Measuring innovation efficiency

INNO-Metrics Thematic Paper

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Executive summary

Following the Lisbon strategy and the Barcelona target of an R&D intensity of 3% in 2010, many countries have taken steps to increase their innovation efforts. Innovation efficiency is related to the concept of productivity. Innovation efficiency is improved when with the same amount of innovation inputs more innovation outputs are generated or when less innovation inputs are needed for the same amount of innovation outputs. Although innovation is not a linear process where inputs automatically transfer into outputs, it is worthwhile to examine differences in efficiency by assuming that efficiency can be defined as the ratio of outputs over inputs. In the European Innovation Scoreboard (EIS) the indicators are divided into 3 innovation input dimensions covering 15 indicators and 2 innovation output dimensions covering 10 indicators. Innovation efficiency will be measured by comparing the ratio between the composite indicator scores for one or more input dimensions and one or more output dimensions. Inputs and outputs can be plotted in a multidimensional space where the most efficient performers will be on or close to the 'efficiency frontier'. The larger the distance to this frontier, the smaller will be the level of innovation efficiency. In the analysis we have employed a constant-returns-to-scale output-oriented DEA (Data Envelopment Analysis) on all combinations of the 3 input and 2 output dimensions. The analyses were done separately for the most innovative countries – as identified in the EIS 2007 report – (Sweden, the innovation leaders and innovation followers) and for the least innovative countries (moderate innovators and catching-up countries). The main results are presented in terms of the efficiency of transforming all innovation inputs into the Applications output dimension and the Intellectual property output dimension.

Although the concept of innovation efficiency is a simplification of the innovation process, it may be a useful tool for guiding policy decisions. In particular for countries with low innovation efficiency an increase in the inputs (e.g. research, education) may not result in a proportionate increase in outputs. Therefore, it may be more effective for such countries to focus on policies that support firms generating new Applications and Intellectual Property, such as demand side measures, innovation management and Intellectual Property (IP) awareness. For countries with high efficiencies a different policy focus may be needed, and it may be more productive to invest in raising the inputs to the innovation process.

All *innovation leaders* (Sweden, Denmark, Finland, Germany, Israel, Japan, Switzerland, the UK and the US) except Sweden have above average efficiency in transforming inputs into Applications. Despite its overall leadership in innovation performance, Sweden has the lowest efficiency in Applications of these countries indicating that it has room to make improvements here. Germany and Switzerland show high efficiency in generating Intellectual property. Some of the innovation leaders, in particular the UK, have relatively low efficiency in transforming inputs into Intellectual property outputs. This may be because the type of their innovation activities does not lead to formal IPRs but it could also indicate that these countries could be creating more IPRs given their level of inputs.

The *innovation followers* (Austria, Belgium, Canada, France, Iceland, Ireland, Luxembourg and the Netherlands) have above average efficiency in transforming inputs into Applications, with Luxembourg and Belgium showing highest efficiency rates. Only Austria, the Netherlands and Luxembourg show above average efficiency in Intellectual property, and hence Belgium, France and Iceland could seek to improve their efficiency rates by generating more IPRs from their innovation inputs.

The *moderate innovators* (Cyprus, Czech Republic, Estonia, Italy, Norway, Slovenia, Spain and Australia) show a range of different efficiencies combining all possible combinations of above or below average efficiency performance. Italy combines above average efficiency scores in both output dimensions. This result suggests that it may be

difficult for Italy to improve its innovation performance without increasing innovation inputs. Australia, Cyprus, Norway and Spain show above average efficiency in Intellectual property and the Czech Republic shows above average efficiency in Applications. Estonia and Slovenia combine below average efficiency in both Applications and Intellectual property.

The *catching-up countries* (Bulgaria, Croatia, Greece, Hungary, Latvia, Lithuania, Poland, Portugal, Romania and Slovakia) also show a variety of efficiencies in transforming innovation inputs into Applications. On Intellectual property efficiency all countries are significantly below average with the exception of Portugal. This may be because IPR is of less relevance for the innovative activities of these countries or that there is the potential to generate higher levels of IPR from the existing inputs. Some of these countries are also still in a process of replacing national patent applications by EPO patent applications which may explain their low Intellectual property efficiencies. For Slovakia and Romania the efficiencies for Applications are relatively high, suggesting that these countries need to increase inputs to increase performance in generating more Applications. The majority of catching up countries has below average efficiencies and this suggests that for these countries an important focus should be to further improve their innovation efficiencies.

Peer countries in efficiency terms can be identified as those countries with higher efficiency scores in either Applications or Intellectual property. For example, Austria's possible peer countries include Germany, Luxembourg, the Netherlands and Switzerland, which combine higher efficiency scores in both Applications and Intellectual property. The innovation policies implemented in these countries could be compared with those in Austria to identify options for policy improvements to improve the efficiency of transferring innovation inputs into outputs.

1. Introduction

Following the Lisbon strategy and the Barcelona target of an R&D intensity of 3% in 2010, many countries have taken steps to increase their innovation efforts. The concept of innovation efficiency is important for innovation policy. Innovation efficiency can be defined as the ability of firms to translate innovation inputs into innovation outputs. Although innovation is not a linear process where inputs automatically transfer into outputs, it is worthwhile to study inputs and outputs as separate dimensions of the innovation process and to explore the following questions: do countries differ in their degree of efficiency of transforming innovation inputs into outputs and have countries made improvements in their innovation efficiency.

Efficiency is an important concept, also in innovation, as investing in innovation is not a desired activity as such: it is the results or outputs of the innovation process which matter for society. One could even go one step further and state that ultimately only the effect on the economic performance of a country is important. The economic effects will not be analysed here, but future studies of innovation efficiency should also take this dimension into account. Innovation efficiency is related to productivity. Higher productivity is achieved when more outputs are produced with the same amount of inputs or when the same output is produced with less input. Innovation efficiency will here be defined similarly: innovation efficiency is improved when with the same amount of innovation inputs more innovation outputs are generated or when less innovation inputs are needed for generating the same amount of innovation outputs. Innovation efficiency can be thus be defined as the ratio of outputs over inputs. The ratio between the EIS composite index for inputs (education, investment in innovation, innovation activities at the firm level, etc.) and outputs (firm turnover coming from new products, employment in high tech sectors, patents, trademarks, designs etc.) provides a simple measure of this relationship for national innovation systems by assuming a linear relationship between inputs and outputs.

The use of intellectual property as an output dimension can be criticized as numbers of patents, trademarks and designs can also be seen as part of an intermediate innovation process, whereas it is the revenues earned from the use of patents, trademarks and designs in the production process or the licensing of these which represent final output. Data on the use of IP in the production process are however scarce and for data availability reasons we follow the approach in mainstream economic literature by treating intellectual property as an output of innovation.

The concept of innovation will be explored using concepts of technical efficiency and efficiency frontiers. In particular Data Envelopment Analysis (DEA) will be used to calculate the efficiency scores for the two output dimensions. Section 2 will explain the methodology. Section 3 will provide the statistical results for the efficiency scores using DEA. Section 4 will analyse the results. Policy conclusions will be made in section 5.

2. Methodology

2.1 Input and output dimensions

In the European Innovation Scoreboard (EIS) innovation performance is measured using data for 25 innovation indicators. These indicators are divided into 3 input dimensions covering 15 input indicators and 2 output dimensions covering 10 output indicators (cf. Table 1). Of the input dimensions, Innovation drivers measure the structural conditions required for innovation potential, Knowledge creation measures the investments in R&D activities and Innovation & entrepreneurship measures the efforts towards innovation at the firm level, Of the output dimensions, Applications measures the performance

expressed in terms of labour and business activities and their value added in innovative sectors, and Intellectual property measures the achieved results in terms of successful know-how.

TABLE 1: EIS 2007 INPUT AND OUTPUT INDICATORS

Innovation inputs

- Innovation drivers
  - S&E graduates per 1000 population aged 20-29
  - Population with tertiary education per 100 population aged 25-64
  - Broadband penetration rate (number of broadband lines per 100 population)
  - Participation in life-long learning per 100 population aged 25-64
  - Youth education attainment level (% of population aged 20-24 having completed at least upper secondary education)
- Knowledge creation
  - Public R&D expenditures (% of GDP)
  - Business R&D expenditures (% of GDP)
  - Share of medium-high-tech and high-tech R&D (% of manufacturing R&D expenditures)
  - Share of enterprises receiving public funding for innovation
- Innovation & entrepreneurship
  - SMEs innovating in-house (% of all SMEs)
  - Innovative SMEs co-operating with others (% of all SMEs)
  - Innovation expenditures (% of total turnover)
  - Early-stage venture capital (% of GDP)
  - ICT expenditures (% of GDP)
  - SMEs using organisational innovation (% of all SMEs)
  - Innovation outputs

Innovation outputs

- Applications
  - Employment in high-tech services (% of total workforce)
  - Exports of high technology products as a share of total exports
  - Sales of new-to-market products (% of total turnover)
  - Sales of new-to-firm products (% of total turnover)
  - Employment in medium-high and high-tech manufacturing (% of total workforce)
- Intellectual property
  - EPO patents per million population
  - USPTO patents per million population
  - Triad patents per million population
  - Community trademarks per million population
  - Community designs per million population

2.2 Efficiency frontier

Innovation efficiency can be measured by comparing the composite indicator scores for the EIS input and output dimensions. Inputs and outputs can be plotted in a multidimensional space where the most efficient performers will be on or close to the 'efficiency frontier'. Here we focus on the concept of technical efficiency, where, under the assumption that one can identify an 'efficiency frontier' of most efficient countries, the degree of technical efficiency is a measure of the degree of inefficiency or distance to that frontier[3]. In a two-dimensional graph with inputs on one axis and outputs on the other axis, the frontier can be visualised as the envelope curve connecting those dots with the most efficient output/input ratios (cf. Figure 1).

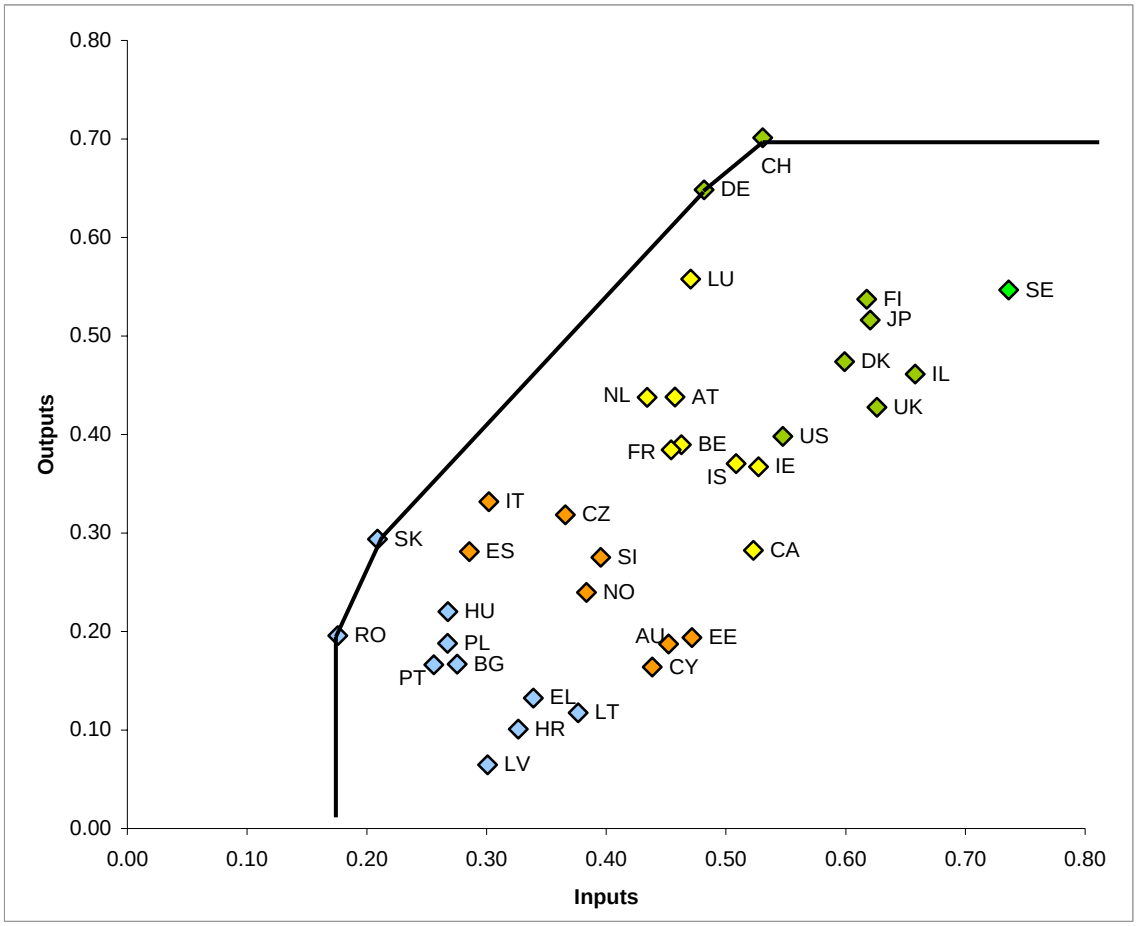
The countries shown in Figure 1 are classified into 4 groups following the country groupings as identified in the EIS 2007 report:

- The innovation leaders include Denmark, Finland, Germany, Israel, Japan, Sweden, Switzerland, the UK and the US of which Sweden is the most innovative country.
- The innovation followers include Austria, Belgium, Canada, France, Iceland, Ireland, Luxembourg and the Netherlands.

[3] For an introduction into and more detailed discussions of efficiency measures see Coelli, Timothy J., D.S. Prasada Rao, Christopher J. O'Donnell and George E. Battese, "An Introduction into Efficiency and Productivity Analysis", Springer, 2nd edition, 2005.

- The moderate innovators include Australia, Cyprus, Czech Republic, Estonia, Italy, Norway, Slovenia and Spain.
- The catching-up countries include Bulgaria, Croatia, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Portugal, Romania and Slovakia.

Figure 1 Efficiency frontier



Colour coding conforms with the groups of countries as identified in the EIS 2007 report: bright green is Sweden, green are the innovation leaders, yellow are the innovation followers, orange are the moderate innovators, blue are the catching-up countries (cf. the cluster results shown in Annex 6).
The bold line is the envelope curve or efficiency frontier which connects those countries with have the highest output-input ratios. The fact that Romania and Slovakia are on the efficiency frontier seems counter-intuitive and may be explained as a statistical artefact due to their overall low levels of absolute input and output performance.

The innovation leaders are performing better, on average, on inputs and outputs, followed by the innovation followers, the moderate innovators and the catching-up countries. But we also observe that for some countries output-input ratios are higher, these countries could be more efficient in transferring inputs into outputs.

The country groups as identified in the EIS 2007 – the innovation leaders, innovation followers, moderate innovators, catching-up countries – clearly make a distinction between the former and the latter country groups (cf. Annex 6 for the hierarchical cluster dendrogram). The innovation leaders and innovation followers make up the "most innovative" countries; the moderate innovators and catching-up countries make up the "least innovative" countries. As the most and least innovative countries clearly differ in their innovation performance, we will analyse the efficiency performance for each of these two groups separately.

Malta has been removed from the analysis because, due to its small size, the country is combining low input with high output scores leading to outlier efficiency scores (cf. Annex 1). Turkey has been removed from the analysis because the country is the least innovative country as measured by its 2007 SII score and Turkey does not statistically form part of the cluster combining the moderate innovators and catching-up countries.

2.3 Data Envelopment Analysis (DEA)

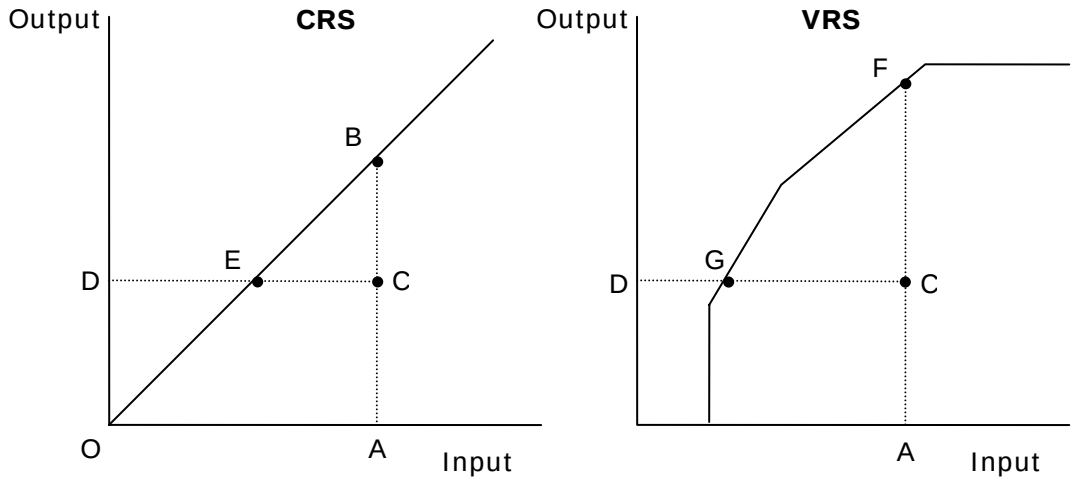
There are two main techniques for estimating the (unobservable) efficiency frontier: the parametric and the non-parametric approach. "The parametric approach assumes a specific functional form for the relationship between the inputs and the outputs as well as for the inefficiency term incorporated in the deviation of the observed values from the frontier. The non-parametric approach calculates the frontier directly from the data without imposing specific functional restrictions." (Herrera and Pang, 2005, p.3)

Lacking a clear underlying theoretical model of the innovation process we do not have a clear functional form relating inputs to outputs. We therefore adopt the non-parametric approach and in particular the Data Envelopment Analysis (DEA) technique. "DEA involves the use of linear programming methods to construct a non-parametric piece-wise surface (or frontier) over the data. Efficiency measures are then calculated relative to this surface." (Coelli et al., 2005, p.162). For the mathematical techniques involved in solving linear programming problems we refer to Chapter 6 in Coelli et al. (2005).

There are several approaches possible in DEA, one can distinguish between a constant returns to scale (CRS) technology and a variable returns to scale (VRS) technology and between an input-oriented version and an output-oriented version.

The difference between CRS and VRS is shown in Figure 2. With CRS there is a linear relation between inputs and outputs: outputs increase with the same percentage as inputs. With VRS, outputs can increase with a higher percentage, the same percentage, or a lower percentage depending on the respective section of the efficiency frontier.

Figure 2 CRS and VRS, input- and output-oriented innovation efficiency



The input-oriented technical efficiency approach looks at by how much input quantities can be reduced without changing the output quantities. The output-oriented technical

efficiency approach alternatively looks at by how much output quantities can be increased without changing the input quantities. The difference is shown in Figure 2. The diagonal line in the left-hand Figure 2 gives the CRS efficiency frontier, point C reflects an inefficient country combining below optimal levels of inputs OA and outputs OD. The input-oriented measure looks at by how much inputs can be reduced keeping outputs unchanged. Country C could produce the same amount of outputs OD by only using DE inputs. The degree of input-oriented innovation efficiency thus equals DE/DC (or the ratio of used inputs over the minimum amount of inputs needed to produce the same amount of outputs). The output-oriented measure looks at by how much outputs can be increased keeping inputs unchanged. Country C could produce as much as AB outputs given its level of inputs OA. The degree of output-oriented innovation efficiency thus equals AC/AB (or the ratio of produced outputs over the maximum amount of outputs that could be produced using the same amount of inputs). Under CRS, input-oriented and output-oriented innovation efficiency will be identical. Under VRS both measures will be different as shown in the right-hand Figure 2. The degree of input-oriented innovation efficiency now equals DG/DC and the degree of output-oriented innovation efficiency equals AC/AF (cf. Table 2 for a summary of all efficiency scores).

Table 2 Efficiency scores under different technologies (cf. Figure 2)

	Input-oriented	Output-oriented
Constant-returns-to-scale (CRS)	DE/DC (=AC/AB)	AC/AB (=DE/DC)
Variable-returns-to-scale (VRS)	DG/DC	AC/AF

Lee and Park (2005) employ the DEA approach to measure R&D efficiency (or R&D productivity) for a sample of 27 OECD countries using 2 input indicators (R&D expenditures and researchers) and 3 output indicators (technology balance receipts, scientific and technical journal articles and triadic patent families). Park and Lee look into six DEA models, one linking all inputs to all outputs and five models linking the different inputs piecewise to all outputs (input-specialized efficiency scores) or the different outputs piecewise to all inputs (output-specialized efficiency scores). Efficiency scores differ for each of these models, with overall efficiency being highest for Austria, Finland, Germany, Hungary, New Zealand and the UK and lowest for China, South Korea, Mexico, Romania and Taiwan. All EU countries except Romania have efficiency scores between 44.1% and 100%. Countries are clustered based on their output-specialized efficiency scores. Finland, France, Germany, Japan and the US are in the "Inventors" cluster (all of which have high efficiency levels in patenting), Austria, Ireland, Norway and Singapore in the "Merchandisers" cluster (all of which have high efficiency levels in their technology balance receipts), Australia, Canada, Hungary, Italy, New Zealand, Spain and the UK in the "Academicians" cluster (all of which have high efficiency levels in publishing scientific and technical journal articles) and the other OECD countries in the fourth cluster of "Duds" with low efficiency levels in all output dimensions. The same methodological approach as Lee and Park (2005) will be followed here using the composite indicators for the five EIS innovation dimensions.

In this thematic paper we employ a constant-returns-to-scale output-oriented DEA on all 3 input and 2 output dimensions. The calculations are done using the DEAFrontier™ software package[4]. One problem with DEA is the treatment of missing values in DEA models. Smirlis et al. (2006) introduce an approach based on interval DEA where the missing values are replaced by intervals in which the unknown values are likely to belong. We use a more direct approach by imputing missing values using the linear regression techniques as discussed in the 2005 EIS Methodology Report (Sajeva et al., 2005).

[4] http://www.deafrontier.com/

2.4 Time lags

An important aspect to keep in mind when analysing the transformation of innovation inputs into innovation outputs is the existence of time lags. It will take time before inputs transfer into outputs and an efficiency analysis should take these time lags into account. As shown in Table 3, there are differences between the innovation dimensions in the timeliness of available data. For the 3 input dimensions for most countries most recent available data are for 2004 to 2006 whereas for the 2 output dimensions most recent available data are for 2003 to 2006. Timeliness of output data thus lags behind that of input data.

Table 3 Data availability for each of the innovation dimensions

Innovation drivers	Most data for 2005 or 2006 (99% of EIS 2007 data)
Knowledge creation	Most data for 2004 or 2005 (88% of EIS 2007 data)
Innovation & entrepreneurship	Most data for 2004 or 2005 (85% of EIS 2007 data)
Applications	Most data for 2004 or 2006 (93% of EIS 2007 data)
Intellectual property	Most data for 2003 or 2006 (80% of EIS 2007 data)

We therefore need to test for robustness if the introduction of time lags between inputs and outputs has an effect on the efficiency scores. For Applications and Intellectual property we have calculated efficiency scores between the latest available output data and 5 different time lags for the input data. The results are summarized in Annex 4 for Applications and Annex 5 for Intellectual property. The results show that the use of time lags has little effect on the efficiency scores involving Knowledge creation and Innovation & entrepreneurship. For Innovation drivers results for efficiency scores fluctuate more between the different time lags, where efficiency scores for shorter time lags increase for most countries. For ease of reference, we will use the most recent available composite indicator scores for all innovation dimensions in the efficiency analysis in the next section.

3. Results and analysis

3.1 Efficiency scores – first results

Efficiency scores for all combinations of input and output dimensions are summarised in Table 4. In Applications Romania is 100% efficient when Knowledge creation is one of the input dimensions and Slovakia is 100% efficient if either Innovation drivers or Innovation & entrepreneurship is one of the input dimensions. Czech Republic, Germany and Luxembourg show efficiency levels of 90% or more in Applications in 4 of the 7 different input combinations. In Intellectual property Germany is 100% efficient when Innovation drivers is one of the input dimensions, Luxembourg is 100% efficient when both Innovation drivers and Knowledge creation are among the input dimensions and Switzerland is 100% efficient if either Knowledge creation or Innovation & entrepreneurship is among the input dimensions. None of the other countries attain efficiency levels of 90% or more. For both output combinations combined, Czech Republic, Germany, Italy, Luxembourg, Romania, Slovakia and Switzerland are 100% efficient for up to 6 different input combinations.

High efficiency scores as such do not guarantee a high innovation performance as these can occur combining low levels of input with moderate levels of output. Romania is a prime example, where low levels of inputs are combined with a moderate performance level in Applications[5].

[5] Where performance in Applications is driven in particular by above average EU performance in sales shares of new-to-firm and new-to-market products, two indicators derived from the Community Innovation Survey (CIS) which, due to differences in perception between countries of what is an innovation product, are most likely biased in some of the New Member States including Romania.

The innovation leaders and innovation followers make up the "most innovative" countries; the moderate innovators and catching-up countries make up the "least innovative" countries. As the most and least innovative countries clearly differ in their innovation performance (cf. the cluster results in Annex 6), we analyse the efficiency performance for each of these two groups separately. The results are shown in Tables 5 and 6.

Most innovative countries

Belgium, Germany and Luxembourg are the efficiency leaders in Applications. Belgium is 100% efficient when Knowledge creation is one of the input dimensions, Germany is 100% efficient when either Innovation drivers or Innovation & entrepreneurship is one of the input dimensions, Luxembourg is 100% efficient when both Innovation drivers and Innovation & entrepreneurship is one of the input dimensions. Also France, the Netherlands, Finland and the UK show high efficiency scores for Applications. Efficiency scores are lowest for Sweden, the absolute innovation leader in the EIS 2007.

Germany, Luxembourg and Switzerland are the efficiency leaders in Intellectual property. Germany is 100% efficient when Innovation drivers is one of the input dimensions, Luxembourg is 100% efficient when both Innovation drivers and Knowledge creation are among the input dimensions and Switzerland is 100% efficient if either Knowledge creation or Innovation & entrepreneurship is among the input dimensions. Except for Austria and the Netherlands, all other countries have efficiency levels of 50% or less. Efficiency scores are lowest for Ireland, the UK, Iceland and Israel.

Least innovative countries

Romania and Slovakia are the efficiency leaders in Applications. Romania is 100% efficient when Knowledge creation is one of the input dimensions. The Czech Republic is almost 100% efficient and for Hungary and Italy efficiency levels are 75% or more when Innovation drivers is one of the input dimensions.

Italy, Cyprus and Australia are the efficiency leaders in Intellectual property. Cyprus is 100% efficient when Knowledge creation is one of the input dimensions. Also Portugal and Spain show very high levels of efficiency for those input-output combinations involving Knowledge creation. For Bulgaria, Croatia and Romania efficiency scores are below 10%.

Table 4 Efficiency scores (CRS, output-oriented): all countries

Innovation drivers	x			x	x		x	x			x	x		x	x			x	x		x		
Knowledge creation		x		x		x	x		x		x		x	x		x		x		x		x	x
Innovation & entrepr.			x		x	x	x			x		x	x	x			x		x	x		x	x
Applications	x	x	x	x	x	x	x								x	x	x	x	x	x	x		
Intellectual property								x	x	x	x	x	x	x	x	x	x	x	x	x	x		
BE	48	8	33	48	48	33	48	33	48	34	48	39	48	48	50	54	51	62	56	56	62		
BG	51	10	44	51	51	44	51	1	1	1	1	1	1	1	51	11	44	51	51	44	51		
CZ	99	11	50	99	99	50	99	13	12	9	14	13	12	14	100	22	53	100	100	53	100		
DK	32	6	26	32	32	26	32	40	66	47	66	48	66	66	40	68	54	68	55	68	68		
DE	94	8	43	94	94	43	94	100	69	68	100	100	69	100	100	72	83	100	100	86	100		
EE	35	16	18	35	35	23	35	5	21	4	21	5	21	21	35	36	19	39	35	36	39		
IE	47	7	33	47	47	33	47	25	29	26	30	29	29	30	48	34	47	48	51	48	52		
EL	43	6	20	43	43	20	43	5	6	4	6	5	6	6	43	11	21	43	43	21	43		
ES	51	9	54	51	54	54	54	27	41	43	41	43	43	43	52	48	76	58	76	78	78		
FR	46	7	38	46	46	38	46	31	39	39	39	39	39	39	47	43	59	53	59	61	62		
IT	76	6	62	76	76	62	76	59	41	71	59	72	71	72	79	44	100	79	100	100	100		
CY	25	5	9	25	25	10	25	25	45	13	45	25	45	45	27	48	17	48	27	48	48		
LV	16	6	9	16	16	11	16	4	15	4	15	5	15	15	16	21	11	21	16	21	21		
LT	23	8	18	23	23	18	23	2	5	2	5	2	5	5	23	12	19	23	23	19	23		
LU	93	8	32	93	93	32	93	99	74	50	100	99	74	100	99	77	61	100	99	77	100		
HU	84	8	69	84	84	69	84	7	5	9	7	9	9	9	84	13	71	84	84	71	84		
NL	35	5	38	35	38	38	38	52	61	83	63	83	83	83	52	63	90	66	90	90	90		
AT	49	5	31	49	49	31	49	70	58	66	74	79	66	79	70	59	73	74	79	73	79		
PL	54	12	49	54	54	49	54	6	12	9	12	9	12	12	54	22	51	54	54	51	54		
PT	67	10	21	67	67	21	67	33	43	15	43	33	43	43	69	50	29	69	69	50	69		
RO	87	100	64	100	87	100	100	0	1	0	1	0	1	1	87	100	64	100	87	100	100		
SI	54	8	40	54	54	40	54	11	13	13	14	14	13	14	55	20	45	55	55	45	55		
SK	100	53	100	100	100	100	100	6	27	9	27	9	27	27	100	78	100	100	100	100	100		
FI	42	6	38	42	42	38	42	38	43	50	45	50	50	50	44	47	65	55	65	67	67		
SE	40	4	22	40	40	22	40	44	39	35	48	47	39	48	44	41	43	50	49	45	52		
UK	46	7	29	46	46	29	46	24	32	22	32	27	32	32	47	37	40	48	47	42	49		
HR	39	5	27	39	39	27	39	2	2	2	3	3	2	3	39	7	27	39	39	27	39		
IS	45	4	30	45	45	30	45	30	23	30	31	34	30	34	46	26	45	46	51	47	51		
NO	23	6	42	23	42	42	42	16	34	42	34	42	42	42	24	37	64	37	64	65	65		
CH	41	6	34	41	41	34	41	82	100	100	100	100	100	100	82	100	100	100	100	100	100		
US	45	5	32	45	45	32	45	35	35	36	40	41	36	41	47	38	51	49	55	53	57		
JP	44	6	31	44	44	31	44	42	44	44	49	49	44	49	47	47	57	56	60	59	62		
IL	52	5	35	52	52	35	52	32	25	32	33	37	32	37	54	29	51	54	57	52	57		
CA	49	6	33	49	49	33	49	34	36	35	40	40	36	40	51	40	51	51	56	54	58		
AU	31	9	26	31	31	26	31	17	44	21	44	21	44	44	32	51	37	51	37	51	51		

Table 5 Efficiency scores (CRS, output-oriented): most innovative countries

Innovation drivers	x			x	x		x	x			x	x		x	x			x	x		x		
Knowledge creation		x		x		x	x		x		x		x	x			x		x			x	x
Innovation & entrepr.			x		x	x	x			x		x	x	x				x		x	x	x	
Applications	x	x	x	x	x	x	x									x	x	x	x	x	x	x	
Intellectual property								x	x	x	x	x	x	x		x	x	x	x	x	x	x	
BE	51	100	77	100	77	100	100	33	48	34	48	39	48	48		51	100	77	100	77	100	100	
DK	34	77	59	77	59	77	77	40	66	47	66	48	66	66		40	82	62	82	62	82	82	
DE	100	93	100	100	100	100	100	100	69	68	100	100	69	100		100	93	100	100	100	100	100	
IE	50	79	77	79	77	83	83	25	29	26	30	29	29	30		50	79	77	79	77	83	83	
FR	49	82	89	82	89	89	89	31	39	39	39	39	39	39		49	82	89	82	89	89	89	
LU	99	100	73	100	99	100	100	99	74	50	100	99	74	100		99	100	73	100	99	100	100	
NL	37	60	87	60	87	87	87	52	61	83	63	83	83	83		52	70	98	70	98	98	98	
AT	52	58	72	59	72	72	72	70	58	66	74	79	66	79		70	67	80	74	80	80	80	
FI	45	70	87	70	87	87	87	38	43	50	45	50	50	50		45	70	87	70	87	87	87	
SE	43	52	51	52	51	55	55	44	39	35	48	47	39	48		44	53	51	53	51	56	56	
UK	49	89	67	89	67	89	89	24	32	22	32	27	32	32		49	89	67	89	67	89	89	
IS	47	51	69	51	69	69	69	30	23	30	31	34	30	34		47	51	69	51	69	69	69	
CH	44	73	79	73	79	79	79	82	100	100	100	100	100	100		82	100	100	100	100	100	100	
US	48	65	73	65	73	73	73	35	35	36	40	41	36	41		48	65	73	65	73	73	73	
JP	47	67	72	67	72	72	72	42	44	44	49	49	44	49		47	67	72	67	72	72	72	
IL	55	60	81	60	81	81	81	32	25	32	33	37	32	37		55	60	81	60	81	81	81	
CA	52	74	77	74	77	79	79	34	36	35	40	40	36	40		52	74	77	74	77	79	79	

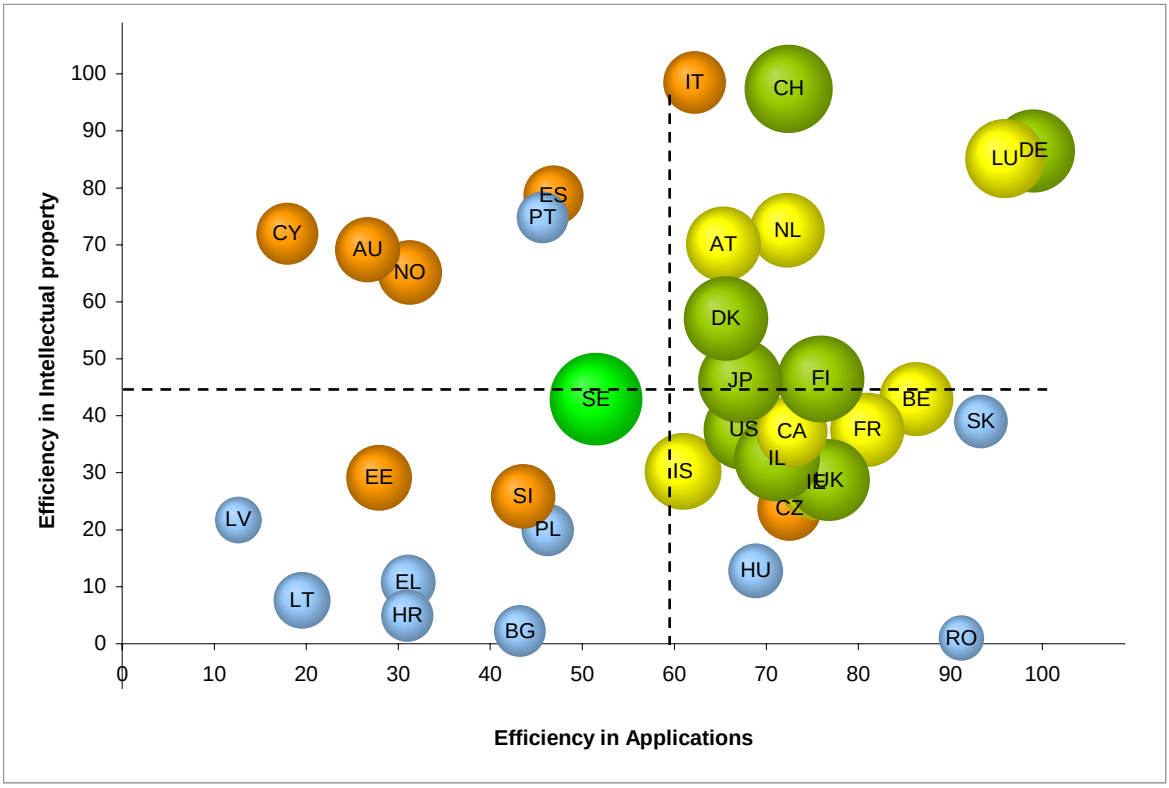
Table 6 Efficiency scores (CRS, output-oriented): least innovative countries

Innovation drivers	x			x	x		x	x			x	x		x	x			x	x		x		
Knowledge creation		x		x		x	x		x		x		x	x			x		x			x	x
Innovation & entrepr.			x		x	x	x			x		x	x	x				x		x	x	x	
Applications	x	x	x	x	x	x	x									x	x	x	x	x	x	x	
Intellectual property								x	x	x	x	x	x	x		x	x	x	x	x	x	x	
BG	51	10	44	51	51	44	51	1	3	1	3	1	3	3		51	12	44	51	51	44	51	
CZ	99	11	50	99	99	50	99	22	26	13	28	22	28	28		100	33	53	100	100	53	100	
EE	35	16	18	35	35	23	35	9	45	6	45	9	45	45		35	56	19	56	35	56	56	
EL	43	6	20	43	43	20	43	9	13	5	14	9	13	14		43	16	21	44	43	21	44	
ES	51	9	54	51	54	54	54	46	91	60	94	60	100	100		61	94	76	96	76	100	100	
IT	76	6	62	76	76	62	76	100	90	100	100	100	100	100		100	90	100	100	100	100	100	
CY	25	5	9	25	25	10	25	43	100	19	100	43	100	100		43	100	19	100	43	100	100	
LV	16	6	9	16	16	11	16	7	33	5	33	7	33	33		17	37	11	37	17	37	37	
LT	23	8	18	23	23	18	23	3	11	3	11	3	11	11		23	17	19	23	23	19	23	
HU	84	8	69	84	84	69	84	12	12	12	13	12	14	14		84	18	71	84	84	71	84	
PL	54	12	49	54	54	49	54	11	25	12	25	12	27	27		54	33	51	55	55	51	55	
PT	67	10	21	67	67	21	67	57	94	22	99	57	96	99		79	98	29	100	79	98	100	
RO	87	100	64	100	87	100	100	0	2	0	2	0	2	2		87	100	64	100	87	100	100	
SI	54	8	40	54	54	40	54	19	29	18	31	19	32	32		57	34	45	57	57	45	57	
SK	100	53	100	100	100	100	100	10	59	12	59	12	60	60		100	100	100	100	100	100	100	
HR	39	5	27	39	39	27	39	4	5	3	6	4	6	6		39	9	27	39	39	27	39	
NO	23	6	42	23	42	42	42	26	74	59	74	59	82	82		29	75	64	75	64	82	82	
AU	31	9	26	31	31	26	31	30	98	30	98	30	100	100		38	100	37	100	38	100	100	

3.2 Efficiency scores – average results

Average efficiency performance on the two output dimensions is summarized in Figure 3. The average efficiency scores were calculated for the most innovative and least innovative countries separately using the different input combinations. The dotted horizontal and vertical lines represent the unweighted efficiency scores of the EU27 countries and these lines divide the countries in 4 groups as they perform above or below the EU27 average efficiency score in Applications and Intellectual property. Innovation performance as measured by the 2007 SII is reflected in the size of each country's bubble.

Figure 3 Efficiency in Applications and Intellectual property



Colour coding is conform the groups of countries as identified in the EIS 2007: bright green is Sweden, green are the innovation leaders, yellow are the innovation followers, orange are the moderate innovators, blue are the catching-up countries. The size of the bubble gives the value of the 2007 Summary Innovation Index (SII). The dotted lines give the unweighted average of the efficiency scores for the EU27 Member States.

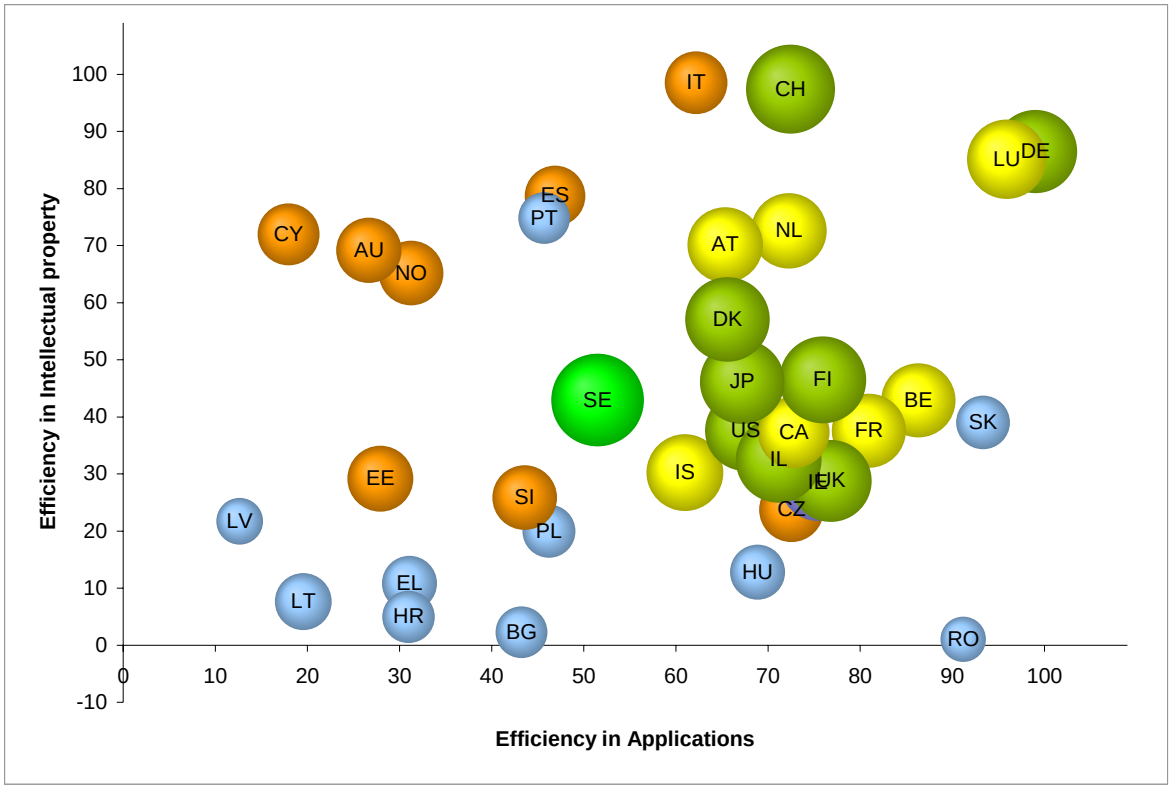
All innovation leaders except Sweden have above average efficiency in transforming inputs into Applications. Despite its overall leadership in innovation performance, Sweden has the lowest efficiency in Applications of these countries indicating that it has room to make improvements here. Germany and Switzerland show high efficiency in generating Intellectual property. Some of the innovation leaders, in particular the UK, have relatively low efficiency in transforming inputs into Intellectual property outputs. This may because the type of their innovation activities does not lead to formal IPRs but it could also indicate that these countries could be creating more IPRs given their level of inputs.

The innovation followers have above average efficiency in transforming inputs into Applications, with Luxembourg and Belgium showing highest efficiency rates. Only Austria, the Netherlands and Luxembourg show above average efficiency in Intellectual property, and hence Belgium, France and Iceland could seek to improve their efficiency rates by generating more IPRs from their innovation inputs.

The moderate innovators show a range of different efficiencies: we find these countries in all four quadrants in Figure 3 combining above or below average efficiency performance. Italy combines above average efficiency scores in both output dimensions. This result suggests that it may be difficult for Italy to improve its innovation performance without increasing innovation inputs. Australia, Cyprus, Norway and Spain show above average efficiency in Intellectual property[6] and the Czech Republic shows above average efficiency in Applications. Estonia and Slovenia combine below average efficiency in both Applications and Intellectual property.

The catching-up countries also show a variety of efficiencies in transforming innovation inputs into Applications. On Intellectual property efficiency all countries are significantly below average with the exception of Portugal. This may be because IPR is of less relevance for the innovative activities of these countries or that there is the potential to generate higher levels of IPR from the existing inputs. Some of these countries are also still in a process of replacing national patent applications by EPO patent applications. For Slovakia and Romania the efficiencies for Applications are relatively high, suggesting that these countries need to increase inputs to increase performance in generating more Applications. The majority of catching up countries has below average efficiencies and this suggests that for these countries an important focus should be to further improve their innovation efficiencies.

Figure 4 Identification of peer countries



Colour coding is conform the groups of countries as identified in the EIS 2007: bright green is Sweden, green are the innovation leaders, yellow are the innovation followers, orange are the moderate innovators, blue are the catching-up countries. The size of the bubble gives the value of the 2007 Summary Innovation Index (SII).

[6] One also has to keep in mind that the efficiency scores for the moderate innovators were calculated within the group of least innovative countries thus excluding the input and output performance scores of the innovation leaders and innovation followers.

3.3 Peer countries

For most countries efficiency gains seem to be possible as only a few countries already have efficiency scores of 90% or more. The efficiency scatter plot in Figure 3 can be used to visually show how the first step in selecting peer countries can be made. For each individual country potential peer countries can be identified as those countries with higher efficiency scores on both output dimensions. These countries are included in a rectangle with its lower left corner starting in the individual country and stretching to the right and upward to full efficiency. Figure 4 shows two examples of such rectangles for Slovenia and Denmark. For Denmark potential peer countries include Germany, Italy, Luxembourg, the Netherlands and Switzerland. For Slovenia there are as many as 21 potential peer countries. But not all of these potential peer countries may be appropriate; only those countries within the same or next best EIS country group provide a good basis for comparison for the same reasons given before for analysing countries separately for the most and least innovative countries (cf. Table 7 for a list of peer countries for each of the European countries).

Core peer countries

Applying more strict conditions can help in identifying a set of core peer countries. Large gains in efficiency cannot be attained in the short run, so we focus on those peer countries where efficiency gains are within a feasible range. For the most innovative countries this feasible range is defined as up to 40% of the country's efficiency score, for the least innovative countries we assume a less strict feasible range up to 80% of the country's efficiency score. Furthermore we require that the peer country's innovation performance is above that of the reviewed country or not too far below that country's innovation performance (40% for the most innovative countries, 80% for the least innovative countries). Core peer countries are identified in bold in Table 7. For the least innovative countries also core peer countries in the most innovative countries are identified.

Peer countries from 2005 Innovation Strengths and Weaknesses report

Table 7 also gives the peer countries for absolute performance and those for most similar performance as identified in the 2005 thematic paper on "Innovation Strengths and Weaknesses" (Arundel and Hollanders, 2005). Peer countries for absolute performance were identified applying hierarchical cluster techniques on the EIS 2005 composite indicator scores for the 5 innovation dimensions plus composite indicator scores for innovation demand and governance. Innovation demand is captured by the following 5 indicators: gross fixed capital formation by the private sector, buyer sophistication, youth share, lack of customer responsiveness to innovation and per capita GDP. Governance is captured by the following 4 indicators: e-Government, innovation policy uptake rate, innovation policy index and cost of business establishment index[7]. Most similar countries with respect to relative performance were identified using multidimensional scaling (MDS) using the ratios of six composite indicator scores relative to the country's SII: the 3 input dimensions, applications, innovation demand and governance. The purpose of applying MDS was to identify countries that share similar patterns of innovation strengths and weaknesses as this could assist policy makers in identifying better performing countries with similar patterns under the assumption that similar countries share similar National Systems of Innovation and economic structures.

[7] Full definitions are given in Annex B in Arundel and Hollanders (2005).

Table 7 Peer countries for the European countries

	Within innovation leaders: CH, DE, DK, FI, IL, JP, SE, UK, US	**Within innovation followers: AT, BE, CA, FR, IE, IS, LU, NL**	**Within moderate innovators: AU, CY, CZ, EE, ES, IT, NO, SI**	**Within catching-up countries: BG, EL, HR, HU, LT, LV, MT, PL, PT, RO, SK**	**Peer countries for performance (2005 S&W report)***	**Most similar countries in relative pattern of strengths and weaknesses (2005 S&W report)***
Sweden (SE)	CH, DE, **DK**, FI, **JP**	AT, LU, NL			DK, FI	BE, FI, UK
Innovation leaders						
Denmark (DK)	CH, DE	LU, **NL**			FI, SE	FI, FR, SE
Finland (FI)	DE	LU			DK, SE	BE, FR, NL
Germany (DE)	---	---			AT, BE, FR, IT, NL, UK	HU
United Kingdom (UK)	DE	BE, **FR**, LU			AT, BE, DE, FR, IT, NL	BE, DK, SE
Switzerland (CH)	---	---			N/A	N/A
Innovation followers						
Austria (AT)	**CH**, DE	LU, **NL**			BE, FR, IT, NL, UK	FI, IT, SE
Belgium (BE)	DE	LU			AT, DE, FR, IT, NL, UK	NL, SE, SI
Ireland (IE)	DE, FI, **UK**	BE, FR, LU			N/A	N/A
France (FR)	DE	**BE**, LU			AT, BE, DE, IT, NL ,UK	ES, FR, SI
Luxembourg (LU)	**DE**	---			N/A	N/A
Netherlands (NL)	**CH**, **DE**	**LU**			AT, BE, DE, FR, IT, UK	BE, ES, FR
Iceland (IS)	CH, DE, DK, FI, **IL**, JP, **US**	AT, BE, **CA**, **FR**, LU, NL			N/A	N/A
Moderate innovators						
Cyprus (CY)			ES, IT	PT	N/A	N/A
Czech Republic (CZ)	**UK**	**CA**, **FR**, **IE**	---	**SK**	HU, SK	FR
Estonia (EE)			ES, IT, NO	PT, SK	EL, LV, PL, PT	LV
Italy (IT)			---	---	AT, BE, DE, FR, NL, UK	AT, FI, FR
Slovenia (SI)	**FI**, **IL**, **JP**, **SE**, **UK**, **US**	**CA**, **IE**,**IS**	ES, IT	PT, SK	ES, LT	BE, ES, FR
Spain (ES)	**CH**		**IT**	---		
Norway (NO)			**ES**, IT	**PT**	N/A	N/A
Catching-up countries						
Bulgaria (BG)			CZ, ES, SI	HU, PL, PT, SK	N/A	N/A
Croatia (HR)			CZ, ES, IT, SI	EL, HU, PL, PT, SK	N/A	N/A
Greece (EL)			CZ, ES, IT, SI	HU, PL, PT, SK	EE, LV, PL, PT	ES, PL
Hungary (HU)			CZ	SK	CZ, SK	DE
Latvia (LV)			AU, CY, CZ, EE, ES, IT, NO, SI	PT, SK	EE, EL, PL, PT	EE
Lithuania (LT)			AU, CZ, EE, ES, IT, NO, SI	**EL**, HU, PL, PT, SK	ES, SI	ES, ES, SI
Poland (PL)	**IL**, **UK**	**IE**, **IS**	**CZ**, ES, IT	PT, SK	EE, EL, LV, PT	EL
Portugal (PT)	**CH**		**ES**, **IT**	---	EE, EL, PV, PL	none
Romania (RO)			---	SK	N/A	N/A
Slovakia (SK)			---	---	CZ, HU	none

* Due to data availability the 2005 Innovation Strengths and Weaknesses report only the following 21 countries were included in the analysis: AT, BE, CZ, DK, DE, EE, EL, ES, FI, FR, HU, IT, LT, LV, NL, PL, PT, SE, SI. SK, UK.

4. Policy options

The efficiency analysis could help to guide countries in improving their policy mix as summarised in Table 8.

For **countries with high efficiencies** in Applications and/or Intellectual property it may be more effective to focus on policies to increase investments in some (or all) of their innovation inputs (research, skills, IT etc.) if they want to increase their output (and hence) overall innovation performance. Moreover, given their high level of efficiencies it may be difficult for such countries to improve their innovation performance if they do not increase levels of innovation inputs. Examples of such countries are Germany and Luxembourg with high efficiencies in both output dimensions, Italy and Switzerland in the case of Intellectual property output efficiency, and Slovakia, Romania and Belgium in terms of Application output efficiency.

For such countries, it will be important that increases in the levels of innovation inputs do not result in lower innovation efficiency. This will depend on the countries' capacity to absorb increases in innovation inputs and may require further investigation.

For **countries with low efficiencies** in one or both output dimensions it may be more effective to focus on policies aimed at improving their efficiency in transforming inputs into outputs. Relevant policies include those aimed at supporting innovation processes in firms (e.g. innovation support services, improving awareness and access to IPRs, innovation management) and policies to stimulating demand for innovation (cf. Aho report[8] and the Lead Market Initiative[9]). Countries with low efficiencies include Bulgaria, Croatia, Estonia, Greece, Latvia, Lithuania, Poland and Slovenia. In addition, the Czech Republic, Hungary, Ireland, Iceland, Romania and the UK have relatively low efficiency for Intellectual property outputs; and Cyprus, Norway, Portugal and Spain have relatively low efficiencies for Application outputs.

By improving their efficiency, the output performance of such countries may be improved without necessarily having to invest more in innovation inputs. In addition, there is a risk that if such countries only invest in raising innovation inputs without policies to increase efficiency, this would have a limited impact in terms of raising outputs.

Table 8 Policy considerations for countries with different levels of performance and efficiencies.

	Low-moderate efficiency	Moderate-high efficiency
Low-moderate input performance	Policies aimed at increasing inputs (weak dimensions, weak indicators) and improving efficiency	Policies aimed at increasing inputs (weak dimensions, weak indicators)
Moderate-high input performance	Policies aimed at improving efficiency	

The identification of peer countries can offer a first step in selecting those countries with similar performance patterns and economic conditions but higher efficiency levels and

[8] The INNO-Policy Trendchart provides a database of innovation policies, see http://www.proinno-europe.eu/index.cfm?fuseaction=page.display&topicID=52&parentID=52

[9] Commission Communication "A Lead Market Initiative for Europe" COM(2007)860.

thus, possibly, better policies directly or indirectly aimed at higher efficiency. The innovation policies implemented in these countries could be compared with those in the own country to identify options for policy improvements to improve the efficiency of transferring innovation inputs into outputs, e.g. by innovation support services, raising IPR awareness, improving innovation management and stimulating demand for innovation.

A further step to identify areas for policy action could then be to consider both innovation efficiency and performance across the five dimensions of innovation. Table 9 summarizes relative innovation performance from the 2007 European Innovation Scoreboard together with the efficiency results. The colour coding shows quickly where each country performs below, close to or above average (red, yellow and green respectively). No country is able to combine high performance in all dimensions with high efficiency rates. Some countries come close, but all of them show weaker performance in at least one dimension or moderate efficiency in either Applications or Intellectual property. This table could be used to help identify areas for improvement, taking into account those areas where the indicators reveal relative weaknesses. For example:

Finland is showing high performance in almost all innovation dimensions but its efficiency in Intellectual property is only moderate. This suggests that improved policies are needed aimed at increasing IP outputs, in particular Community trademarks and designs but also triad patents.

The Netherlands is combining high performance and efficiency in Intellectual property with moderate performance in the other input dimensions and moderate efficiency in Applications. The country's relative weakness is in the following indicators: supply of new S&E graduates, business R&D and innovation expenditures, early-stage venture capital and sales shares of new-to-market and new-to-firm products. The country may therefore benefit from further policies aimed at motivating more students to study science & engineering and to increase innovation activities within enterprises resulting in higher sales shares of new products.

Italy is not performing exceptionally well in any of the innovation dimensions, but the country is showing a very high efficiency in Intellectual property. This indicates that the country is getting the most out of its inputs in terms of patents, trademarks and designs albeit at relatively low levels of inputs. For Italy it may therefore be most appropriate to focus on increasing its efficiency in Applications and on increasing its performance in Innovation drivers (in particular there are weaknesses in the indicators of share of population with a tertiary education and participation in life-long learning) and Innovation & entrepreneurship (in particular to address the weaknesses in the indicators of SMEs innovating in collaboration with others and of early-stage venture capital).

Slovakia is showing high performance and efficiency in Applications, but there appears to be scope to improve its IP efficiency and look for policies to raise performance across the various input dimensions, in particular in considering the low levels on the indicators of broadband penetration, R&D expenditures and the supply of early-stage venture capital.

Table 9 Relative performance and efficiency

	Innovation drivers	Knowledge creation	Innovation & entrepreneurship	Applications	Intellectual property	Applications efficiency	Intellectual property efficiency
Sweden (SE)	0.79	0.91	0.89	0.55	0.60	51	43
Innovation leaders							
Denmark (DK)	0.82	0.52	0.64	0.46	0.57	66	57
Finland (FI)	0.81	0.73	0.56	0.59	0.53	76	46
Germany (DE)	0.41	0.62	0.55	0.67	0.71	99	86
United Kingdom (UK)	0.73	0.57	0.72	0.59	0.31	77	29
Switzerland (CH)	0.70	0.60	0.52	0.51	1.00	72	97
Innovation followers							
Austria (AT)	0.46	0.58	0.44	0.39	0.56	65	70
Belgium (BE)	0.57	0.41	0.51	0.48	0.33	86	43
Ireland (IE)	0.61	0.55	0.53	0.50	0.27	75	28
France (FR)	0.60	0.51	0.44	0.48	0.33	81	38
Luxembourg (LU)	0.35	0.49	0.64	0.57	0.61	96	85
Netherlands (NL)	0.61	0.54	0.35	0.38	0.56	72	73
Iceland (IS)	0.58	0.77	***0.53***	0.45	0.30	61	30
Moderate innovators							
Cyprus (CY)	0.40	0.23	0.69	0.18	0.17	18	72
Czech Republic (CZ)	0.33	0.38	0.41	0.58	0.07	73	24
Estonia (EE)	0.56	0.15	0.67	0.34	0.05	28	29
Italy (IT)	0.30	0.46	0.23	0.40	0.31	62	99
Slovenia (SI)	0.49	0.44	***0.41***	0.46	0.10	44	26
Spain (ES)	0.43	0.30	0.25	0.38	0.20	47	79
Norway (NO)	0.72	0.35	0.25	0.29	0.20	31	65
Catching-up countries							
Bulgaria (BG)	0.36	0.23	0.25	0.32	0.00	43	2
Croatia (HR)	0.34	0.34	***0.41***	0.24	0.01	31	5
Greece (EL)	0.30	0.29	0.41	0.23	0.03	31	11
Hungary (HU)	0.28	0.39	0.21	0.41	0.04	69	13
Latvia (LV)	0.36	0.11	0.37	0.10	0.03	13	22
Lithuania (LT)	0.52	0.19	0.40	0.21	0.02	20	8
Poland (PL)	0.36	0.21	0.24	0.33	0.04	46	20
Portugal (PT)	0.20	0.16	0.39	0.23	0.11	46	75
Romania (RO)	0.25	0.03	0.21	0.38	0.00	91	1
Slovakia (SK)	0.32	0.07	0.20	0.55	0.03	93	39

Composite indicators for innovation dimensions classified by high scores (above mean + 0.75*standard deviation) (green), medium scores (in between mean +/- 0.75*standard deviation) (yellow) and low scores (below mean – 0.75*standard deviation). Composite indicator scores highlighted in bold and italic are estimates.

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Annex 1 Efficiency scores (CRS, output-oriented): all countries (including Malta and Turkey)

Innovation drivers	x			x	x		x	x			x	x		x	x			x	x		x		
Knowledge creation		x		x		x	x		x		x		x	x		x		x		x		x	x
Innovation & entrepreneurship			x		x	x	x			x		x	x	x			x		x	x		x	x
Applications	x	x	x	x	x	x	x								x	x	x	x	x	x	x		
Intellectual property								x	x	x	x	x	x	x	x	x	x	x	x	x	x		
BE	13	8	33	15	37	33	37	33	48	34	48	39	48	48	35	50	51	50	54	55	57		
BG	14	10	44	17	46	44	46	1	1	1	1	1	1	1	14	10	44	17	46	44	46		
CZ	28	11	50	28	59	50	59	13	12	9	14	13	12	14	28	17	53	28	59	53	59		
DK	9	6	26	11	27	26	27	40	66	47	66	48	66	66	40	67	54	67	55	67	67		
DE	26	8	43	27	52	43	52	100	69	68	100	100	69	100	100	70	83	100	100	86	100		
EE	10	16	18	23	21	23	25	5	21	4	21	5	21	21	10	27	19	27	21	27	27		
IE	13	7	33	13	37	33	37	25	29	26	30	29	29	30	28	30	47	32	48	48	50		
EL	12	6	20	12	24	20	24	5	6	4	6	5	6	6	12	8	21	12	24	21	24		
ES	14	9	54	16	54	54	54	27	41	43	41	43	43	43	30	43	76	43	76	78	78		
FR	13	7	38	13	40	38	40	31	39	39	39	39	39	39	33	40	59	40	59	61	61		
IT	21	6	62	22	66	62	66	59	41	71	59	72	71	72	61	42	100	61	100	100	100		
CY	7	5	9	9	11	10	11	25	45	13	45	25	45	45	25	46	17	46	25	46	46		
LV	4	6	9	10	11	11	11	4	15	4	15	5	15	15	6	17	11	17	12	17	17		
LT	6	8	18	12	20	18	20	2	5	2	5	2	5	5	6	10	19	12	20	19	20		
LU	26	8	32	27	40	32	40	99	74	50	100	99	74	100	99	75	61	100	99	75	100		
HU	23	8	69	24	73	69	73	7	5	9	7	9	9	9	24	10	71	24	74	71	74		
MT	97	56	76	100	100	89	100	64	86	21	86	64	86	86	100	100	84	100	100	100	100		
NL	10	5	38	10	38	38	38	52	61	83	63	83	83	83	52	62	90	63	90	90	90		
AT	14	5	31	14	35	31	35	70	58	66	74	79	66	79	70	58	73	74	79	73	79		
PL	15	12	49	20	50	49	50	6	12	9	12	9	12	12	15	17	51	20	52	51	52		
PT	19	10	21	19	27	21	27	33	43	15	43	33	43	43	38	45	29	45	38	45	45		
RO	24	100	64	100	70	100	100	0	1	0	1	0	1	1	24	100	64	100	70	100	100		
SI	15	8	40	15	44	40	44	11	13	13	14	14	13	14	17	15	45	17	48	45	48		
SK	28	53	100	73	100	100	100	6	27	9	27	9	27	27	28	67	100	73	100	100	100		
FI	12	6	38	12	39	38	39	38	43	50	45	50	50	50	38	44	65	46	65	67	67		
SE	11	4	22	11	26	22	26	44	39	35	48	47	39	48	44	40	43	48	49	45	49		
UK	13	7	29	13	33	29	33	24	32	22	32	27	32	32	27	34	40	34	42	42	44		
HR	11	5	27	11	30	27	30	2	2	2	3	3	2	3	11	6	27	11	30	27	30		
TR	100	10	47	100	100	47	100	5	1	1	5	5	1	5	100	11	47	100	100	47	100		
IS	12	4	30	13	33	30	33	30	23	30	31	34	30	34	32	24	45	32	48	47	48		
NO	6	6	42	10	42	42	42	16	34	42	34	42	42	42	17	35	64	35	64	65	65		
CH	12	6	34	12	36	34	36	82	100	100	100	100	100	100	82	100	100	100	100	100	100		
US	13	5	32	13	35	32	35	35	35	36	40	41	36	41	36	36	51	41	54	53	55		
JP	12	6	31	13	34	31	34	42	44	44	49	49	44	49	43	45	57	50	60	59	60		
IL	15	5	35	15	39	35	39	32	25	32	33	37	32	37	35	26	51	35	54	52	54		
CA	14	6	33	14	37	33	37	34	36	35	40	40	36	40	36	37	51	41	54	54	56		
AU	9	9	26	15	27	26	27	17	44	21	44	21	44	44	19	46	37	46	37	46	46		

Annex 2 Efficiency scores (CRS, output-oriented): most innovative countries

Innovation drivers	x			x	x		x		x			x	x		x		x			x	x		x	
Knowledge creation		x		x		x	x			x		x		x	x			x		x		x	x	
Innovation & entrepreneurship			x		x	x	x				x		x	x	x				x		x	x	x	
Applications	x	x	x	x	x	x	x										x	x	x	x	x	x	x	
Intellectual property									x	x	x	x	x	x	x		x	x	x	x	x	x	x	
BE	51	100	77	100	77	100	100		33	48	34	48	39	48	48		51	100	77	100	77	100	100	
DK	34	77	59	77	59	77	77		40	66	47	66	48	66	66		40	82	62	82	62	82	82	
DE	100	93	100	100	100	100	100		100	69	68	100	100	69	100		100	93	100	100	100	100	100	
IE	50	79	77	79	77	83	83		25	29	26	30	29	29	30		50	79	77	79	77	83	83	
FR	49	82	89	82	89	89	89		31	39	39	39	39	39	39		49	82	89	82	89	89	89	
LU	99	100	73	100	99	100	100		99	74	50	100	99	74	100		99	100	73	100	99	100	100	
NL	37	60	87	60	87	87	87		52	61	83	63	83	83	83		52	70	98	70	98	98	98	
AT	52	58	72	59	72	72	72		70	58	66	74	79	66	79		70	67	80	74	80	80	80	
FI	45	70	87	70	87	87	87		38	43	50	45	50	50	50		45	70	87	70	87	87	87	
SE	43	52	51	52	51	55	55		44	39	35	48	47	39	48		44	53	51	53	51	56	56	
UK	49	89	67	89	67	89	89		24	32	22	32	27	32	32		49	89	67	89	67	89	89	
IS	47	51	69	51	69	69	69		30	23	30	31	34	30	34		47	51	69	51	69	69	69	
CH	44	73	79	73	79	79	79		82	100	100	100	100	100	100		82	100	100	100	100	100	100	
US	48	65	73	65	73	73	73		35	35	36	40	41	36	41		48	65	73	65	73	73	73	
JP	47	67	72	67	72	72	72		42	44	44	49	49	44	49		47	67	72	67	72	72	72	
IL	55	60	81	60	81	81	81		32	25	32	33	37	32	37		55	60	81	60	81	81	81	
CA	52	74	77	74	77	79	79		34	36	35	40	40	36	40		52	74	77	74	77	79	79	

Annex 3 Efficiency scores (CRS, output-oriented): least innovative countries (including Malta and Turkey)

Innovation drivers	x			x	x		x	x			x	x		x	x			x	x		x		
Knowledge creation		x		x		x	x		x		x		x	x		x		x		x		x	x
Innovation & entrepreneurship			x		x	x	x			x		x	x	x			x		x	x	x		
Applications	x	x	x	x	x	x	x								x	x	x	x	x	x	x		
Intellectual property								x	x	x	x	x	x	x	x	x	x	x	x	x	x		
BG	14	10	44	17	46	44	46	1	1	1	1	1	3	3	14	10	44	17	46	44	46		
CZ	28	11	50	28	59	50	59	20	14	13	20	21	24	24	28	17	53	28	59	53	59		
EE	10	16	18	23	21	23	25	8	24	6	24	9	24	24	10	27	19	27	21	27	27		
EL	12	6	20	12	24	20	24	8	7	5	8	9	11	11	12	8	21	12	24	21	24		
ES	14	9	54	16	54	54	54	42	48	60	48	60	91	91	42	48	76	48	76	91	91		
IT	21	6	62	22	66	62	66	92	47	100	92	100	100	100	92	47	100	92	100	100	100		
CY	7	5	9	9	11	10	11	39	53	19	53	41	59	59	39	53	19	53	41	59	59		
LV	4	6	9	10	11	11	11	7	17	5	17	7	18	18	7	17	11	17	12	18	18		
LT	6	8	18	12	20	18	20	3	6	3	6	3	8	8	6	10	19	12	20	19	20		
HU	23	8	69	24	73	69	73	11	6	12	11	12	13	13	24	10	71	24	74	71	74		
MT	97	56	76	100	100	89	100	100	100	29	100	100	100	100	100	100	84	100	100	100	100		
PL	15	12	49	20	50	49	50	10	13	12	13	12	23	23	15	17	51	20	52	51	52		
PT	19	10	21	19	27	21	27	52	50	22	52	54	63	63	52	50	29	52	54	63	63		
RO	24	100	64	100	70	100	100	0	1	0	1	0	1	1	24	100	64	100	70	100	100		
SI	15	8	40	15	44	40	44	18	15	18	18	19	28	28	18	15	45	18	48	45	48		
SK	28	53	100	73	100	100	100	9	31	12	31	12	38	38	28	67	100	73	100	100	100		
HR	11	5	27	11	30	27	30	4	3	3	4	4	5	5	11	6	27	11	30	27	30		
TR	100	10	47	100	100	47	100	8	1	1	8	8	3	8	100	11	47	100	100	47	100		
NO	6	6	42	10	42	42	42	24	39	59	39	59	77	77	24	39	64	39	64	77	77		
AU	9	9	26	15	27	26	27	27	51	30	51	30	74	74	27	51	37	51	37	74	74		

Annex 4 Efficiency scores (CRS, output-oriented): all countries (excluding Malta and Turkey) for Applications and different time lags for the input dimensions

	Innovation drivers					Knowledge creation					Innovation & entrepreneurship				
	2007	**2006**	**2005**	**2004**	**2003**	**2007**	**2006**	**2005**	**2004**	**2003**	**2007**	**2006**	**2005**	**2004**	**2003**
BE	48	44	38	33	31	8	8	8	7	7	33	30	31	30	28
BG	51	51	47	35	39	10	10	9	10	11	44	53	76	71	73
CZ	99	100	100	87	89	11	11	11	10	11	50	49	50	47	48
DK	32	32	29	25	24	6	6	6	6	6	26	21	20	21	21
DE	94	89	81	70	69	8	8	7	7	7	43	40	42	40	40
EE	35	35	32	29	29	16	16	19	20	20	18	17	19	18	18
IE	47	46	43	41	40	7	6	6	6	7	33	30	31	28	30
EL	43	43	40	36	38	6	6	5	5	5	20	19	19	17	18
ES	51	48	44	38	39	9	10	8	9	9	54	52	57	54	53
FR	46	43	40	36	38	7	7	7	6	6	38	35	36	33	35
IT	76	74	70	70	81	6	6	6	6	6	62	60	62	57	59
CY	25	27	25	20	20	5	6	6	6	6	9	9	9	8	9
LV	16	15	14	13	13	6	12	13	11	11	9	9	11	10	11
LT	23	22	22	20	21	8	8	9	8	9	18	19	23	21	22
LU	93	82	79	100	100	8	8	8	8	8	32	31	32	30	31
HU	84	81	76	65	70	8	8	7	7	7	69	68	79	74	74
NL	35	32	30	25	25	5	5	5	5	5	38	38	37	35	31
AT	49	47	42	38	35	5	5	5	5	5	31	28	30	27	29
PL	54	55	53	48	52	12	11	11	12	11	49	50	55	51	51
PT	67	65	66	68	90	10	10	11	10	9	21	17	19	17	21
RO	87	86	82	86	85	100	100	100	100	100	64	67	98	77	79
SI	54	52	49	43	48	8	7	8	7	7	40	38	42	38	41
SK	100	99	97	84	87	53	51	46	52	47	100	100	100	100	100
FI	42	40	37	31	32	6	6	6	6	6	38	30	34	27	28
SE	40	37	35	29	30	4	4	4	4	4	22	19	20	19	19
UK	46	44	39	33	35	7	7	7	7	7	29	35	36	34	38
HR	39	38	34	31	32	5	5	5	5	5	27	27	29	26	26
IS	45	40	37	28	30	4	4	4	4	4	30	28	30	27	29
NO	23	22	20	18	17	6	6	5	5	5	42	32	36	29	30
CH	41	36	32	28	29	6	6	6	6	6	34	31	33	29	29
US	45	42	37	31	29	5	5	5	5	5	32	29	30	27	27
JP	44	41	36	30	31	6	6	5	5	5	31	29	30	28	29
IL	52	48	42	36	41	5	5	5	4	5	35	32	33	31	32
CA	49	46	41	34	35	6	6	6	5	5	33	31	31	28	29
AU	31	31	29	27	27	9	9	10	9	9	26	25	26	24	24

Annex 5 Efficiency scores (CRS, output-oriented): all countries (excluding Malta and Turkey) for Intellectual property and different time lags for the input dimensions

	Innovation drivers					Knowledge creation					Innovation & entrepreneurship				
	2007	**2006**	**2005**	**2004**	**2003**	**2007**	**2006**	**2005**	**2004**	**2003**	**2007**	**2006**	**2005**	**2004**	**2003**
BE	33	34	31	21	20	48	47	44	43	41	34	35	34	36	34
BG	0	0	0	0	0	1	1	1	1	1	1	1	2	2	2
CZ	3	3	3	2	2	12	12	11	11	11	9	10	10	11	11
DK	46	52	50	33	32	66	65	59	60	59	47	44	39	45	45
DE	92	99	94	64	63	69	67	63	64	63	68	71	69	74	74
EE	1	2	2	1	1	21	20	22	25	24	4	4	4	5	5
IE	26	30	29	21	21	29	28	27	29	28	26	26	26	26	28
EL	4	5	5	3	3	6	6	5	5	5	4	4	4	4	4
ES	28	30	29	20	20	41	42	36	39	39	43	46	47	51	49
FR	30	32	31	21	23	39	38	36	35	35	39	39	38	40	42
IT	55	60	59	47	54	41	40	38	37	35	71	76	74	78	79
CY	16	19	18	12	11	45	45	44	46	47	13	14	14	15	15
LV	0	1	1	0	0	15	28	28	25	24	4	4	5	5	5
LT	0	0	0	0	0	5	5	5	5	6	2	2	3	3	3
LU	100	100	100	100	100	74	71	67	68	67	50	54	53	56	57
HU	4	4	4	3	3	5	5	5	5	5	9	10	11	11	11
NL	47	50	47	32	32	61	61	62	60	58	83	92	86	91	80
AT	55	60	56	40	37	58	58	56	56	58	66	66	67	69	71
PL	1	1	1	1	1	12	11	10	11	10	9	10	10	11	11
PT	19	21	22	18	24	43	43	42	41	37	15	14	15	15	18
RO	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0
SI	5	5	5	4	4	13	12	13	12	11	13	13	14	14	15
SK	1	1	1	1	1	27	25	22	26	22	9	10	9	11	10
FI	41	45	43	29	29	43	42	41	41	41	50	44	48	42	44
SE	48	51	49	33	33	39	38	35	34	34	35	35	33	36	36
UK	27	29	27	18	19	32	32	30	29	28	22	30	29	31	34
HR	3	3	3	2	2	2	2	3	3	3	2	3	3	3	3
IS	20	21	20	12	13	23	23	21	21	21	30	31	31	32	33
NO	15	16	16	11	11	34	35	28	26	27	42	36	38	35	36
CH	74	73	68	47	49	100	100	100	100	100	100	100	100	100	100
US	36	38	35	23	21	35	34	33	33	31	36	37	36	37	36
JP	39	40	37	25	25	44	43	40	41	41	44	46	44	47	48
IL	33	34	31	21	24	25	24	22	23	22	32	32	31	33	34
CA	27	29	27	18	18	36	35	32	30	28	35	36	35	35	35
AU	14	16	15	11	11	44	43	43	41	41	21	23	22	23	23

Annex 6 EIS 2007 country groupings – Hierarchical clustering: Dendrogram using average linkage (between groups)