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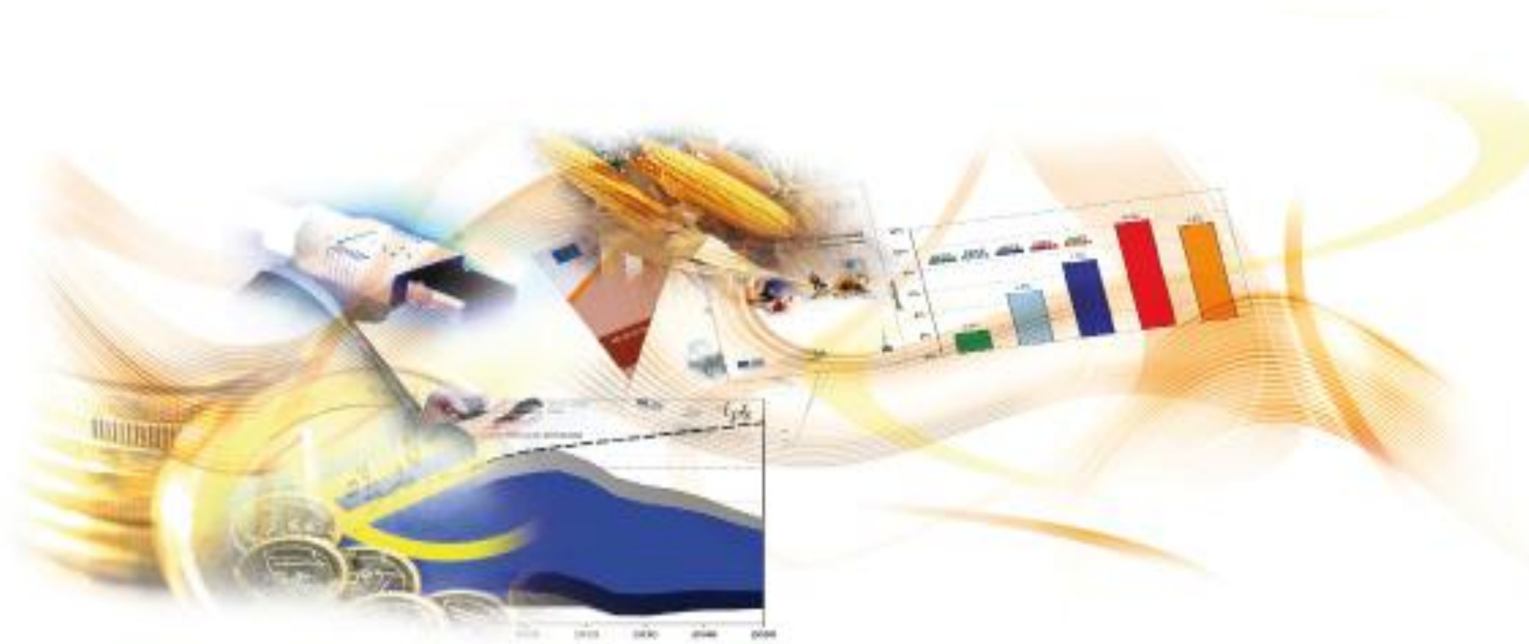

How much does ICT contribute to innovation output?

An analysis of the ICT component in the innovation output indicator

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Abstract

During the past few years, the role of ICT as a key driver and enabler of innovation has been widely recognized. The advent and development of ICT has clearly transformed the economy and society However, what and how ICT contributes to this value creation process and its full potential remains hard to detect. There is a need for continuous monitoring of ICT impacts in order to provide policy makers with appropriate tools to define the right policies to seize ICT benefits. In the light of this, a final aim for policy makers is to develop methodologies and tools to measure the performance of ICT innovation in Europe. This report analyses the ICT component within the newly-released innovation output indicator and provides additional background information on the role of ICT and its relation to innovation output.

Acknowledgements

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Preface

This report was prepared in the context of the three-year research project on European Innovation Policies for the Digital Shift (EURIPIDIS) jointly launched in 2013 by JRC-IPTS and DG CONNECT of the European Commission. This project aims to improve understanding of innovation in the ICT sector and ICT-enabled innovation in the rest of the economy.

The purpose of the EURIPIDIS project is to provide evidence-based support to the policies, instruments and measurement needs of DG CONNECT for enhancing ICT Innovation in Europe, in the context of the Digital Agenda for Europe and of the ICT priority of Horizon 2020. It focuses on the improvement of the transfer of best research ideas to the market.

EURIPIDIS aims to:

1. better understand how ICT innovation works, at the level of actors such as firms, and also of the ICT “innovation system” in the EU;

2. assess the EU's current ICT innovation performance, by attempting to measure ICT innovation in Europe and measuring the impact of existing policies and instruments (such as FP7 and Horizon 2020); and

3. explore and suggest how policy makers could make ICT innovation in the EU work better.

This report concentrates on point 2 above, and analyses the ICT component within the newly released innovation output indicator. The study described in this report aims to establish and measure the ICT component of the selected indicators, collect the measurements and present the results.

Executive Summary

This report aims to develop and implement methodologies and tools to measure the performance of ICT innovation in Europe. The ICT component in innovation can refer to either ICT as defined by the classification of economic activities or to ICT use as a general purpose technology, according to the indicator analysed and data availability.

This report analyses the ICT component within the newly released EU innovation output indicator. The contribution of ICT has been computed for each underlying component of the innovation output indicator for all Member States. The ICT contributions for Europe are:

1. 26% in technological innovation as measured by patents;
2. 19% in absorption of skills as measured by employment in knowledge intensive activities;
3. 25% in competitiveness of knowledge goods as measured by exports of medium-high tech goods;
4. 20% in competitiveness of knowledge services as measured by exports of knowledge intensive services;
5. 23% in innovative firm's dynamics as measured by employment of innovative fast-growing firms.

All data refer to 2012 with the exception of data on patents which refer to 2011.

These contributions form the basis of the ICT innovation output indicator derived in Section 4. The indicator delivers a measure of output-oriented ICT innovation that captures both the technological and non-technological aspects of innovation in ICT and ranks Member States' performances. The three top performing countries in ICT innovation output are Finland, Ireland and Sweden.

Finally, Section 5 presents a list of additional existing indicators for which the ICT contribution can be isolated.

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1. Introduction

There is widespread agreement on the importance of innovation as a key driver for Europe's competitiveness, growth and jobs. The European Union has set itself the goal of becoming an "Innovation Union"[1]. In this context, the sound measurement of innovation performance is crucial for policy makers.

So far, measurement of innovation has focused mainly on the determinants of innovation (i.e. R&D expenditure) and less on the development of metrics of innovation outputs that can be linked to economic performance.

One of the targets of the Europe 2020 strategy is to improve the conditions for Research & Development (R&D), with a view to raising combined public and private investment levels for R&D to 3% of GDP. In order to complement the R&D indicator, broaden the perspective on measurement of innovation and eventually increase the efficiency of national systems of innovation, a new indicator of innovation output was developed at the request of the European Council.[2]

On 13 September 2013, the Commission adopted its Communication 'Measuring innovation output in Europe: towards a new indicator'[3] that presents an indicator to measure performance in innovation output and to benchmark Member States' innovation policies.

The new indicator of innovation output "measures the extent to which ideas stemming from innovative sectors are capable of reaching the market, providing better jobs and making Europe more competitive."[4] The indicator also fulfils a commitment under the Innovation Union flagship initiative to "launch the necessary work for the development of a new indicator measuring the share of fast-growing innovative companies in the economy".[5] It will support policy-makers in establishing "new or reinforced actions to remove bottlenecks preventing innovators from translating ideas into successful products and services that can be successful in the markets".[6]

The role of ICT as a key driver and enabler of innovation in the last few decades has been widely recognized.[7] The advent and development of ICT transformed the economy and society in ways that are evident in everyday life. However, what and how ICT contributes to this value creation process and its full potential remains hard to detect. Continuous monitoring of its impacts is required in order to provide policy makers with the appropriate tools to define the right policies to grasp the full benefit from ICT. In light of this, analysis of the ICT component in the new innovation output indicator will provide additional background information on the role and relation between ICT and innovation output.

The report presents a first estimate of the ICT contribution to the innovation output indicator, measuring the ICT contribution of each component indicator and providing a measure of outcome innovation for the ICT economy by Member State. Section 2 describes the innovation output indicator released by the Commission. Section 3 presents the ICT contribution by components. Section 4 estimates the ICT innovation output indicator for the EU economy. Section 5 proposes a series of additional indicators from which it could be possible to isolate the ICT contribution.

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1 "Turning Europe into a true Innovation Union" European Commission - MEMO/10/473 06/10/2010 http://europa.eu/rapid/press-release_MEMO-10-473_en.htm?locale=en

2 Conclusions of 4/2/2011 (Council doc. EUCO 2/1/11 REV1) and 1-2/3/2012 (EUCO 4/2/12 REV2).

3 Measuring innovation output in Europe: towards a new indicator" COM(2013) 624 final http://ec.europa.eu/research/press/2013/pdf/indicator_of_innovation_output.pdf

4 Ibidem

5 Ibidem

6 Ibidem

7 "Information & Communication Technologies" World Bank Approach Paper 2011 http://siteresources.worldbank.org/INTICTSTRATEGY/Resources/2010-12-27_ICT_Sector_Strategy_Approach_Paper_EN.pdf
and Word Summit on Information Society –Outcome documents 2014 http://www.itu.int/wsis/implementation/2014/forum/inc/doc/outcome/E_Outcome_Document_2014_V2.pdf

2. Measuring innovation output

Innovation is a broad concept which encompasses an ample variety of activities and processes. According to the Oslo Manual,[8] innovation can be classified into market, product, process and organizational innovation. Based on this definition, innovation surveys (i.e. the Community Innovation Survey, etc.) were introduced to extend the range of collected information to: the types of innovations, the reasons for innovating, the impacts of innovation, collaboration and linkages among firms or public research organizations, flows of knowledge and skills and organization. The collection of quantitative data on output of innovation is essential for policy makers to develop effective innovation policies.

In addition, composite indicators have been introduced in order to provide a thorough description of innovation processes and dynamics and a sound framework for policy makers to address policy interventions. The use of composite indicators allows policy makers to capture the variation in degree and type of innovations, offering a more complete picture of a country's innovation performance. They describe multi-dimensional aspects that cannot be drawn from the analysis of single indicators. However, composite indicators could be misleading if not grounded in a sound theoretical framework and could lead to inappropriate policy conclusions if important dimensions are not measured or are poorly constructed.

The novelty of the new EU innovation output indicator[9] is that it is a composite indicator focussed on innovation output. The final composite indicator comprises four components; three of which come from the Innovation Union Scoreboard (hereafter IUS). The four components are described below:

- The first is technological innovation as measured by patents. The number of patent applications per billion GDP is used as a measure of the economy ability to transform knowledge into technology. The statistics used refer to patent applications[10] filed at international phase to the European Patent Office (EPO) under the Patent Cooperation Treaty (PCT)[11].
- The second focuses on the absorption of skills. Skilled labour is essential for the expansion and the efficient deployment of knowledge. Europe's ultimate aim as regards innovation is to create the conditions for the development of a knowledge-based economy to generate growth and competitiveness. This component portrays the structural trends of knowledge-intensive activities as measured by the number of employees with higher education degrees in business industries over total employment.
- The third is the competitiveness of knowledge-intensive goods and services. This measure captures the linkages between innovation and internationalization looking at both the export shares of high-tech and medium-tech products and of knowledge-intensive services in the total product and service exports of a country. This component indicates the ability of an economy to take part in knowledge-intensive global value chains.

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[8] "OSLO Manual" OECD/Eurostat(2005) http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/OSLO/EN/OSLO-EN.PDF

[9] For more details see Daniel Vertesy, Stefano Tarantola (2014) "The Innovation Output Indicator 2014. Methodology Report" EUR 26936 EN.

[10] The number of patent application based on the priority date represents the first date of a patent application anywhere in the world and therefore closest to the invention date. The priority date does not depend on the administrative process of the patent office or the procedure used to file the patent application. On the opposite, looking at granted patent introduces a time lag (and a bias) depending on the patent office. Furthermore, the information reported is old, and it refers to inventions from different years. (OECD -Compendium of Patent Statistics, 2008).

[11] The PCT offers the possibility to seek patent rights in a large number of countries by filing a single international application with a single patent office (receiving office).

- Finally, the last measures employment in fast-growing firms in innovative sectors. Several studies[12] suggest that a lower number of young and innovative firms may account for the underperformance in firm growth dynamics and employment growth of Europe with respect to the US. The aim of this component is to reflect "the degree of innovativeness of successful entrepreneurial activities".[13] In order to derive the statistics, data on employment in fast-growing firms have been collected and weighted by apposite sector-specific innovation coefficients built to reflect the level of innovativeness of each sector.

In such a multi-dimensional approach to measure innovation output, it becomes crucial to understand the role played by ICT in favouring and/or accelerating the innovation process. The ICT innovation output indicator seeks to measure the evolution of ICT development and the potential of ICT for development, based on the capabilities to develop new ICT technology, the level of ICT skills, the internalization of ICT and infrastructural and social indicators reflecting the influence of ICT on the economic process. Indeed, ICT use and diffusion could help to explain the differences in innovation performance between European countries, thereby supplying policy makers with scope for tailored intervention.

[12] Bravo-Biosca (2011) "A look at business growth and contraction in Europe" JRC-CONCORD Paper; Haltiwanger, J., Jarmin, R. and Miranda, J. (2010) „Who Creates Jobs? Small vs. Large vs. Young." NBER Working Paper No. 16300. Cambridge, MA: NBER.

[13] Measuring innovation output in Europe: towards a new indicator" COM(2013) 624 final http://ec.europa.eu/research/press/2013/pdf/indicator_of_innovation_output.pdf

3. The Innovation output indicator

This section presents a detailed analysis of the composite indicator (henceforth innovation output indicator) and for each of its components the ICT contribution is derived.

The Innovation output indicator focuses on four output-oriented innovation measures and is represented by the following equation:

$$I = w_1 PCT + w_2 KIA + w_3 COMP + w_4 DYN \quad (1)$$

Where:

1. PCT is patent applications per billion GDP and corresponds to indicator 2.3.1 of the IUS.[14]

2. KIA is employment in knowledge-intensive activities in business industries as a % of total employment (IUS 3.2.1)

3. COMP= 0.5*GOOD+0.5*SERV is the average sum of two sub-components:

   - GOOD: The contribution of the trade balance of high-tech and medium-tech products to the total trade balance (IUS 3.2.2) and

   - SERV: Knowledge-intensive services as a share of the total services exports (IUS 3.2.3).

4. DYN is the component of employment in fast-growing firms of innovative sectors. This new component will be integrated in the future into the Innovation Union Scoreboard.

To improve comparability, each component has been standardized.[15] The weights w_1, w_2, w_3, w_4 are the weights of the component indicators, fixed over time and country. "These are statistically computed in such a way that the component indicators are equally balanced[16]".

The aim of this report is to assess the ICT contribution to the innovation output indicator. In line with the above definition of the innovation output indicator, the ICT contribution has been computed for each component of the composite indicator. The definition of ICT contribution varies according to the nature of the specific indicator. KIA and DYN statistics are based on economic activities, thus available data are broken down by sector following the statistical classification of economic activities NACE rev2. The ICT sector is defined in line with the definition used in the JRC-IPTS PREDICT project[17] according to the NACE rev2 classification, see Box 1 below.

14 http://ec.europa.eu/enterprise/policies/innovation/policy/innovation-scoreboard/index_en.htm

15 This procedure implies subtracting from each component its mean and then dividing the result by the component's standard variation.

16 "Developing an indicator of innovation output" Commission Staff Working Document- SWD(2013) 325 final, from pages 12-13: *Weights are used as 'scaling coefficients' and not as 'importance coefficients', with the aim to arrive at composite scores that are balanced in their underlying components. Paruolo P., Saisana M., Saltelli A., "Ratings and Rankings: Voodoo or Science?", Journal Royal Statistical Society, A176(3), 609-634, show that in weighted arithmetic averages, the ratio of two nominal weights gives the rate of substitutability between the two indicators, and hence can be used to reveal the relative importance of individual indicators. Subsequently, a correction of the 'scaling coefficients' can be made to achieve component indicators with the desired relative importance.* http://www.google.com/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&cad=rja&uact=8&ved=0CBwQFjAA&url=http%3A%2F%2Fec.europa.eu%2Fresearch%2Fpress%2F2013%2Fpdf%2Fstaff_working_document_indicator_of_innovation_output.pdf&ei=jEjaU9PWJsL8ywPy0YGYCA&usg=AFQjCNGNt8i6LWICqwW7Yn3LBJEiDcoMHQ

17 The PREDICT project provides an analysis of private and public R&D investments in the EU ICT sector and of ICT R&D performance. Further details can be found at http://is.jrc.ec.europa.eu/pages/ISG/PREDICT.html

Box 1: List of NACE Rev. 2 ICT Sub-sectors:

NACE rev.2	Description
	ICT Manufacturing sub-sectors
261	Manufacture of electronic components and boards
262	Manufacture of computers and peripheral equipment
263	Manufacture of communication equipment
264	Manufacture of consumer electronics
268	Manufacture of magnetic and optical media
	ICT Services sub-sectors
4651	Wholesale of computers, computer peripheral equipment and software
4652	Wholesale of electronic and telecommunications equipment and parts
5820	Software publishing
61	Telecommunications
62	Computer programming, consultancy and related activities
631	Data processing, hosting and related activities; web portals
951	Repair of computers and communication equipment

Source: PREDICT report, JRC-IPTS[18]

The PCT and COMP (both for GOOD and SERV) components are based correspondingly on patent applications classified according to the International Patent Classification (IPC) and on product classification. That is, PCT and COMP are not statistics based on economic activities, which makes the identification of ICT sector impossible. For those components, the definition of ICT is based respectively on ICT patents and the ICT goods and services definition[19].

The following sections describe the data and methodology used for the computation of the ICT contribution of each component.

3.1. Technological Innovation

The first component of the composite indicator, labelled PCT in equation (1), is indicator 2.3.1 of the Innovation Union Scoreboard. The PCT component reflects the ability of the economy to transform knowledge into marketable innovation.

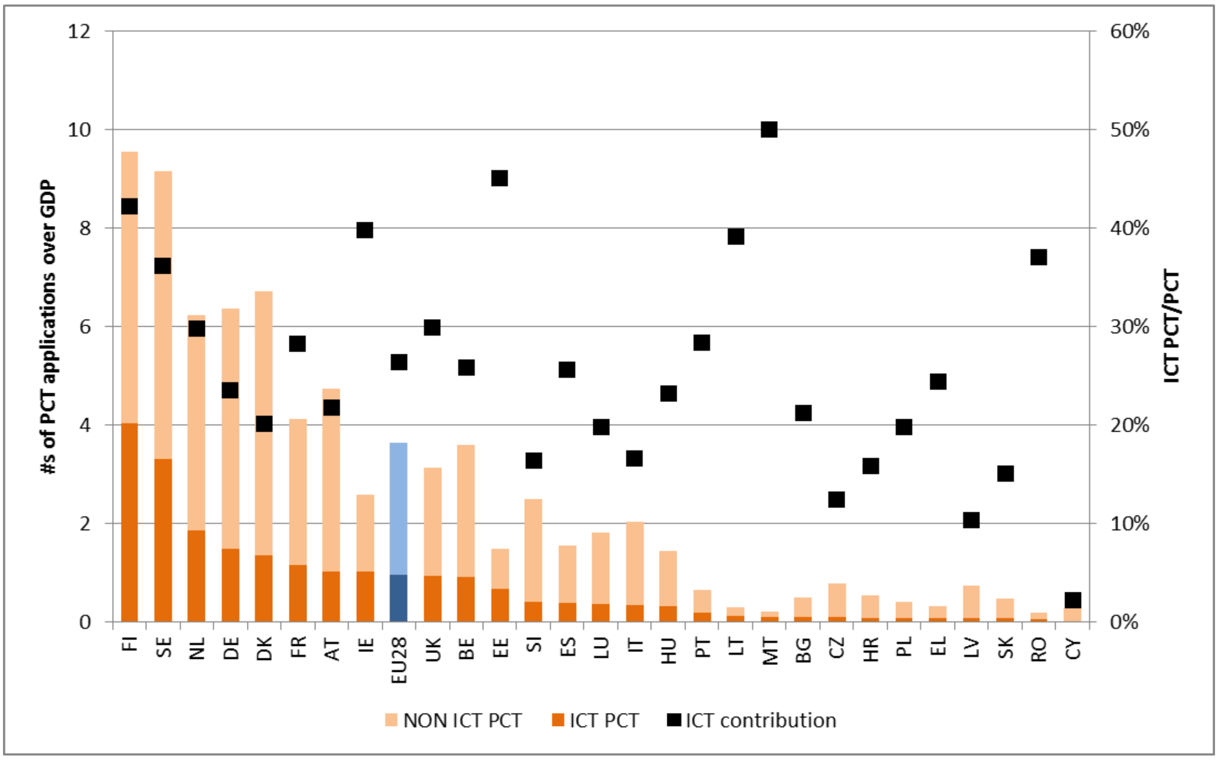
Patents are classified according to the International Patent Classification (IPC). According to this classification, an invention is assigned to an IPC class "by its function or intrinsic nature, or by its field of application". That is, the contribution of ICT has been computed as the number of patent applications filed under the ICT IPC class[20] rather than the number of patents applications filed by the ICT sector.

[18] Juraj Stančík and Paul Desruelle (2012) "THE 2012 PREDICT REPORT An Analysis of ICT R&D in the EU and Beyond" *JRC Scientific and Policy Report* http://is.jrc.ec.europa.eu/pages/ISG/documents/OnlineversionFINALPredict2012withnumbersv2.pdf

[19] See Annex A1 for further details.

[20] Patents in the ICT sector can be split into four fields, based on selected IPC codes: Telecommunications, Consumer Electronics, Computers and office machinery and Other ICT. See Annex A1 for further details.

Figure 1: Technological innovation, 2011



Source: OECD-PatStat and Eurostat GDP in PPS, elaborated by JRC-IPTS

Note: Number of patent applications (Total and ICT) filed under the PCT, at the international phase, designating the European Patent Office (EPO). Patent counts are based on the priority date and the inventor's country of residence.

Figure 1 shows the number of applications filed under PCT for ICT and Non-ICT patents per billions of GDP in Euro-based purchase power parities. Namely, the NON ICT bar is given by (NON ICT PCT/GDP) and the ICT bar corresponds to (ICT PCT/GDP). The right-hand scale shows the contribution of ICT computed as ICT patent over the total number of patent applications (ICT PCT/PCT). Data refer to the latest available year, which is 2011, and cover all European Member States and the EU average.

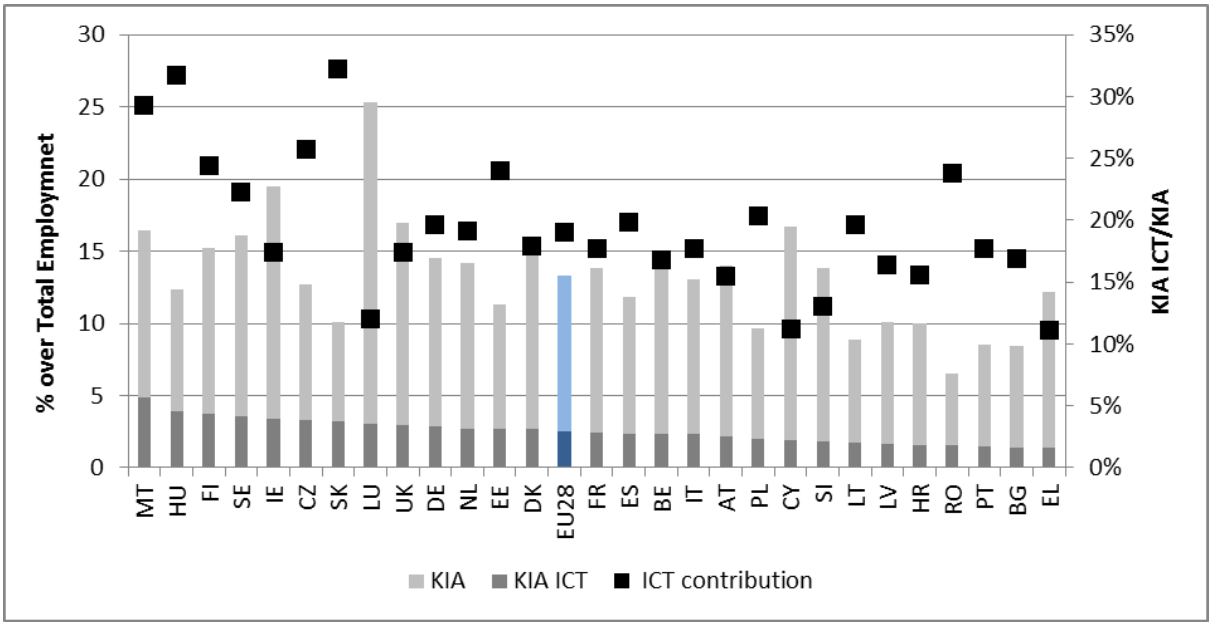
The Scandinavian countries have the highest total number of patent applications per billions of GDP, a total of 9.5 applications including 4 ICT applications for Finland and a total of 9 applications including 3 ICT applications for Sweden. These two countries have ICT contribution shares of 42% and 36% respectively - well above the European aggregate of 26%. The Netherlands, Germany, Denmark, France and Austria follow with values above Europe for both the total number of patent applications and ICT patent applications over GDP. However, Germany, Denmark and Austria have ICT contributions lower than the European aggregate. Interestingly enough, the highest ICT contributions are registered for less patent-intensive countries, namely Malta (50%), Estonia (45%)

and Ireland (40%). These countries registered lower total patent application levels, but higher concentrations of ICT patents. Ireland's total number of patent applications is lower than the European aggregate (2.5 against over 3.5 for EU) but its number of ICT patents is above Europe aggregate. (1.03 against the 0.96 for Europe).

3.2. Absorption of skills

The second component is indicator 3.2.1 of the IUS and measures the percentage of employees in knowledge-intensive activities (KIA) over total employees in total economy. Knowledge-intensive activities are defined following the NACE rev2 classification at 2-digit level as those sectors where at least 33% of employees have higher education degrees (ISCED5 or ISCED6). The ICT component has been computed taking the share of employees in sectors that are both defined as knowledge-intensive activities and are part of the ICT sector (according to definition provided in Box 1) over the number of total employees in the economy.

Figure 2: Absorption of skills, 2012



Source: Labour Force Survey Eurostat, elaborated by JRC-IPTS

The left hand scale of Figure 2 shows the percentage of KIA employees and KIA ICT employees over total employment in the economy - (KIA Employment/Total Employment) and (KIA ICT Employment/Total Employment) respectively. The right-hand scale shows the contribution of ICT to KIA employment that has been computed as the relative share of KIA ICT employees over total KIA employees (KIA ICT Employment/KIA Employment). Data refer to 2012 and cover all European Member States and the EU28 aggregate. The same time and country coverage applies for all the remaining indicators described in following sub-sections.

Malta and Hungary have the highest percentage of KIA ICT employees over total employment, 4.8% and 3.9% respectively compared to the European aggregate of 2.5%. However, Hungary has a higher ICT contribution (31%) than Malta (29%) and both are 10 percentage points above the European ICT contribution of 19%. The country with the highest ICT contribution is Slovakia (32%) followed by Hungary and Malta, while Greece and Cyprus have the lowest ICT contribution, both at 11%. Although Luxembourg has a similar ICT contribution to that of Greece and Cyprus, its overall share of KIA ICT employees over total employment is above the European aggregate value and the small contribution of ICT is due to the high number of KIA employees in the country.

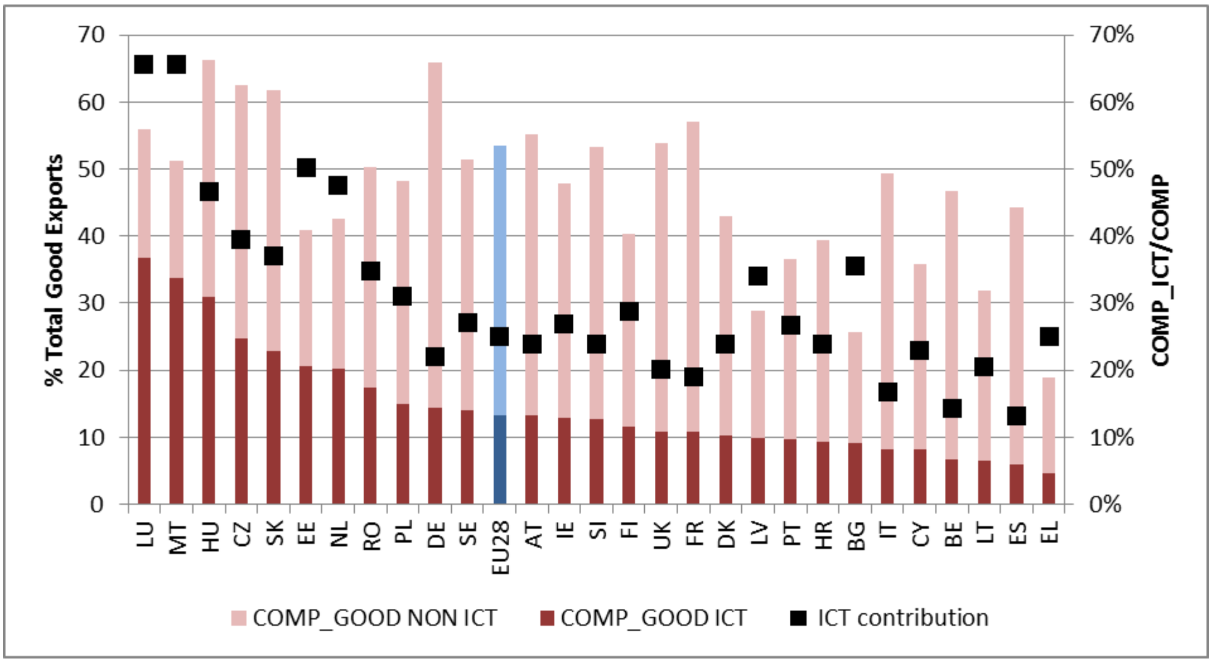
3.3. Competitiveness of knowledge-intensive sectors

The third component (COMP) is the weighted sum of indicators 3.2.2 and 3.2.3 of the IUS that measure respectively: the share of medium-high tech good exports over total product exports and the share of knowledge-intensive service exports over total service exports.

3.3.1. Medium-high tech goods

Medium-high tech export statistics are defined following the Standard International Trade Classification (SITC rev3) of products. The medium-high tech products are defined as product code: 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. Following the definition of ICT goods provided by the OECD,[21] the ICT medium-high tech good codes are: 751,752,759,76,77,87 and 88.[22]

Figure 3: Competitiveness of knowledge-intensive goods, 2012



Source: COMEXT Eurostat, elaborated by JRC-IPTS

The left hand scale of Figure 3 shows data on the share of medium-high tech (MHT) exports over total good exports (MHT exports/Total good exports) and on the share of the ICT component. The ICT component has been computed taking the share of ICT medium-high tech exports over total good exports (MHT ICT exports/Total good exports). The ICT contribution, shown on the right-hand scale, has been derived as the ratio of ICT medium-high tech exports over total medium-high tech exports (MHT ICT exports/MHT exports).

Luxembourg and Malta have the highest ICT component, around 35% against the 13% of the European aggregate, and the highest ICT contribution over total medium-high exports, 66% against the European aggregate value of 25%.

3.3.2. Knowledge-intensive services

The second part of the COMP indicator measures knowledge-intensive services export shares. According to the Extended Balance of Payments Services Classification (EBOPS), knowledge-

[21] "Working Party on Indicators for the Information Society" OECD DSTI/ICCP/IIS(2003)1/REV2 http://www.oecd.org/internet/ieconomy/22343094.pdf

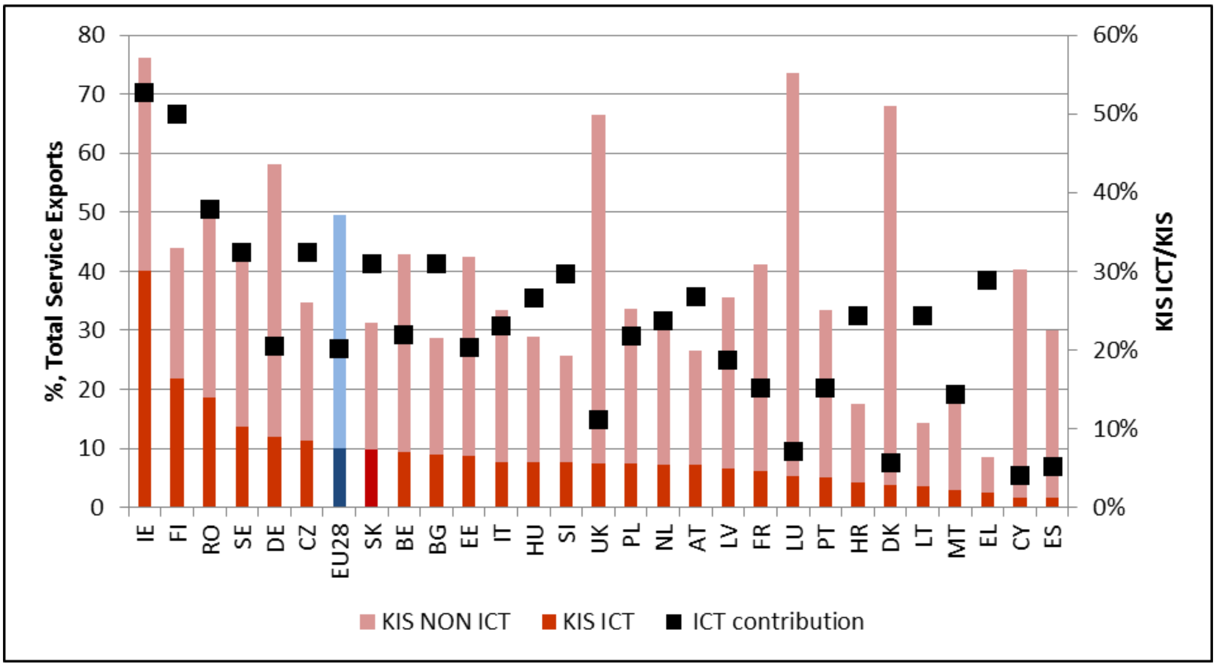
[22] See Annex A1 for detailed code description.

intensive services are computed by the sum of credits for codes: 207, 208, 211, 212, 218, 228, 229, 245, 253, 260, 263, 272, 274, 278, 279, 280 and 284. ICT knowledge-intensive services have been defined following the classification proposed by the World Bank[23] and correspond to EBOPS codes 245 and 263.[24]

[23] ""The little data book on Information and Communication Technology", World Bank (2013)

[24] See Annex A1 for detailed code description.

Figure 4: Competitiveness of knowledge-intensive services, 2012



Source: International Trade in Services Eurostat, elaborated by JRC-IPTS

The left-hand scale of Figure 4 shows data on knowledge-intensive services (KIS) exports share over total services exports (KIS exports/Total services exports). Here again the ICT component has been computed taking the share of ICT KIS exports over total services export (KIS ICT exports/Total services exports). The ICT contribution on the right-hand scale shows the share of ICT KIS exports over total KIS exports (KIS ICT exports/KIS exports).

Ireland is the best performing country with an ICT component of 40% over total services exports and an ICT contribution of 53%. Finland follows immediately after with a an ICT contribution of 50% although its ICT overall component (22%) is about half that of Ireland. The European aggregate ICT KIS component is 10% and the ICT contribution is about 20%.

3.4. Employment in fast-growing firms in innovative sectors

The last component of the Innovation Output Indicator is employment in innovative fast-growing firms[25] (DYN). This component aims to capture innovation dynamism by looking at employment in fast-growing innovative enterprises. It is therefore necessary to define both the level of innovation of a firm and what constitutes a fast-growing firm:

- In order to define the level of innovation of enterprises, sector-specific innovation coefficients characterising the degree of innovation in each sector in the business economy have been computed by the OECD.[26] These coefficients are built on scores which take into account the share of tertiary-educated employees (the KIA score) and how innovative firms identify themselves as being (the CIS score). To derive the measure of innovation dynamism for firms in general, the innovation coefficients are multiplied by the share of employment in fast-growing firms.

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[25] This component is proposed to be integrated in the future into the Innovation Union Scoreboard under the placeholder (3.1.3 'High-growth innovative firms').

[26] "Developing an indicator of innovation output" Commission Staff Working Document- SWD(2013) 325 final http://www.google.com/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&cad=rja&uact=8&ved=0CBwQFjAA&url=http%3A%2F%2Fec.europa.eu%2Fresearch%2Fpress%2F2013%2Fpdf%2Fstaff_working_document_indicator_of_innovation_output.pdf&ei=jEjaU9PWJsL8ywPy0YGYCA&usg=AFQjCNGNt8i6LWICqwW7Yn3LBJEiDcoMHQ

- According to the "Developing an indicator of innovation output" Commission Staff Working Document,[27] fast-growing firms are those with 10 or more employees and an average employee growth of more than 10% per year, over 3 years. The employment data on fast-growing firms for 2011 and 2012 have been released by Eurostat on February 2014. The data published by Eurostat covered only 23 out of the 28 Member States in 2012. Data for France and Ireland are only available for 2011 and these numbers have been used as proxy for 2012. Data for Greece, Croatia and the United Kingdom are not reported for these years and have been imputed by the Joint Research Centre, following the Expectation-Maximization (EM) algorithm technique.[28]

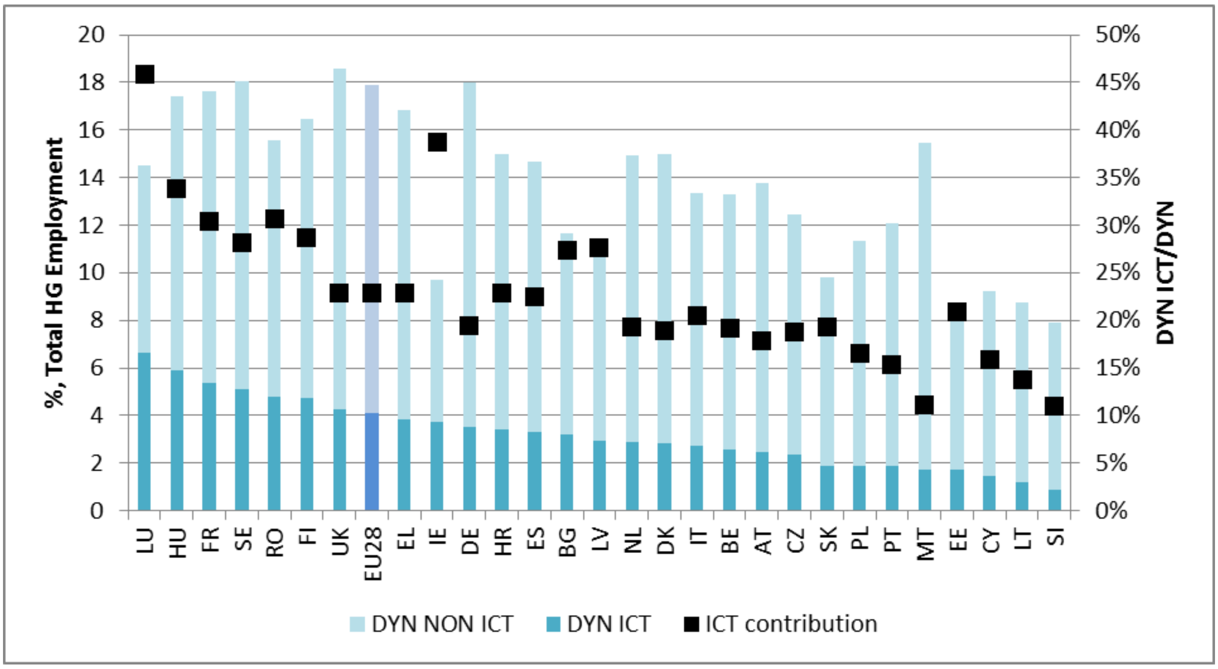
Therefore, the DYN component is computed as:

$$DYN = \sum_s (CIS^{score} * KIA^{score})_s \frac{E_{sc}^{HG}}{E_c^{HG}} \qquad (2)$$

where $(CIS^{score} * KIA^{score})_s$ is the innovation coefficient sector of sector s at EU level, and E_{sc}^{HG} is the employment of fast-growing firms in sector s and country c.

The ICT component of DYN has been computed deriving the innovation coefficient assigned to the ICT sector and multiplying it by the ICT sector employment share for each country. The definition of the ICT sector is provided in Box 1. For Greece, Croatia and the United Kingdom data were not available, therefore the average share of ICT contribution over all available country data has been used to proxy their ICT contribution.

Figure 5: Employment in fast-growing firms in innovative sectors, 2012



Source: Structural Business Statistics Eurostat, elaborated by JRC-IPTS

The left hand scale of Figure 5 shows the share of NON ICT and ICT innovative high-growth employment (HGE) over total high-growth employment, respectively (DYN NON ICT employment/HGE) and (DYN ICT employment/HGE). The right-hand scale shows the ICT contribution computed as (DYN ICT employment/DYN employment).

[27] Ibidem footnote 23

[28] Ibidem

As shown in

Figure **5**, Luxembourg has the highest value for innovative high-growth employment in ICT over total high-growth employment (6.6%) and the highest ICT contribution (46%) compared to the European average of 4.1% and 23% respectively. However, Luxembourg has a lower value of total innovative high-growth employment over high-growth employment compared to Europe, namely 14% against 18%. The highest levels of total innovative high-growth employment over high-growth employment are reported by Germany and Sweden. The UK also has a comparable level to Germany and Sweden; however data for the UK are estimates and will need further checking. The countries with the highest ICT contribution are Luxembourg and Ireland, 46% and 39% respectively, whereas the European average is 23%.

3.5. Overview of the data on ICT indicators and reference periods

This section presents an overview of the ICT contributions computed so far and the data and reference periods for each component that will be used in Section 4 to derive the ICT Innovation output indicator.

First, the ICT contributions for Europe computed in the sub-sections above are summarised below:

- 26% in technological innovation as measured by patents;
- 19% in absorption of skills as measured by employment in knowledge intensive activities;
- 25% in competitiveness of knowledge goods as measured by exports of medium-high tech goods;
- 20% in competitiveness of knowledge services as measured by exports of knowledge intensive services;
- 23% in innovative firm dynamics as measured by the employment in innovative fast-growing firms.

Second, Table 1 presents the ICT innovation indicators by country and year. For each component (ICT PCT, ICT KIA, etc.) the highest ICT values have been highlighted in green and the lowest values have been highlighted in red. Missing values for DYN have been imputed by the JRC following the Expectation-Maximization technique,[29] the ICT shares have been derived taking the European average share for ICT contribution in DYN.

In the computation of the ICT innovation output indicator for 2012, data for components of different years have been used. This is due to different time span availability for data. In particular data for PCT refer to 2010, while for all the other components data refer to 2012. Similarly the sector innovation coefficients used to derive the DYN component as measured by equation (2) are built on data from the CIS 2008 (CIS score) and LFS data for 2010 (KIA score). Box 2 below gives the details for each year of the ICT innovation output indicator.

[29] Ibidem footnote 23

Box 2: ICT innovation output reference period by component

ICT Innovation output indicator	ICT PCT	ICT KIA	ICT COMP	ICT DYN		
				CIS score	KIA score	High-growth employment
2010	2008	2010	2010	2006/8	2009/10	2010 with imputation
2011	2009	2011	2011	2006/8	2009/10	2011 with imputation
2012	2010	2012	2012	2006/8	2009/10	2012 with imputation

Note: JRC-DDG1 is currently updating the innovation coefficient (CIS score and KIA score) with the latest CIS data for 2010.

Table 1: ICT innovation indicators by country and year

	ICT_PCT			ICT_KIA			ICT_GOOD			ICT_SERV			ICT_DYN		
	2008	2009	2010	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
EU	1.05	1.04	1.01	2.36	2.50	2.53	14.5	13.5	13.4	9.06	9.26	10.00	3.96	4.16	4.09
BE	0.73	0.84	0.85	2.50	2.24	2.34	7.19	6.84	6.71	8.42	9.59	9.40	3.33	3.31	2.55
BG	0.06	0.10	0.09	1.36	1.42	1.43	10.8	9.20	9.10	7.76	8.46	8.85	4.07	3.96	3.18
CZ	0.20	0.13	0.14	3.10	3.54	3.27	25.8	25.4	24.7	8.40	9.83	11.26	3.08	3.19	2.34
DK	1.56	1.50	1.36	2.80	2.69	2.70	10.1	9.93	10.2	3.94	3.55	3.85	3.92	4.11	2.84
DE	1.65	1.72	1.68	2.81	2.84	2.84	15.5	14.7	14.4	9.08	9.21	11.93	3.82	3.60	3.50
EE	0.89	1.21	0.86	2.64	3.21	2.71	16.8	20.7	20.5	8.72	8.32	8.67	3.01	3.39	1.72
IE	1.12	0.97	0.95	3.05	3.13	3.39	14.1	12.8	12.8	37.9	39.0	40.1	8.33	8.45	3.75
EL	0.09	0.08	0.06	1.23	1.24	1.36	4.85	5.13	4.71	1.10	2.48	2.47	3.87	3.79	3.84
ES	0.31	0.36	0.38	2.21	2.26	2.35	6.58	6.17	5.85	1.70	1.60	1.53	3.73	3.57	3.29
FR	1.18	1.20	1.16	2.49	2.55	2.46	11.4	11.0	10.8	5.64	6.32	6.23	6.00	6.33	5.36
IT	0.35	0.37	0.35	1.54	2.28	2.31	9.02	8.69	8.28	8.91	8.37	7.70	3.51	3.53	2.74
CY	0.15	0.24	0.01	1.32	1.73	1.88	14.0	11.4	8.23	1.68	1.36	1.64	2.94	2.45	1.46
LV	0.03	0.16	0.10	2.21	1.96	1.66	9.33	8.59	9.87	5.89	5.92	6.66	3.84	2.62	2.95
LT	0.13	0.00	0.07	1.43	1.71	1.73	6.61	6.30	6.52	3.68	3.27	3.46	1.86	1.68	1.20
LU	0.37	0.26	0.35	2.94	2.60	3.03	33.1	29.9	36.7	5.69	5.11	5.28	12.3	9.62	6.64
HU	0.43	0.39	0.33	3.79	4.01	3.91	38.2	34.7	30.8	8.28	7.45	7.68	6.15	6.32	5.88
MT	0.36	0.08	0.00	3.85	4.50	4.83	40.4	34.4	33.6	3.21	3.01	2.83	1.91	1.87	1.72
NL	2.25	2.14	1.73	2.84	2.70	2.72	21.9	19.9	20.3	4.18	7.28	7.24	3.31	3.17	2.89
AT	1.09	1.08	1.00	2.28	2.16	2.17	13.1	12.4	13.1	5.73	6.26	7.13	2.86	2.98	2.46
PL	0.08	0.11	0.10	1.83	1.82	1.96	17.5	14.8	14.9	5.96	6.71	7.33	2.87	2.58	1.88
PT	0.14	0.15	0.18	1.60	1.47	1.51	10.2	9.81	9.73	4.17	4.37	5.09	2.18	2.17	1.86
RO	0.09	0.06	0.06	1.24	1.33	1.55	20.0	19.5	17.4	18.3	17.3	18.5	4.66	4.90	4.77
SI	0.45	0.47	0.43	2.26	2.21	1.80	14.9	14.1	12.7	6.74	7.18	7.63	1.68	1.88	0.87
SK	0.15	0.10	0.12	3.11	3.38	3.24	26.1	22.8	22.8	9.03	9.95	9.70	3.75	3.27	1.90
FI	4.42	4.60	4.78	3.75	3.74	3.73	13.6	12.1	11.6	25.0	24.3	21.9	5.31	4.39	4.73
SE	4.16	3.97	3.49	3.18	3.38	3.59	16.49	15.58	13.95	14.08	14.7	13.5	5.92	5.41	5.08
UK	1.10	1.01	1.02	2.69	2.89	2.95	12.26	10.71	10.85	6.71	6.55	7.41	3.80	4.30	4.25
HR	0.17	0.06	0.14	1.68	1.71	1.56	10.01	8.86	9.39	1.99	4.25	4.26	3.42	3.47	3.42

Source: JRC-IPTS calculations based on OECD and Eurostat Data. For a detailed description, refer to the single component description in Section 3.

4. The ICT Innovation output indicator

The ICT innovation output indicator delivers a measure of output-oriented ICT innovation that captures both the technological and non-technological aspects of innovation in ICT. The ICT innovation indicator allows policy makers to compare the ICT innovation performance of Member States and address country-specific needs.

In order to compute the ICT innovation output indicator, the methodology described in the "Developing an indicator of innovation output" Commission Staff Working Document[30] has been followed. Equation (1) has been adapted so as to take into account only the ICT contribution of each component and becomes:

$$I_{ICT} = w_1 PCT_{ICT} + w_2 KIA_{ICT} + w_3 COMP_{ICT} + w_4 DYN_{ICT} \qquad (3)$$

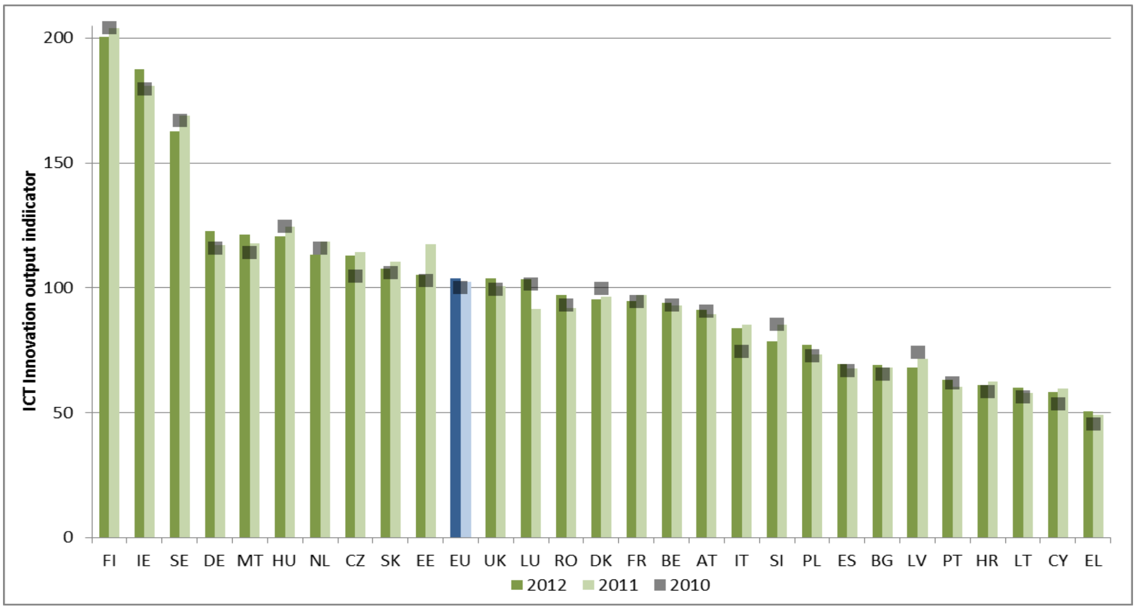
Where the ICT components are the indicators computed in Section 3 and presented in Table 1. With a view to improving comparability between indicators, each ICT component has been normalised by subtracting its average and dividing by its standard deviation.[31] The normalised scores obtained for each component are then multiplied by the weights $w_1,\ w_2,\ w_3,\ w_4$ to obtain the score of the composite ICT Innovation output indicator. In line with the methodology mentioned above, the weights have been computed so that the score of the composite indicator is unbiased in their underlying components. In other words, the weights are chosen in such a way that the correlations between each component score and the score of the final innovation indicator are balanced. In this context, balanced should be understood as assigning to the weights those values that ensure truly equal statistical importance to all components. The resulting weights are correspondingly 18, 17, 10 and 17.

Figure 6 shows the composite ICT Innovation output indicator for European Member States over the period 2010-2012. The benchmark has been set to equal 100 for Europe in 2010. As shown by the picture below, Finland has the highest score (200) in 2012, followed by Ireland (187) and Sweden (162). Those three countries all report scores higher than 150 in ICT innovation output followed by Germany with 122. As reported by Table 1, the three top high scores in ICT innovation output result from very high ICT contributions in trade of knowledge intensive services for all the three countries, above average levels of fast-growing innovative ICT employment for Ireland and remarkable results for ICT patenting in Finland and Sweden. The graph also shows that the score of the ICT Innovation output indicator are fairly steady over the years. Yet both Finland and Sweden display lower scores in 2012 with respect to previous years, while Ireland improved its score in 2012.

30 Ibidem footnote 23

31 Radar charts for the scores of each component by country are presented in the Annex A2

Figure 6: ICT Innovation output indicator



Source: JRC-IPTS calculations

Table 2 below shows the Member States' scores for the ICT innovation output indicator in comparison with the overall score for the EU. The scores cover a period of three years showing an overall improvement in performance for the EU. The ranking of countries is based on the scores for 2012. The highest scores are highlighted in green, the medium-high in light green and so on down to the medium-low and low scores which are highlighted in red. The ranking is quite stable over the years, with the three top countries in the same position throughout, though there are some minor changes for other countries.

Table 2: ICT Innovation output indicator scores

Country	2010	2011	2012
FI	204.2	204.1	200.4
IE	179.5	180.9	187.5
SE	167.2	169.1	162.6
DE	115.8	117.2	122.8
MT	114	117.8	121.4
HU	124.7	124.3	120.5
NL	115.8	118.4	113.3
CZ	104.8	114.3	113
SK	106	110.3	107.6
EE	102.8	117.3	105.2
EU	100	102.2	103.9
UK	99.5	100.6	103.8
LU	101.4	91.6	103.5
RO	93.2	91.8	97.3
DK	99.9	96.3	95.4
FR	94.4	97	94.7
BE	93.2	92.9	94.1
AT	90.7	89.5	91.1
IT	74.4	85.3	83.9
SI	85.3	85.3	78.4
PL	72.7	73.3	77.1
ES	66.8	67.8	69.3
BG	65.4	68	69
LV	74.2	71.5	68.2
PT	62.1	60.3	63
HR	58.5	62.4	61.1
LT	56.3	58	59.9
CY	53.5	59.5	58.1
EL	45.6	49	50.5

Source: JRC-IPTS calculations

5. ICT contribution to additional indicators

One of the aims of the EURIPIDIS project was to derive the contribution made by ICT to additional existing indicators. Table 3 below presents a list of indicators drawn from the Innovation Union Scoreboard for which, subject to the data availability, the ICT contribution can be isolated.

Indicators of interest have been identified for relevant sub-headings of the Innovation Union Scoreboard, namely firm investment, linkages and entrepreneurship, intellectual assets, innovators and economic effects. Some of these indicators also belong to the innovation output indicator, as shown in column 2 of Table 3, and the ICT contribution has been already presented above. For the latter, up-to-date data can be computed for future years so long as raw data are published by the respective sources.

Data for indicator 2.1.1 Business R&D expenditures as % of GDP are published by Eurostat in the BERD statistics. Note that ICT BERD have already been analysed in detail by the JRC-IPTS PREDICT project[32] and will therefore not be covered again in EURIPIDIS,

All the other indicators come from the Community Innovation Survey (CIS).[33] The CIS is carried out every two years and results are published with approximately 2.5 years delay. In other words, the release of data from CIS 2012 is expected by mid-2014. The CIS is a voluntary survey for the countries, thus different waves of the CIS may cover different countries.

The CIS reports information about innovation activity in enterprises. The survey provides information on the innovativeness of sectors by type of enterprises, on the different types of innovation and on various aspects of the development of an innovation.

The CIS provides statistics broken down by country, type of innovator, economic activity and size. Thus, subject to data availability and non-confidentiality issues, it will allow us to identify the ICT sector on the basis of economic activity definition. In order to do this, access to micro-data in the Eurostat Safe Centre in Luxembourg is required as publicly-available information on the CIS does not allow us to isolate the ICT component.

Country coverage and being able to identify the ICT sector depends on the quality and availability of the micro data collected at the Eurostat Safe Centre. Data can only be accessed at the Eurostat Safe Centre.

[32] http://is.jrc.ec.europa.eu/pages/ISG/PREDICT.html

[33] Hollanders H.,Tarantola S.(2010) "Innovation Union Scoreboard 2010 –Methodology report" http://ec.europa.eu/enterprise/policies/innovation/policy/innovation-scoreboard/index_en.htm

Table 3: ICT contribution to additional indicators

	Innovation Output Indicator	Innovation Union Scoreboard	Source	Comment
Firm Investments				
2.1.1 Business R&D expenditures as % of GDP	—	√	BERD Eurostat	Already analysed in detail by the PREDICT project
2.1.2 Non-R&D innovation expenditures as % of GDP	—	√	CIS	Access to microdata needed
Linkages & entrepreneurship				
2.2.1 SMEs innovating in-house as % of SMEs	—	√	CIS	Access to microdata needed
2.2.2 Innovative SMEs collaborating with others as % of SMEs	—	√	CIS	Access to microdata needed
Intellectual assets				
2.3.1 PCT patent applications per billion GDP (in PPS €)	√	√	OECD/Eurostat	Available up to 2011
Innovators				
3.1.1 SMEs introducing product or process innovations as % of SMEs	—	√	CIS	Access to microdata needed
3.1.2 SMEs introducing marketing or organisational innovation as % of SMEs	—	√	CIS	Access to microdata needed
3.1.3 High-growth innovative enterprises	√	√	Eurostat	Available for 2012
Economic effects				
3.2.1 Employment in Knowledge-intensive activities (manufacturing and services) as % of workforce	√	√	LFS Eurostat	Available up to 2013
3.2.2 Medium and high-tech products exports as % of total product exports	√	√	Eurostat	Available up to 2013
3.2.3 Knowledge-intensive services exports as % of total services exports	√	√	Eurostat	Available up to 2012
3.2.4 Sales of new to market and new to firm innovation as % of turnover	—	√	CIS	Access to microdata needed

Annex

A1. Code description for ICT patents, ICT goods and services

Patents in the ICT sector can be split into four fields, based on selected IPC codes[34]:

ICT Patent	IPC codes
Telecommunications	G01S, G08C, G09C, H01P, H01Q, H01S3/ (025, 043, 063, 067, 085, 0933, 0941, 103, 133, 18, 19, 25), H1S5, H03B, H03C, H03D, H03H, H03M, H04B, H04J, H04K, H04L, H04M, H04Q
Consumer Electronics	G11B, H03F, H03G, H03J, H04H, H04N, H04R, H04S
Computers and office machinery	B07C, B41J, B41K, G02F, G03G, G05F, G06, G07, G09G, G10L, G11C, H03K, H03L
Other ICT	G01B, G01C, G01D, G01F, G01G, G01H, G01J, G01K, G01L, G01M, G01N, G01P, G01R, G01V, G01W, G02B6, G05B, G08G, G09B, H01B11, H01J (11/, 13/, 15/, 17/, 19/, 21/, 23/, 25/, 27/, 29/, 31/, 33/, 40/, 41/, 43/, 45/), H01L

As a consequence, the distinction between ICT and non-ICT technologies is not related to the ISIC classification of economic activity or to NACE codes.

The fractional counts approach has also been applied in the case where applications refer to more than one technology class.

34 OECD PATENT DATABASES-Identifying Technology Areas For Patents http://www.oecd.org/science/inno/oecdpatentdatabases.htm

Goods and services codes:

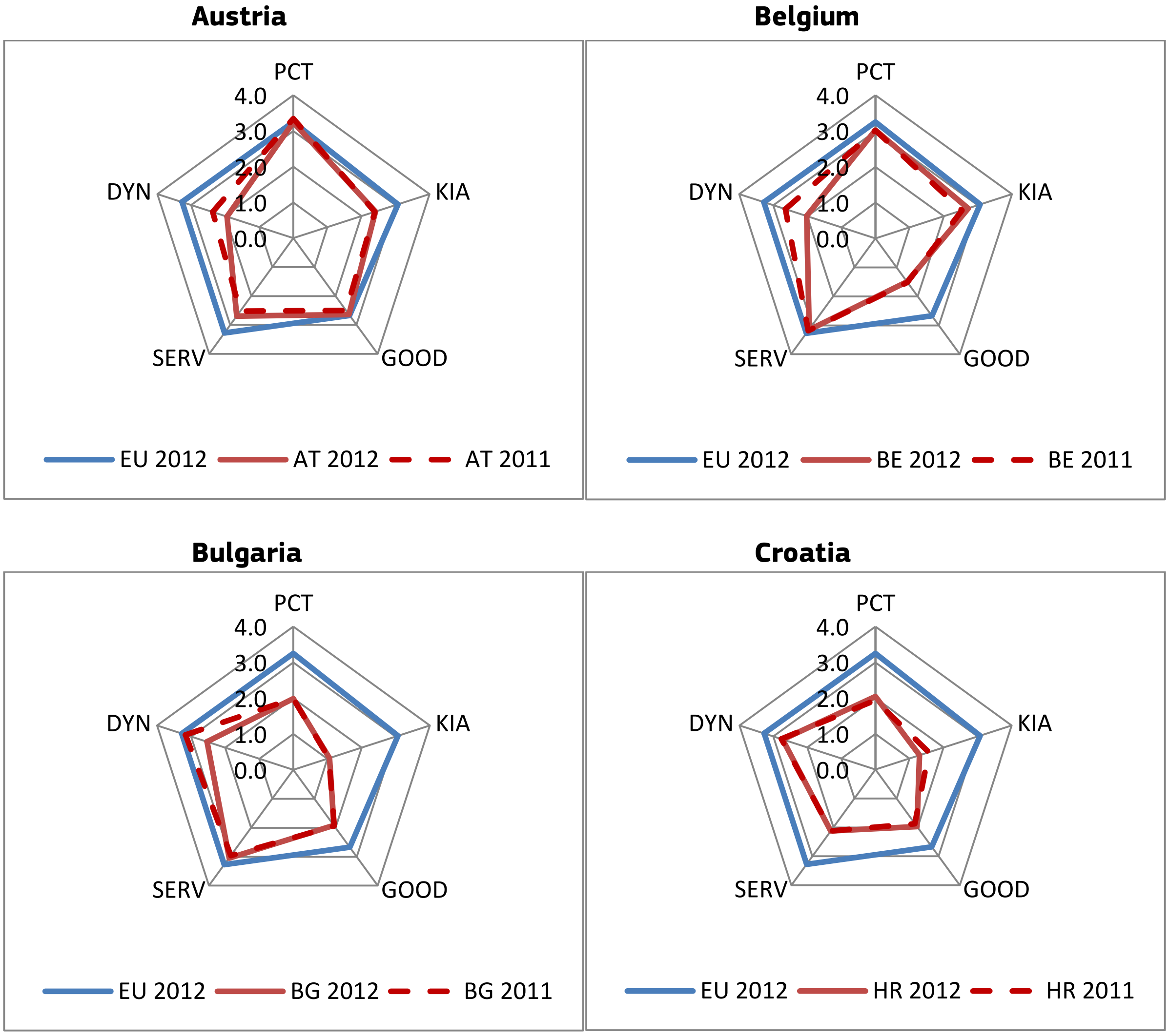
ICT Medium-High Tech goods	SITC code
Office Machines	751
Automatic data-processing machines and units thereof; magnetic or optical readers, machines for transcribing data onto data media in coded form and machines for processing such data, n.e.s.	752
Parts and accessories (other than covers, carrying cases and the like) suitable for use solely or principally with machines falling within groups 751 and 752	759
Telecommunications and sound-recording and reproducing apparatus and equipment	76
Electrical machinery, apparatus and appliances, n.e.s., and electrical parts thereof (including non-electrical counterparts, n.e.s., of electrical household-type equipment)	77
Professional, scientific and controlling instruments and apparatus, n.e.s.	87
Photographic apparatus, equipment and supplies and optical goods, n.e.s.; watches and clocks	88
ICT Knowledge-intensive services	**EBOPS code**
Communications services	245
Computer services	263

A2. Analysis of the innovation indicators by country

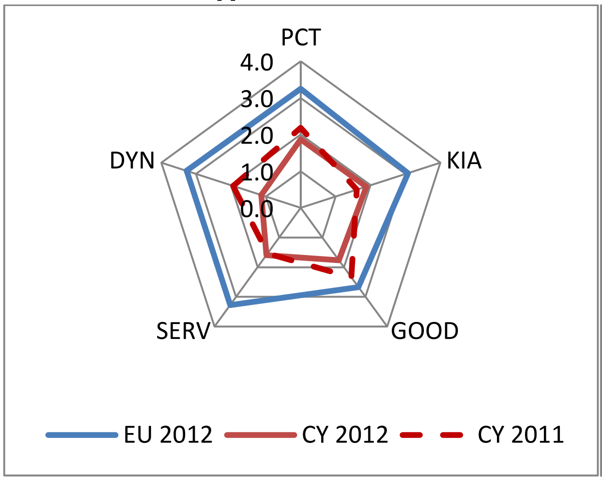
In order to better understand the drivers behind the scores shown in Table 2, Section 4, this annex presents the radar charts of ICT innovation indicators by country. The data represent the scores obtained in each component after the normalisation process described in Section 4. The values in the axis represent the score achieved by each country in every component. Note that the scale is not fixed, in order to make visible the changes between years for those countries with lower component scores: the scale generally goes from 1 to 10, although for some countries the value range is between 0 and 5. At the same time, to allow for comparability between countries, the European aggregate values in 2012 are shown in each graph in blue and should be used as benchmark.

The graphs show that the countries scoring the highest value in the composite ICT innovation output indicator are in the top positions for at least two of the components, and in the lowest positions for the countries at the bottom. For example, Finland and Ireland, which have the two highest scores in the composite ICT innovation output indicator, respectively display the highest ICT score in PCT and SERV and both hold top positions in KIA. At the other end of the scale, Greece, which has the lowest value for the ICT innovation output indicator, scores the lowest values in both KIA and GOOD.

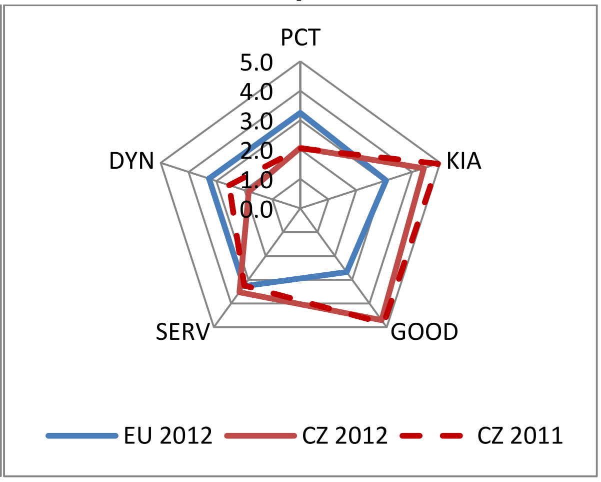
Figure 7: ICT performance by country



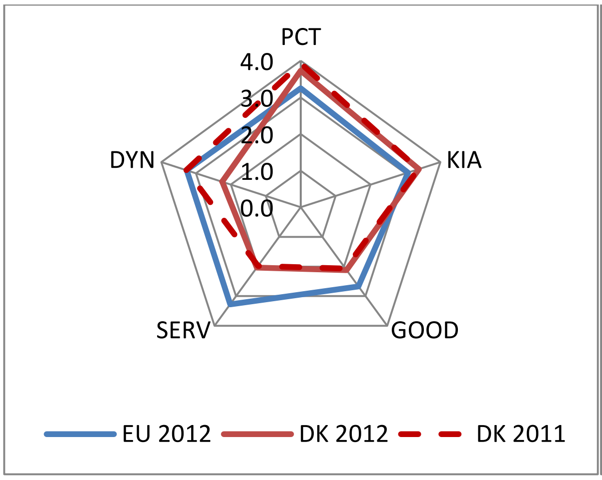
Cyprus



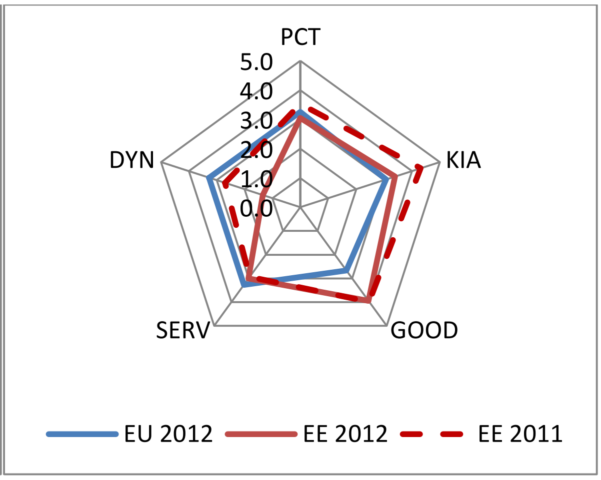
Czech Republic



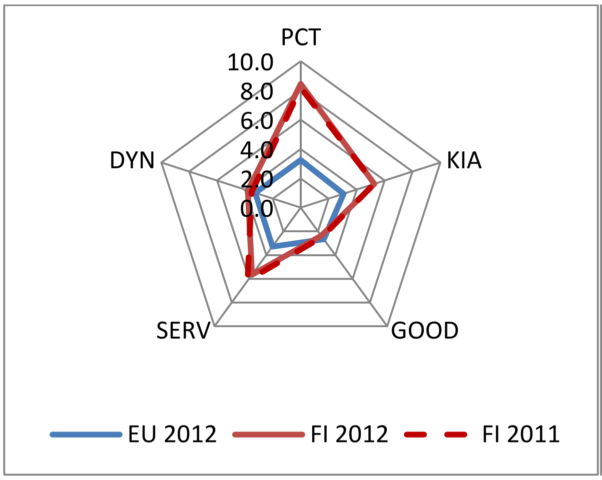
Denmark



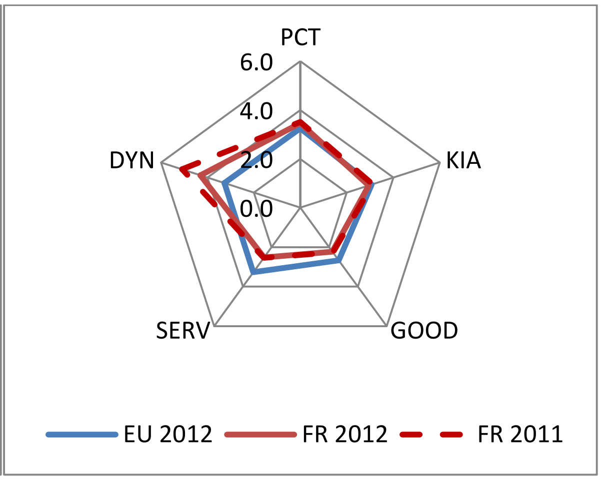
Estonia



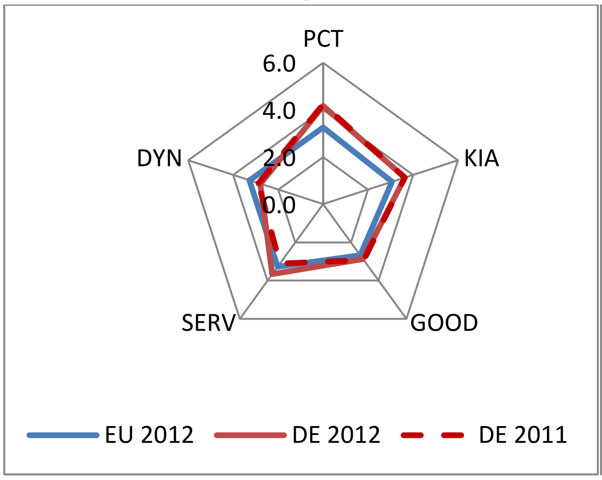
Finland



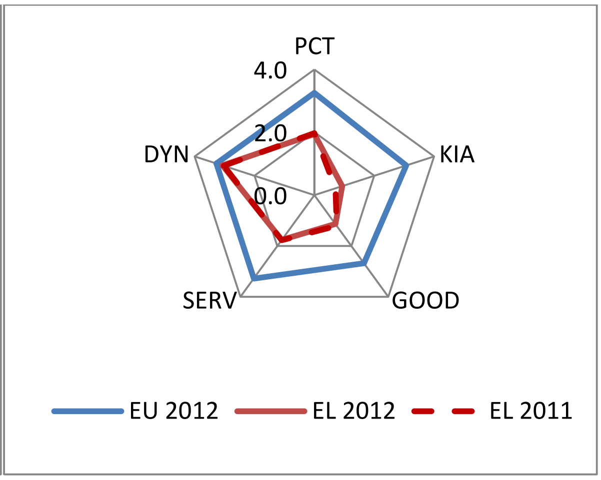
France



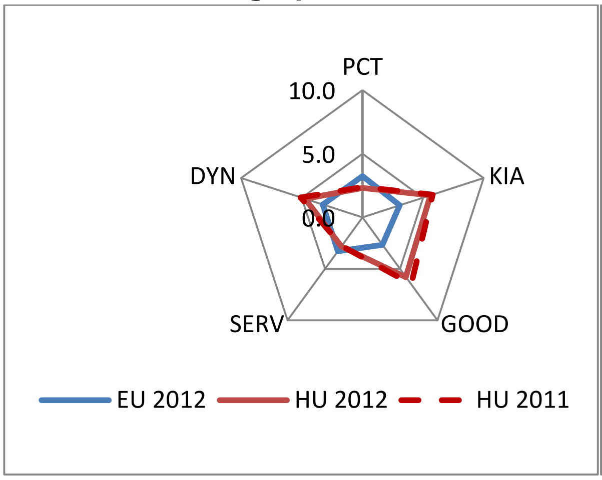
Germany



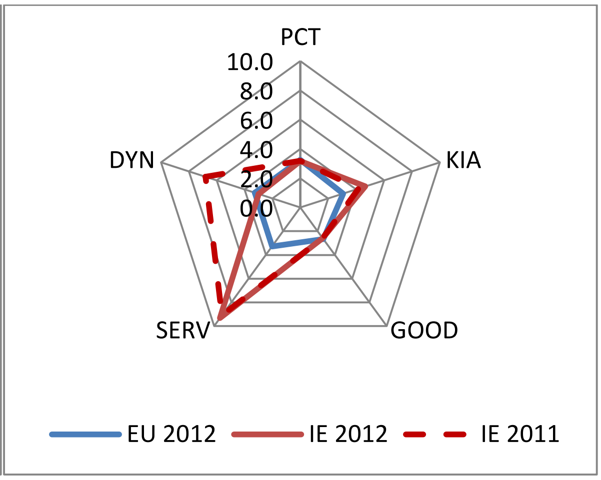
Greece



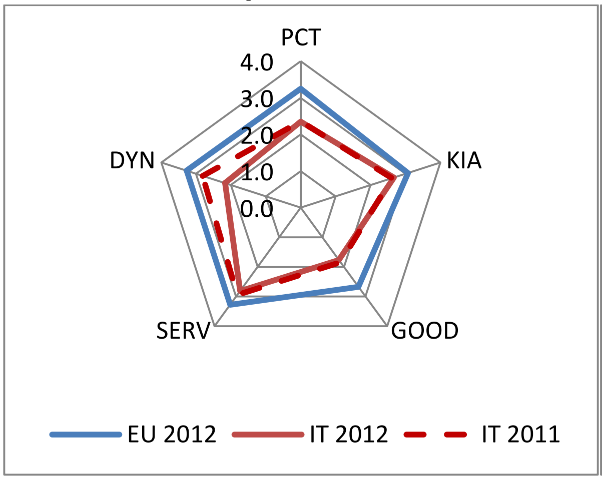
Hungary



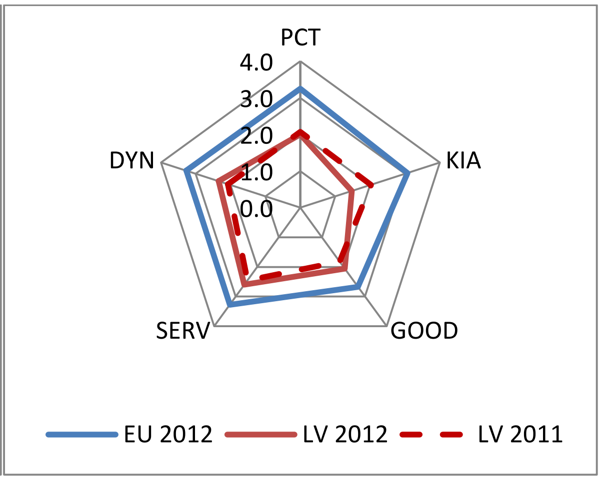
Ireland



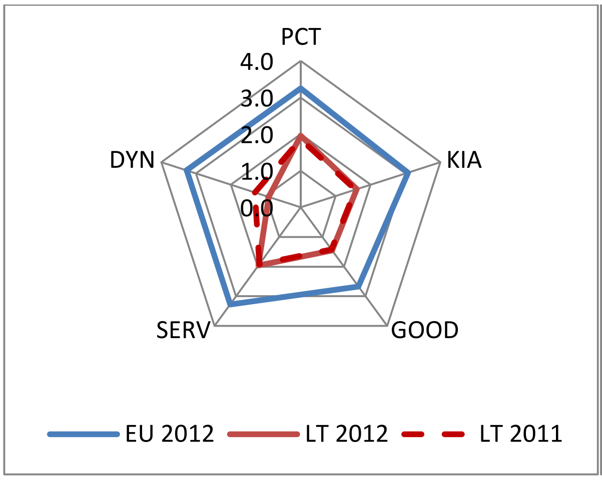
Italy



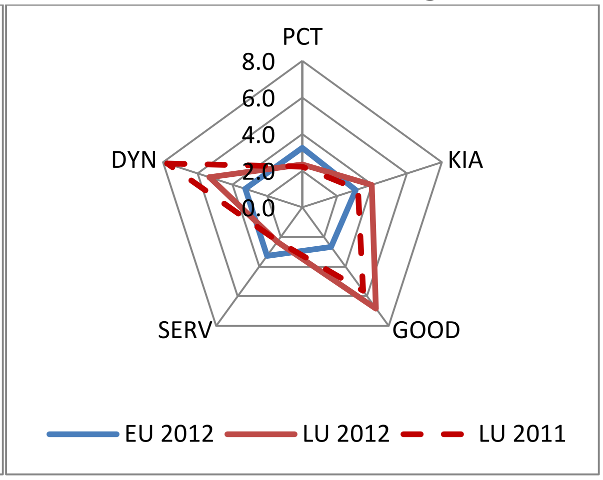
Latvia



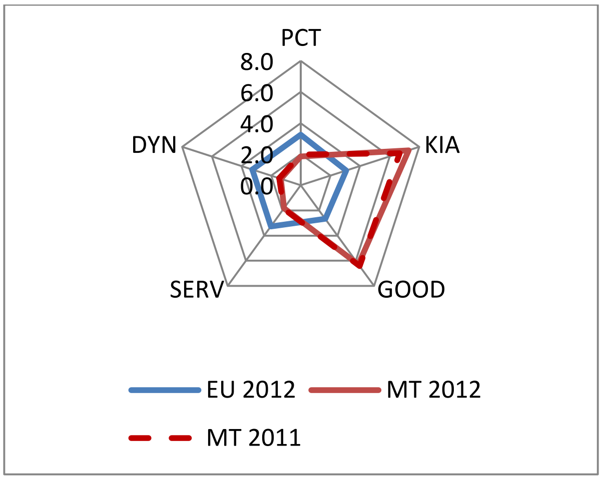
Lithuania



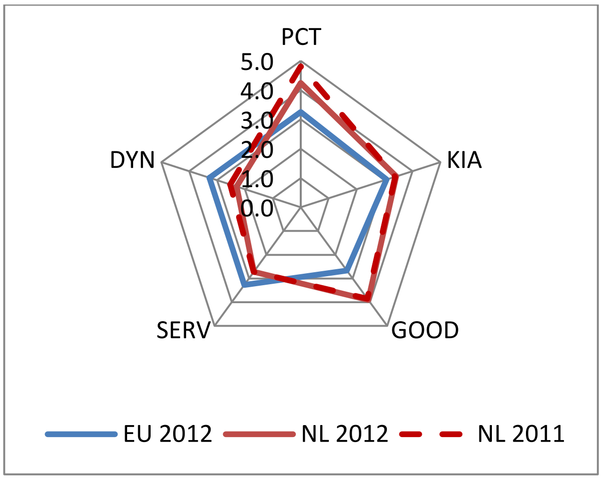
Luxembourg



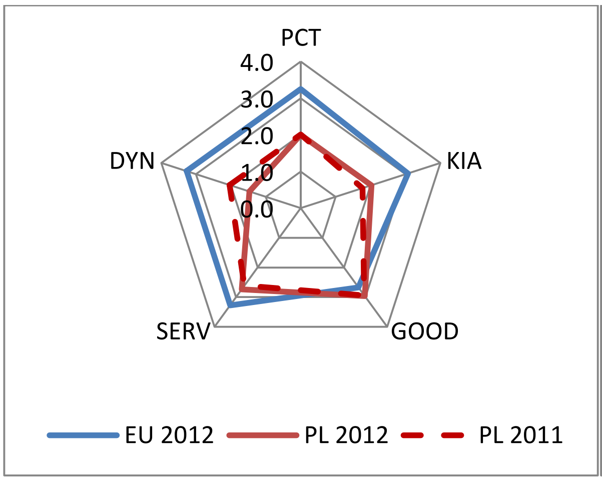
Malta



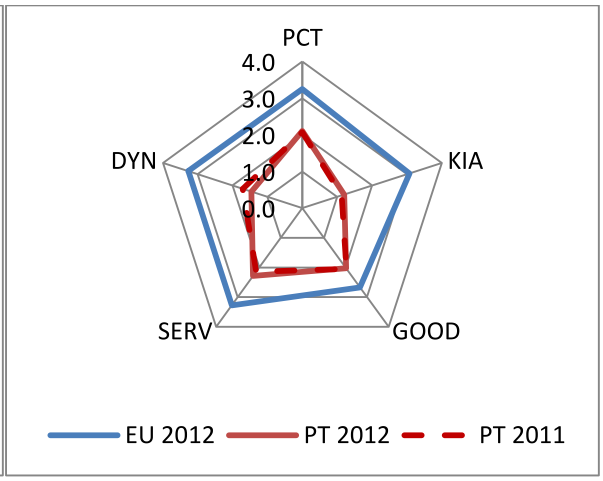
Netherlands



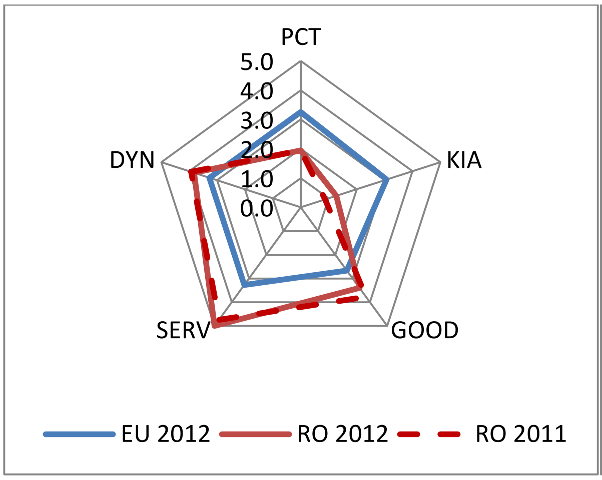
Poland



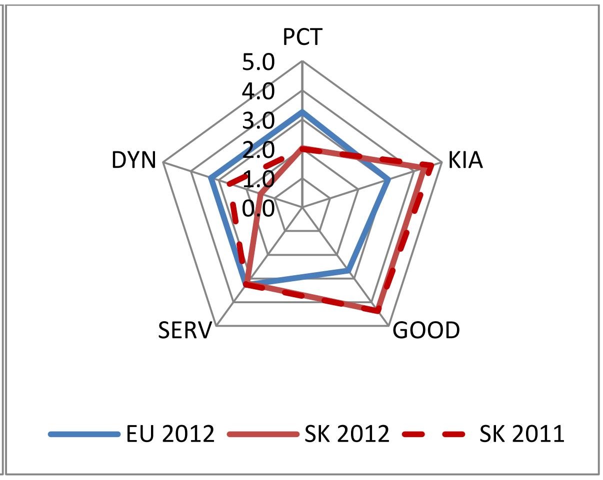
Portugal



Romania



Slovakia



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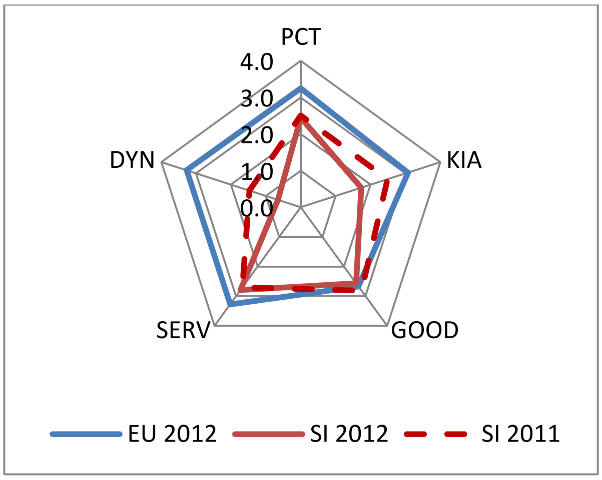

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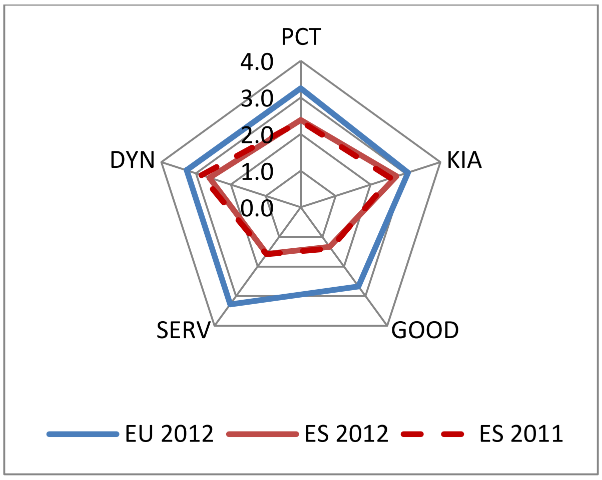

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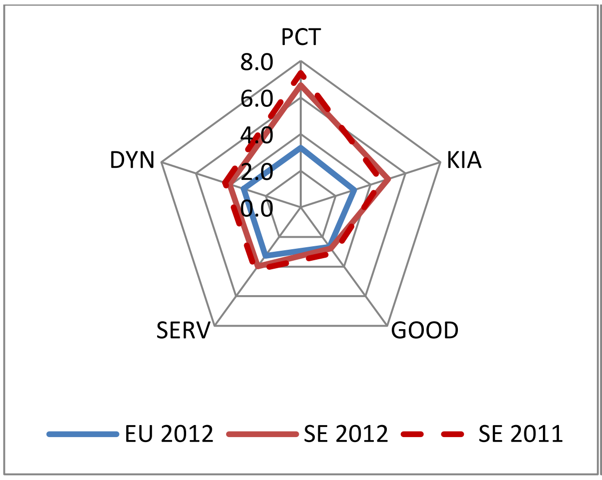

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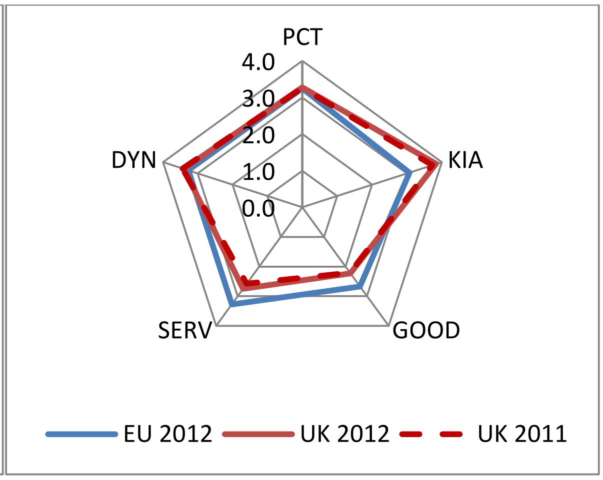

Source: JRC-IPTS calculations

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