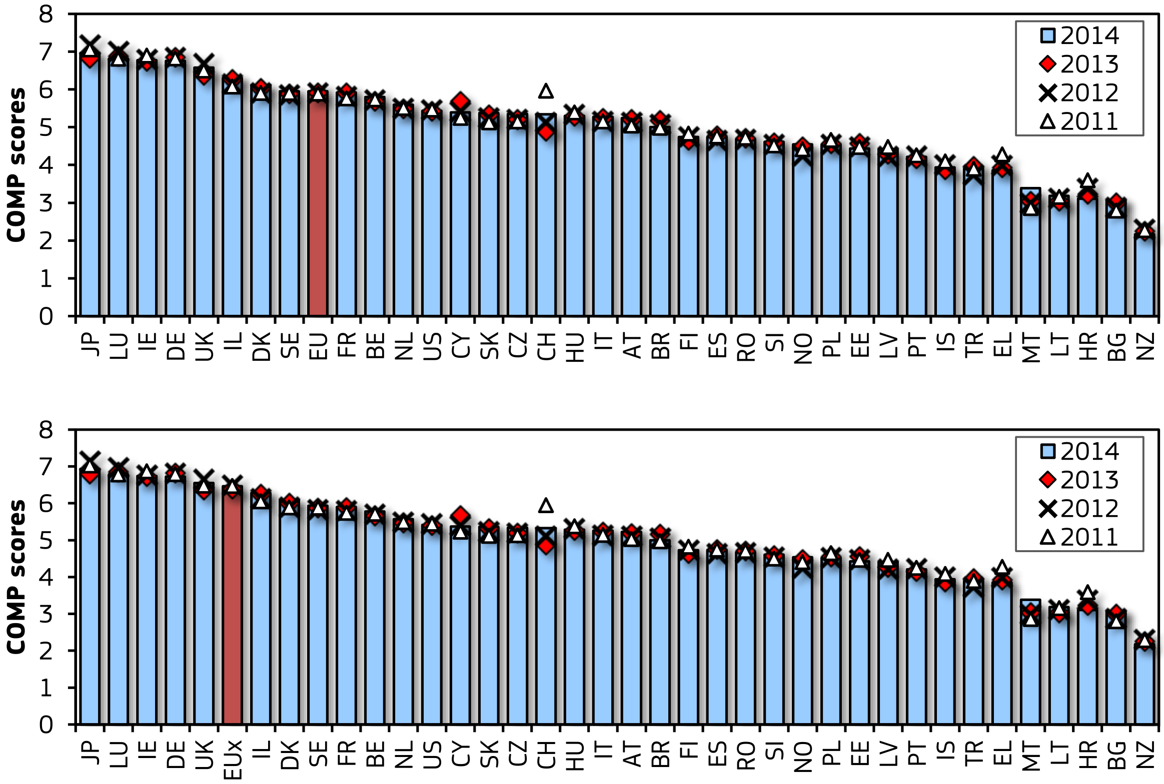


Sources: Eurostat; UN Service Trade Statistics;
Notes: EUx refers to Extra-EU 28 trade only, EU refers to both intra- and extra-EU trade for EU28 aggregate. Years refer to actual year of data.

3.3.3 COMP Scores

Comp is the unweighted arithmetic average of GOOD and SERV. Most recent country scores are presented in Figure 5 below.

Figure 5 COMP scores, the arithmetic average of z-score normalized GOOD and SERV, using equal weights; European (upper panel) and Global comparison (lower panel)



Source: JRC calculations

3.4 The DYN Component

The purpose of the DYN component is to measure countries' capacity to create employment in high-growth enterprises that operate in innovative sectors. It is computed by weighting sectoral innovation coefficients with sectoral shares of employment in high-growth enterprises, according to the following formula:

$$DYN_c = \sum_{s}^{1} (CIS^{score} * KIA^{score})_s \frac{E_{sC}^{HG}}{E_C^{HG}}$$

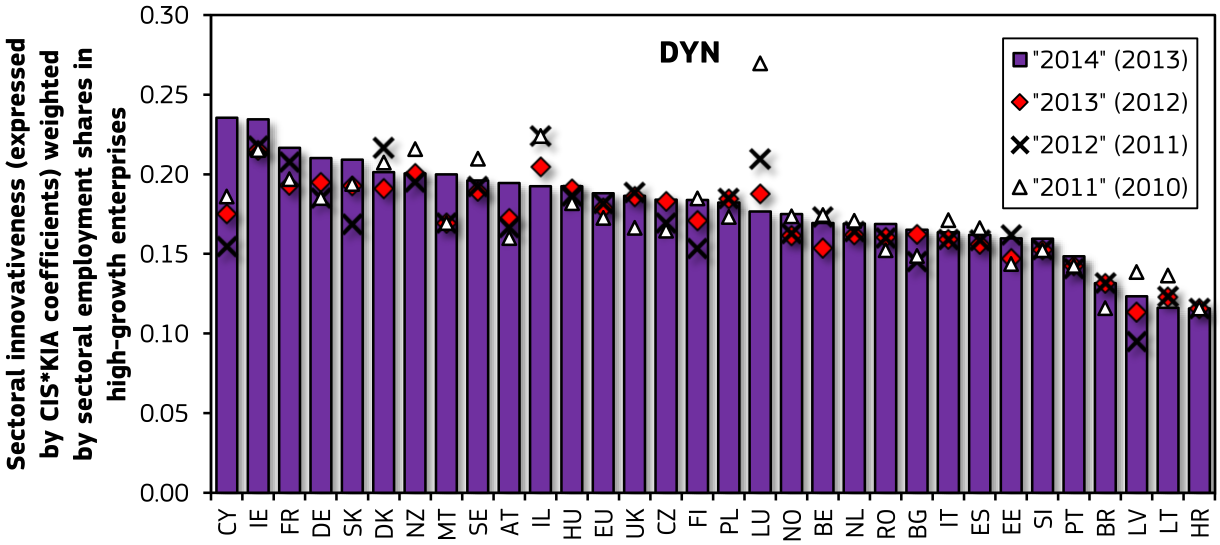
Equation 1*. Component DYN (dynamism) of the IOI*

where $(CIS^{score} * KIA^{score})_s$ is the innovation coefficient, and E_{sC}^{HG} is the number of employees in high-growth enterprises in sector *s* and country *c*, being $E_C^{HG} = \sum_s E_{sC}^{HG}$. High-growth enterprises are defined as enterprises with average annualised growth in number of employees of more than 10 % a year, over a three-year period, and with 10 or more employees at the beginning of the observation period (period of growth). Note that in this formula the term $\frac{E_{sC}^{HG}}{E_{C}^{HG}}$ plays the role of a weight as $\sum_{s}^{1} \frac{E_{sC}^{HG}}{E_{C}^{HG}} = 1$.

The economic sectors covered are the **three-digit NACE business economy sectors**, including the financial sector (i.e. NACE Rev. 2 sections B-N & S95), as identified by the national statistical office based on national business register data and based on the number of employees in these enterprises.[9] The reason for using NACE three-digit level statistical breakdown is to capture cross-sectoral differences in innovativeness.

DYN figures for the most recent time point were computed using updated innovation coefficients based on CIS2010 microdata and updated KIA scores, while previous DYN figures use CIS2008-based innovation coefficients.

Figure 6 Employment dynamism of high-growth enterprises in innovative sectors



Source: Eurostat (final data for 2013).
Notes: Years in quotation marks refer to a 1-year shift relative to actual (i.e., "2014" refers to 2013 data). Countries with missing data (EL, CH, IS, TR, JP, US) are not shown on graph.

[9] The financial sector 'K' is included from the 2014 version of the Innovation Output Indicator onward.

4 Innovation Output Indicator Scores

4.1 Conclusions from uni- and multivariate analysis

Following the main methodological reference on calculating composite indicators (OECD-JRC, 2008), uni- and multivariate statistical analyses were conducted to test whether the quality profile of the indicators and their pairwise correlation poses make it feasible to combine them in a single composite score (See Table 4). Dataset consists of 4 recent years for 38 countries (N = 152). Outlier treatment not necessary; missing DYN scores were identified, which were imputed using Expectation-Maximization method. Correlation patterns follow those observed for data used in previous years' editions of the IOI, nevertheless, due to the larger dataset, some re-balancing of weights for the aggregation was found necessary.

Table 4 Descriptive statistics and Correlation Table for non-normalized set of variables

Descriptives	PCT	KIABI	GOOD_EUR	SERV_EUR	GOOD_INT	SERV_INT	DYN
N.Obs.	152	152	152	152	152	152	128
Min	0.2	4.7	0.08	0.17	0.08	0.17	0.10
Max	12.7	27.1	0.74	0.89	0.74	0.89	0.27
Mean	3.3	14.3	0.39	0.52	0.39	0.52	0.17
Std.Dev.	3.2	4.5	0.14	0.19	0.14	0.19	0.03
Skewness	1.2	0.6	-0.3	0.0	-0.3	0.0	0.0
Kurtosis	0.5	0.9	-0.1	-0.8	-0.1	-0.8	0.4
Correlation	**PCT**	**KIABI**	**GOOD_EUR**	**SERV_EUR**	**GOOD_INT**	**SERV_INT**	**DYN**
PCT	1	0.567	0.432	0.356	0.431	0.355	0.496
KIABI	0.567	1	0.193	0.595	0.190	0.590	0.647
GOOD_EUR	0.432	0.193	1	0.194	0.998	0.198	0.438
SERV_EUR	0.356	0.595	0.194	1	0.198	0.998	0.433
GOOD_INT	0.431	0.190	0.998	0.198	1	0.206	0.437
SERV_INT	0.355	0.590	0.198	0.998	0.206	1	0.432
DYN	0.496	0.647	0.438	0.433	0.437	0.432	1

Source: JRC calculations. *Note:* Pearson correlation coefficients significant at least at 5%.

4.2 Aggregating component scores

The IOI is obtained by aggregating its components in two steps. First, a weighted average of z-score normalized data[10] is computed according to the formula:

$$I = w_1 PCT + w_2 KIABI + w_3 COMP + w_4 DYN$$

***Equation 2**. Aggregation formula for the IOI*

Where w_1, w_2, w_3, w_4 are the weights of the component indicators (27, 19, 33, 21), that are computed in such a way that the IOI is statistically equally balanced in its underlying components. This procedure aims to avoid that the variables are equally important in nominal terms but that, statistically, the IOI depends more on some variables and less on the others.[11]

[10] In the normalization procedure, each country score is transformed by subtracting the mean and dividing by the standard deviation for the 152 pooled country-year combinations for the selected indicator. The thus obtained z-scores are re-scaled to a positive range using the following formula: z*1.5+5.

[11] Paruolo et al (2013) show that the relative importance of variables are variance based, hence they are ratios of quadratic forms of nominal weights, while target relative importance are often deduced as ratios of nominal weights. A correction of the 'scaling coefficients' can be made to achieve component indicators with the desired relative target importance.

In a final step, the obtained scores are re-normalized to EU2011 = 100, for ease of communication.

The aggregation is carried out for two datasets. The first one aims at comparing EU Member States with one another as well as with selected international benchmark countries (a dataset which includes intra- plus extra-EU scores for the EU-28 (labelled 'EU'), and referred to as EU Member States' comparison). The other dataset ('EU's worldwide comparison') which aims to compare the EU aggregate with selected international benchmark countries (in which only extra-EU scores are used, for a more valid comparison[12].) Given the difference in the level of EU scores and the second normalization step which relates scores to EU2011=100, composite scores obtained from the two datasets are not directly comparable with one another.

To compare trends over time, see results for different years **from current edition**, as comparing results across editions would not be valid given the differences in dataset (country and year range) and definition changes, which affect normalization, weighting and aggregation procedure, and thus, final scores and ranking of countries.

[12] Considering that export values for the US similarly exclude trade between the various States.

4.3 Results for the Innovation Output Indicator 2016

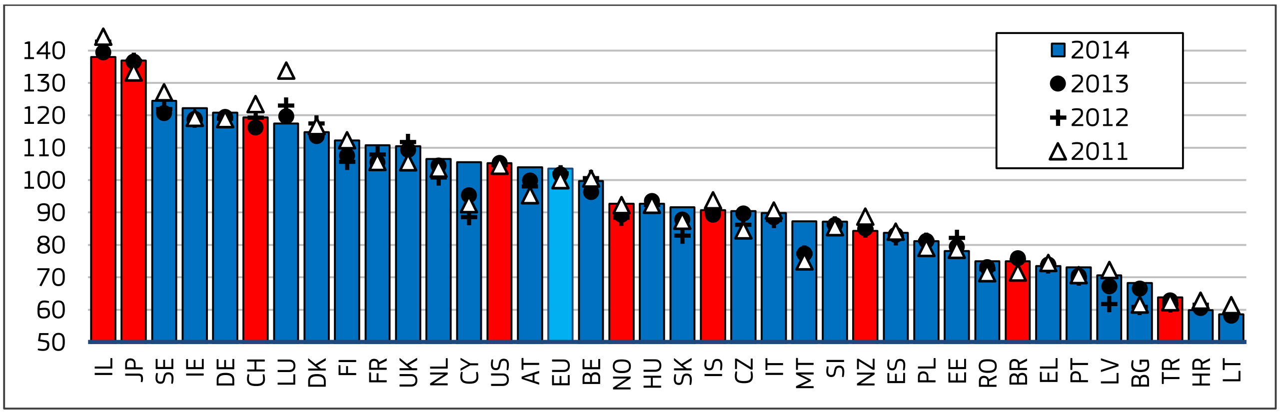
The results for the IOI 2016 edition are reported in Table 5 and the various graphs below.

Table 5 Composite IOI Scores for European and worldwide comparisons

EU Member States' comparison (EU2011 = 100)					EU's worldwide comparison (EUx2011 = 100)				
Country	**2011**	**2012**	**2013**	**2014**	**Country**	**2011**	**2012**	**2013**	**2014**
IL	144.3	142.8	139.5	138.0	**IL**	139.1	137.7	134.5	133.0
JP	133.3	136.8	136.6	136.9	**JP**	128.4	131.9	131.7	131.9
SE	127.2	122.0	120.7	124.5	**SE**	122.6	117.6	116.4	120.0
IE	119.3	118.7	119.0	122.3	**IE**	115.0	114.4	114.6	117.8
DE	118.9	119.1	119.6	120.8	**DE**	114.6	114.7	115.2	116.4
CH	123.5	119.3	116.3	119.4	**CH**	119.1	115.0	112.1	115.1
LU	133.8	123.1	119.7	117.5	**LU**	129.0	118.6	115.3	113.2
DK	116.7	117.5	113.7	114.9	**DK**	112.5	113.3	109.5	110.7
FI	112.4	105.7	107.6	112.2	**FI**	108.4	102.0	103.7	108.2
FR	105.7	108.0	105.5	110.8	**FR**	101.9	104.1	101.7	106.8
UK	105.6	111.8	109.4	110.5	**UK**	101.7	107.7	105.4	106.4
NL	103.5	100.8	104.5	106.5	**EUx**	100.0	102.1	101.0	103.0
CY	92.7	88.6	95.4	105.5	**NL**	99.8	97.2	100.8	102.7
US	104.4	104.7	105.3	105.3	**CY**	89.3	85.4	91.9	101.7
AT	95.3	98.1	99.9	104.0	**US**	100.7	100.9	101.5	101.5
EU	100.0	102.1	101.7	103.6	**AT**	91.9	94.6	96.3	100.2
BE	100.5	100.7	96.3	99.8	**BE**	96.8	97.1	92.9	96.1
NO	92.3	88.4	89.4	92.8	**NO**	89.0	85.3	86.2	89.5
HU	92.4	92.4	93.6	92.7	**HU**	89.0	89.0	90.3	89.4
SK	87.5	82.9	87.9	91.6	**SK**	84.3	79.9	84.7	88.3
IS	93.8	90.4	89.4	90.7	**IS**	90.5	87.2	86.2	87.5
CZ	84.6	86.2	89.8	90.4	**CZ**	81.5	83.1	86.6	87.1
IT	90.6	87.7	88.6	89.9	**IT**	87.4	84.6	85.4	86.6
MT	75.0	77.4	77.4	87.3	**MT**	72.4	74.7	74.7	84.2
SI	85.5	86.3	86.2	87.2	**SI**	82.4	83.2	83.1	84.0
NZ	88.7	84.8	85.2	84.3	**NZ**	85.7	81.8	82.2	81.4
ES	84.2	82.4	83.1	83.7	**ES**	81.1	79.4	80.2	80.7
PL	79.1	81.3	81.3	81.2	**PL**	76.3	78.4	78.4	78.3
EE	78.5	82.2	79.5	78.1	**EE**	75.7	79.2	76.6	75.3
RO	71.3	72.6	73.1	75.0	**RO**	68.8	70.0	70.5	72.3
BR	71.5	75.3	75.9	74.9	**BR**	68.9	72.6	73.2	72.2
EL	74.5	73.7	74.0	73.5	**EL**	71.8	71.1	71.4	70.9
PT	70.7	70.0	70.5	73.0	**PT**	68.2	67.5	68.0	70.4
LV	72.3	61.8	67.2	70.6	**LV**	69.7	59.6	64.8	68.0
BG	61.6	60.9	66.6	68.3	**BG**	59.5	58.8	64.2	65.9
TR	62.4	61.7	62.9	63.8	**TR**	60.1	59.5	60.6	61.5
HR	62.9	61.5	60.5	59.8	**HR**	60.6	59.4	58.4	57.7
LT	61.5	59.1	58.2	58.5	**LT**	59.3	57.0	56.2	56.5

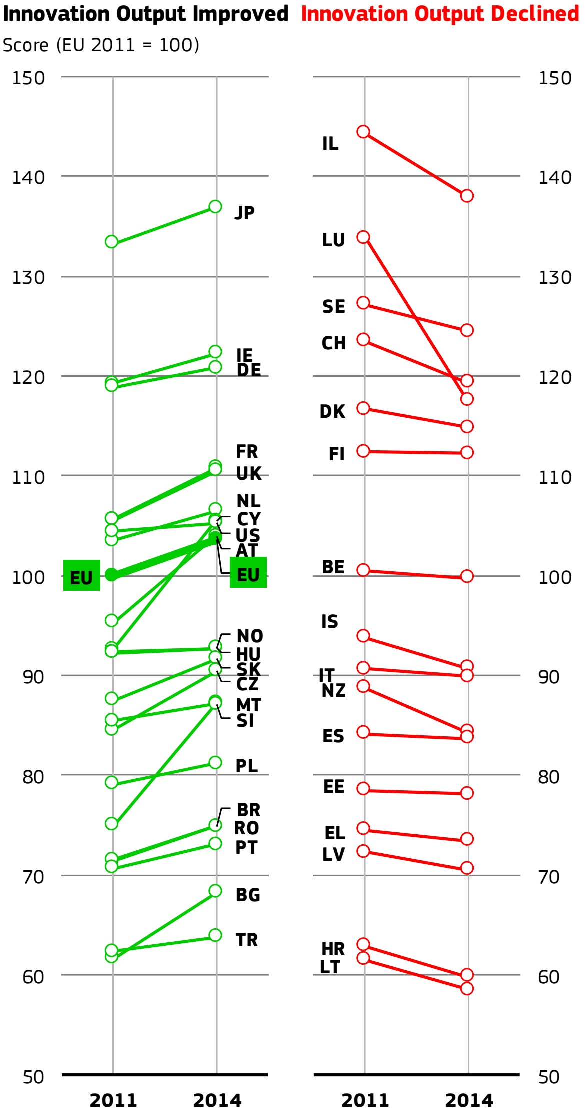
Notes: Years indicate the actual years used for most of the component indicators. For details see preceding text. The scores for Member States in the left table (EU Member States' comparison) can be compared with the EU [weighted] average as well as with selected benchmark countries. To compare the EU overall scores with selected benchmark countries, please use 'EUx' scores from the 'EU's worldwide comparison' table.

Figure 7 IOI Scores, EU Member States' Comparison with EU average as well as benchmark countries



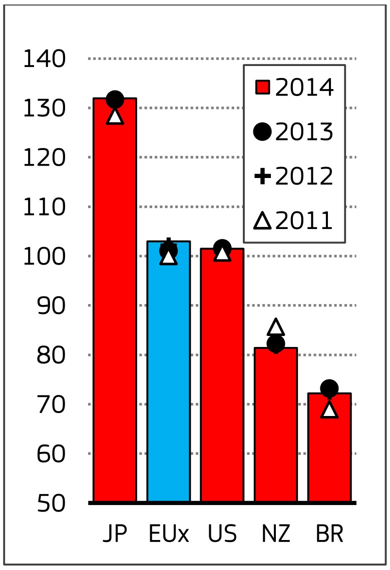
Source: JRC Calculations.
Notes: red bars indicate non-EU countries. The scores Member States can be compared with the EU [weighted] average as well as with selected benchmark countries. These EU scores should not be compared with selected benchmark countries -- for that purpose, please use 'EUx' from the 'EU's worldwide comparison' instead.

Figure 8 Innovation Output trends (EU Member States' Comparison)



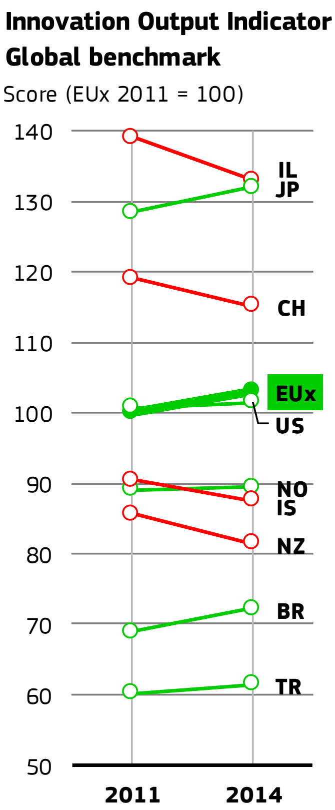
Source: JRC calculations

Figure 9 IOI Scores, EU's Worldwide Comparison



Source: JRC Calculations. *Note:* use this graph to compare the EUx scores with those of selected benchmark countries.

Figure 10 Innovation Output trends (EU's worldwide comparison)



Source: JRC calculations

Figure 11 Infographic: IOI scores and components, EU's worldwide comparison

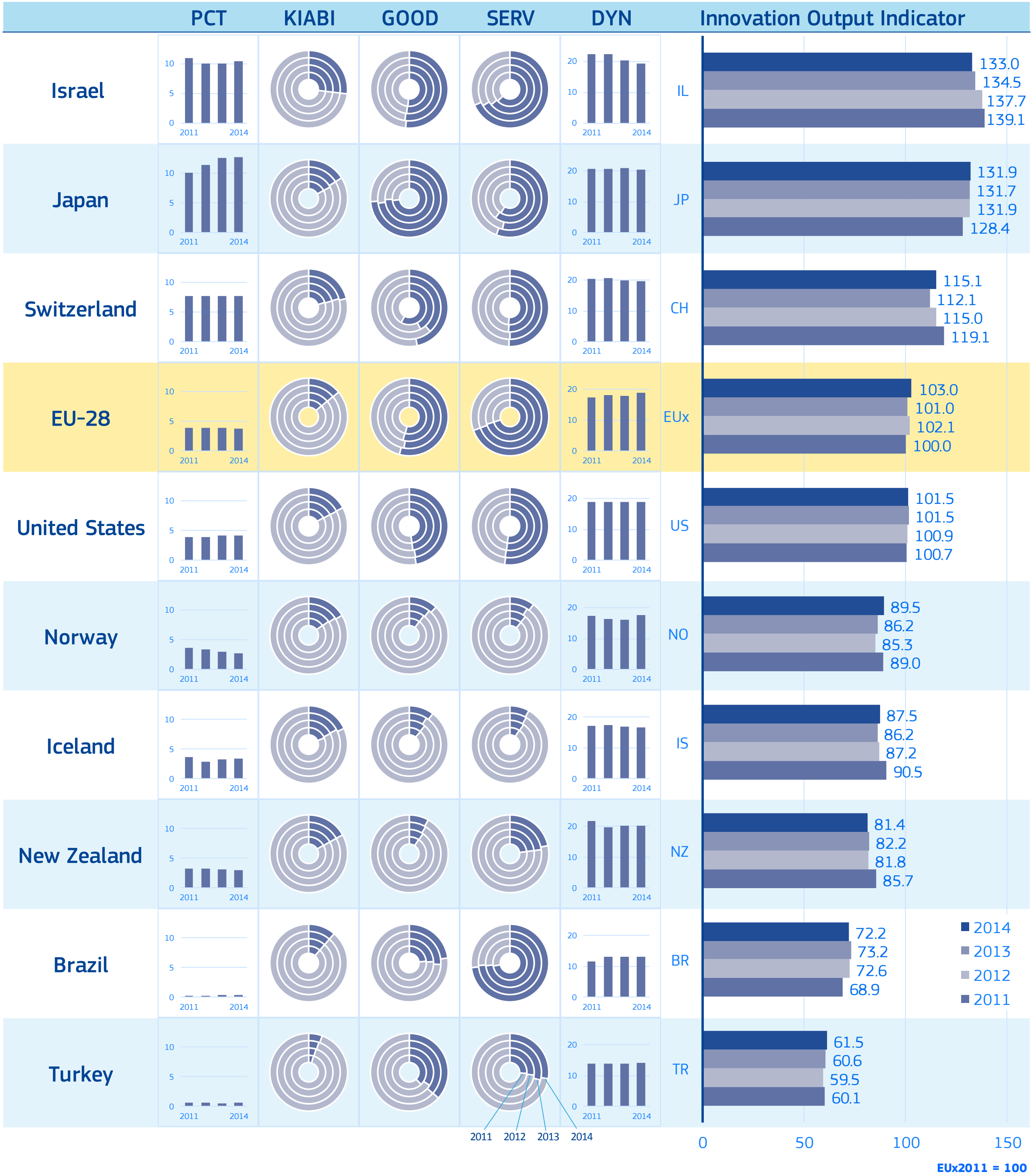
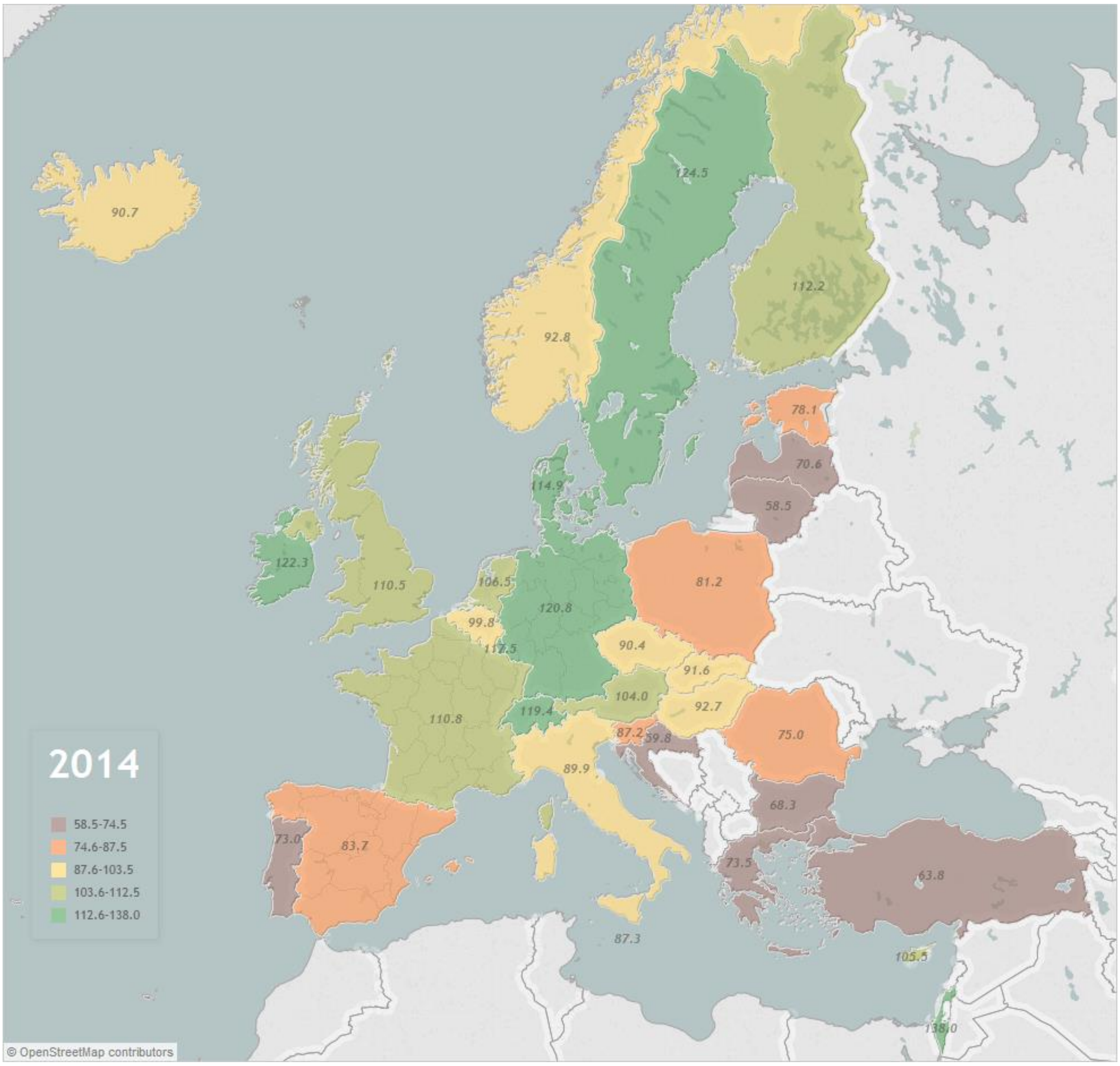


Figure 12 Heat map of innovation output by country (EU Member States' comparison, 2014)



Note: Visualisation prepared by the Research and Innovation Observatory (DG JRC) [https://rio.jrc.ec.europa.eu/]

Figure 13 Component scores (non-normalized) for the 4 most recent years available

	PCT				KIABI				GOOD				SERV				DYN			
Year nom.:	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014
EU	3.9	3.9	3.9	3.7	13.6	13.8	13.9	14.0	47.8	48.0	47.7	48.8	62.7	62.9	63.6	63.1	0.173	0.182	0.179	0.188
AT	5.0	5.3	5.2	4.8	14.0	14.2	14.6	14.7	46.6	48.2	49.6	50.3	43.2	43.2	43.2	43.2	0.160	0.167	0.172	0.194
BE	3.7	3.8	3.7	3.4	14.8	15.2	15.3	15.4	44.1	44.3	43.7	44.6	63.8	63.2	63.0	64.6	0.174	0.173	0.154	0.169
BG	0.3	0.4	0.5	0.6	8.7	8.3	9.1	9.5	20.0	19.2	19.5	21.1	21.8	24.7	27.3	27.1	0.149	0.145	0.162	0.165
CY	0.6	0.3	0.5	0.3	15.1	16.9	17.2	17.2	30.7	32.0	39.3	33.4	69.0	71.4	68.9	69.0	0.186	0.155	0.175	0.235
CZ	0.8	0.7	0.9	0.9	12.0	12.5	12.9	12.3	53.6	53.1	52.8	54.1	36.8	38.8	39.3	41.1	0.164	0.170	0.183	0.184
DE	7.6	7.5	7.2	6.6	15.1	15.3	14.7	14.6	58.2	58.9	58.9	59.2	72.5	72.1	72.3	69.6	0.185	0.185	0.195	0.210
DK	6.9	6.5	6.9	6.2	15.6	15.5	15.2	15.4	38.6	39.2	40.2	42.5	75.3	74.5	76.0	75.1	0.207	0.217	0.191	0.201
EE	2.4	2.3	1.8	0.7	10.8	11.0	11.9	11.4	32.6	33.7	35.6	34.5	47.4	45.9	45.7	43.9	0.144	0.162	0.147	0.160
EL	0.4	0.4	0.4	0.5	11.4	12.4	12.5	12.2	18.4	16.2	15.6	17.2	61.0	56.6	55.8	51.8	0.150	0.150	0.152	0.152
ES	1.5	1.6	1.6	1.5	12.0	12.2	12.7	12.6	43.1	40.4	42.1	41.6	40.7	41.4	42.2	42.2	0.166	0.159	0.156	0.162
FI	9.9	10.0	9.5	9.9	15.3	15.5	15.5	15.9	36.9	35.2	33.5	35.1	50.6	50.6	50.6	50.6	0.185	0.153	0.171	0.184
FR	4.1	4.1	4.2	4.1	14.4	14.3	14.0	14.5	50.2	51.3	51.3	51.5	56.4	56.4	58.6	58.6	0.197	0.208	0.193	0.217
HR	0.7	0.7	0.7	0.6	10.6	10.5	10.6	10.7	36.1	32.4	30.0	28.9	20.8	20.1	19.7	17.8	0.116	0.116	0.116	0.116
HU	1.5	1.5	1.6	1.3	13.0	12.5	12.9	12.3	57.1	54.9	54.9	55.3	38.3	39.6	38.5	38.3	0.182	0.187	0.191	0.192
IE	2.7	2.3	2.7	2.4	19.7	20.1	20.1	20.2	47.0	45.1	44.4	44.9	88.9	88.9	88.9	88.5	0.215	0.218	0.215	0.234
IT	2.1	2.0	2.0	2.0	13.5	13.3	13.5	13.6	45.3	44.8	45.9	46.9	47.6	48.2	48.9	48.5	0.171	0.159	0.159	0.163
LT	0.3	0.4	0.3	0.8	8.9	9.1	9.0	8.8	30.0	29.1	28.2	30.1	17.7	17.9	17.1	18.3	0.136	0.123	0.123	0.116
LU	1.8	1.7	2.0	1.8	24.8	25.4	26.2	27.1	45.6	49.2	47.1	45.8	88.6	88.7	88.4	88.4	0.270	0.210	0.188	0.177
LV	1.2	0.5	0.8	1.0	9.0	10.3	10.8	10.9	27.7	25.6	27.1	29.5	53.8	50.2	49.6	49.8	0.139	0.095	0.113	0.123
MT	0.3	0.7	0.2	0.6	16.2	16.7	17.4	17.9	18.2	20.4	21.4	28.0	25.8	25.8	25.9	25.9	0.169	0.169	0.169	0.200
NL	5.9	5.2	6.0	5.9	14.9	15.2	17.1	17.2	38.6	38.4	38.2	40.1	65.3	65.3	65.3	65.3	0.171	0.164	0.162	0.169
PL	0.5	0.5	0.5	0.5	9.2	9.7	9.6	9.9	42.3	41.1	41.5	41.8	39.3	37.8	37.8	36.7	0.173	0.185	0.185	0.182
PT	0.7	0.6	0.7	0.7	9.1	9.0	9.4	10.3	31.7	31.2	30.1	30.8	43.1	43.1	42.8	43.2	0.142	0.141	0.143	0.148
RO	0.2	0.2	0.2	0.2	6.5	6.5	6.6	6.9	39.4	38.4	39.2	38.6	44.7	44.7	44.7	44.7	0.152	0.160	0.160	0.169
SE	10.3	9.5	9.1	9.9	17.2	17.6	17.7	17.9	48.5	46.1	47.7	47.3	62.3	64.1	63.0	65.0	0.210	0.192	0.189	0.196
SI	3.1	3.1	3.0	2.8	13.7	14.1	14.0	14.0	44.5	44.2	45.4	46.3	32.7	34.0	33.4	32.9	0.152	0.153	0.153	0.160
SK	0.4	0.5	0.5	0.4	10.4	10.1	9.6	9.9	54.4	56.5	58.2	59.1	35.3	35.3	35.3	35.3	0.194	0.169	0.193	0.209
UK	3.3	3.3	3.3	3.1	17.3	17.8	17.8	18.0	46.9	50.1	44.6	49.3	79.3	79.4	79.2	77.9	0.166	0.188	0.186	0.187
CH	7.7	7.7	7.7	7.7	19.9	20.5	20.4	21.2	58.0	42.3	38.5	46.7	51.4	50.9	50.0	50.4	0.205	0.206	0.199	0.196
IS	3.7	2.9	3.3	3.3	18.5	17.5	17.2	18.2	11.2	11.0	9.2	10.4	65.6	63.8	62.9	62.9	0.171	0.172	0.168	0.167
NO	3.7	3.3	3.0	2.8	15.1	15.3	15.8	16.4	10.0	10.2	10.9	12.1	75.3	70.7	75.8	75.8	0.174	0.163	0.162	0.175
IL	11.0	10.1	10.1	10.4	26.9	26.9	26.9	26.9	51.4	51.8	52.3	51.5	62.8	64.1	66.3	68.3	0.224	0.224	0.205	0.193
JP	10.1	11.3	12.6	12.7	17.2	17.2	16.1	16.1	73.1	74.3	72.6	73.7	59.0	60.3	53.9	55.7	0.207	0.206	0.208	0.203
NZ	3.3	3.3	3.1	3.0	16.8	16.9	16.9	16.9	9.3	9.6	8.7	8.1	22.9	22.9	22.9	21.6	0.216	0.195	0.200	0.200
US	4.0	4.0	4.2	4.2	16.8	17.1	17.2	17.1	47.5	47.6	46.8	47.2	52.6	52.3	52.4	52.2	0.188	0.187	0.188	0.188
TR	0.6	0.6	0.5	0.6	4.7	5.0	5.3	5.7	37.7	34.1	36.7	36.6	26.2	26.9	29.0	27.7	0.139	0.138	0.137	0.140
BR	0.3	0.3	0.3	0.3	11.4	11.4	11.4	11.4	23.3	24.1	25.8	23.0	72.1	73.2	73.7	73.1	0.116	0.132	0.132	0.132
EUx	3.9	3.9	3.9	3.7	13.6	13.8	13.9	14.0	53.8	54.2	52.8	54.1	70.1	70.2	69.4	69.4	0.173	0.182	0.179	0.188

Notes: KIABI, GOOD and SERV expressed in percentages. EUx denotes extra-EU trade only as opposed to extra- as well as intra-EU trade shown for 'EU'.

5 Sensitivity and Robustness Analysis

The final ranking of countries is shaped by a number of uncertainties associated with the modelling choices made in the process of constructing the composite Innovation Output Indicator. The purpose of the sensitivity and robustness analyses reported in this section is to better understand the impact of methodological changes and modelling choices on the ranking of countries. We followed two different approaches, conducting global analyses as well as focused analyses of single indicators' impact.

5.1 A global analysis on the impact of methodological changes on country rankings

In a first set of robustness analyses, we aimed at assessing the simultaneous and joint impact of the most important changes in this latest edition on country rankings. In contrast with "*ceteris paribus* analyses", the global analysis can take into consideration the interactive effect of all the different sources of uncertainties on the outcomes. In effect, these studies complement the IOI ranks with error estimates stemming from the unavoidable uncertainty in the modeling choices made. The robustness assessment of the IOI was based on a multi-modelling approach, following good practices suggested in the composite indicators literature (Saisana et al, 2005 and Saisana et al, 2011).[13]

We identified 4 main issues in this latest update of the IOI that may lead to differences in contrast to the previous edition (summarized Table 6). As discussed in section 2, most of the modifications are necessary consequences of definition changes in source data (as in the case of PCT and SERV) or of the update scaling coefficients to create effectively equal weighting of the components reflecting the new set of variables and expanded number of country-year observations.

Table 6 Definition and parameter changes affecting the robustness of country ranking

Issue	Reference	Alternative
GDP definition change (PCT)	GDP updated to ESA2010	GDP defined according to ESA95
KIS classification change (SERV)	include air-, space and maritime transport services in numerator	exclude all transport services from numerator and denominator
		Exclude maritime transport service exports from numerator
		Exclude maritime transport service exports from both numerator and denominator
Timeliness:	Use of most recent data available (2014 for KIABI, GOOD and SERV)	Align data to 2013 (all but PCT)
Weighs (scaling coefficients):	Effective equal weights (rebalanced for 2015 dataset)	Apply weights of the 2014 edition
		Apply nominally equal weights for the 4 components

For each of the modifications, we made an attempt to compare revised component scores with scores calculated according to the old version (where it was possible). The alternatives thus considered are reported in the third column of Table 6. A direct comparison was possible for all the four time points and for all the countries in our dataset in the case of PCT, where GDP was available both according to the older ESA95

[13] While conducting a Monte-Carlo simulation to test the uncertainty of weights is also common in the literature, for this study we decided that it may be more informative to select two distinct alternatives to the application of adjusted weights as scaling factors.

as well as the new ESA2010 definition, and similarly for the issues of timeliness and the update of the scaling coefficients[14].

However, making **a direct comparison of the old and new scores was impossible for SERV**, given that not only were knowledge-intensive services reclassified into a new breakdown, but also the classes themselves refer to different export activities. Part of the differences stem from the re-classification of maritime service exports in the new BPM6 / EBOPS2010-based dataset. However, the other classes are not directly overlapping the old BPM5 / EBOPS2002-based classification – in a few cases, there is a significant difference in the total value of service exports calculated according to the two methodologies.[15] Furthermore, the time coverage of statistics produced according to the two methodologies do not properly overlap. Most countries stopped reporting BPM5-based data after 2012 and that BPM6-based data is available incompletely for typically less than 3 years for most countries makes it impossible to test a "what-if-nothing-changed" scenario. Therefore, for alternative scores, we simulated three alternative sets of SERV scores: one in which maritime services are excluded from the list of selected services (numerator), another set maritime services are excluded both from the numerator and denominator, and a third set in which all transport services are excluded from the indicator: air-, space- and maritime transport from the numerator and all transport sectors from the denominator. (The reasoning behind this third option was not to put countries with relatively large knowledge-intensive transport services export share in a disadvantageous position).

In our simulation, we computed 48 different IOI scores for 152 country-year combinations (38 countries, four time points), which we contrasted with the IOI baseline scores for the European comparison (taking the most recent year available).[16]

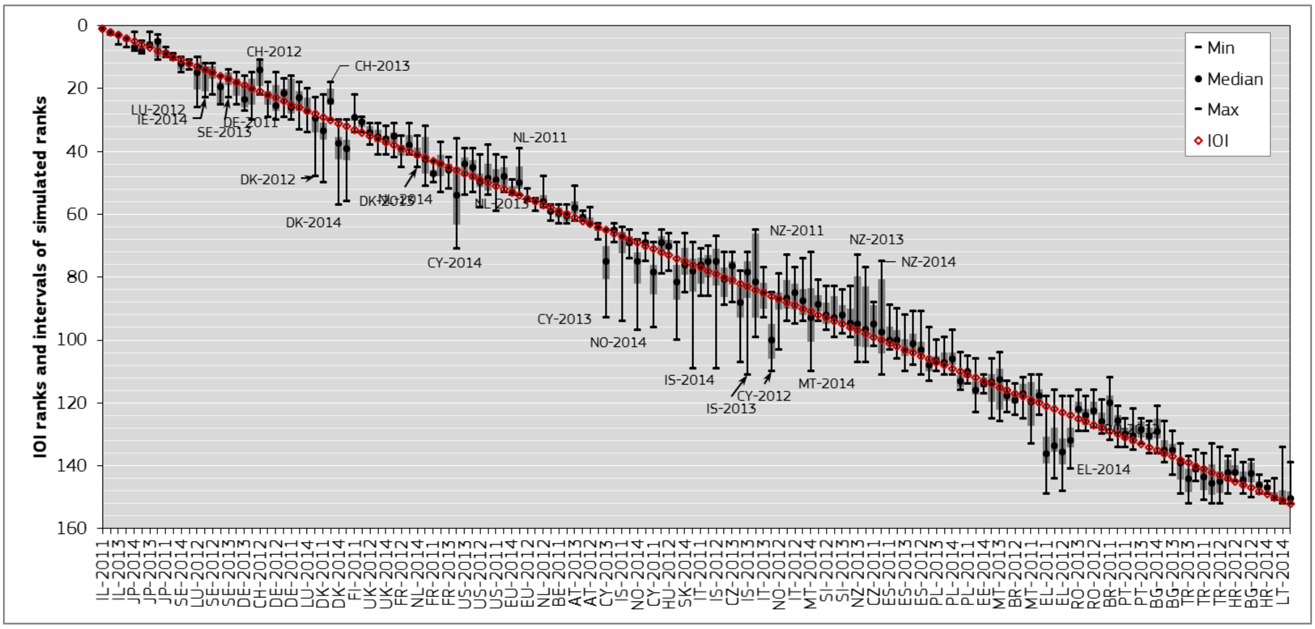
We first estimated the combined impact of the selected issues on the relative positions of countries in the rank. Resulting confidence intervals are shown both for all four time year (Figure 14) as well for the latest time point (Figure 15). A general observation is that the ranking for most of the countries is rather robust, but there are countries whose ranks are somewhat sensitive to the modifications and modeling choices. Iceland, Malta, Cyprus, Denmark, Norway and New Zealand are among the countries with rankings most sensitive to modelling choices, while Israel, Japan, Sweden, Finland, Belgium, the EU28, Portugal, Latvia and Croatia are affected the least. While the graphs capture the extremities, they also show the median scores which offer an interesting comparison with IOI benchmark scores. For half of the countries the IOI scores and the medians are the same considering the latest time point (Figure 15), and for the most sensitive cases (Denmark, Greece, the Netherlands and Norway) the difference is at most 3 positions. The difference between median and the benchmark IOI scores is less than 3 positions for the majority of the countries when comparing all four time points (Figure 14). The most notable exceptions are Greece, Cyprus, Denmark, Portugal and Switzerland (in one or more of the four years). The latest IOI scores for Israel, Sweden and Norway appear to be the best of all possibilities tested, while the opposite is true for Finland, the US, Austria, the EU28 and Portugal – although these could only achieve very limited improvements when changing any some of the modelling assumptions.

[14] We used the 3 selected sets of weights as fixed for all combinations for our simulations. We note that the 'balanced' set of weights were computed for the baseline scenario and imposed on all others, which may cause some imbalance for some of the aggregations including more extreme modification of certain indicators. Nevertheless, this can be considered as a reflection of uncertainty.

[15] This may partly explain the fact that a concordance table for the two EBOPS classifications was still "under construction" at the time of the preparation of this report.

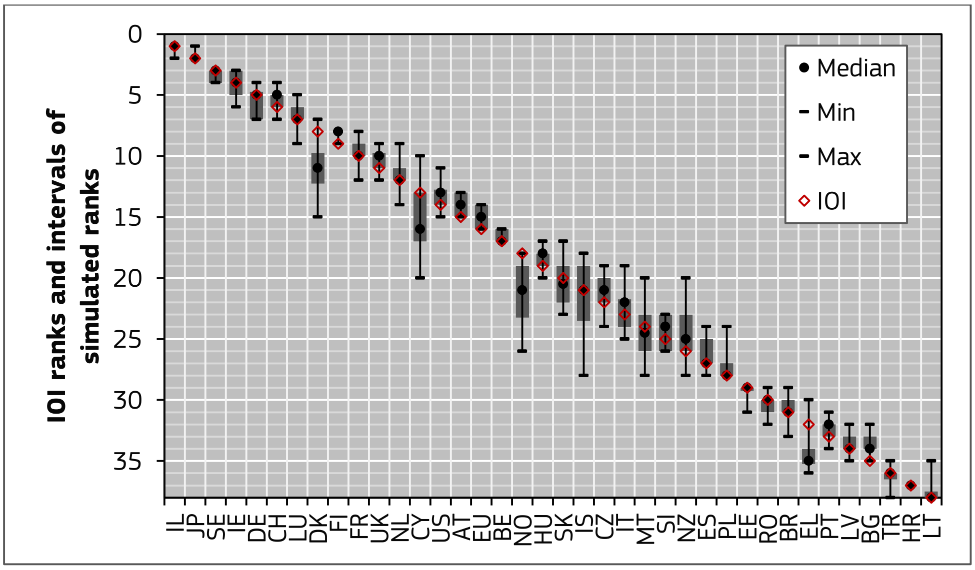
[16] We only report the outcomes for the first, EU Member states' comparison, because it is highly similar to the outcomes of the EU's worldwide comparison.

Figure 14 Robustness of IOI Ranks due to changing modelling choices (all 4 years)



Source: JRC calculations. *Notes:* 152 country-year combinations ranked; based on 48 scenarios. IOI baseline scores refer to baseline ranking, EU Member States' comparison. Shaded boxes indicate interquartile range, whiskers span over min-max range of simulated ranks.

Figure 15 Robustness of IOI ranks due to changing modelling choices (latest time point)

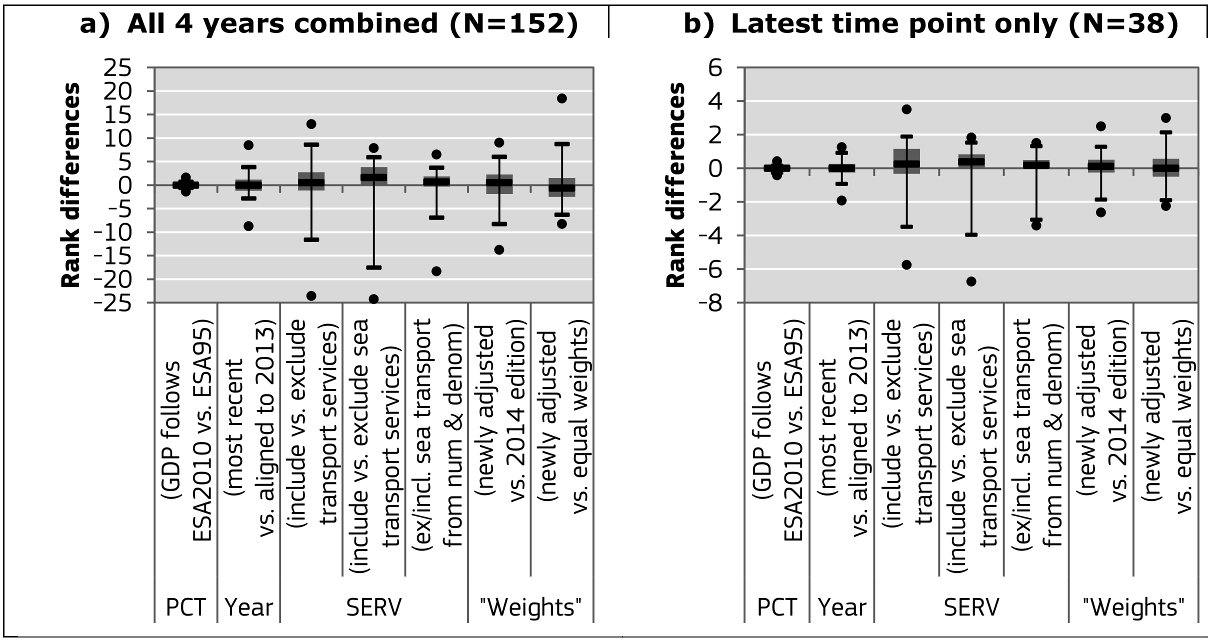


Source: JRC calculations. *Notes:* 38 countries ranked; based on 48 scenarios. IOI baseline scores refer to baseline ranking, EU Member States' comparison. Shaded boxes indicate interquartile range; whiskers span over min-max range of simulated ranks.

The global sensitivity analysis also revealed which of the various modifications or modelling choices have the highest impact on country ranks. Box plots presented in Figure 16 show rank shifts for the five issues tested. The median shift in rank across all simulations is the black mark inside the grey-shaded 'boxes'. The shaded areas show the 50% of the distributions (from percentiles P25 to P75), while the whiskers cover 90% of the distribution (P05-P95). The minimum and maximum shifts are shown by dots. Panel

a) of Figure 16 captures rank shifts from all four years combined, while panel b) of in Figure 16 shows simulation results for the latest time point only.

Figure 16 Robustness of ranks due to changing modelling choices



Source: JRC calculations. *Notes:* Graph shows rank differences for 152 country-year combinations (left panel) and for 38 countries (right panel), based on 48 scenarios for the EU Member States' comparison. Shaded boxes indicate interquartile range; whiskers cover 90% of rank differences, min and max values shown by dots.

We observe in the boxplots in Figure 16 that two of the choices are relatively more influential: that is, the adjusting the SERV classification to exclude the entire transport services (both from numerator and denominator, 3^{rd} box), the exclusion of maritime transport from the numerator (4^{th} box) and, to a lesser extent, the use of effectively equal vs. nominally equal weights (6^{th} and 7^{th} boxes). Considering country ranks in the most recent time point, we see that rank shifts never exceed 7 positions in the most extreme of cases, 4 positions or less in 90% of the cases, and less than 1 position for half of the cases. In contrast, it is reassuring to find that the application of the new definition of GDP (1^{st} box), aligning years or using the most recent data available (2^{nd} box) has very little overall impact on the ranking. In the following section, we take a closer look at the various issues highlighted. We do not discuss the issue of weighting as we consider the use of nominally equal weights as an unfair option.[17]

5.2 The impact of changes in selected indicators on country ranking

In a second set of sensitivity analyses, we looked more closely at the individual effect of some of the issues deemed relevant in the global robustness analyses. Rather than considering the changes in combination, focusing on some of the key issues individually helps in the fine-tuning of the indicator. However, it is important to keep in mind that this approach might over-amplify the impact which could be evened out when assessed in conjuncture. For ease of communication, we report ranks for the last time point only;

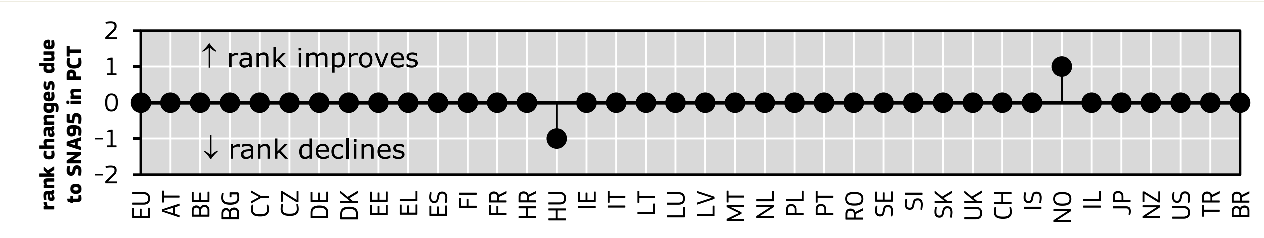
[17] See Paruolo *et al.* (2013)

these were found to be typical for country performance across the time span considered. Thus, ranks range from 1 to 38, where 1 indicates best performance.

5.2.1 The impact of change in the system of national accounts

The global sensitivity analysis showed that the impact of changes in the GDP methodology had a very limited impact on the scores. We compared rankings based on simulated scores of IOI in which the number of PCT applications are divided by GDP defined according to the older ESA95 with the new scores using the newer ESA2010 definition. The results reported in Figure 17 show that only 2 countries are affected: Hungary and Norway, but the mere impact of this change is 1 position for these countries (Hungary would rank 1 position lower according to the old definition).

Figure 17 IOI Country rank position shifts due to the use of ESA95 vs. ESA2010 in PCT



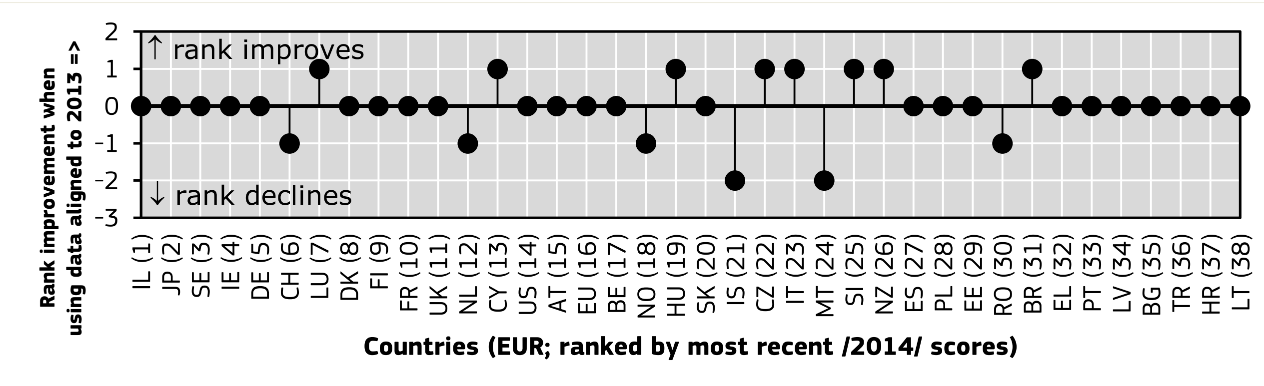
Notes: N = 38; average of absolute position shifts = 0; positive scores indicate number to rank positions improvement when GDP is defined according to ESA95 as opposed to ESA2010 (EU Member States' comparison, 2014)

5.2.2 The impact of using most recent data vs. aligned data

This analysis addresses the impact of the choice to improve timeliness of the data. We decided to use for our benchmark IOI scores the most recent year available for all variables (2014 for KIABI, GOOD and SERV) as opposed to align them all (but PCT) to 2013 – see discussion in section 2.3.

Results in Figure 18 indicate that improving timeliness has very little impact on country scores. With the exception of Iceland and Malta (decline by 2 positions), 12 countries would see 1 rank position shift, while 24 remain stable in case we aligned all data (but PCT) to 2013.

Figure 18 IOI Country rank position shifts due to using data aligned to 2013 (EU Member States' comparison; last time point)



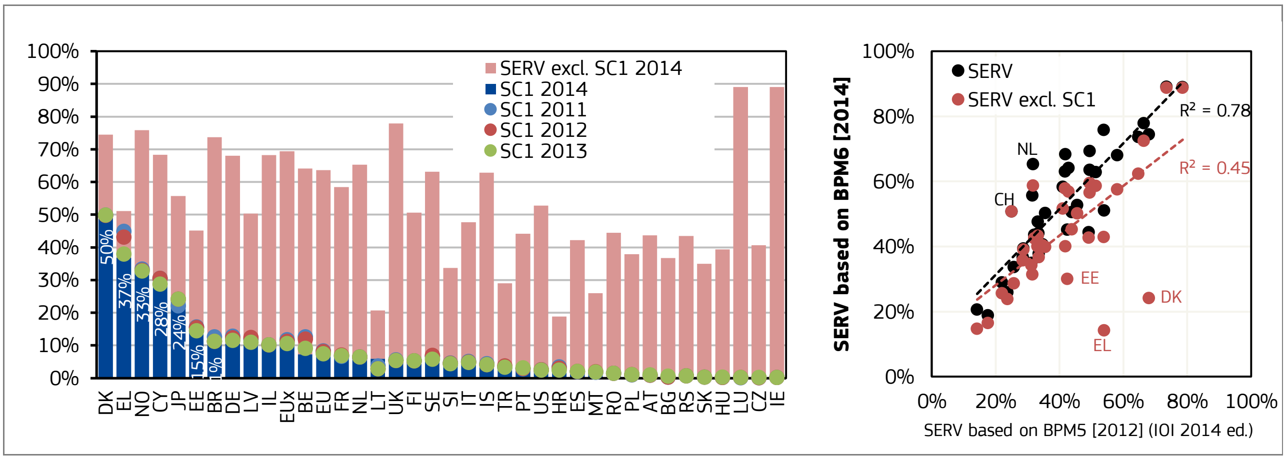
Notes: N = 38; average of absolute position shifts = 0.4; positive scores indicate number to rank positions improvement when using data aligned to 2013 (all but PCT) as opposed to the most recent available year (last time points compared)

We can conclude that it can be a viable option to improve the timeliness of the IOI by using the latest available data. Nevertheless, the effects we observed were those of two component indicators that relate mostly to the structure of the economy (KIABI and GOOD), and evolve gradually over time.

5.2.3 The impact of revising KIS classification, with special focus on the Transport sector

The classification of knowledge-intensive services in the business industry used in previous editions of the IOI had to be revised due to the changes in the classification of International Trade Statistics (see discussion in section 2.1.2). Maritime transport services has received special attention in the testing because it has belonged to the BPM5 / EBOPS 2002-based KIS classification, however, is not considered to be part of the knowledge-intensive activities (KIA). It is also a special sector prone to cause distortion given that land-locked countries are unlikely to export maritime transport services. Excluding Maritime transport services (class SC1) from the revised SERV indicator was shown to have a significant impact on the scores of countries with strong export-oriented sea transport industry, most prominently, Denmark, Greece, Norway, Cyprus or Japan. The scale of maritime services in total service export can be seen in the left panel of Figure 19. The right panel of Figure 19, which compares SERV scores of the last IOI edition with scores based on the revised classification both including and not sea transport services shows that it is a particularly important issue when it comes to the benchmarking of Greece and Denmark.

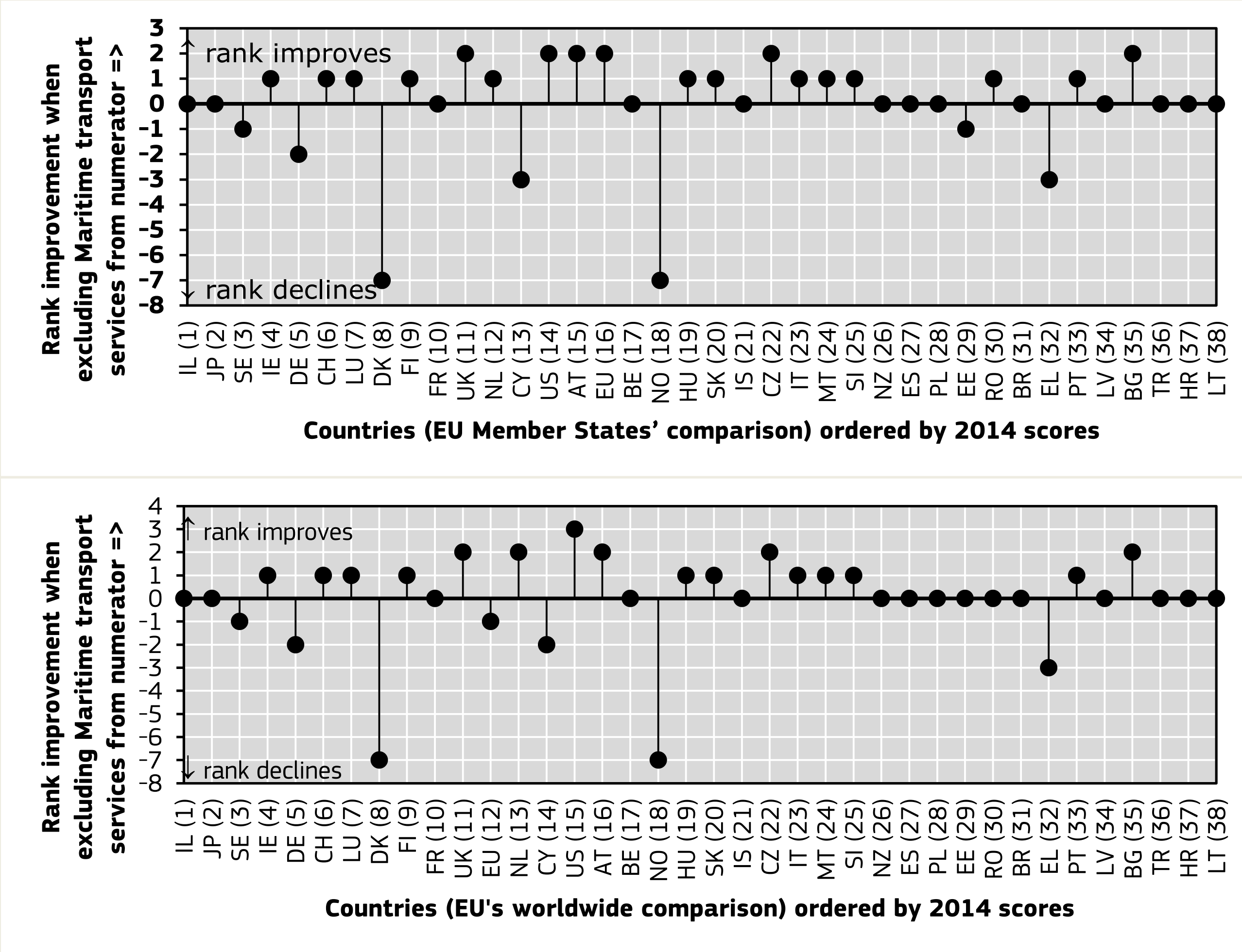
Figure 19 Share of Sea Transport within knowledge-intensive and total service export by country (left panel) and alternative SERV scores plotted against BPM5-based SERV scores used in the 2014 edition (right panel)



Note: missing data appears as 0 for most recent year.

In order to better understand the impact of this reclassification, we performed three different simulations. In the first one, we computed IOI ranks using modified SERV scores that excluded maritime transport (SC1), in the second one, we removed maritime transport from both the numerator and denominator of SERV, and in a third one, we considered removing the entire transport sector from the numerator and denominator.

Figure 20 IOI Country rank position shifts due to removing maritime transport services from SERV numerator (last time points)



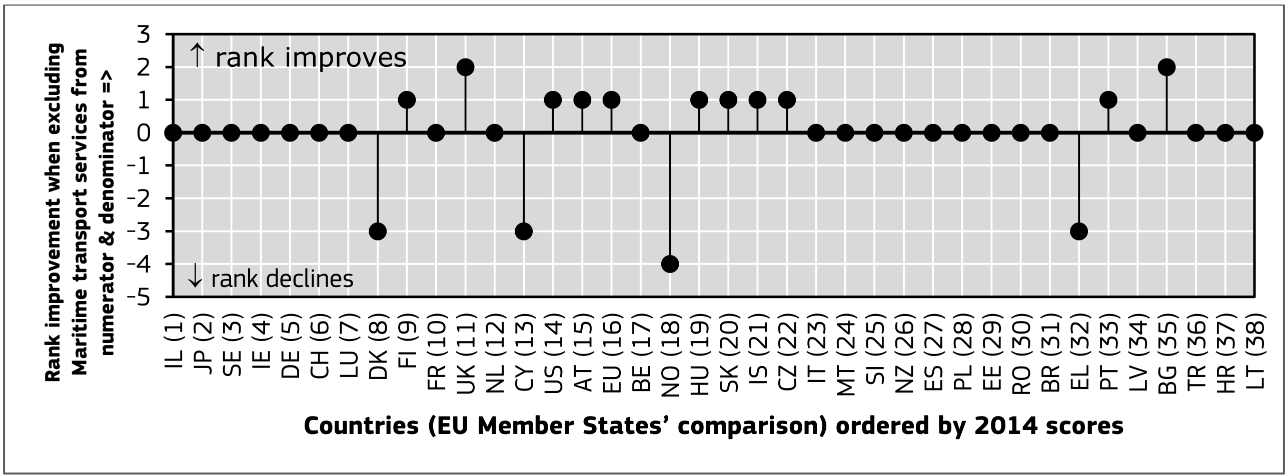
Notes: N = 38; average of absolute position shifts = 1.2. Positive scores refer to improvement in number of rank positions when excluding maritime transport services from the numerator of SERV.

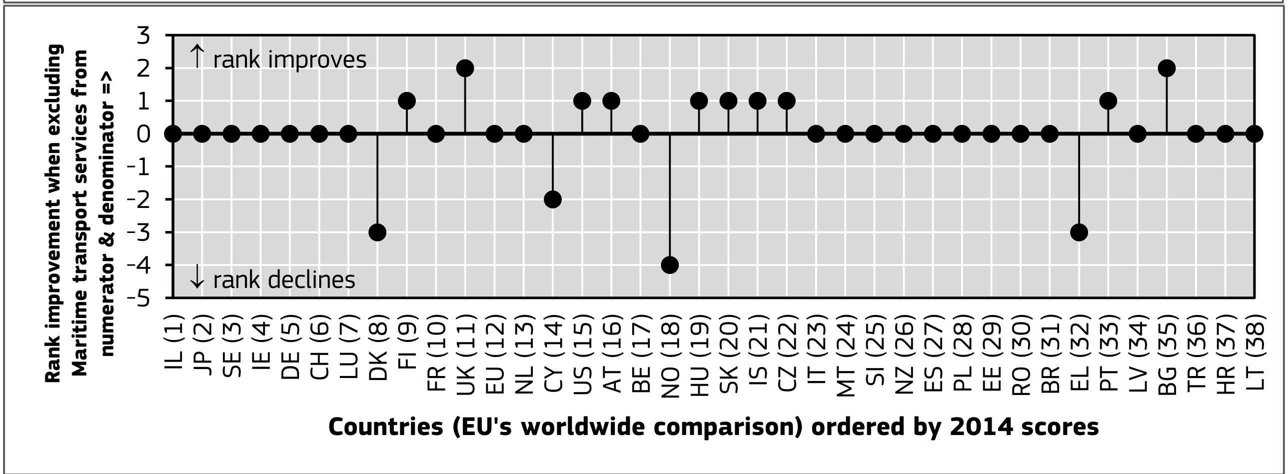
Country rank differences between benchmark scores and scores resulting from the former simulation are reported in Figure 20. Evidently, the revised classification has the biggest impact on the Innovation Output Indicator scores of Norway and Denmark: these countries would be 7 positions ahead in the ranking should maritime transport be added to SERV. Other countries with a high share of maritime transport among service exports are also affected, but to a lesser extent: Greece and Cyprus are penalized by 3 positions (in the European comparison) should maritime transport be excluded from SERV. As a cautionary remark for this test, it should be added that official export data for both maritime and other service sector was missing for many of the countries, for which we used International Trade Centre's estimates from the nearest available year, which could, in some cases, be based on BPM5-based classification.

Similar, but somewhat dampened results can be observed for the case when maritime transport services are removed not only from the numerator, but also from the denominator of SERV (Figure 21). The rationale for this test is to ensure that maritime transport sector does not contribute either to the advantage or the

Rank shifts are limited to 4 positions, mostly to the detriment of the Norway, Denmark, Cyprus and Greece benefiting countries. Such change would be for a minor advantage of, apart from the UK, US and EU, many landlocked countries – this advantage is however a mere 1 or 2 rank positions.

Figure 21 IOI Country rank position shifts due to removing maritime transport services from both numerator and denominator of SERV (last time points)

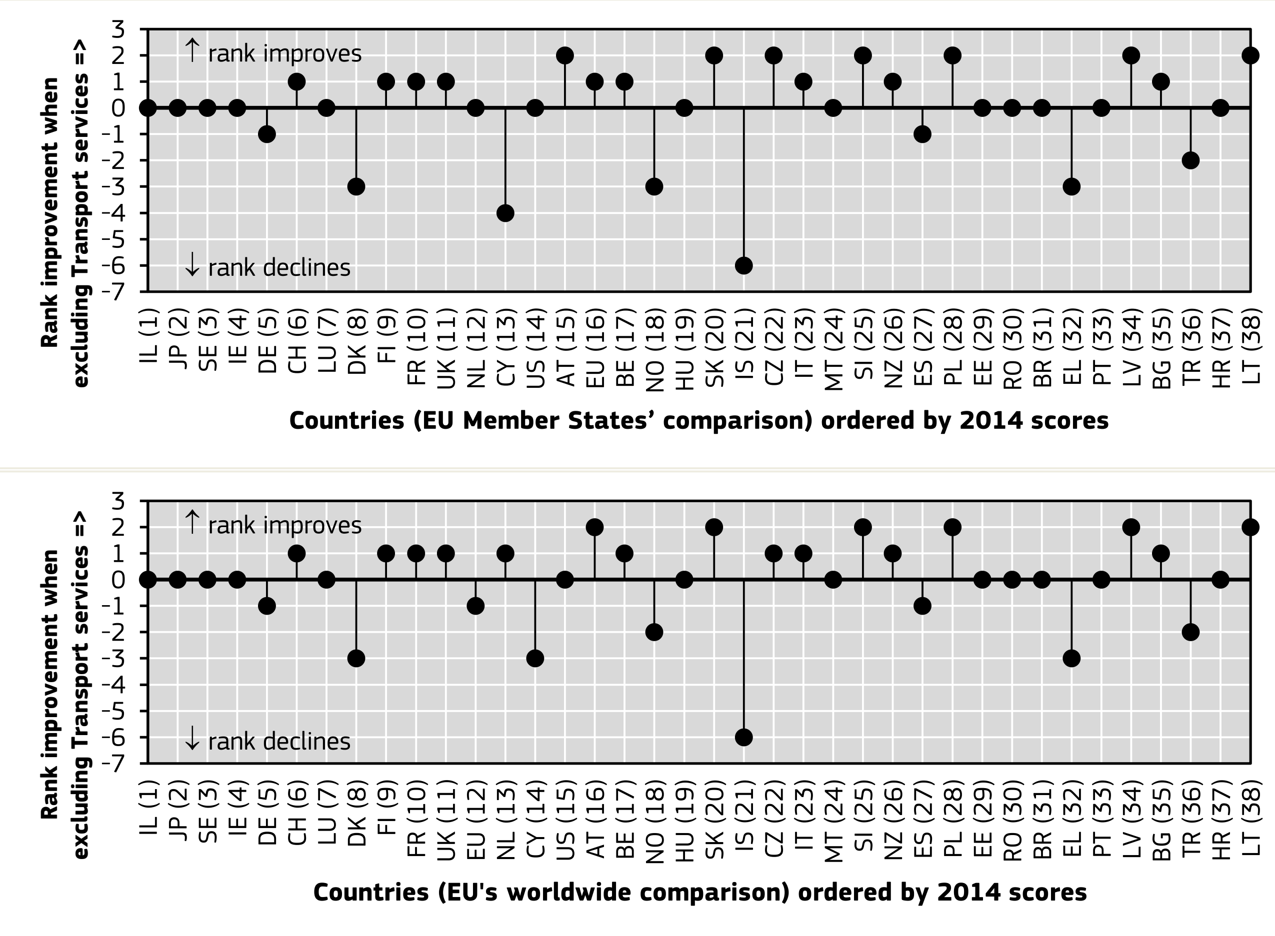




Notes: N = 38; average of absolute position shifts = 0.7. Positive scores refer to improvement in number of rank positions when excluding maritime transport services from both the numerator and denominator of SERV.

The results of the second country-level simulations looking into the impact of removing the entire transport services sector from both numerator and denominator of SERV are shown for the last time point for both the European and International comparisons in Figure 22. We observe that the absolute average rank shifts amount to about 1 position, where the countries most affected are Iceland (6 positions decline); Cyprus (5), Denmark, Norway and Greece (4 positions decline). The results are similar for the European as well as the international comparisons. We also observe that landlocked, transit countries, such as Austria, Slovakia, the Czech Republic and Slovenia (but not Hungary) would gain at most 2 rank positions from the complete exclusion of transport services.

Figure 22 IOI Country rank position shifts due to excluding transport services from SERV (last time points)



Notes: N = 38; average of absolute position shifts = 1.2. Positive scores refer to improvement in number of rank positions when excluding transport services from both numerator and denominator of SERV.

Beyond the heterogeneity of the sectoral composition of countries and their service exports, it is also important to note that transport services on the whole across Europe constitutes an industry in which the share of tertiary educated labour force – the determinant of KISBI classification – depends on the granularity of analysis. At the aggregate level, it is not knowledge intensive, mostly due to the maritime and road transport segments, while at a lower level, air and space transport distinguishes itself with its higher share of tertiary graduates.

6 Validation of Scores

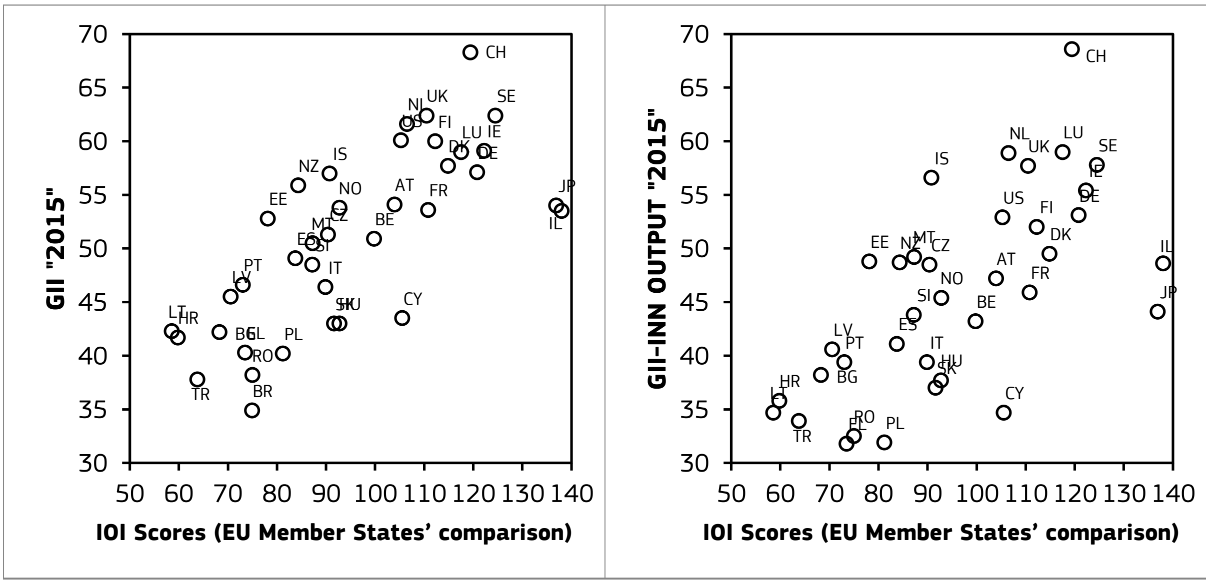
In order to validate the latest obtained scores of the IOI, we benchmarked them against the most recent scores from the Global Innovation Indicator 2015 (GII) – against the overall composite, as well as the Innovation Output Pillar.[18] In addition, we compare the most recent IOI scores against the 2014 edition of the IOI.

The GII 2015, published in collaboration by the WIPO, INSEAD and Cornell University, is a very comprehensive index. It is a composite of 79 indicators which encompass the political, regulatory and business environment, higher education, infrastructures, business sophistication, knowledge and technology as well as creative outputs of countries. In other words, the index goes beyond the scope of the IOI – nevertheless, it is a frequently used index with an established methodology, intuitively offering a benchmark ranking for the validation of any composite indicators of innovation. As seen in the *left panel* of Figure 23, there is an overall alignment of the GII and IOI scores (corr. 0.74), despite the heterogeneity of the GII. Some notable outliers are Japan and Israel, which are top performers in the IOI, while would rank around not too far above the average of European countries in terms of the GII.

One may consider applying a more appropriate comparison when selecting only the "Innovation Output" Sub-index of the GII (a composite of 27 indicators within the 'knowledge and technology' and 'creative outputs' pillars). As shown in the *right panel* of Figure 23, the countries are somewhat more dispersed (corr. 0.683). This is due to the different understanding of innovation output applied by the IOI and GII sub-index, whereby the latter provides for a much broader scope.

Each approach may have its own strengths and weaknesses; it may be worth a dedicated study to compare the differences and merits of the regularly published composite indicators of innovation that receive public attention – including, alongside the Global Innovation Index, the Commission's Summary Innovation Index, the Fraunhofer Institute's Innovation Indicator.

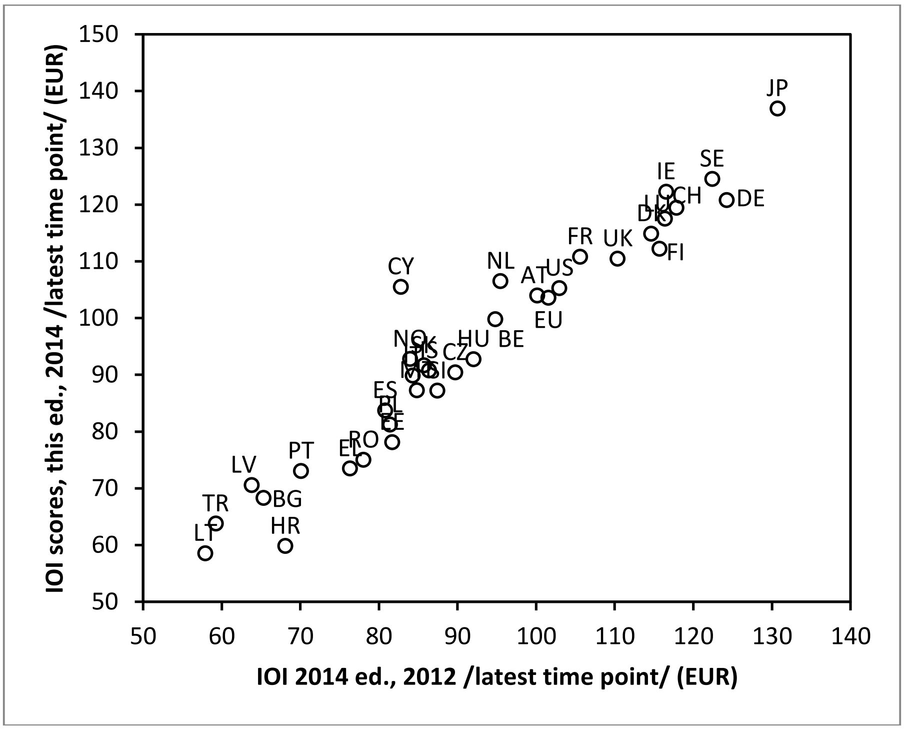
Figure 23 Comparison of Innovation Output Indicator and Global Innovation Indicator Scores



Source: Global Innovation Index 2015 and author's calculations.
Notes: Pearson correlation coeff. between IOI and GII overall index: 0.74; with GII-Innovation Output Pillar: 0.67

[18] Report and dataset available at the following URL: [http://www.globalinnovationindex.org; Retrieved: Nov 2015]

Figure 24 Comparison of Innovation Output Indicator scores from the 2015 and 2014 editions (EU Member States' comparison, latest time points considered)



Note: Pearson correlation coeff. 0.97.

We further compared the newly obtained IOI scores from this present edition with the most recent scores of the 2014 edition (Figure 24) in order to observe how the refinements and definition changes affected country rankings. Notwithstanding the very strong correlation between the two sets of scores (r = 0.97), the definition changes have caused some rank changes, affecting slightly the scores of Cyprus, Croatia and somewhat Germany. Given these changes, it is even more important to emphasize that comparisons over time are only valid when carried out using scores of the same edition, and avoid comparing scores from different editions.

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List of country abbreviations

Code	Country
AT	Austria
BE	Belgium
BG	Bulgaria
BR	Brazil
CH	Switzerland
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
EL	Greece
ES	Spain
EU	EU28
EUx	Extra-EU28
FI	Finland
FR	France
HR	Croatia
HU	Hungary
IE	Ireland
IL	Israel
IS	Iceland
IT	Italy
JP	Japan
LT	Lithuania
LU	Luxembourg
LV	Latvia
MT	Malta
NL	Netherlands
NO	Norway
NZ	New Zealand
PL	Poland
PT	Portugal
RO	Romania
SE	Sweden
SI	Slovenia
SK	Slovakia
TR	Turkey
UK	United Kingdom
US	United States

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