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The 2005 European e-Business Readiness Index

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The 2005 European e-Business Readiness Index

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Abstract: Assessment of the eEurope 2005 Action Plan Benchmarking Index "E-Business Readiness Composite Indicator" using data collected by National Statistical Institutes and harmonised by Eurostat, using surveys "ICT usage of enterprises", with reference years 2003 and 2004. This report contains data from 26 countries as collected in 2004 and as reported by Eurostat in June 2005. Performed analyses include robustness analysis, uncertainty and sensitivity analysis for two categories of ICT (Adoption and Use), univariate analysis of basic indicators; principal component analysis and finally assessment of resulted country rankings and methodological notes.

Keywords: ICT, e-business, adoption, composite, indicator, eEurope, e-Europe, EU, multiple imputation

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Executive Summary

> *"Increasingly firm level evidence suggest that effective diffusion and the use of ICTs are key factors in broad-based growth when combined with effective human resource strategies involving education and training and organisational change" - OECD: Information Technology Outlook 2004*

Research shows that efficient adoption of Information and Communication technologies (ICT) counts for about half of the productivity growth of enterprises in the EU. Still, the EU could do much better, as the example of US shows.

This report describes the results of the composite indicator on e-business readiness for European countries, using data from the 2004 European Union enterprise survey, as available from Eurostat in June 2005[1]. It is the second edition of the report which follows the pilot study conducted in 2004 on the enterprise survey 2003 (Nardo *et al*. 2004). A comprehensive guide on constructing and using composite indicators for policy-makers and other interested parties can be found in a joint OECD/JRC handbook (Nardo *et al*. (2005)).

The evaluation of the index has been conducted by the Joint Research Centre of the European Commission using the enterprise survey data collected by Directorate General Eurostat. The text of this report has been prepared by the Joint Research Centre and by the Directorate General Enterprise and Industry.

The 2004 enterprise survey, contrarily to the 2003 survey, includes data also for the new European Member States. It is important to underline that, on June 15th 2005, not all Member States had provided the data sets as requested, and therefore the outcome of the exercise can be considered neither exhaustive nor definitive.

The index is made of two core dimensions: adoption of (ICT) by business, and use of ICT by business. The index has proven to be a useful tool for gauging country progress and a useful mechanism for benchmarking e-business adoption and use by firms against other comparative business. The higher a country's e-business readiness score, the better its position to adopt and use ICT.

The top-rank enterprises are in countries Sweden, Denmark, Finland and Germany for the category adoption and Belgium, Finland, Germany, Netherlands and Denmark for the category use. The bottom rank enterprises are in countries Hungary, Latvia, Slovakia, Bulgaria and Romania for the category adoption and Spain, Poland, Slovakia, Latvia and Bulgaria for the category use.

[1] In October 2005, a representative of the National Statistical Institute (ONS) of UK reported that their survey questions for indicators b3 and b4 (see explanation in Table 1) were worded differently compared to the model questionnaire of Eurostat. In particular, UK questions asked for links with electronic *systems for placing or receiving orders*, rather than the specific Eurostat questions on *electronic systems to manage orders*. This resulted in lower values of indicators b3 and b4 for UK. As such, the index values for UK cannot be compared directly with the remaining countries.

The index provides a valuable summary measure of the e-business readiness of the European enterprises. There are significant differences across the 26 European countries in both categories adoption and use. Some countries do well in adoption and much less in use of ICT even if the correlation between the rankings of adoption and use of ICT is quite high.

One should also note that the generic level of e-Business Readiness Index underlies rather remarkable variation of the ICT adoption and use among different industry sectors, among different size of companies and among individual companies. Electronic business practices can achieve their potential only when management of enterprises is committed to push through re-engineering of the working and business processes, with necessary training of personnel. More detailed level analysis can be found on the e-Business W@tch – project website (www.ebusiness-watch.org).

In its current form the index lacks some important dimensions - e.g. the impact of the e-business activity, the legal framework, the human capital dimension - because the relevant data has not been collected. As already observed in the pilot study, the inspection of the 2004 data confirms the existence of a partial overlapping of the category adoption with the category use and the need for the reallocation of some component variables to be more consistently classified as "use" or "adoption".

A critical revision of the conceptual model for e-business readiness that takes into account perspectives and barriers, in view of the i2010 initiative, is currently ongoing at Eurostat in collaboration with the Joint Research Centre and the Directorate General (DG) Enterprise and Industry and DG Information Society. Because of the developmental nature of e-business, such a study is designed as experimental and the results should contribute to the dynamic review of the basic sub-indicators for e-business readiness.

Document structure: This document contains an introductory section within the general framework, the composition of the index and the data available. The second section describes the index results for the category adoption and use of ICT and their comparisons. The third section describes the evolution of the index in the period 2003 – 2004 enlightening the comparison for the countries which provided data for both years. The fourth section draws the results of the robustness assessment to the assumptions and methodological choices made for the construction of the index. An overview of the values of the indicators is given in the fifth section where some comparisons with the values of the previous survey are also illustrated. The last section draws the conclusions and the Appendix describes the methodologies used for the construction of the index: imputation of missing data, the weighting of the component indicators and the sensitivity analysis.

1. THE BASIC INDICATORS AND DATA COVERAGE

The e-business readiness index is one of the policy sub-indicators selected by the Council Resolution of 28 January 2003 (5197/03) of the European Union to monitor progress in the implementation of the eEurope 2005 Action Plan (COM(2002) 263 final).

The survey measures the level and the type of the ICT used by European business. For this reason the indicators of the index are grouped into two categories measuring the various components of a country's technological development: 6 basic indicators for the group 'Adoption of ICT by business' and 6 basic indicators for the group 'Use of ICT by business'. These components are listed in the Annex 2.H of the said Council Resolution and reported in Table 1 and Table 2 for simplicity. The raw data for the basic indicators are expressed as percentages: 11 indicators are percentages of enterprises and one indicator (*a4*) is percentage of employees.

Ideally, these indicators would include all relevant aspects of the phenomenon, be different in causal-effect relationships, be easily quantifiable and be scale neutral. Due to significant data gaps and conceptual limitations, the actual indicator set falls short of the ideal. For example, a number of important issues including the impact of cost connections and other barriers on the e-business activity were omitted. The validity, interpretability and explanatory power of the e-business readiness index depends on the quality and completeness of the data. The basic indicators are being updated in view of the i2010 initiative. Although the index as it stands is partial and constrained by data limitations, we see it as a valuable comparative tool that helps to identify the leaders and laggards with regard to some aspects of e-business.

Table 1. 2005 e-business readiness Index: list of basic indicators for adoption of ICT

Adoption of ICT: basic indicators	*Code*
Percentage of enterprises that use Internet	*a1*
Percentage of enterprises that have web/home page	*a2*
Percentage of enterprises that use at least two 2 security facilities at the time of the survey	*a3*
Percentage of total number of persons employees using computer with their normal work routine	*a4*
Percentage of enterprises having broadband connection to internet	*a5*
Percentage of enterprises with LAN and using an Intranet and Extranet	*a6*

Table 2. 2005 e-business readiness Index: list of base indicators for use of ICT

Use of ICT: basic indicators	*Code*
Percentage of enterprises that have purchased products / services via the internet, EDI[2] or any other computer mediated network where these are >1% of total purchases	*b1*
Percentage of enterprises that have received orders via the internet, EDI or any other computer mediated network where these are >1% of total turnover	*b2*
Percentage of enterprises whose IT systems for managing orders or purchases are linked automatically with other internal IT systems	*b3*
Percentage enterprises whose IT systems are linked automatically to IT systems of suppliers or customers outside their enterprise group	*b4*
Percentage of enterprises with Internet access using the internet for banking and financial services	*b5*
Percentage of enterprises that have sold products to other enterprises via a presence on specialised internet market places	*b6*

2. MAIN FINDINGS

The 2004 survey data on e-business readiness for 26 Countries are reported in Table 17 and Table 18. The dataset has been completed by imputing the 11 missing values (shaded in tables). Details of the imputation method and of the calculation of the index are given in Appendix A. The data has been provided by Eurostat in June 2005.[3]

The results evaluating the index are firstly presented as a weighted average of the basic indicators by considering three alternative weighting methods: equal weights, budget allocation, and principal components weights.

For the budget allocation method, rather than comparing the individual expert opinions, which vary substantially, we focus on the 'consensus' among the group of experts. Such 'consensus weights' are obtained by taking the average across the experts' weights for each basic indicator.

2.1. Adoption of ICT: scores and rankings

The scores and rankings (see Table 3) for adoption of ICT provide a relative gauge of e-business progress in 26 European countries and the score value for the EU25 aggregate (this latter includes the 25 Member States of the European Union but France and Malta that did

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[2] Electronic Data Interchange

[3] Due to different wording of the questions for indicators b3 and b4 used by ONS, these index values for UK cannot be compared with the remaining countries (see footnote 1)

not participate in the survey). The Nordic countries, Sweden, Denmark and Finland steadily occupy the top ranks and have consistently done so in the previous 2004 index. These countries are highly developed in the adoption of information technologies. At the bottom of the rankings there are Eastern Europe countries such as Latvia, Slovakia, Bulgaria and Romania for which the data was not available in the previous 2004 index. These countries, all at the developing stage of their e-business environment, suffer from the existence of barriers, costs and infrastructure problems.

The relative positions of the middle-ranked countries are slightly affected by the weighting scheme employed in the study. Small oscillations of the index scores may result in larger changes in rankings compared to countries at the top and bottom positions. Countries at various stages of economic development and geographical size and location have adoption score values in the mid-range of 40-60. The diversity of the underlying institutions – including economic systems, with different prevalence of enterprises of small, medium and large size and different strategic sectors, adds to the complexity of the picture. However, the country rankings for adoption seem reasonably stable to the change of the weighting scheme.

2.2. Use of ICT: scores and rankings

The pattern of country performance for the category use of ICT is globally similar to that of adoption and stable across the different weighting schemes, see Table 4. Quantitatively, the country scores are much lower for use than adoption, as the percentage of the firms that are using e-business are much less than those that have adopted it. Belgium overtakes the Scandinavian countries. Sweden, on the other hand, performs 6th in use, while it is on the top of the list for adoption. Luxembourg loses 5 positions in use compared with adoption. The most evident high variation is Spain which is 22nd in using e-business, whereas it is 12th in adoption. Ireland and Estonia are the most efficient using e-business given their efforts to adopt it. Indeed, they are respectively 8th and 10th in use, whilst they are 15th and 14th in adoption.

Table 3. 2005 e-Readiness ICT Adoption – Scores and rankings according to three different weighting schemes: equal, budget allocation expert average and factor analysis weights for the 26 European countries and the average of EU 25

Countries	Rankings - Equal Weights	Scores – Equal Weights	Rankings – Weights based on Budget Allocation (consensus weights)	Rankings – Weights based on Factor Analysis
Sweden	1	73.7	1	1
Denmark	2	72.3	2	2
Finland	3	72.2	3	3
Belgium	4	68.0	4	4
Germany	5	65.6	5	5
Netherlands	6	62.3	6	6
Luxembourg	7	61.9	7	8
Austria	8	61.8	8	7
Norway	9	60.5	9	9
United Kingdom	10	59.5	12	10
Slovenia	11	57.8	11	11
Spain	12	57.7	10	12
Italy	13	54.2	14	14
Estonia	14	54.1	13	13
Ireland	15	51.0	16	15
Czech Republic	16	51.0	15	16
Greece	17	46.4	20	17
Poland	18	45.9	18	18
Lithuania	19	44.6	17	19
Hungary	20	42.8	23	21
Portugal	21	42.4	21	22
Cyprus	22	41.7	19	20
Latvia	23	39.5	22	23
Slovakia	24	35.4	24	24
Bulgaria	25	30.0	25	25
Romania	26	19.2	26	26
EU25	-	**58.0**	-	-

Table 4. 2005 e-Readiness ICT Use – Scores and rankings according to three different weighting schemes equal, budget allocation expert average and factor analysis weights for the 26 European countries and the average of EU 25

Countries	Rankings - Equal Weights	Scores – Equal Weights	Rankings – Weights based on Budget Allocation (consensus weights)	Rankings – Weights based on Factor Analysis
Belgium	1	34.3	1	1
Finland	2	33.3	2	2
Denmark	3	31.3	5	5
Germany	4	31.0	4	4
Netherlands	5	30.7	3	3
Sweden	6	29.6	6	6
United Kingdom	7	28.5	8	7
Ireland	8	27.1	9	8
Austria	9	26.9	11	11
Estonia	10	26.5	13	13
Italy	11	26.5	7	9
Luxembourg	12	26.4	10	10
Norway	13	25.4	12	12
Czech Republic	14	24.4	14	14
Slovenia	15	24.3	16	16
Greece	16	21.8	18	18
Portugal	17	21.3	17	17
Romania	18	20.3	15	15
Cyprus	19	19.2	19	19
Lithuania	20	19.0	21	20
Hungary	21	17.7	20	21
Spain	22	17.3	22	23
Slovakia	23	15.9	23	24
Poland	24	15.8	24	22
Latvia	25	14.5	25	25
Bulgaria	26	6.8	26	26
EU25	**-**	**25.4**	-	-

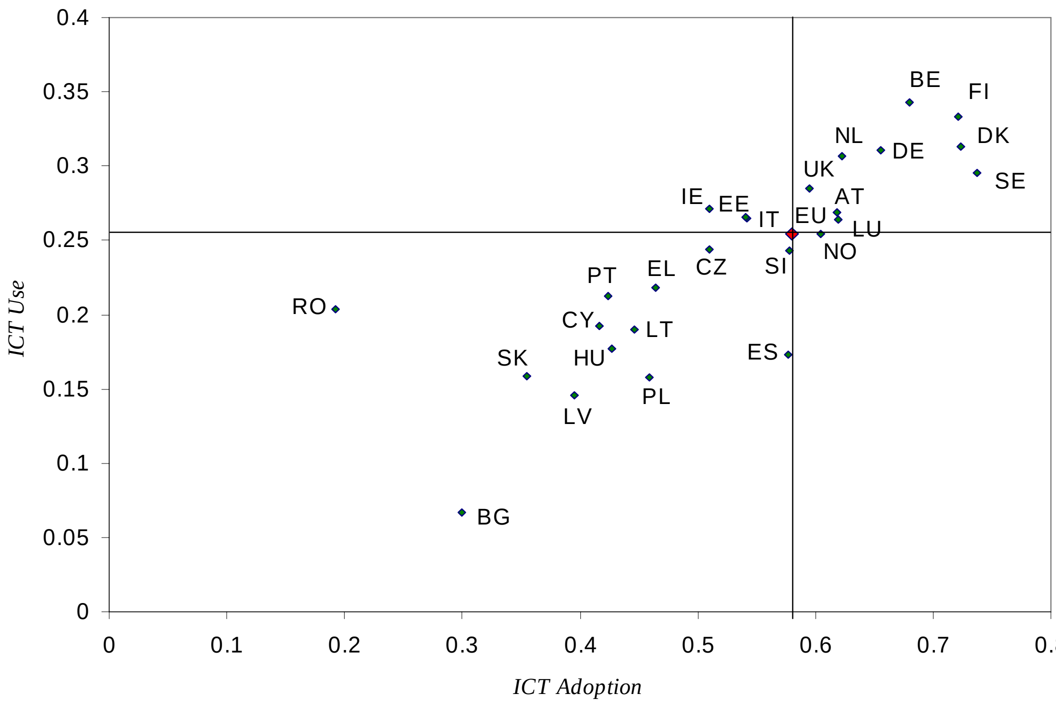

Figure 1. ICT Adoption scores vs. ICT use scores employing the equal weighting scheme, the red diamond indicates the EU25 aggregate score values whose value is in bold in Table 3 and in Table 4

2.3. Adoption vs. use scores

Figure 1 shows a graphical representation of adoption scores versus use scores for the 26 countries based on the equal weighting scheme. The code for each country is shown in Table 16. High scores in adoption are generally associated with high scores in use. The Spearman correlation coefficient for the rankings of adoption and use is equal to 0.86 with a confidence interval given by (0.71, 0.94), meaning that a strong positive correlation exists between the rankings for the two categories. The same results are confirmed for the country scores obtained using the alternative weighting schemes.[4]

It should be noted that, judging from the available data of Eurostat, Romania uses its very limited infrastructures very efficiently: indeed, given its minimum level of adoption, its use of e-business is at the level of Portugal and Greece.

Among the New Member States, Slovenia and Estonia are top performers; the Czech Republic also performs very well as they are approaching parity with the other west European countries in term of ICT adoption and usage. The index score for the category use for Italy and Ireland is above the EU25 aggregate value whilst the level of adoption is below

[4] Due to different wording of the questions for indicators b3 and b4 used by ONS, these index values for UK cannot be compared with the remaining countries (see footnote 1)

the EU25 aggregate: such countries are effectively using their ICT infrastructures. Among the Countries of the former EU 15, Ireland and Portugal seem to be the more efficient, when compared with their ratio of use divided by adoption, they have maximum ratio between use and adoption scores.

2.4. Overview of the adoption vs. use scores by company size

The basic indicators on Adoption and Use of ICT have been also broken down by firm size. Three categories of firms have been considered: large (with more than 250 employees), medium (50 to 249 employees), and small (10 to 49 employees). In Figure 2 we report the scores results depending upon firm size, using equal weighting scheme only for 19 countries, which do not have missing data. The graph is based on the score values reported in Table 5. Large firms have in general a better e-business environment than small and medium enterprises, which seem to perform likewise for both adoption and use of ICT. Large firms for some of the new Member States have a level of performance similar to that of small and medium enterprises of former EU15.

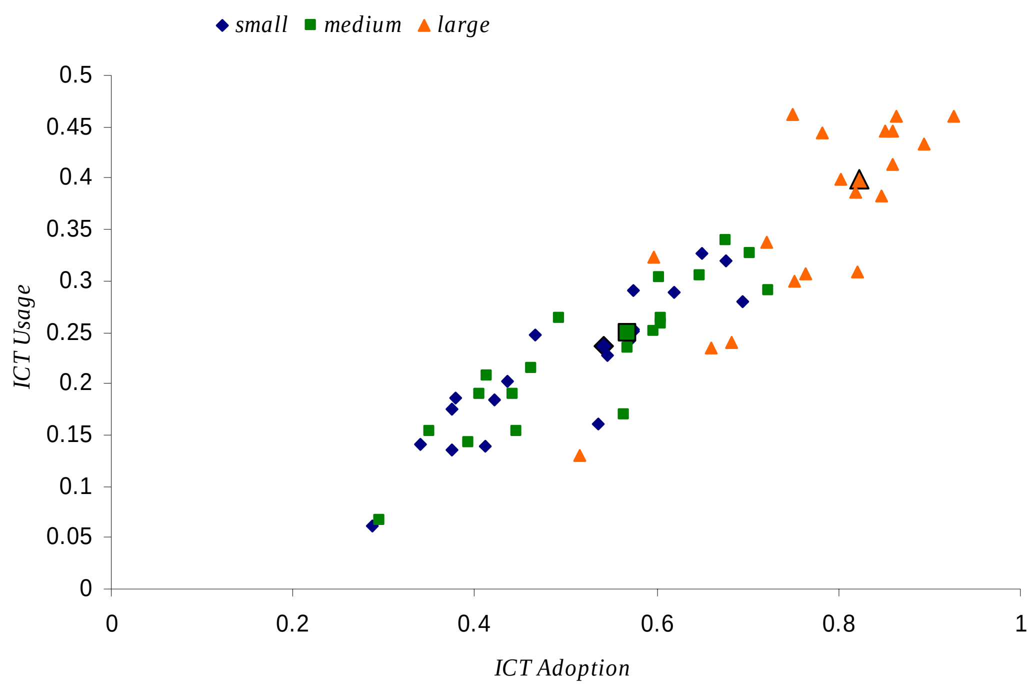

Figure 2. ICT Adoption scores vs. ICT use scores by firm size: orange triangle – large firms, green rectangle – medium firms, blue diamond – small firms, employing the equal weighting scheme, the EU25 aggregate score values are in bold. The values are reported in Table 5

Table 5. 2005 e-Readiness ICT Use – Scores and rankings according to three different weighting schemes equal, budget allocation expert average and factor analysis weights for 19 European countries and the average of EU 25

Countries	Small Firms Scores Adoption	Small Firms Scores Use	Medium Firms Scores Adoption	Medium Firms Scores Use	Large Firms Scores Adoption	Large Firms Scores Use
Eu25	**54.1**	**23.7**	**56.9**	**25.0**	**82.2**	**40.0**
Belgium	65.0	32.7	67.6	33.9	86.4	46.1
Germany	62.0	28.9	64.8	30.6	86.0	41.4
Greece	43.6	20.3	46.2	21.6	72.0	33.8
Spain	53.6	16.1	56.4	17.0	82.1	30.8
Ireland	46.7	24.8	49.2	26.3	75.0	46.1
Cyprus	37.5	17.5	40.5	19.0	75.2	29.9
Latvia	37.5	13.6	39.2	14.3	66.0	23.4
Lithuania	42.1	18.4	44.2	18.9	68.2	24.1
Luxembourg	57.7	25.3	66.5	25.9	80.2	39.9
Netherlands	57.5	29.1	60.2	30.3	85.1	44.6
Austria	57.4	25.1	60.5	26.3	85.9	44.6
Poland	41.1	13.9	44.5	15.3	76.3	30.7
Portugal	37.8	18.6	41.4	20.8	78.2	44.4
Slovenia	54.6	22.7	56.9	23.5	81.8	38.6
Slovakia	34.0	14.1	35.1	15.3	59.7	32.3
Finland	67.6	32.0	70.4	32.7	89.4	43.2
Sweden	69.5	28.0	72.4	29.1	92.7	46.0
Bulgaria	28.7	6.2	39.6	6.6	51.5	12.9
Norway	57.1	24.1	596	25.1	84.8	38.4

3. Development of e-business in 2004 and comparison with 2003 survey data

3.1. Development of e-business in 2004

The e-Business W@tch – project is a portrait of e-business in 10 sectors of the EU economy.[5] Although it does not cover the full EU-25, with limited sample sizes in surveys, it can provide a general indication on the level of progress and trends. Main highlights of development observed in 2004:[6]

(1) Electronic business is reaching technological maturity. This is aided by increased penetration of broadband connections to internet, proliferation

[5] The European e-Business W@tch, launched by the European Commission, Directorate General for Enterprise and Industry in 2001, monitors the growing maturity of electronic business across different sectors of the economy in the enlarged European Union and in EEA countries. A total of 17 financial, manufacturing and service sectors have been analysed. Complete set of publications is available via following links: http://europa.eu.int/comm/enterprise/ict/policy/econ-anal/index.htm or http://www.ebusiness-watch.org).

[6] e-Business W@tch Synthesis Report 2004, http://www.ebusiness-watch.org.

of data exchange standards and recommendations, constantly increasing performance / cost – ratio of the ICT hardware and a maturing understanding of the importance of ICT in the quest for an increase of productivity.

(2) Increase in B2B online trading. Almost half of firms' purchases occur online, but volumes are still limited.

(3) B2C electronic commerce gains speed in specific markets, especially in e-tourism, where about a third of firms indicate that they sell their services online.

(4) Business process integration is still the big question, with mainly large enterprises in the frontline with new system acquisitions.

Potential challenges:

(1) E-procurement and e-sourcing. Saving procurement costs is an opportunity for buyers, but equally puts pressure on suppliers – thus efficiency gains compete with pressure on margins.

(2) Unequal gains from e-business due to high fixed costs. Larger firms are still in a better position to benefit and smaller companies are facing partly unfavourable scales of economies.

(3) Vanishing advantage. As ICT penetrates to enterprises, becoming a commonplace, the use of ICT to differentiate and gain strategic advantage needs more skills from management.

3.2. Country – level progress between 2003 - 2004

A comparison is made on all the countries of the former EU15 plus Norway but Greece and France, see Table 6 and Table 7. Northern European countries take the first rankings, with proactive policy implementation and the presence of a solid IT infrastructure. Some of them, in particular Norway, have slipped slightly in the rankings from last year, yet the other Nordic countries are still prominent among the e-readiness leaders for the category adoption of ICT. [7]

All countries improve their performance scores between 2003 and 2004 in the category adoption, and Spain does it at the most rapid pace (from 44.4% to 57.7%). On the other hand, Spain deteriorates its performance score in the category use in the same period. All the other countries, except Netherlands, improve their performance in this category, where Germany shows the largest improvement (we have to take into account that in 2003

[7] Due to different wording of the questions for indicators b3 and b4 used by ONS, these index values for UK cannot be compared with the remaining countries (see footnote 1)

Germany had imputed values for two indicators of the category use). Based on the data, we can see, in which countries the enterprises gained most from 2003 to 2004.

From Table 8 we can see that Spain, Germany, Belgium and Italy were leading movers in 2004, gaining remarkably from their 2003 score levels in the ICT adoption.

Respectively we can look at the ICT Use – gains. The calculation in Table 9 shows, that a rather fast harmonising process is taking place, where many but not all countries are making big gains, notably Italy, Germany, Belgium and Portugal. Spain does not show as remarkably progress as in the ICT adoption – side**.** One may assume that traditional S-curve of the penetration is also valid here. With current speed of yearly progress, those fast developing enterprises in the observed EU Member States should become a rather homogenous group within a couple of years

Table 6. 2005 and 2004 e-Readiness ICT adoption score and rankings with equal weighting scheme for 14 European Member States

Countries	Rankings – 2005 Equal Weights	Scores – 2005 Equal Weights	2004-Score	2004-Rankings
Sweden	1	73.7	70.9	1
Denmark	2	72.3	69.4	2
Finland	3	72.2	69.1	3
Belgium	4	68.0	60.1	4
Germany	5	65.6	56.4	9
Netherlands	6	62.3	57.8	7
Luxembourg	7	61.9	56.7	8
Austria	8	61.8	58.9	6
Norway	9	60.5	59.4	5
United Kingdom	10	59.5	54.1	10
Spain	11	57.7	44.4	13
Italy	12	54.2	46.9	11
Ireland	13	51.0	45.2	12
Portugal	14	42.4	42.4	14

Table 7. 2005 and 2004 e-Readiness ICT use score and rankings with equal weighting scheme for 14 European Member States

Countries	Rankings -2005 Equal Weights	Scores – 2005 Equal Weights	2004-Score	2004-Rankings
Belgium	1	34.3	28.3	3
Finland	2	33.3	33.2	1
Denmark	3	31.3	28.1	4
Germany	4	31.0	19.1	12
Netherlands	5	30.7	31.3	2
Sweden	6	29.6	24.1	8
United Kingdom	7	28.5	25.6	5
Ireland	8	27.1	24.7	7
Austria	9	26.9	25.2	6
Italy	10	26.5	12.3	14
Luxembourg	11	26.4	22.5	10
Norway	12	25.4	24.1	9
Portugal	13	21.3	16.8	13
Spain	14	17.3	19.2	11

Table 8. Progress from 2003 to 2004. e-Readiness ICT adoption score differences with equal weighting scheme for 14 European Member States

Countries	2005 score (2004 data) - Equal Weights	2004-Score (2003 data) – Equal Weights	Gain from 2004 to 2005 Score
Spain	57.7	44.4	13.30
Germany	65.6	56.4	9.20
Belgium	68.0	60.1	7.90
Italy	54.2	46.9	7.30
Ireland	51.0	45.2	5.80
United Kingdom	59.5	54.1	5.40
Luxembourg	61.9	56.7	5.20
Netherlands	62.3	57.8	4.50
Finland	72.2	69.1	3.10
Denmark	72.3	69.4	2.90
Austria	61.8	58.9	2.90
Sweden	73.7	70.9	2.80
Norway	60.5	59.4	1.10
Portugal	42.4	42.4	0.00

Table 9. Progress from 2003 to 2004. e-Readiness Use of ICT- score differences with equal weighting scheme for 14 European Member States

Countries	2005 score (2004 data) - Equal Weights	2004-Score (2003 data) – Equal Weights	Gain from 2004 to 2005 Score
Italy	26.5	12.3	14.2
Germany	31	19.1	11.9
Belgium	34.3	28.3	6.0
Sweden	29.6	24.1	5.5
Portugal	21.3	16.8	4.5
Luxembourg	26.4	22.5	3.9
Denmark	31.3	28.1	3.2
United Kingdom	28.5	25.6	2.9
Ireland	27.1	24.7	2.4
Austria	26.9	25.2	1.7
Norway	25.4	24.1	1.3
Finland	33.3	33.2	0.1
Netherlands	30.7	31.3	-0.6
Spain	17.3	19.2	-1.9

4. ROBUSTNESS ANALYSIS

The robustness of the country rankings depends on a number of factors including: the amount of missing data, the choice of the imputation algorithm, in this case Markov Chain Monte Carlo simulations, and the choice of weights, e.g. equal weights, or weights derived from principal component analysis, or based on expert opinion.

A synergic use of the uncertainty analysis and sensitivity analysis of the composite indicators has recently been applied to gauge the robustness of the index and to increase its transparency (Saisana *et al*., 2005). We follow this approach, although it deviates from original deterministic formulations of the index, in that, we allow both the imputed values and the weighting procedures to vary and we sample input factors, e.g. imputed values and weights, rather than keep them equal and fixed as in the previous section. The methodology to run the robustness and the sensitivity analysis is described in Appendix A.

We consider three alternative weighting schemes: equal, principal component and budget allocation weights. The weights of the budget allocation have been provided by twelve national representatives of the e-business support network (e-BSN[8]). A detailed description of the assignment of weights can be found in the Annex of the pilot study 2004 (Nardo *et al*. 2004).

[8] e-Business Support Network is a body established as part of eEurope 2005 Action Plan. http://www.e-bsn.org/portal/home.do

Table 10. Weights obtained from national representatives of the e-BSN for the category adoption of ICT

Indicators	*Budget allocation weights*											
a1	*0.25*	*0.10*	*0.17*	*0.10*	*0.15*	*0.15*	*0.20*	*0.30*	*0.10*	*0.20*	*0.05*	*0.36*
a2	*0.15*	*0.10*	*0.17*	*0.10*	*0.15*	*0.10*	*0.25*	*0.20*	*0.10*	*0.10*	*0.05*	*0.39*
a3	*0.10*	*0.20*	*0.17*	*0.00*	*0.15*	*0.15*	*0.10*	*0.05*	*0.05*	*0.10*	*0.15*	*0.01*
a4	*0.15*	*0.15*	*0.17*	*0.00*	*0.10*	*0.20*	*0.10*	*0.15*	*0.20*	*0.30*	*0.20*	*0.15*
a5	*0.25*	*0.20*	*0.17*	*0.40*	*0.25*	*0.30*	*0.15*	*0.10*	*0.25*	*0.20*	*0.25*	*0.05*
a6	*0.10*	*0.25*	*0.17*	*0.40*	*0.20*	*0.10*	*0.20*	*0.20*	*0.30*	*0.10*	*0.30*	*0.03*

Table 11. Weights obtained from national representatives of the e-BSN for the category use of ICT

Indicators	*Budget allocation weights*											
b1	*0.10*	*0.10*	*0.17*	*0.10*	*0.15*	*0.15*	*0.20*	*0.25*	*0.25*	*0.20*	*0.15*	*0.16*
b2	*0.15*	*0.15*	*0.17*	*0.10*	*0.15*	*0.15*	*0.20*	*0.25*	*0.25*	*0.20*	*0.15*	*0.16*
b3	*0.20*	*0.20*	*0.17*	*0.40*	*0.25*	*0.25*	*0.15*	*0.15*	*0.25*	*0.20*	*0.10*	*0.16*
b4	*0.15*	*0.25*	*0.17*	*0.40*	*0.25*	*0.30*	*0.15*	*0.05*	*0.10*	*0.20*	*0.30*	*0.16*
b5	*0.25*	*0.20*	*0.17*	*0.00*	*0.10*	*0.10*	*0.10*	*0.15*	*0.05*	*0.10*	*0.05*	*0.20*
b6	*0.15*	*0.10*	*0.17*	*0.00*	*0.10*	*0.05*	*0.20*	*0.15*	*0.10*	*0.10*	*0.25*	*0.16*

Table 12. Equal weights and weights obtained using the principal component analysis for the categories adoption and use of ICT

Adoption of ICT	*Equal Weights*	*Principal component weights*	*Usage of ICT*	*Equal Weights*	*Principal component weights*
a1	*0.17*	*0.20*	*b1*	*0.17*	*0.16*
a2	*0.17*	*0.19*	*b2*	*0.17*	*0.20*
a3	*0.17*	*0.14*	*b3*	*0.17*	*0.17*
a4	*0.17*	*0.18*	*b4*	*0.17*	*0.20*
a5	*0.17*	*0.16*	*b5*	*0.17*	*0.11*
a6	*0.17*	*0.13*	*b6*	*0.17*	*0.16*

Table 13. Twelve uncertain input factors for the robustness analysis

Input factor	*Definition*	*Pdf*
X_1	Imputed value (a3) UK	*N(0.89, 0.26)*
X_2	Imputed value (a5) HU	*N(0.26,0.13)*
X_3	Imputed value (b1) IT	*N(0.22,0.10)*
X_4	Imputed value (b2) IT	*N(0.10,0.05)*
X_5	Imputed value (b3) CZ	*N(0.31,0.16)*
X_6	Imputed value (b4) CZ	*N(0.11,0.06)*
X_7	Imputed value (b1) RO	*N(0.10,0.16)*
X_8	Imputed value (b2) RO	*N(0.03,0.07)*
X_9	Imputed value (b5) UK	*N(0.72,0.12)*
X_{10}	Imputed value (b6) UK	*N(0.01,0.01)*
X_{11}	Imputed value (b6) EE	*N(0.01,0.01)*
X_{12}	Choice of the Weighting scheme	*Discrete uniform(1,14)*

Table 10 and Table 11 present the values of the budget allocation weights for each basic indicator provided by the experts, the values for the principal component weights and the equal weights. It can be seen that the weights provided by the budget allocation are quite spread for each basic indicator.

The input factors are illustrated in Table 13 with their probability density function. The input factor X_{12} has a discrete uniform distribution and it selects among 14 different sets of weights: equal weights, principal component weights and the 12 sets provided by the national representatives. A multivariate sample of a given size (see next section) is generated from the 12 distributions of the input factors. For each sample point, the e-readiness index is evaluated for all the countries, thus obtaining a set of index values of the same size of the sample. In the generation of the multivariate sample, we had in some instances to truncate some distribution tails for the imputed values, so as to remove values outside the natural range (0%; 100%).

4.1. Uncertainty and sensitivity analysis results for the category adoption

The results of the robustness analysis for the category adoption are shown in Figure 3. The countries are shown in decreasing order of ranking. The graph displays the median (black horizontal bar) and the corresponding 5th and 95th percentile bounds of the distribution of the output which reflects the uncertainty due to the input factors. We interpret the 5th percentile of a country's rank distribution as its best rank and we define the 'volatility' as the difference between a country's best and worst rank which are given by the 5th and the 95th percentiles of the rank distribution.

Sets of box plots partially overlapping indicate situations when the ranking of the corresponding countries can interchange, so showing similar degree of performance. For example, Finland and the Netherlands have non overlapping bounds: the policy inference is robust, no matter what weighting scheme is used or what expert is selected.

The large confidence bounds for United Kingdom and Hungary are essentially due to the imputation of one basic indicator (*a3*, and *a5* respectively). On the other hand, Ireland shows a large confidence bound associated to its index of adoption, though there is no uncertainty due to imputation of missing data. This happens because Ireland has some basic indicators with very large or very small value associated to weights varying in a broad range.

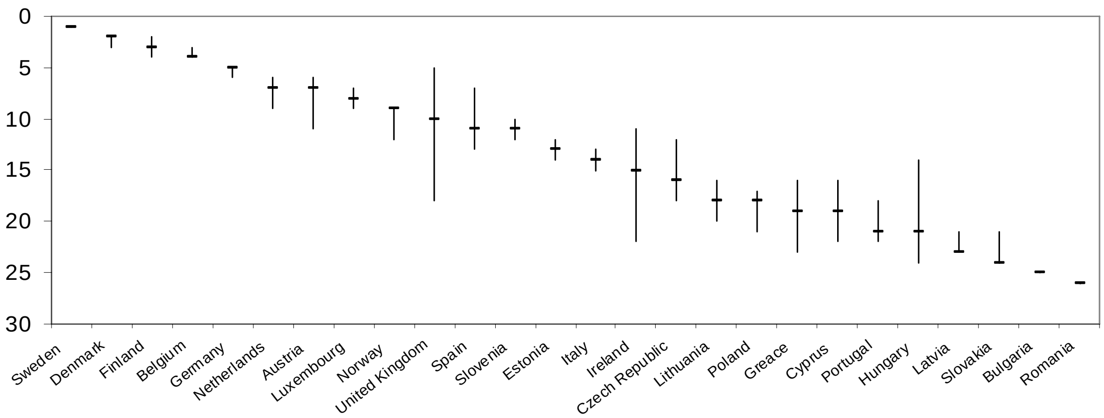

Figure 3. Results of the robustness analysis showing the median (-) and the corresponding 5th and 95th percentiles (bounds) of the distribution of the adoption rankings for the 26 European countries. Countries are ordered according to their median ranking. Uncertain input factors for all the countries are the weighting scheme; UK and HU have additional uncertain factors for the imputed values

Table 14. Sobol' sensitivity measures of the first-order and total effect for the output average adoption ranks for United Kingdom and Hungary

Input factors UK	*First order sensitivity measure*	*Total effect sensitivity measure*	*Input factors HU*	*First order sensitivity measure*	*Total effect sensitivity measure*
X_1	0.582	0.712	X_2	0.694	0.714
X_{12}	0.058	0.345	X_{12}	0.187	0.311
Sum	*0.640*	*1.057*	*Sum*	*0.881*	*1.025*

For United Kingdom and Hungary we are interested in understanding whether the uncertainty coming from imputation is more influential than the uncertainty due to the choice of weights. We show in Table 14 the results of the sensitivity analysis for these two countries based on the first order and total effect sensitivity measures calculated with the method presented in Appendix A.

A sequential approach has been used to estimate the first order and the total effect indices for all the factors with an accuracy of 1% in the estimates. The total cost of the analysis is quite small, approximately 835 model runs. Looking at the first order sensitivity measure we can quantify the extent to which the variance of the distribution would be reduced on average if we were able to reduce the uncertainty of the corresponding input factor. It can be seen that the imputation system is the most influential input factor both for United Kingdom and Hungary. The choice of the weighting scheme (X_{12}) is much less relevant for them. The non-linear part of the variance that is not explained by the first order sensitivity measures is 36% for United Kingdom and 12% for Hungary. The uncertainty in the country rankings would be strongly reduced if we were able to collect the missing values of the indicators *a3* for United Kingdom and *a5* for Hungary. The values of the total effects show that the relation between the input factors and the country rankings is substantially linear.

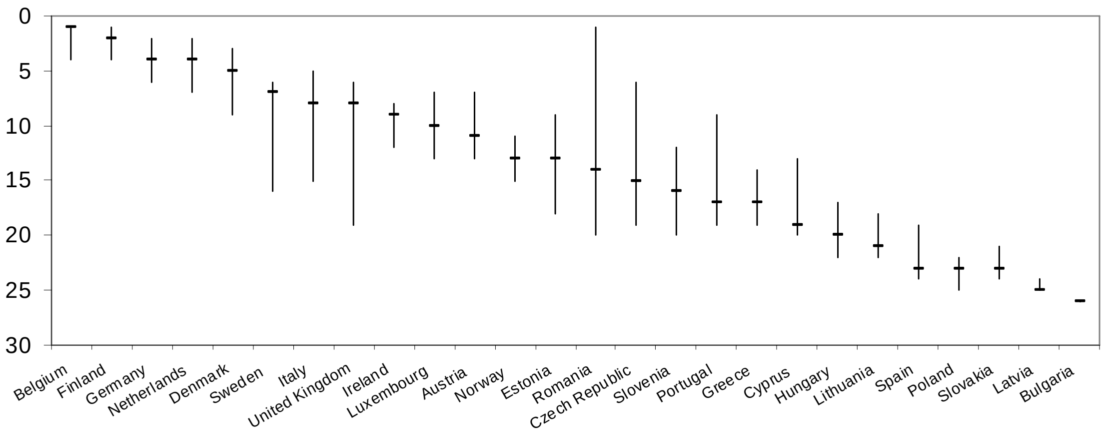

Figure 4. Results of the robustness analysis showing the median (-) and the corresponding 5th and 95th percentiles (bounds) of the distribution of the use rankings for the 26 European countries. Uncertain input factors for all the countries are the weighting scheme; IT, RO, CZ, UK and EE have additional uncertain factors for the imputed values. Countries are ordered according to their median ranking

4.2. Uncertainty and sensitivity analysis results for the category use

The graph in Figure 4 shows the median (black horizontal bar) and the corresponding 5th and 95th percentile bounds of the distribution of the country rankings for the category use.

Although the largest confidence bounds are associated to countries for which there is at least one imputation due to missing data, there are a consistent number of countries which have rather large confidence bounds in their rankings. The reason is because the set of weights is quite heterogeneous (see Table 11 and Table 12), and, correspondently there are some basic indicators that possess very large or very small values.

The middle-ranked countries in Figure 4 show a wide, often full overlap of the confidence bounds for their rankings. This may induce the reader to conclude that, given the uncertainties at play, countries such as Italy and Czech Republic show equal performance (though other 7 countries lie in between). However, the situation is not such and can be explained by plotting the empirical distribution of the difference between the scores of Italy and Czech Republic (see Figure 5). This empirical distribution is due to the effect of five factors: one is the choice of the weights and the other four are related to the imputations (two for Italy and two for Czech Republic).

In Figure 5, the empirical distribution is due to the propagation of the uncertainty in the weighting scheme and of the uncertainty due to the imputation of the missing indicators for Italy and Czech Republic.

The histogram shows that Italy performs generally better than Czech Republic for most of the combinations of weights and imputations (in particular this occurs in approximately 80% of the cases).

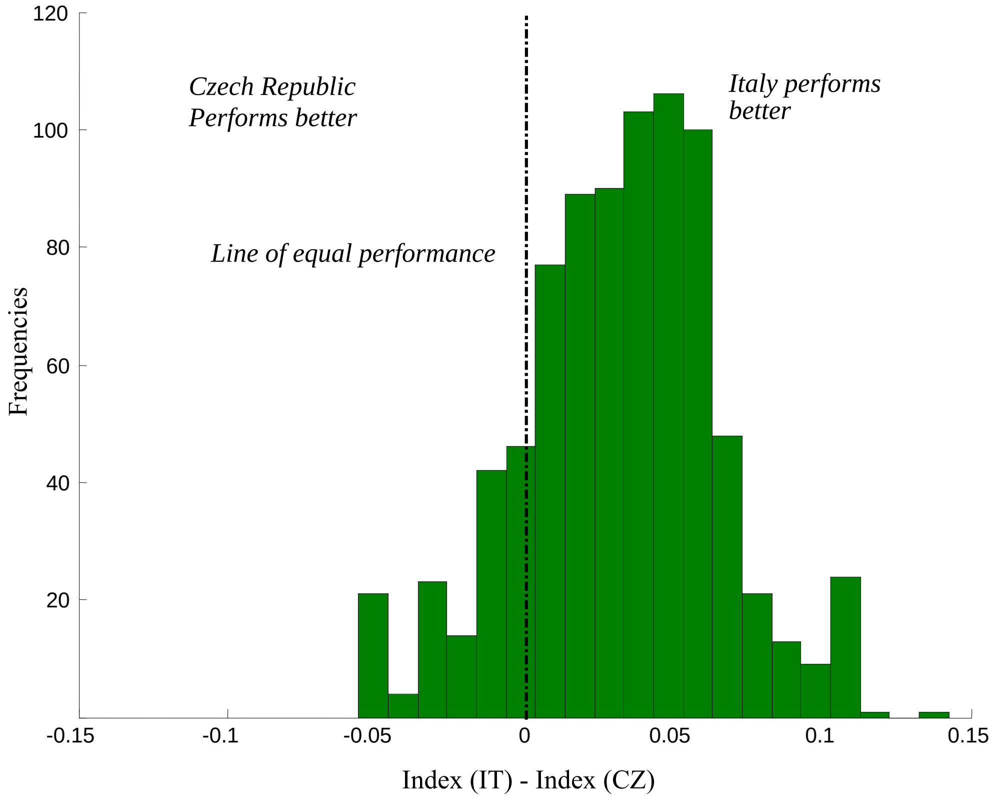

Figure 5. Plot of the difference between the scores of Italy and those of Czech Republic for the category Use, given the uncertainties at play

Table 15. Sensitivity analysis of the difference between the scores of Italy and Czech Republic. First order measures and total effect measures are provided by the analysis

Input factors	*First order sensitivity measure*	*Total effect sensitivity measure*
X_3 IT (b1)	0.241	0.243
X_4 IT (b2)	0.072	0.072
X_5 CZ (b3)	0.484	0.572
X_6 CZ (b4)	*0.012*	*0.013*
X_{12} Choice of weights	0.171	0.254

Global sensitivity analysis can help to identify which of the five factors is mostly responsible for the distribution of Figure 5. The sensitivity analysis is conducted on the difference between the scores of Italy and Czech Republic with the method described in Appendix A and the results are reported in Table 15.

The first order sensitivity measures quantify the extent to which the variance of the distribution in Figure 5 would be reduced, on average, if we were able to remove the uncertainty of a given factor. The table shows that the most important factor is CZ (*b3*), which denotes the uncertainty coming from the imputation of the indicator *b3* for Czech Republic. If this indicator was known, the variance of the distribution in Figure 5 would be reduced by 48%, and a more robust answer could be given on the ranking of Czech Republic with respect to other countries with overlapping bounds.

On another side, the imputations of the indicator *b2* for Italy and *b4* for Czech Republic are practically irrelevant. This means that, for a robust evaluation of the index, the availability of data for such two indicators is not important.

Note that the input factor ‘choice of weights’ has a relatively low importance (17%) in comparison to the other factors, which jointly are responsible for 80% (the sum of the first order measures in Table 15) of the variance of the distribution in Figure 5. This fact is confirmed for all the other pairs of countries having at least one imputed basic indicator. This means that the index is well defined in the sense that the relative performance of the countries does not depend on the subjective process of choosing the weights.

The total effect measures are very similar to the corresponding first order measures, except for CZ (*b3*) and ‘choice of weights’ for which the total effects are somewhat larger than the corresponding first order effects (0.08). This indicates that the variance of the distribution in Figure 5 is weakly affected (approximately 8%) by the two-way interaction between the two factors.

5. UNIVARIATE ANALYSIS OF BASIC INDICATORS

5.1. Survey Data

The data used throughout the analysis reported in Table 17 and Table 18 refer to the EU businesses of all sizes and of all the sectors of economic activity covered by the 2004 survey, businesses with less than four employees were excluded from the survey. The data provided are weighted to be consistent with the number and profile of businesses in the economy of the involved countries.

Table 16. European countries involved in the survey and data coverage for 2003 and 2004

Member State	Code	2003 survey	2004 survey
Austria	AT	X	X
Belgium	BE	X	X
Bulgaria	BG	-	X
Cyprus	CY	-	X
Czech Republic	CZ	-	X
Denmark	DK	X	X
Estonia	EE	-	X
Finland	FI	X	X
France	FR	-	-
Germany	DE	X	X
Greece	EL	-	X
Hungary	HU	-	X
Ireland	IE	X	X
Iceland	IS	X	-
Italy	IT	X	X
Latvia	LV	-	X
Lithuania	LT	-	X
Luxembourg	LU	X	X
Malta	MT	-	-
Netherlands	NL	X	X
Norway	NO	X	X
Poland	PL	-	X
Portugal	PT	X	X
Romania	RO	-	X
Slovakia	SK	-	X
Slovenia	SI	-	X
Spain	ES	X	X
Sweden	SE	X	X
United Kingdom	UK	X	X
Total		*15*	*26*

On April 1st 2005, not all the Member States and the new European Member States and other European countries had provided the data sets as requested by the survey. Full data set was completely missing for France, Malta, Island, Latvia and Luxembourg. On June 15th 2005 the data set was updated with the data from Latvia and Luxembourg. A total of 26 countries were included in the final data set. France and Malta had completely missing values and we could not impute them because this would have generated inaccurate results. Table 16 shows the names of the Member States and their abbreviation: the countries which provided the data for 2003 and/or 2004 survey are identified with an X. The data collected in 2004 are shown in bar chart form for each basic indicator and for each country ordered from the lowest to the highest value from Figure 6 to Figure 17. The values with shaded background in Table 17 and Table 18 are the imputed values, obtained with the method described in Appendix A.

Table 17. Full data set for the 26 European countries and the EU25 aggregate for the construction of the adoption e-business readiness index with imputed missing values in shaded background. The values are expressed as percentages

Countries	*Indicators*					
	a1	*a2*	*a3*	*a 4*	*a5*	*a6*
BE	96.0	67.6	69.3	63.2	69.9	42.1
CZ	90.1	60.9	60.0	34.9	38.0	22.0
DK	97.4	80.9	85.3	61.4	79.8	29.0
DE	94.1	72.4	87.4	47.2	53.6	38.9
EE	90.0	51.7	63.2	31.6	67.7	20.4
EL	87.4	49.0	67.4	33.4	20.6	20.6
ES	87.4	39.7	74.1	43.6	71.6	29.9
IE	91.8	59.5	66.6	50.2	31.5	6.6
IT	87.4	44.1	81.5	41.1	51.3	19.6
CY	82.3	44.7	4.70	49.7	35.4	33.3
LT	80.7	38.8	47.0	22.8	50.1	28.2
HU	77.5	34.7	71.5	36.9	25.6	10.4
NL	88.5	65.5	75.1	58.1	53.7	32.9
AT	93.7	70.8	74.6	49.9	54.8	27.1
PL	85.0	43.8	58.4	33.5	27.8	26.6
PT	77.3	29.4	46.5	32.8	48.6	20.0
SI	93.1	58.0	68.5	40.1	61.8	25.1
SK	71.3	46.7	20.1	31.0	24.8	18.7
FI	97.1	75.4	87.0	65.6	70.9	37.1
SE	95.9	82.1	87.9	65.5	74.7	36.2
UK	86.6	66.3	90.0	43.5	44.1	26.5
BG	61.8	24.9	35.7	16.0	28.4	13.3
RO	52.2	18.7	15.5	14.4	7.0	7.6
NO	85.5	61.5	74.3	56.7	60.3	24.5
LU	89.8	59.5	75.6	56.2	48.0	42.5
LV	74.1	32.7	41.9	23.1	44.8	20.7
EU25	**89.9**	**57.7**	**75.7**	**44.7**	**52.1**	**28.8**

Table 18. Full data set of the 26 European countries and the EU25 aggregate for the construction of the use e-business readiness index with imputed missing values in shaded background. The values are expressed as percentages

Countries	*Indicators*					
	b1	*b2*	*b3*	*b4*	*b5*	*b6*
BE	40.8	17.5	50.1	13.8	82.2	1.20
CZ	19.0	10.6	31.1	10.7	73.9	1.22
DK	28.0	25.2	35.8	10.5	84.7	3.8
DE	47.0	17.6	38.4	13.9	66.7	2.6
EE	31.6	8.0	27.7	4.9	86.0	0.4
EL	13.9	5.7	39.1	9.0	62.1	1.2
ES	3.2	2.4	13.5	5.0	79.6	0.3
IE	33.0	18.6	28.7	13.8	67.1	1.7
IT	21.7	9.78	38.7	23.2	65.5	0.3
CY	14.2	5.2	34.8	14.9	44.9	1.4
LT	13.1	4.9	19.3	6.6	69.9	0.3
HU	14.3	6.3	33.9	5.2	45.5	0.8
NL	21.5	16.9	58.9	20.5	63.7	2.5
AT	21.8	11.6	32.8	14.8	79.1	1.3
PL	9.1	4.4	15.5	10.4	55.0	0.4
PT	8.0	6.2	33.1	24.0	55.8	0.6
SI	16.7	14.9	20.5	6.2	86.6	0.7
SK	2.8	6.2	21.2	7.1	57.3	0.5
FI	18.6	17.3	60.7	16.0	84.2	3.2
SE	38.4	20.5	24.9	8.9	80.8	4.0
UK	49.5	26.6	11.3	8.5	71.7	1.08
BG	4.0	2.7	6.0	2.1	25.8	0.4
RO	10.2	3.03	49.8	36.3	22.8	0.0
NO	27.0	12.6	30.4	12.0	66.4	4.2
LU	33.9	10.6	14.9	4.01	66.1	0.36
LV	1.23	0.63	14.9	4.01	66.1	0.36
EU25	**26.7**	**13.5**	**29.6**	**13.1**	**68.3**	**1.43**

(Note: The data is provided by Eurostat. For index values b3 and b4, some countries, like RO, show rather high values. RO was asked to verify this data, but this resulted no revisions. ICT surveys are conducted ny National Statistical Institutes and the the survey questions and forms are translated and accomodated to national needs. This process may introduce some variations in the process. Due to different wording of the questions for indicators b3 and b4 used by ONS, such index values for UK cannot be compared with the remaining countries (see footnote 1)).

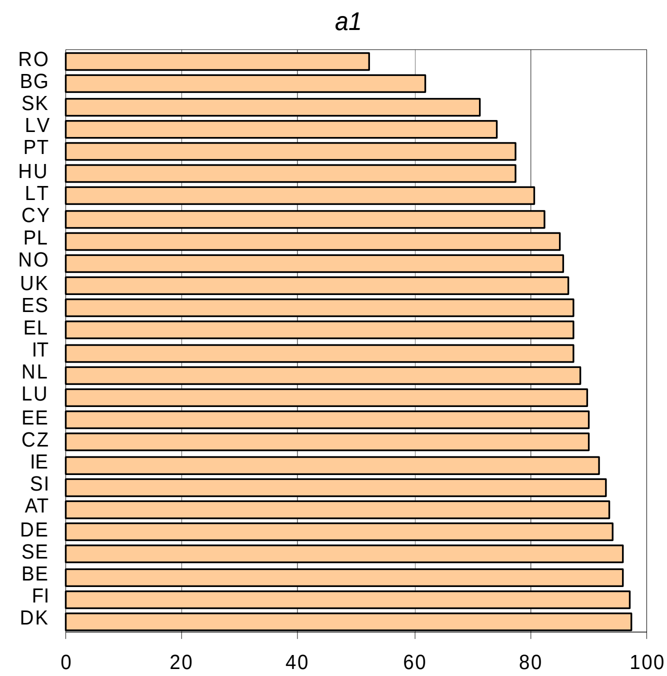

Figure 6. ICT adoption - component *a1*: Percentage of enterprises that use Internet, 2004 ordered data

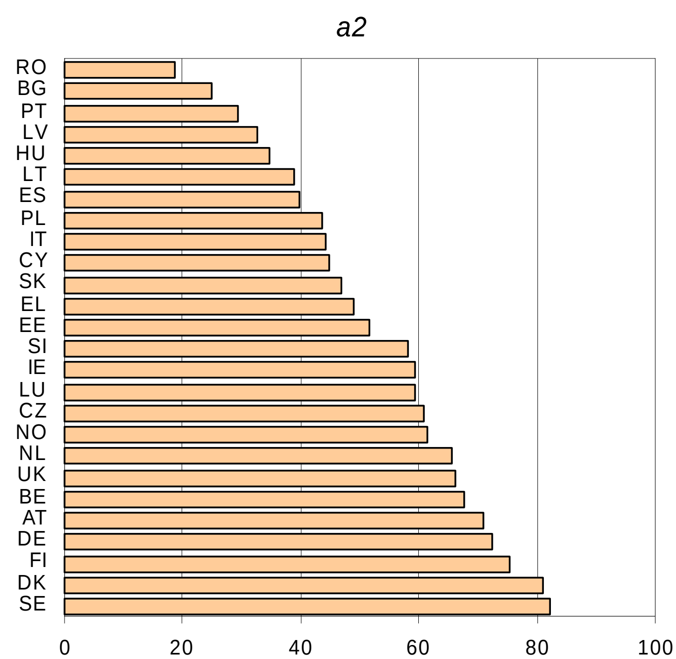

Figure 7. ICT adoption - component *a2*: Percentage of enterprises that have web/home page, 2004 ordered data

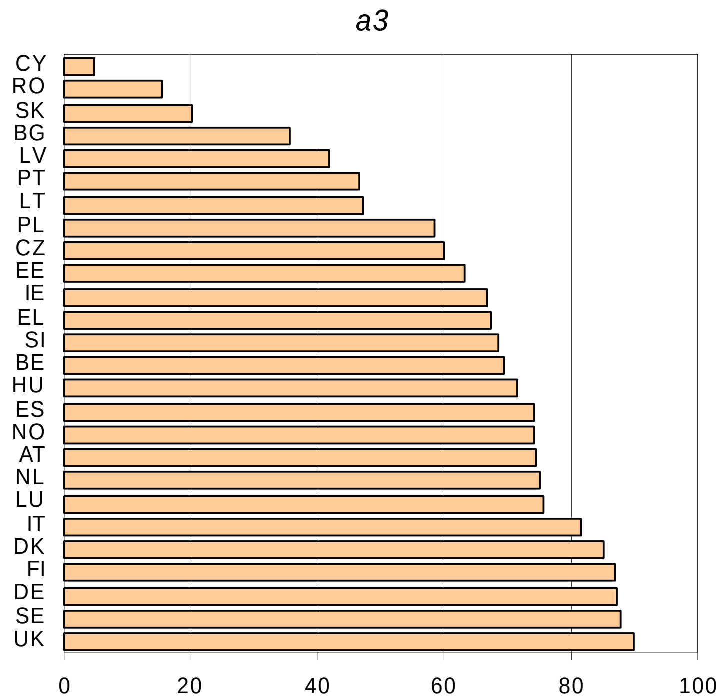

Figure 8. ICT adoption - component *a3*: Percentage of enterprises that use at least two security facilities at the time of the survey, 2004 ordered data

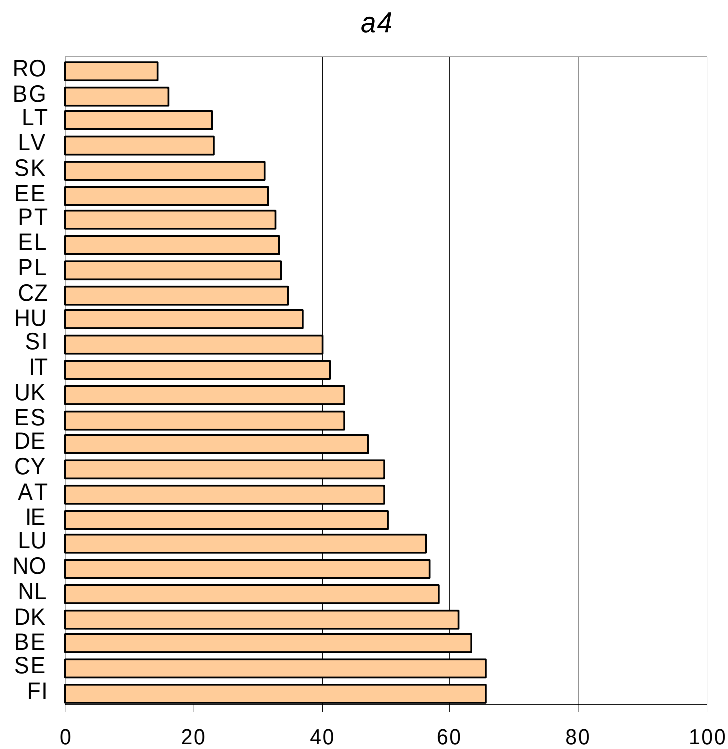

Figure 9 ICT adoption - component *a4*: Percentage of total number of persons employees using computer with their normal work routine, 2004 ordered data

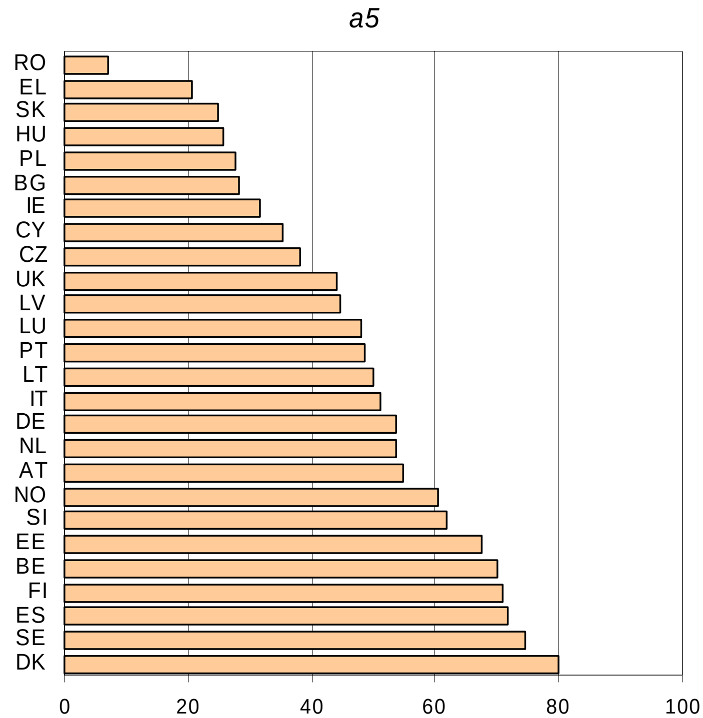

Figure 10 ICT adoption - component *a5*: Percentage of enterprises having broadband connection to internet, 2004 ordered data

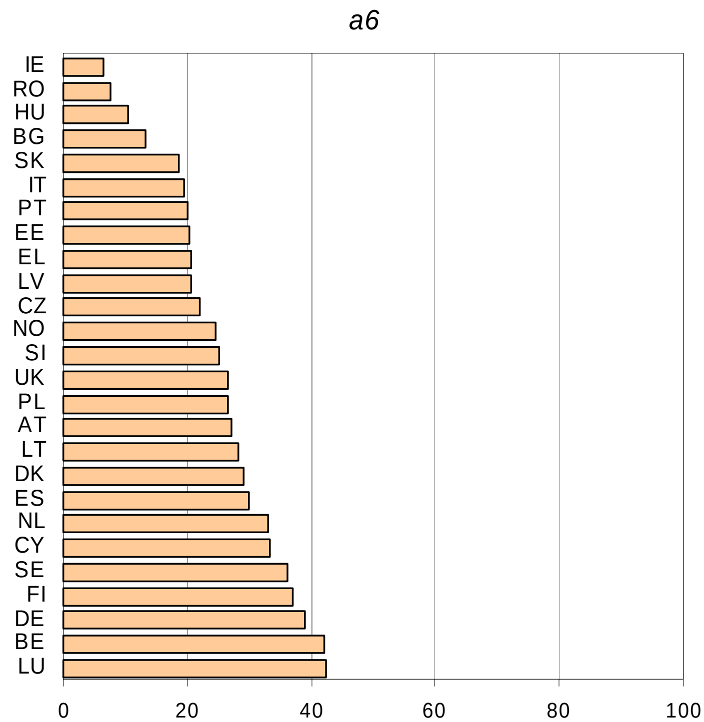

Figure 11 ICT adoption - component *a6*: Percentage of enterprises with LAN and using an Intranet and Extranet, 2004 ordered data

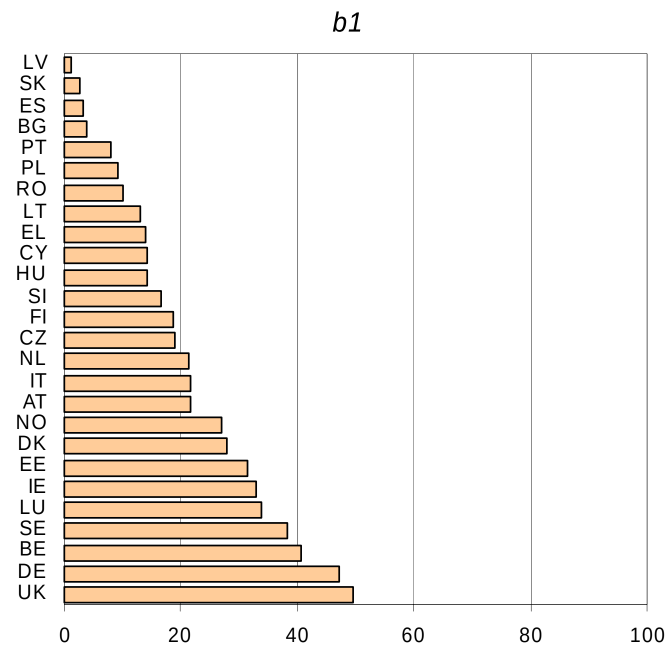

Figure 12. ICT Use - component *b1*: Percentage of enterprises that have purchased products / services via the internet, EDI (Electronic Data Interchange) or any other computer mediated networks where these are more than 1 % of total purchases of the enterprise, 2004 ordered data

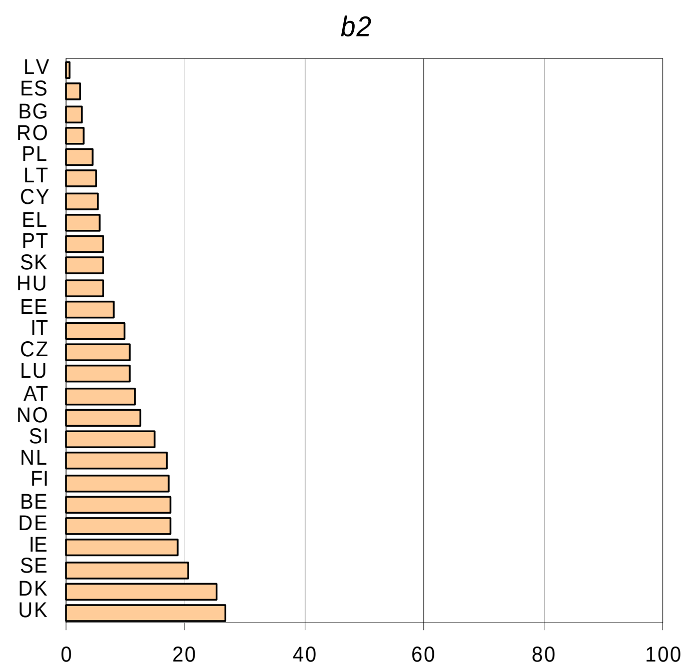

Figure 13. ICT Use - component *b2*: Percentage of enterprises that have received orders via the internet, EDI (Electronic Data Interchange) or any other computer mediated networks where these are more than 1 % of total orders of the enterprise

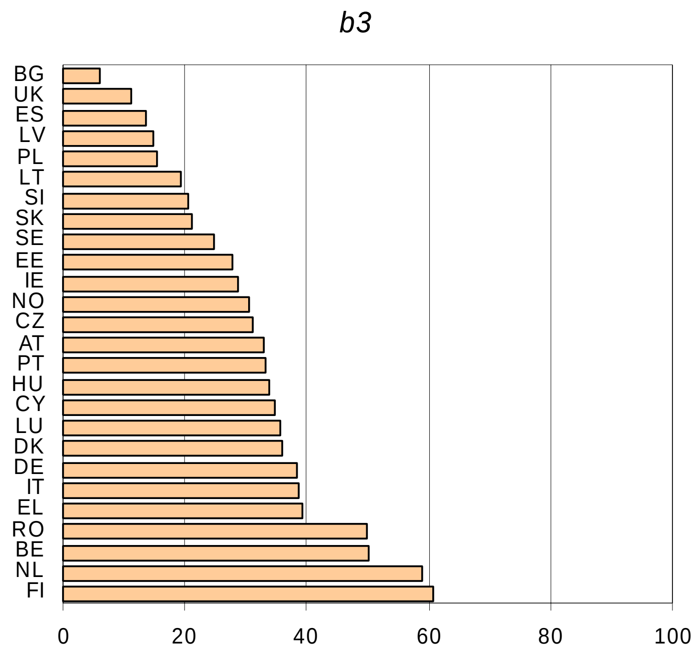

Figure 14 ICT Use - component *b3*: Percentage of enterprises whose IT systems for managing orders or purchases are linked automatically with other internal IT systems, 2004 ordered data

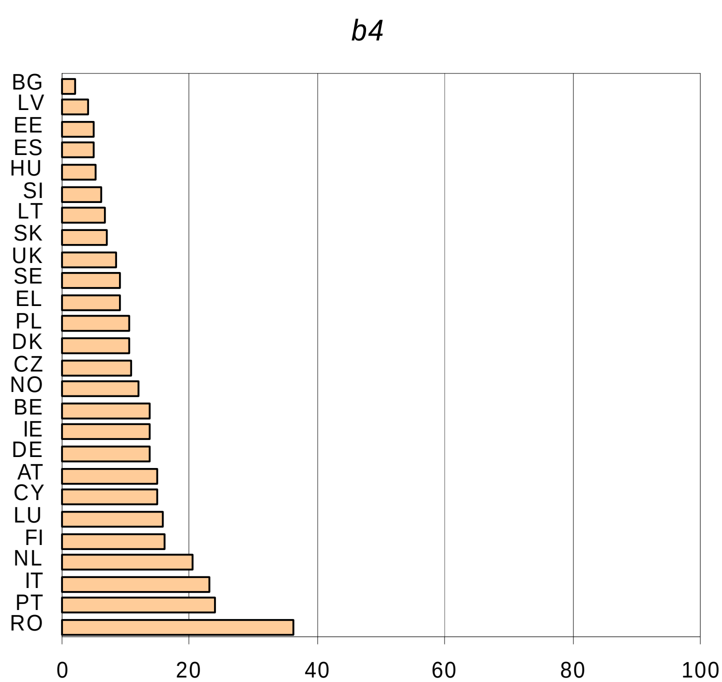

Figure 15 ICT Use - component *b4*: Percentage of enterprises whose IT systems are linked automatically to IT systems of suppliers or customers outside their enterprise group, 2004 ordered data

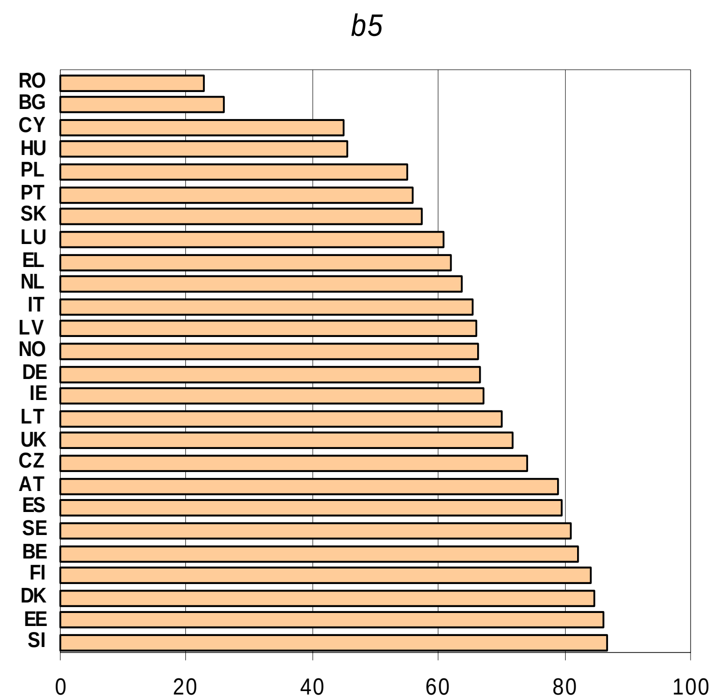

Figure 16 ICT Use - component *b5*: Percentage of enterprises with Internet access using the Internet for banking and financial services 2004 ordered data

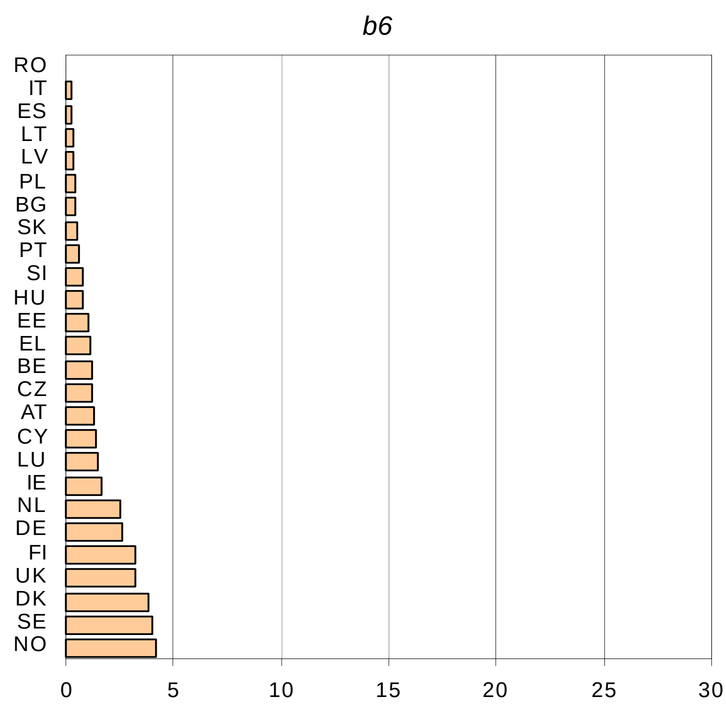

Figure 17 ICT Use - component *b6*: Percentage of enterprises that have sold products to other enterprises via a presence on specialised internet market places. 2004 data

5.2. Technologies employed and levels of e-readiness: comparisons with the 2003 survey data

One measure of the change in the level of e-readiness is the number of business that reported the use of personal computer or the use of internet or similar devices. The values reported in this section are averages over the 14 European Member States for which data are available in both 2003 and 2004.

In 2004, 52 % of businesses reported the use of PCs (*a4*) with no substantial increase compared with 2003. This can be seen also in Figure18, where the values of each indicator are reported for the 2003 and 2004 survey for those countries for which the data where available for both years. The number of business with internet access (*a1*) stands at 91% in 2004, compared with 85 per cent in 2003.

The number of businesses reporting broadband connections (*a5*) rises from 48% in 2003 to 59% in 2004. In the same year, the number of businesses that have a web site (*a2*) rises to 63% (60% in 2003). Local Area Networks (LAN) and intranet and extranet connections (*a6*) were used by 30% of businesses in 2004 and by 28% in 2003. Improved securities problems and hacker attacks have resulted in a near 10% rise in the number of businesses reporting to use at least two securities facilities when compared with 2003.

More businesses reported that they have sold product or services on-line (*b1*) with 28% of businesses in 2004 and 17% in 2003. Referring to the number of businesses that have a web site (63 %), the fact that less than 25% of businesses sell on line suggests that most of them use their web site for purposes other than selling, e.g. products and company information. The number of businesses using the internet for banking and financial services rose from 67% in 2003 to 72% in 2004.

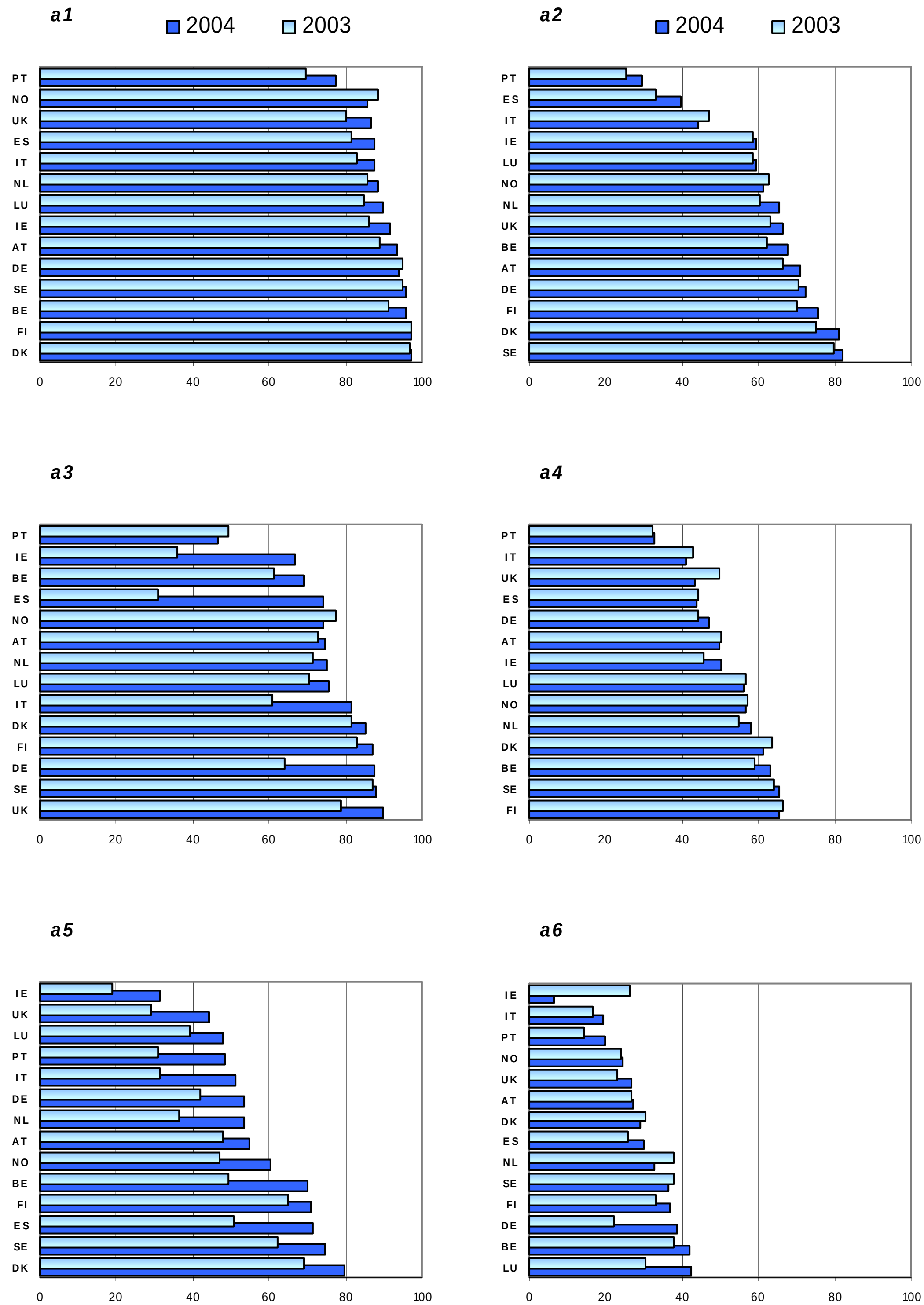

Figure18 Bar chart for each component of the category ICT adoption for 14 European countries, 2003 and 2004 data. The values are expressed as percentage and ordered from the lowest to the highest according to the 2004 data

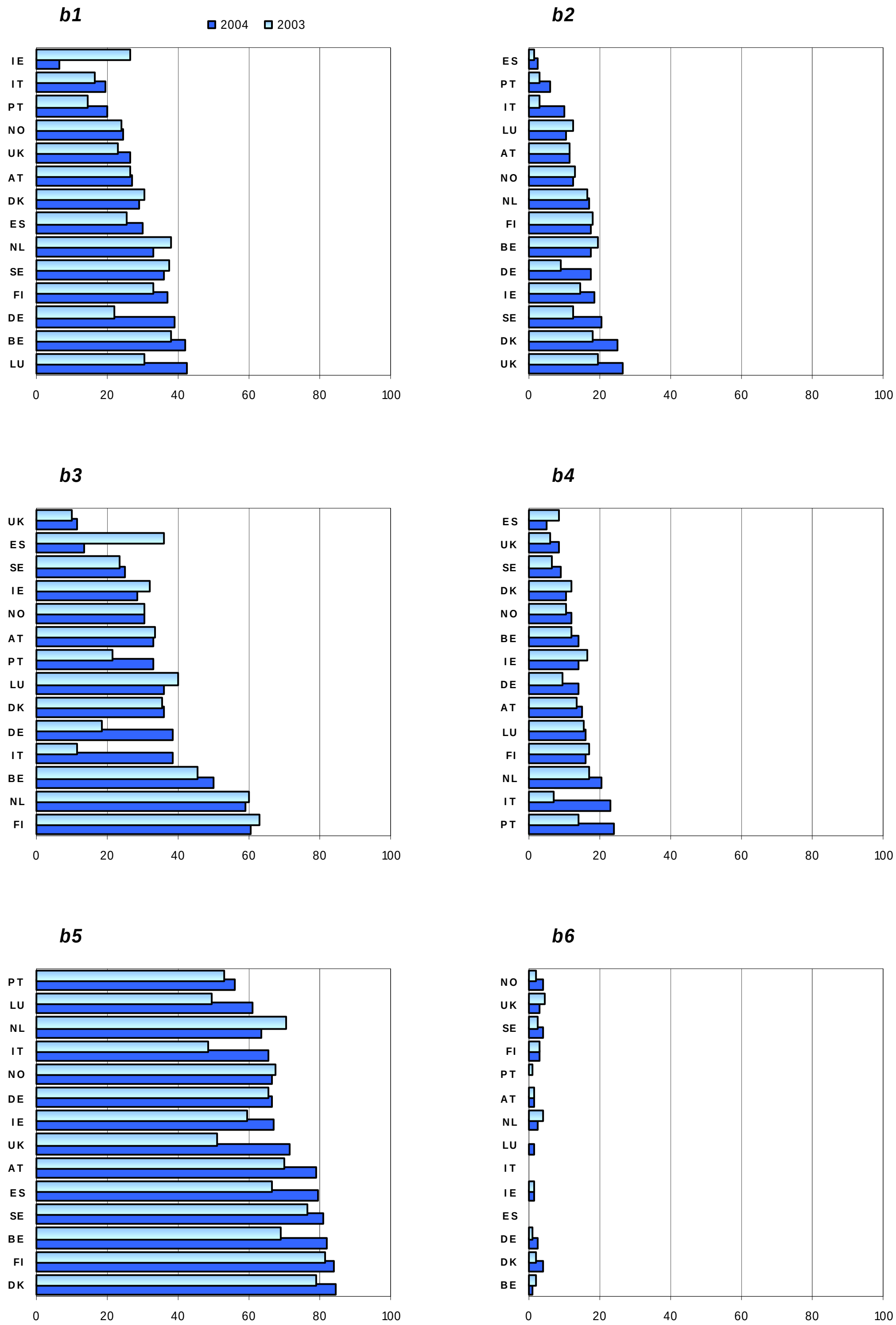

Figure 19 Bar chart for each component of the category ICT usage for 14 European countries, 2003 and 2004 data. The values are expressed as percentage and ordered from the lowest to the highest according to the 2004 data.

6. PRINCIPAL COMPONENT ANALYSIS

Principal component analysis is a useful tool when investigating the relationship between the 12 indicators of the e-readiness. The objective is to capture those features in the data that help better understand an issue of interest or to discover interesting new patterns among the relationships between variables. We present the results for the 12 indicators analysed jointly and then we make a separate analysis for each group.

We report the correlation matrix Table 19 of the input data for the principal component analysis showed in Table 17 and Table 18. Correlation analysis reveals that fourteen pairs of indicators have a correlation coefficient that is higher than 0.70.

The principal component analysis yields the following summary. Table 20 is the table of the total variance explained which shows the eigenvalues of the covariance matrix. Our results indicate the existence of three principal components for the 12 indicators, which explain more than 80% of the variation in the data. The choice of the right number of component is also highlighted by the screen-plot (Figure 20) where the eigenvalues are plotted in decreasing order. The point where the transition from strong decrease to more gradually decline occurs is often chosen to decide the number of components. From Table 20 it can be seen that the first principal component (PC) explains the 58% of the total variance and the second PC explains the 15% of the total variance and the third explain the 8% of the total variance, so that jointly they explain the 82% of the total variance. From the results it is possible to represent the units (countries) in a reduced space dimension with three principal components with a limited loss of information, the remaining part of the variance is the residual not explained part.

After deciding to keep three principal components in the model, the model was repeated in order to re-allocate the indicator loadings on the selected components. For better interpretability of the results we chose a varimax rotation, which rotates the principal components in three-dimensional space in such a way that maximizes each indicator's loadings on only one of the three directions. The rotated component matrix is shown in Table 21.

Table 19 Correlation matrix for the data in Table 17 and Table 18

a1	1										
a2	0.86	1									
a3	0.76	0.71	1								
a4	0.80	0.85	0.63	1							
a5	0.72	0.65	0.62	0.64	1						
a6	0.63	0.63	0.40	0.67	0.64	1					
b1	0.61	0.73	0.63	0.61	0.41	0.45	1				
b2	0.67	0.86	0.68	0.71	0.52	0.39	0.82	1			
b3	0.23	0.31	0.17	0.47	0.17	0.27	0.23	0.27	1		
b4	-0.20	-0.09	-0.14	0.08	-0.20	-0.04	0.07	0.05	0.67	1	
b5	0.86	0.73	0.66	0.58	0.82	0.50	0.44	0.55	0.06	-0.32	1
b6	0.55	0.80	0.58	0.75	0.52	0.44	0.65	0.79	0.25	-0.03	0.41
Indicators	*a1*	*a2*	*a3*	*a4*	*a5*	*a6*	*b1*	*b2*	*b3*	*b4*	*b5*

Table 20 Determination of the number of principal components – Total, percentage and cumulative variance explained

Component	*Initial Eigenvalues*		
	Total	*% of Variance*	*Cumulative %*
1	6.939	57.822	57.822
2	1.875	15.626	73.448
3	1.009	8.412	81.859
4	.609	5.079	86.938
5	.432	3.597	90.535
6	.347	2.894	93.429
7	.296	2.470	95.899
8	.176	1.471	97.370
9	.137	1.144	98.514
10	.106	.882	99.396
11	.038	.317	99.712
12	.035	.288	100.000

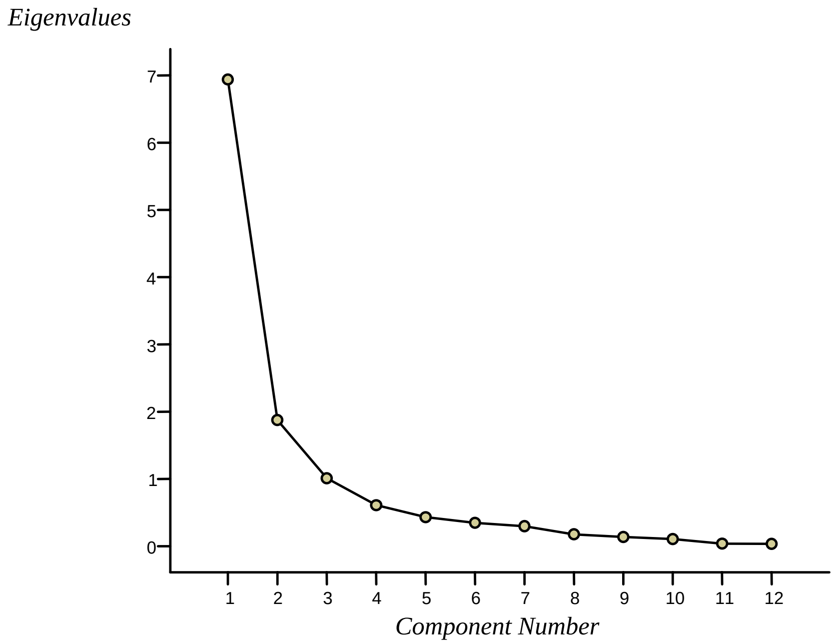

Figure 20 Screen plot of eigenvalues v. number of principal components

Table 21 Rotated component loading matrix: the values are in red(**) if they are greater or equal to 0.755, in blue(*) if they are greater or equal to 0.50. Rotation method: varimax

Indicators	*Principal Component*		
	1	*2*	*3*
a1	0.517(*)	0.779(**)	-0.038
a2	0.754(**)	0.585(*)	0.068
a3	0.656(*)	0.497	-0.094
a4	0.602(*)	0.634(*)	0.296
a5	0.287	0.848(**)	-0.080
a6	0.196	0.774(**)	0.200
b1	0.854(**)	0.205	0.096
b2	0.908(**)	0.277	0.088
b3	0.157	0.205	0.894(**)
b4	0.011	-0.228	0.896(**)
b5	0.337	0.819(**)	-0.223
b6	0.824(**)	0.274	0.087

From Table 21 as expected the most indicators would load highly on the first component because they have the highest eigenvalues. Since the eigenvalues are calculated using the correlation matrix of the input data they represent the variance explained by each principal component.

The results demonstrate several important characteristic of the e-readiness index. Firstly it is a multidimensional index, three components instead of two are required to capture at least the 82% of the variation in the data. Secondly, the analysis of the component loading matrix in Table 21 suggests that some indicators relate more closely to each other than others. Thirdly, since no indicator has low loadings on all three principal components, we can conclude that none of them is redundant for the e-readiness index.

The first principal component is determined predominantly by indicators *b1*, *b2* and *b6* which relates with purchase or receive orders via internet which are linked with having a web/home page (*a2*). Aside from these, principal component 1 is also dominated by the securities facilities (*a3*) the number of people using a computer (*a4*) and use of internet (*a1*).

Other interesting findings exist for component 2 and 3. While the second component correlate strongly with several adoption indicators and just with one use indicator (*b5*), the last component is determined by only two use indicators (*b3* and *b4*). Given that all axes are orthogonal to each other, this means that the indicator loading on principal component 3 measure distinctly different aspects of the ICT usage than are captured by component 1 and 2. The last component highlights clearly the importance of the links of the IT systems with other internal systems or with systems outside the enterprise group.

The second important application of principal component analysis consists in its ability to determine the statistical weights of the indicators which have been used for the calculation of the e-readiness index in Section 4. The principal component weights showed in Table 12 have been calculated performing the principal component analysis for the indicators of the two categories separately. For the first group - the ICT adoption indicators -just one principal component is needed to explain the 73% of the total variation in the data. Using the varimax rotated component loading matrix the factor loading of each indicator is squared and then divided by the explained variance (see Johnson and Wichern (2002), Nardo *et al*. 2005) and then re-scaled so that the final weights add up to one. If an indicator has comparative strong capacity to explain the variation in the data, it would be expected to receive a relatively high weight, and vice versa.

For the category usage of ICT the results indicate that two principal components for the six indicators explain more than 78 % of the total variation in the data. After the varimax rotation the first principal component is determined by all the indicators except for *b3* and *b4* which are correlated mainly with the second principal component. The weights showed in Table 12 are then obtained as illustrated above.

7. CONCLUSIONS AND NEXT STEPS

The 2005 European e-business readiness index, evaluated using data from the 2004 European enterprise survey, is a useful mechanism for comparing e-business adoption and use by firms in the various European countries.

In the calculation of the index we made an extensive use of statistical modeling and analysis techniques to (*i*) impute missing data, (*ii*) investigate similarities and differences among the European countries with respect to their business performance, (*iii*) understand better the relationships between the sub-indicators, (*iv*) rigorously test the sensitivity of the index to the implicit and explicit assumptions and methodological choices made. Such results and comparisons have facilitated the interpretation of the index.

The results indicate that the participating countries form three categories with regard to e-readiness: the more advanced countries, the in-between ones, and those needing further impetus for a widespread adoption and use of ICT. The Nordic countries, Sweden, Denmark and Finland occupy stably the top ranks of the adoption index and have consistently done so in the previous 2004 index. At the bottom of the rankings there are Eastern Europe countries such as Latvia, Slovakia, Bulgaria and Romania for which the data were not available in the previous 2004 index.

Quantitatively, the country scores are much lower for use than adoption, as the percentage of the firms that are using e-business are much less than those that have adopted it. Belgium overtakes the Scandinavian countries in the ICT usage index. Romania is using very efficiently its very limited infrastructures: given its minimum level of adoption, its use of e-business is at the level of Portugal and Greece[9]. Among the New Member States, Hungary is top performer; also Estonia, Slovenia and Czech Republic perform very well as they are approaching parity with the other west European countries in term of ICT adoption and usage.

Uncertainty and sensitivity analysis allow us to assess the impact in the two main methodological sources of uncertainty: variability in the imputation of missing data, equal versus principal component analysis or expert opinion weighting of indicators. Among the main findings we outline that the top ten ranking countries in the e-readiness adoption index all have modest volatility. This small degree of sensitivity implies a robust evaluation of performance for those countries with respect to the weighting scheme. The United Kingdom and Hungary's high volatility is mainly attributed to imputation and its combined effect with choice of the weighting scheme.

The same can be said for the top ten countries in the e-readiness use index with the exception of Sweden, Italy and United Kingdom. For the last two countries we have two imputed indicators values, also Czech Republic and Romania which have quite high volatility have two imputed values each.

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[9] Please see also the note on the table 17.

The imputation appears to be very influential for countries where there are two missing data and the analysis shows only a small sensitivity to the weighting assumption.

As mentioned in the previous report, we consider that the components of the e-business readiness need to be revised in view of the i2010 initiative, as some important elements in the category adoption and use are currently missing. A critical revision of the conceptual model of e-business is currently ongoing between Eurostat, the Joint Research Centre and the Directorate General Enterprise and Industry and the Directorate General Information Society.

8. APPENDIX A: METHODOLOGY

8.1. Composite Indicators

A composite indicator Y_c for a given country *c* is a simple linear weighted sum of *k* normalized sub-indicators $I_{c,i}$, $i= 1,\ldots,k$, $c=1,\ldots,p$ with weights w_i

$$Y_c = \sum_{i=1}^{k} w_i I_{ic} \qquad (1)$$

where $\sum_{i=1}^{k} w_i = 1$ and $0 \le w_i \le 1$ for all $i=1,\ldots,k$ and $c=1,\ldots,p$

Linear aggregation method is useful when all sub-indicators have the same measurement unit. Several other less widespread aggregation techniques have been proposed in the literature, some of them are described in Saisana and Tarantola (2002). An extensive discussion on composite indicators can be found in a joint OECD/JRC handbook on constructing composite indicators (Nardo *et al*. (2005)).

The construction and the evaluation of the composite indicator is made of several steps one of which is the data selection. If the data set contains missing values for some countries on some sub-indicators a first step is to impute missing data. The second step is to decide upon the weighting scheme for the sub-indicators and to assign the weights values. A third step is the calculation of the CI and then the application of the uncertainty analysis (UA) and the sensitivity analysis (SA) to gauge the robustness of the CI and to improve the transparency of the process.

8.2. Multiple imputation of missing data

We assume that the missing values, which can be present in some sub-indicators, depend on the observed values (Missing At Random assumption, MAR) and in order to minimize the uncertainty due to the missing values we use a multiple imputation technique (Rubin, 1978). We use in particular the Markov Chain Monte Carlo (MCMC) based imputation algorithm (Little and Rubin, 2002), which assumes a multivariate normal distribution of the full data set and generates imputation from the posterior distribution of the missing data given the observed data using a Bayesian approach. The missing values are imputed iteratively using a sequence of Markov chains. The procedure generates *M* imputed data sets from which we derive *m* imputed values for each missing value. The standard deviation of the *m* values reflects the *a priori* uncertainty over the true value of each missing number and the average over the *m* estimates is used as imputed value to complete the final data set of sub-indicators.

8.3. Selection of weights

Different methods to determine the weights for a set of sub-indicators can be found in the literature: they include equal weights, multivariate methods, judgment based on expert opinions and budget allocation schemes (for a review see Nardo *et al*. (2005) and Moldan *et al*. (1997)). In most cases there exists no unique set of weights and it is useful to take all of them into account as they influence heavily the outcome of the CI and country rankings.

We consider in particular three types of weighting schemes: equal weights, principal component analysis and budget allocation. *Equal weighting* is based on the hypothesis that no objective mechanism exists to determine the relative importance of the different sub-indicators. Weighting based *principal component analysis* only intervenes to correct for the overlapping information of two or more correlated indicators. On the other hand the *budget allocation* method can be used to elicit weights, based on the opinion of experts that know policy priorities and theoretical backgrounds, so as to reflect the multiplicity of stakeholders' viewpoints. Each expert is given a "budget" of 100 points, and is asked to distribute the budget over the sub-indicators by allocating more points to those indicators which are felt as more relevant to the phenomenon.

Contrarily to the common use of average weights, where the information from the single expert vanishes, we believe it is important to acknowledge the identity of the experts in the evaluation of the CI and to analyse how much the country rankings are influenced by the choice of the experts and by the other two types of weighting schemes.

8.4. Uncertainty analysis

In the present context, the uncertainty on the estimation of the output Y_c, the score or the ranking of each country, includes the variability in the weighting scheme, the selection of the expert and the uncertainty due to the imputation of the missing data. We translate these uncertainties into a set of input factors and we perform multiple evaluation of (1) based on the Monte Carlo approach proposed by Saisana *et al*. (2005a) and applied also by Saisana *et al*. (2005b) in order to take into account all uncertainty sources simultaneously to capture all possible effects among input factors. It consists of the following steps:

- A probability distribution function (PDF) is assigned to each input factor X_j, $j=1,\dots,J$. One of the input factors is a trigger to select the weighting scheme: one of the expert of the budget allocation weights, equal or principal component analysis weights. Other factors are random variables, according with the number of multiple imputations, with a multivariate normal distribution with mean and standard deviation based on the multiple imputation results to reflect the uncertainty of the imputation process. If some values resulting from the imputation fall outside the range (0-100) % of plausible values, we suitably truncated the distribution such that the values remain in that range.

- $\mathbf{X}^l$ combinations of size N of input factors are generated randomly according to a sample strategy based on Sobol' sequences vectors (LP_τ sequences, Sobol' (1967)) which are quasi random sequences to produce sample points that best scan the entire space of possible combinations between input factors.
- The composite indicator is then computed N times for each trial sample X^l generating values for the scalar output variable of interest Y^l where Y^l is the rank assigned by the index to each country.
- The sequence of Y^l is used to evaluate the empirical PDF of the output for each country.

8.5. Sensitivity analysis

At this step it is useful to use sensitivity analysis to quantify how much of the uncertainty in the CI is due to the weighting scheme and to the imputation process. We use a generalization of variance based techniques proposed in Saltelli (2002), (a review is also offered in Saltelli *et al.* 2004) which are model free techniques of sensitivity analysis. In such approach the importance of a given input factor X_j can be measured via the so called sensitivity measure, which is defined as the fractional contribution to the output variance due to the uncertainty in X_j. For k independent input factors, the sensitivity measures can be computed using the decomposition formula for the total output variance *V(Y)*

$$V(Y) = \sum_j V_j + \sum_j \sum_{t>j} V_{tj} + \ldots + V_{12\ldots J} \qquad (2)$$

where

$V_j = V_{X_j}(E_{\mathbf{X}_{-j}}(Y|X_j))$ and $V_{jt} = V_{X_j X_t}(E_{\mathbf{X}_{-jt}}(Y|X_j, X_t)) - V_{X_j}(E_{\mathbf{X}_{-j}}(Y|X_j)) - V_{X_t}(E_{\mathbf{X}_{-t}}(Y|X_t))$
are the first order and second order conditional variances.

Note that in computing $V_{X_j}(E_{\mathbf{X}_{-j}}(Y|X_j))$, the expectation $E_{\mathbf{X}_{-j}}$ would call for an integral over $\mathbf{X}_{-j}$, i.e. over all factors but X_j, including the marginal distributions for these factors, while the variance V_{X_j} would imply a further integral over X_j and its marginal distribution.

A first measure of the fraction of the unconditional output variance *V(Y)* that is accounted for by the uncertainty in X_j, is the first order sensitivity index for the factor X_j defined as

$$S_j = V_j / V(Y).$$

Terms above the first term in equation (2) are known as interactions. A model without interactions among its input factors is said to be additive. In this case, $\sum_{i=1}^{k} S_i = 1$ and the first order conditional variances are all what we need to know to decompose the model output variance.

Another compact sensitivity measure is the total effect sensitivity measure, which concentrates in one single term all the interactions involving a given factor X_j. To exemplify, for a model of $k = 3$ independent factors, the three total sensitivity indices would be:

$$S_{T1} = \frac{V(Y) - V_{X_2 X_3}(E_{X_1}(Y|X_2, X_3))}{V(Y)} = S_1 + S_{12} + S_{13} + S_{123}.$$

And analogously:

$$S_{T2} = S_1 + S_{12} + S_{23} + S_{123}$$

$$S_{T3} = S_1 + S_{13} + S_{23} + S_{123}.$$

We use the Sobol' method (Sobol', 1993) in its improved version due to Saltelli *et al*. 2004 to estimate the first and the total order sensitivity measure.

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Abstract

Assessment of the eEurope 2005 Action Plan Benchmarking Index "E-Business Readiness Composite Indicator" using data collected by National Statistical Institutes and harmonised by Eurostat, using surveys "ICT usage of enterprises", with reference years 2003 and 2004. This report contains data from 26 countries as collected in 2004 and as reported by Eurostat in June 2005. Performed analyses include robustness analysis, uncertainty and sensitivity analysis for two categories of ICT (Adoption and Use), univariate analysis of basic indicators; principal component analysis and finally assessment of resulted country rankings and methodological notes.

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