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European Trend Chart on Innovation

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November 14, 2003

European Commission
Enterprise Directorate-General

A discussion paper from the Innovation/SMEs Programme

The European Trend Chart on Innovation

Innovation is a priority of all Member States and of the European Commission. Throughout Europe, hundreds of policy measures and support schemes aimed at innovation have been implemented or are under preparation. The diversity of these measures and schemes reflects the diversity of the framework conditions, cultural preferences and political priorities in the Member States. The 'First Action Plan for Innovation in Europe', launched by the European Commission in 1996, provided for the first time a common analytical and political framework for innovation policy in Europe.

Building upon the Action Plan, the *Trend Chart on Innovation in Europe* is a practical tool for innovation policy makers and scheme managers in Europe. Run by the European Commission (Innovation Directorate of DG Enterprise), it pursues the collection, regular updating and analysis of information on innovation policies at national and Community level, with a focus on innovation finance; setting up and developing innovative businesses; the protection of intellectual property rights; and the transfer of technology between research and industry.

The Trend Chart serves the "open policy co-ordination approach" laid down by the Lisbon Council in March 2000. It delivers summarised and concise information and statistics on innovation policies, performances and trends in the European Union. It is also a European forum for benchmarking and the exchange of good practices in the area of innovation policy.

The Trend Chart products

The Trend Chart on Innovation has been running since January 2000. It tracks innovation policy developments in all EU Member States, plus Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Iceland, Israel, Latvia, Lithuania, Norway, Poland, Romania, Slovak Republic, Slovenia and Switzerland. The Trend Chart website (www.cordis.lu/trendchart) provides access to the following services and publications:

- the European Innovation Scoreboard and other statistical reports;
- regular country reports for all countries covered;
- a database of policy measures across Europe;
- a "who is who?" of agencies and government departments involved in innovation;
- regular trend reports covering each of the four main themes;
- benchmarking reports from the Trend Chart workshops;
- a news service and thematic papers;
- the annual reports of the Trend Chart.

The present report was prepared by **Anthony Arundel** and **Hugo Hollanders** of **MERIT, Maastricht University** (www.merit.unimaas.nl). The information contained in this report has not been validated in detail by either the Member States or the European Commission.

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European Innovation Scoreboard

The European Innovation Scoreboard (EIS) was developed at the request of the Lisbon European Council in 2000[1]. It focuses on high-tech innovation and provides indicators for tracking the EU's progress towards the Lisbon goal of becoming the most competitive and dynamic knowledge-based economy in the world within the next decade.

The 2003 EIS contains 19 main indicators, selected to summarize the main drivers and outputs of innovation. These indicators are divided into four groups: Human resources for innovation (5 indicators); the Creation of new knowledge (4 indicators); the Transmission and application of knowledge (3 indicators); and Innovation finance, output and markets (7 indicators).

The EIS complements the *Enterprise Policy Scoreboard*[2] and other benchmarking exercises of the European Commission. It mainly uses Eurostat data. Six indicators are drawn from the European Commission's Structural indicators. Eight indicators are also used by DG Research under the "Investing in Research" Action Plan for Europe[3].

All indicators have been updated based on data availability as of September 23, 2003. The 2003 EIS offers a number of improvements compared to the 2002 EIS. Most importantly, it will uses new and more detailed data from the 3rd Community Innovation Survey (CIS-3). It provides a substantially improved coverage of innovation in services. A supplementary technical report, the *Sectoral Innovation Scoreboard* (SIS), replicates the EIS, where possible, for four manufacturing classes: high medium-high, medium-low, and low technology. The background national context that influences innovation performances across the 15 EU member states is described in a second supplementary report on *National Innovation Systems* (NIS).

The EIS is complemented by six technical papers:

- Technical Paper No 1: Indicators and definitions
  Full definitions and graphs for all indicators.
- Technical Paper No 2: Analysis of national performances
  Detailed EIS results for current and trend data, innovation leaders, relative strengths and weaknesses per country, and country pages with both current and trend graphs.
- Technical Paper No 3: Regional innovation performances
  Detailed results for current data, innovation leaders, a revealed regional summary innovation index, and cluster analysis for 173 regions in 13 Member States using 13 regional innovation indicators.
- Technical Paper No 4: Sectoral Innovation Scoreboards
  Replicates the EIS for four classes of manufacturing sectors.
- Technical Paper No 5: National Innovation System Indicators
  Includes nine structural and 14 socio-cultural-institutional indicators that shape the background conditions for innovative activity in each EU Member State.
- Technical Paper No 6: Methodology report
  Describes the methodology underlying the EIS, including different methods for calculating a Summary Innovation Index.

All technical papers are available from the Trend Chart website (www.cordis.lu/trendchart).

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[1] A first provisional EIS was published in September 2000: COM(2000) 567. The first full version of the EIS was published in October 2001: SEC(2001) 1414. The second full version was published in December 2002: SEC(2002) 1349.
[2] SEC(2002) 1213.
[3] SEC(2003) 489.

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1. Introduction

This report looks at several methodological issues involving the European Innovation Scoreboard (EIS). Section 2 describes changes to the EIS indicators and the reasons for the addition of four new indicators, plus splitting six other indicators into manufacturing and service sub-indicators. Section 3 describes the method used to calculate a composite innovation index for the 2003 EIS and for the accompanying papers on a Sectoral Innovation Scoreboard and on National Innovation System Indicators. Section 3 also provides further details on the EIS composite indices. Section 4 evaluates indicator trends. Section 5 provides additional analyses of specific EIS indicators, including the relationship between the indicators for the service and manufacturing sectors, between indicators for diffusion and creative innovation, and for the market sales indicators. Section 6 provides a brief evaluation of the macro-economic relationship between innovation and GDP. Finally, section 7 explains a few statistical details, including the method used to estimate EU 15 means and for identifying national strengths and weaknesses.

2. Choice of Indicators

The EIS indicators are selected to capture both 1) the main drivers and outputs of innovation (human resources, creation of new knowledge, transmission and application of knowledge, and innovation finance, outputs and markets) and 2) aspects of the innovation process that are amenable to policy interventions. The latter is an important feature of the EIS and is why principal component analysis or other techniques are not used to reduce the number of EIS indicators[4]. Instead, the EIS includes 20 main indicators that are useful for identifying national strengths and weaknesses and that can subsequently aid policy development.

2.1 Additions to the 2003 EIS

The 2003 EIS expands on previous versions of the EIS. Four completely new indicators have been added and six indicators have been split to cover both manufacturing and services. These additions to the CIS indicators were made to address two main weaknesses of the EIS: inadequate coverage of innovation as a diffusion process, and inadequate coverage of innovation in the private service sector. The additions to the EIS indicators increase the number of diffusion indicators from six to eight indicators and the number of service sector indicators from one to seven indicators.

[4] In the 2002 EIS Methodology Report, we used PCA (Principal Components Analysis) to identify six key indicators that explained 97% of the total variation. The correlation analyses between all 2003 EIS indicators (see Appendix Table A) also show that between one and four key variables from each of the four EIS indicator categories are correlated with ten or more EIS indicators. These include the working population with a tertiary education (1.2), employment in high tech services (1.5), business R&D (2.2), USPTO high tech patents (2.3.2),

The four new indicators are as follows:

- *Total EPO and USPTO patents*: This covers patenting in all sectors, thereby expanding coverage to many low technology sectors that are not covered by the indicator for high technology patenting.
- *Early-stage venture capital*: Research shows that a crucial problem for many new firms is to obtain seed or early-stage venture capital. This indicator also covers all venture capital investments, thereby extending coverage to non-high tech areas.
- *Sales from new-to-firm products (but not new-to-market)*: The majority of firm sales from innovative products are from those that are not new to the market, but based on either imitating products first introduced by competitors or by selling-through innovations. This indicator captures this component of innovation as a diffusion process.
- *Firm volatility*: Total firm births plus deaths (averaged over three years between 1998 and 2000). Research in the United States shows that the total churn of firms (births plus deaths) is a strong indicator of innovation through the process of creative destruction. New firms introduce new ideas (births) and can replace existing firms that are unable to adapt quickly enough (deaths).

The six split indicators for manufacturing and services include SMEs innovating in-house (3.1), SMEs involved in innovation cooperation (3.2), total innovation expenditures (3.3), new-to-market sales (4.3.1), new-to-firm sales (4.3.2), and volatility (4.7). All but one (firm volatility) of these split indicators are drawn from the CIS.

The 2003 EIS includes 20 separate indicators. Once split indicators for services/ manufacturing and USPTO/EPO patents are counted, there are 28 indicators in total.

Although the EIS coverage of diffusion and service sector innovation has been improved, the EIS still includes more indicators for innovation as a creative process than for innovation as a diffusion-based activity, and more indicators for innovation in manufacturing than in services. Another disadvantage of the EIS, due to inadequate data, is that it does not cover innovation in the public sector, even though this sector accounts for between a minimum of 16% (Luxembourg) and a maximum of 26% (Denmark and Sweden) of total 2001 GDP among the 15 EU member states.

manufacturing SMEs that cooperate on innovation (3.2MAN), early stage venture capital (4.2), and internet access/use (4.4).

3. EIS Composite Innovation Indices

Composite indices are widely used to summarize diverse data. There are three main challenges for constructing a composite index: determining the weights given to each sub-indicator, converting different units of measurement into the same unit, and developing rules for treating interval level data when there are outliers. The 2002 EIS Methodology Report provided an extensive evaluation for each of these three issues and evaluated five methods for calculating a composite innovation index (summarized in Table 1). The 2001 EIS data were used to construct a Summary Innovation Index (SII) based on each of the five methods. All five versions of the 2001 SII were highly correlated with each other, with R^2 values ranging between a low of 0.89 and a high of 0.99. This shows that the choice of which method to use has only a minor effect on the results.

The 2003 EIS uses Method 4 from Table 1 above. This method is more transparent and readily understandable than method 3, even though it is statistically slightly more complex. The value of the indicator for country *x* equals its proportional distance between the lowest and highest observed values. For example, assume that the lowest and observed values for business R&D are 0.5% and 2.5% and that country *x* has a score of 1.5%. For this indicator, the re-scaled score for country *x* is 0.5, which is equal to its position halfway between the lowest and highest observed values. Each re-scaled score is then multiplied by the weight assigned to the indicator. Section 3.4 below gives a full example of how the re-scaled composite index is calculated.

Table 1. Five methods for calculating a composite innovation index

	Advantages	**Disadvantages**
1. Number of indicators above the mean minus the number below the mean (SII). $CI_i^t = \frac{y_i^t}{\sum_{j=1}^m q_j}$, where	Simplest method, unaffected by outliers either below or above the mean. $y_i^t = \# \left\{ j \ s.t. \frac{x_{ij}^t}{x_{EUj}^t} > 1 + p \right\} -$ $\# \left\{ j \ s.t. \frac{x_{ij}^t}{x_{EUj}^t} < 1 + p \right\}$	Loss of interval information, leaving only ordinal level data for each indicator; arbitrary nature of the thresholds.
2. Summing percentage differences from the mean $CI_i^t = \frac{\sum_{j=1}^m q_j y_{ij}^t}{\sum_{j=1}^m q_j}$, where	Simple to construct. $y_{ij}^t = \frac{x_{ij}^t}{x_{EUj}^t}$	Values less than the mean contribute less than values above the mean. One result is that large positive values count considerably more than small negative values. This effectively destroys equal weighting and makes the index sensitive to positive outliers.

3. Standardized values (z scores) for each indicator $CI_i^t = \frac{\sum_{j=1}^m q_j y_{ij}^t}{\sum_{j=1}^m q_j}$, where	Maintains interval level information. $y_{ij}^t = \frac{x_{ij}^t - x_{EUj}^t}{\sigma_{EUj}^t}$	Variables with a large variance have a *de facto* greater weight; index sensitive to both positive and negative outliers.
4. Re-scaled values. The re-scaled scores vary within the identical range for each indicator (0 to 1). $CI_i^t = \frac{\sum_{j=1}^m q_j y_{ij}^t}{\sum_{j=1}^m q_j}$, where	Maintains interval level information, lowest sensitivity to outliers of the methods that maintain interval level data. $y_{ij}^t = \frac{x_{ij}^t - Min(x_j^t)}{Max(x_j^t) - Min(x_j^t)}$	Statistically more complex than other methods.
5. Best performance. (Special case of Method 4) $CI_i^t = \frac{\sum_{j=1}^m q_j y_{ij}^t}{\sum_{j=1}^m q_j}$, where	Maintains interval level information. Simpler version of method 4. $y_{ij}^t = \frac{x_{ij}^t}{Max(x_j^t)}$	Sensitive to positive outliers.

Notes: x_{ij}^t is the value of indicator *j* for country *i* at time *t*. q_j is the weight given to indicator *j* in the composite index. y_{ij}^t equals the value of the transformed indicator for country *i* at time *t*. In equation 1, *p* = an arbitrarily chosen threshold above and below the mean.

3.1 Weighting indicators

Except for one study[5], most compilations of innovation indicators that have developed a composite index either give equal weightings to each indicator or give a subjective weighting in simple units such as '0.5' or '0.75'[6]. The rationale for the use of simple weightings is that it is impossible to carefully calculate weights without a measure of the latent phenomena, such as national innovative capability. The weights for each of the 28 EIS indicators are given in Table 2.

In most cases a weight of 1 is used. A weight of 0.5 is used for each pair of the eight split indicators: the two USPTO/EPO patenting indicators and the six manufacturing/services indicators.

Of note, the private service sector in all EU countries accounts for a greater share of private sector GDP than manufacturing, with its share ranging from a low of 54% in Finland to a high of 77% in Luxembourg, versus a manufacturing share of 35% in Finland and 15% in Luxembourg (the remaining share is due to construction and resource extraction sectors). One

[5] Porter and Stern, *The New Challenge to America's Prosperity: Findings from the Innovation Index*. Council on Competitiveness, Washington DC, 1999.

[6] The State New Economy Index 2002 (Progressive Policy Institute; http://www.neweconomyindex.org) uses weights of both 0.5 and 0.75.

possibility is to use weights that equal the relative share of the manufacturing and private service sectors to GDP. However, the manufacturing sector is a major source of innovative inputs (new equipment, etc) to service sector innovation. For this reason, we use weights of 0.5 for both the manufacturing and service sectors.

Table 2. Indicator weights for the 2003 SII

Indicator	Weight	Indicator	Weight
1.1 S&E graduates	1.0	3.3 Innov expenditures manufacturing	0.5
1.2 Work pop with 3rd education	1.0	3.3 Innov expenditures services	0.5
1.3 Lifelong learning	1.0	4.1 Hi tech venture capital	1.0
1.4 Employment med/hi-tech manuf	1.0	4.2 Early stage venture capital	1.0
1.5 Employment hi-tech services	1.0	4.3.1 New-to-mark prods manufacturing	0.5
2.1 Public R&D expenditures	1.0	4.3.1 New-to-mark prods services	0.5
2.2 Business R&D expenditures	1.0	4.3.2 New-to-firm prods manufacturing	0.5
2.3.1 EPO hi-tech patents	0.5	4.3.2 New-to-firm prods services	0.5
2.3.2 USPTO hi-tech patents	0.5	4.4 Internet access/use	1.0
2.4.1 EPO patents	0.5	4.5 ICT expenditures	1.0
2.4.2 USPTO patents	0.5	4.6 Value added hi-tech manufacturing	1.0
3.1 SMEs innovating in-house manuf	0.5	4.7 Volatility manufacturing	0.5
3.1 SMEs innovating in-house serv	0.5	4.7 Volatility services	0.5
3.2 SMEs innov co- operation manuf	0.5		
3.2 SMEs innov co-operation serv	0.5	Total	20.0

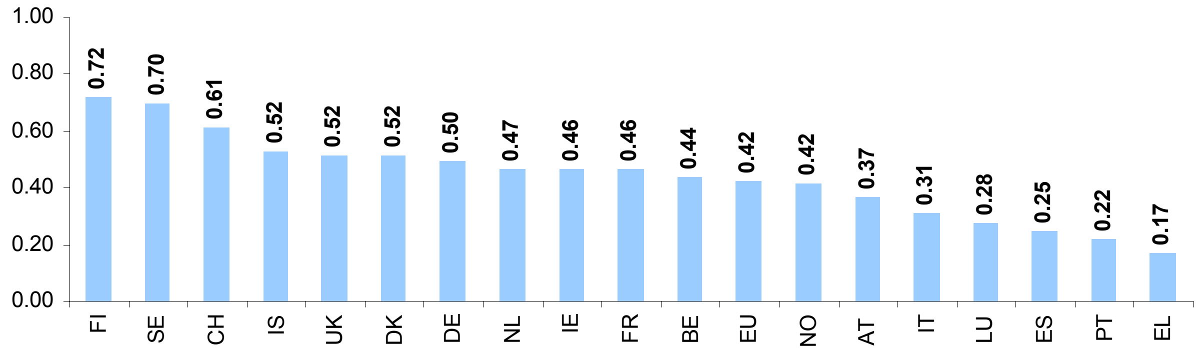
3.2 Four composite EIS indicators

The 2003 EIS includes four composite indices:

1. SII-1: This is the main summary innovation index, based on all 20 main EIS indicators. The SII-1 is calculated for the EU member states plus Switzerland, Iceland and Norway. It is not calculated for the Acceding and Candidate countries and for the US and Japan because of missing data for many of the indicators. The weights are as listed in Table 2.

Figure 1 shows the SII-1 scores for the EU member states and the three Associate countries. Data availability is good for all countries except Ireland and Luxembourg. For Ireland this is due to the absence of CIS-3 data.

Figure 1. SII-1: Finland and Sweden - European innovation leaders

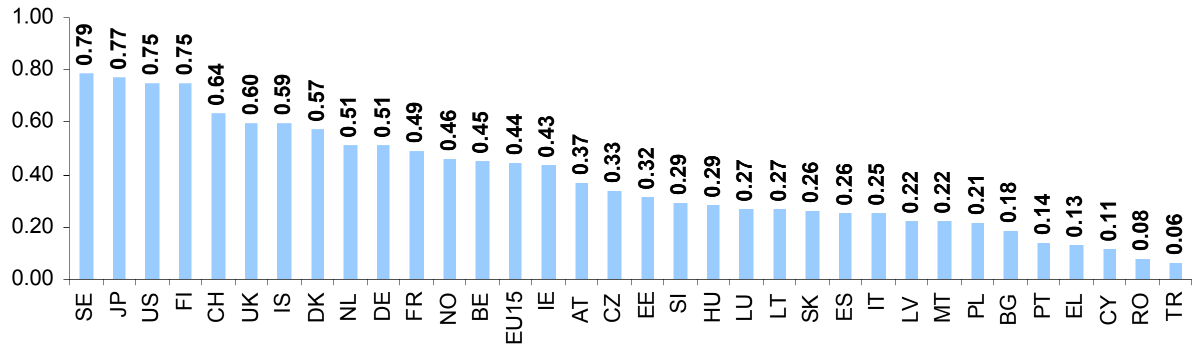


SII-1 data: percent of 20 main indicators available for each country

BE	DK	DE	EL	ES	FR	IE	IT	LU	NL	AT	PT	FI	SE	UK	CH	IS	NO
100%	100%	90%	90%	100%	95%	70%	100%	80%	95%	95%	100%	100%	100%	93%	83%	88%	95%

2. SII-2: This index uses a restricted set of ten indicators that are available for almost all countries. The indicators include: S&E graduates (1.1), working population with a tertiary education (1.2), lifelong learning (1.3), employment in high tech manufacturing (1.4), employment in high tech services (1.5), public R&D (2.1), business R&D (2.2), high tech patents (2.3 split between the EPO and USPTO), all patents (2.4 split between the EPO and USPTO) and ICT expenditures. The weights are as listed in Table 2.

Figure 2. SII-2: Sweden, Japan, US and Finland - World innovation leaders



SII-2 data: percent of 10 indicators available for each country

BE	DK	DE	EL	ES	FR	IE	IT	LU	NL	AT	PT	FI	SE	UK	US	JP
100%	100%	100%	90%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	70%	60%

CH	IS	NO	BG	CY	CZ	EE	HU	LT	LV	MT	PL	RO	SI	SK	TR
95%	100%	100%	100%	90%	95%	95%	100%	100%	95%	70%	90%	95%	100%	100%	70%

Figure 2 shows the SII-2 scores for the EU member states, the Associate, Acceding and Candidate countries, the US and Japan. Data availability is good for all countries *except* the

US, Japan, Malta and Turkey. Of note, the index for the US and Japan is based on only seven and six indicators respectively, which will reduce comparability with EU member states.

The SII-2 indicators are mainly drawn from two of the four EIS indicator categories, ‘human resources’ and ‘knowledge creation’, with no indicator from the categories ‘transmission and application of knowledge’ and only one indicator from ‘innovation finance, outputs and markets’. Consequently, the SII-2 focuses on creative innovation and human resource inputs into the innovation process. Nevertheless, the SII-1 and SII-2 are highly correlated, with an R^2 value of 0.985 for 18 countries for which both composite indices are available. The rank orders are also highly correlated, with an R^2 value of 0.973. This high degree of correlation could be due to a dependence of diffusion-based innovation and innovation outputs on inputs from human resources and creative innovation activities.

3. Services versus manufacturing: The EIS includes separate composite indices to summarize innovation in the services and the manufacturing sectors. The indices are limited to eight relevant indicators that are available for each of these two main sector groups:

- Manufacturing:

  Employment in high-tech manufacturing (1.4); Business R&D in manufacturing (2.2.1); Manufacturing SMEs that innovate in-house (3.1); Manufacturing SMEs involved in innovation cooperation (3.2); Total innovation expenditures in manufacturing (3.3); New-to-market product sales in manufacturing (4.3.1); New-to-firm product sales in manufacturing (4.3.1); Volatility of manufacturing firms (4.7).

- Services:

  Employment in high-tech services (1.4); Business R&D in services (2.2.2); Service SMEs that innovate in-house (3.1); Service SMEs involved in innovation cooperation (3.2); Total innovation expenditures in services (3.3); New-to-market product sales in services (4.3.2); New-to-firm product sales in services (4.3.2); Volatility of service firms (4.7)

All weights for the service and manufacturing composite indices are equivalent to the weights in Table 2. Of note, the major drawback of the separate service and manufacturing indices is that they do not cover human resource inputs, patenting, venture capital, and ICT expenditures.

4. R&D-based versus diffusion-based innovation: The EIS includes separate composite indices to summarize innovation based on R&D or other creative activities, and innovation that is primarily a diffusion process. The latter includes the adoption of innovations developed by other firms or institutions, plus the diffusion of knowledge and capabilities. Two EIS indicators are relevant to both R&D-based and diffusion-based innovation: SMEs involved in innovation cooperation (3.2) and total innovation expenditures (3.3). Indicator 3.2

captures both investment in R&D plus the diffusion of knowledge, while total innovation expenditures includes both investment in creative activities such as R&D and the acquisition of new equipment or licenses (diffusion).

- The *R&D-based innovation index* includes twelve indicators that are not included in the diffusion-based index plus the two indicators that are relevant to both R&D and diffusion based innovation. The first group of indicators are given a weight of 1 when they lack a split indicator pair and a weight of 0.5 when they are paired (ie. patenting in two locations or separate service and manufacturing versions). The two indicators that cover both R&D-based and diffusion-based innovation are both paired indicators and are therefore given weights of 0.25 each:
  - A weight of 1 is given for indicators: S&E graduates (1.1), employment in high-tech manufacturing (1.4), employment in high tech services (1.5), public R&D (2.1), business R&D (2.2), high-tech venture capital (4.1), early-stage venture capital (4.2) and value-added in high tech manufacturing (4.6).
  - A weight of 0.5 is given for indicators: EPO high tech patents (2.3.1), USPTO high tech patents (2.3.2), total EPO patents (2.4.1), total USPTO patents (2.4.2), manufacturing SMEs innovating in-house (3.1) service SMEs innovating in house (3.1), new-to-market product sales in manufacturing (4.3.1) and new-to-market product sales in services (4.3.1).
  - A weights of 0.25 is given for indicators: manufacturing SMEs involved in innovation cooperation (3.2), service SMEs involved in innovation cooperation (3.2), total manufacturing innovation expenditures (3.3) and total services innovation expenditures (3.3).
- The *diffusion-based innovation index* includes six indicators that are not included in the R&D-based innovation index plus the two indicators that are relevant to both R&D and diffusion based innovation. These indicators are given a weight of 1 when they lack a pair and a weight of 0.5 when they are paired (ie. separate service and manufacturing versions). The two indicators that cover both R&D-based and diffusion-based innovation are both paired indicators and are therefore given weights of 0.25 each:
  - A weight of 1 is given for indicators: working population with a tertiary education (1.2), lifelong learning (1.3), internet access/use (4.4) and ICT expenditures (4.5).
  - A weight of 0.5 is given for indicators: new-to-firm manufacturing product sales (4.3.2), new-to-firm services product sales (4.3.2), volatility in manufacturing (4.7), and volatility in services (4.7).
  - A weight of 0.25 is given for indicators: manufacturing SMEs involved in innovation cooperation (3.2), service SMEs involved in innovation

cooperation (3.2), total manufacturing innovation expenditures (3.3) and total services innovation expenditures (3.3).

Of note, the EIS includes twice as many indicators that capture R&D-based innovation alone (12 indicators) than for diffusion-based innovation (6 indicators). This focus on R&D or creative innovation is not intentional but due to a lack of adequate indicators to cover innovation diffusion.

3.3 Three regional composite innovation indicators

The 2003 EIS is supported by a regional innovation scoreboard (RIS). The 2003 RIS included three composite indicators[7]:

1. Revealed Regional Summary Innovation Index (RRSII): A SII is largely calculated for the NUTS 2 regional level for the 15 EU member states. No results are provided for other countries due to a lack of data. The RRSII equals the average of the re-scaled values of the following indices:

2. Regional national summary innovation index (RNSI): The average of the re-scaled indicator values using only regional data for each specific country:

$$RNSII_{jk} = \sum_{j=1}^{m} x_{ijk}^{n} \text{ where } x_{ijk}^{n} = \frac{X_{ijk} - \min(X_{jik})}{\max(X_{ijk}) - \min(X_{ijk})}$$

3. Regional summary innovation index (RRSI): The average of the re-scaled indicator values using data for all regions for all countries:

$$RSII_{jk} = \sum_{j=1}^{m} x_{ijk}^{eu} \text{ where } x_{ijk}^{eu} = \frac{X_{ijk} - \min(X_{ij})}{\max(X_{ij}) - \min(X_{ij})}$$

where X_{ijk} is the value of indicator i for region j in country k and m is the number of indicators for which regional data are available. The RRSII is then calculated as the unweighted average of the re-scaled values for RNSII and RSII.

The RRSII uses 10 main indicators that are available at the regional level: population with tertiary education (1.2), lifelong learning (1.3), employment in medium/high-tech manufacturing (1.4), employment in high-tech services (1.5), public R&D expenditures (2.1), business R&D expenditures (2.2), EPO high-tech patent applications (2.3.1), all EPO patent applications (2.4.1), and five indicators using regional CIS-2 data: the share of innovative

[7] For more details cf. Technical Paper No 6: Regional innovation performances.

enterprises in both manufacturing and services (3.1), innovation expenditures as a percentage of turnover in both manufacturing and services (3.3), and the share of sales of new-to-the-firm products in manufacturing (4.3).

3.4 Other composite indicators

Composite indicators are calculated in the Sectoral Innovation Scoreboard (SIS) for each of four groups of manufacturing sectors (high technology, medium-high technology, medium-low technology, and low technology) and in the National Innovation Systems (NIS) report for four five NIS characteristics (demand, openness, creativity, social equity, and entrepreneurship). Full details are provided in the relevant technical reports. Of note, for presentational reasons both the SIS and the NIS use method 5 in Table 1[8].

3.5 An example

The 2003 Summary Innovation Index is calculated using Method 4 in Table 1:

$$SII_i = \frac{\sum_{j=1}^{m} q_j y_{ij}}{\sum_{j=1}^{m} q_j} \qquad (1)$$

where

$$y_{ij} = \frac{x_{ij} - \min(x_j)}{range(x_j)} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \qquad (2)$$

x_{ij} is the value of indicator j for country i, q_j is the weight given to indicator j in the composite index, and y_{ij} equals the value of the transformed indicator for country i.

In other words, each indicator value for country i is re-scaled, using equation (2), by first subtracting the minimum or lowest value found for each indicator within the set of countries and then dividing it by the range of values, with the latter being defined as the difference between the maximum or largest value and the minimum or lowest value found within the set of countries. The country with the lowest indicator value will thus have a re-scaled value of 0, the country with the highest indicator value will have a re-scaled value of 1.

These re-scaled values are then substituted in equation (1) to calculate the SII, using the following weights:

[8] The NIS and SIS use radar diagrams to present results. Method 4 can produce composite indices, particularly when based on only a few indicators, which place a country at or close to zero. In a radar diagram, this can be misread as zero performance, although the correct interpretation is that zero equals the lowest *observed* performance. Experience has shown that this type of misreading is common, and for this reason the NIS and the SIS use method 5, where a score at or close to zero would be highly unusual.

- $q_j = 1$ for indicators 1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 2.2, 4.1, 4.2, 4.4, 4.5 and 4.6,
- $q_j = 0.5$ for indicators 2.3.1, 2.3.2, 2.4.1, 2.4.2 and the manufacturing and services sub-indicators of indicators 3.1, 3.2, 3.3, 4.3.1, 4.3.2 and 4.7.

A simple example using 2 indicators will help clarify the calculation method. Rows 1 and 2 in the table below give the original values for indicators 2.2 (business R&D expenditures) and 2.3.1 (EPO high-tech patent applications).

These are then converted into re-scaled values in rows 3 and 4. For example, the value for business R&D is adjusted by first subtracting the minimum value (0.19 for Greece) and then dividing by the difference between the maximum value (3.31 for Sweden) and the minimum value. The original value of 1.60 for Belgium thus becomes (1.60 – 0.19) / (3.31 – 0.19) = 0.45.

The re-scaled values for both indicators are then combined to calculate the SII. As business R&D has a weight of 1, and EPO high-tech patents of 0.5, the formula becomes as follows:

$$SII_i = \frac{1*(re\_scaled\_value\_2.1) + \frac{1}{2}*(re\_scaled\_value\_2.3.1)}{1+\frac{1}{2}}$$

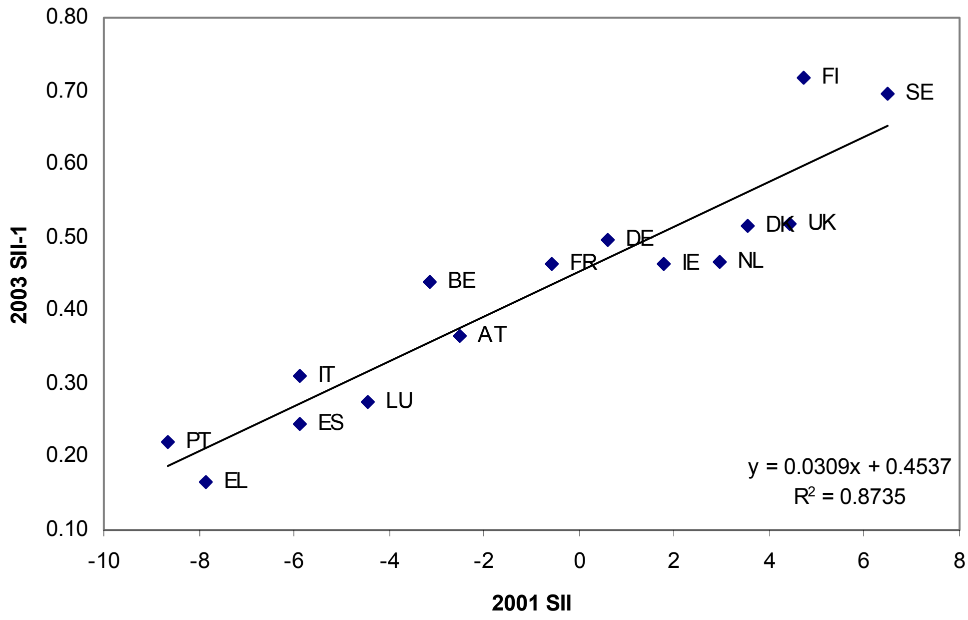
For Belgium, we thus get (1*0.45 + 0.5*0.17) / (1.5) = 0.36.

		BE	DK	DE	EL	ES	FR	IE	IT	LU	NL	AT	PT	FI	SE	UK	EU15	IS	NO
	Original values																		
1	2.2 Business R&D exp	1.60	1.65	1.76	0.19	0.50	1.41	0.87	0.56	1.58	1.08	1.13	0.27	2.42	3.31	1.28	1.30	1.81	0.97
2	2.3.1 EPO h-tech pats	23.4	42.1	48.8	2.1	3.6	30.3	30.7	6.5	10.9	68.8	18.8	0.7	136.1	100.9	35.6	31.6	31.0	49.6
	Re-scaled values																		
3	2.2 Business R&D exp	0.45	0.47	0.50	0.00	0.10	0.39	0.22	0.12	0.45	0.28	0.30	0.03	0.71	1.00	0.35	0.36	0.52	0.25
4	2.3.1 EPO h-tech pats	0.17	0.31	0.36	0.01	0.02	0.22	0.22	0.04	0.08	0.50	0.13	0.00	1.00	0.74	0.26	0.23	0.22	0.36
5	SII	0.36	0.41	0.45	0.00	0.07	0.33	0.22	0.09	0.32	0.36	0.25	0.02	0.81	0.91	0.32	0.31	0.42	0.29

3.6 Rank order changes since 2001

The 2001 SII was calculated using different indicators and a different method (option 1 in Table 1) compared to the 2003 SII. Nevertheless, as shown in Figure 3, the two SIIs are highly correlated, with an R^2 value of 0.87 for the 15 EU member states.

Figure 3 Correlation between 2001 SII and 2003 SII



Germany and Italy show the largest change in their SII rank order between 2001 and 2003 (compare columns (1) and (5) in Table 3), moving up by two places. This change could be due to a real improvement, a change in the set of indicators, or a change in the method of calculating the SII.

Column (2) re-calculates the 2001 SII using the re-scaled method 4 in Table 1 and the original indicators and data for 2001[9]. A direct comparison between the ranks in columns (1) and (2) confirms that the method of calculating the SII does not have a real effect on the rank order (a change in rank of only 1 place is considered to be a marginal change without significance).

The second test searches for a real change, using the same set of indicators[10] and the same re-scaled calculation method, but comparing 2003 data (column 3) with the 2001 data (column 2). The observed change in the rank order is given in column (4). Any improvement in the rank order between columns (2) and (3) would be a *real* improvement based on the 2001 EIS set of indicators. With an unchanged set of indicators, France shows an improvement of 3 ranks and Italy of 2 ranks. The Netherlands shows a decline of 3 ranks and Spain of 2 ranks.

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[9] See Annex B in SEC(2001) 1414.

[10] These include the following 2003 EIS indicators: S&E graduates (1.1), tertiary education (1.2), lifelong learning (1.3), med/hi-tech manufacturing employment (1.4), hi-tech services employment (1.5), public R&D (2.1), business R&D (2.2), hi-tech EPO patents (2.3.1), hi-tech USPTO patents (2.3.2), manufacturing SMEs innovating in-house (3.1), manufacturing SMEs involved in innovation co-operation (3.2), innovation expenditures in manufacturing (3.3), hi-tech venture capital (4.1), early stage venture capital (4.2), new-to-market sales in manufacturing (4.3.1), internet access/use (4.4), ICT expenditures (4.5) and hi-tech manufacturing value-added (4.6).

Table 3. Rank order of 2001 and 2003 Summary Innovation Index (15 = least innovative and 1 = most innovative)

	2001 SII 'original'	**2001 SII re-scaled method**	**2003 SII-1 '2001 EIS indicators'**	**Observed rank Impro-vement**	**2003 SII-1**	**Change due to different set of indicators**
	(1)	**(2)**	**(3)**	**(4) = (3) – (2)**	**(5)**	**(6) = (5) – (3)**
Belgium	*10*	10	9	+1	9	--
Denmark	*4*	3	3	--	4	-1
Germany	*7*	7	7	--	5	+2
Greece	*14*	15	15	--	15	--
Spain	*12*	11	13	-2	13	--
France	*8*	8	5	+3	8	-3
Ireland	*6*	6	6	-1	7	-1
Italy	*13*	13	11	+2	11	--
Luxembourg	*11*	12	12	--	12	--
Netherlands	*5*	5	8	-3	6	+2
Austria	*9*	9	10	-1	10	--
Portugal	*15*	14	14	--	14	--
Finland	*2*	2	1	+1	1	--
Sweden	*1*	1	2	-1	2	--
United Kingdom	*3*	4	4	--	3	+1

The third possible cause for a change in rank order is due to the change in indicators, with the 2003 EIS including four new indicators, plus split indicators for manufacturing and services. The fact that the changes in the rank order visible in column (4) are not seen in the 2003 SII-1, as shown in column (5), is due to the change in the set of indicators. Consequently, the rank order for Netherlands only declines by 1 place (from 5 to 6) and the rank for France stays the same (at rank 8).

Column (6) of Table 3 shows the change in rank order due to the change in indicators. Germany's improvement of two places is entirely due to the change in indicators. The change in indicators would have resulted in a fall of 3 places for France, but France's improvement of 3 places in the original set of indicators (column 4) balances this fall, resulting in no change in the rank order for France. Conversely, the rank order for the Netherlands fell by 3 places using the original set of indicators, but improved by two places due to the change in the set of indicators. The net result is a fall of one place for the Netherlands (compare column 5 against column 2).

3.7 Effect of weightings on SII-1

The SII for each country is influenced by the weights assigned to each indicator. Optimally, the weights for each indicator would be based on an empirically tested theory of the contribution of each indicator to national innovative capability. Unfortunately, neither such a theory or empirical test are available and consequently the weighting scheme is based on assigning equal weights to all indicators, with split indicators assigned a weight of one-half the normal weight. However, it is possible that some indicators are worth more than others. To explore the effect of the choice of weightings on the relative rankings of each country, we randomly varied the weights for each indicator for SII-1 to vary between plus and minus 100% around the value used in Table 2. Weights set to 0.5 are therefore randomly varied to equal between zero and 1, while weights set to 1 vary between zero and 2.

The results are given in Table 4. The first data column gives the original SII-1 score for 18 countries. The second and third data columns give the minimum and maximum observed SIIs after 500 iterations using randomized weighting for all indicators. The column ‘sensitivity’ shows how sensitive the results for each country are to the weighting scheme, with the result equal to the percentage change in the maximum SII randomized score compared to the original SII-1 score. A large percentage change indicates higher sensitivity to the choice of the weighting scheme. Sensitivity will be high when there is a large variation in the re-scored values of the indicators, and low when all indicators are relatively similar. For example, sensitivity would be zero if all indicators had the same relative value, such as ‘0.5’ or ‘1.0’. Under this condition, it would not matter what weights are used and the SII would always be the same.

Table 4. Randomized indicator weightings (countries ranked in order of SII-1 scores)

		SII scores after randomized weights				
Country	**SII score**	**Min**	**Max**	**Sensitivity**	**Max rank order change**	**Best case order change**
Finland	0.72	0.66	0.77	7%	0	0
Sweden	0.70	0.62	0.78	11%	0	1
Switzerland	0.61	0.53	0.69	13%	0	0
Iceland	0.52	0.40	0.63	21%	0	1
UK	0.52	0.42	0.62	19%	0	2
Denmark	0.52	0.41	0.58	12%	-1	2
Germany	0.50	0.44	0.58	16%	-1	3
Netherlands	0.47	0.41	0.53	13%	0	5
Ireland	0.47	0.33	0.60	28%	2	4
France	0.46	0.39	0.53	15%	0	6
Belgium	0.44	0.39	0.49	11%	0	3
Norway	0.42	0.35	0.48	14%	0	4
Austria	0.37	0.31	0.42	14%	0	0
Italy	0.31	0.24	0.38	23%	0	1
Luxembourg	0.28	0.21	0.35	25%	0	1
Spain	0.25	0.19	0.32	28%	0	2
Portugal	0.22	0.17	0.28	27%	0	2
Greece	0.17	0.10	0.23	35%	0	1

The sensitivity results show that Finland has the least variation in the relative value of the indicators, with only a 7% difference between the original SII score and the maximum score using randomized weightings[11]. Conversely, Greece, Spain, Ireland, Portugal, and Luxembourg have sensitivities above 25%.

The fifth data column gives the change in the rank order for each country comparing the original SII score to the maximum observed score using randomized weightings. There are very few changes. Denmark and Germany both decline one position, while Ireland increases one position.

The final data column gives the best case results for each country. This occurs from comparing the maximum SII randomized score for each country against the original SII scores for all other countries. The greatest improvement of 4 or more rank order changes would be for Norway, the Netherlands, Ireland and France. However, these relatively large

[11] Of note, the mean randomised score is always equal to the original SII score.

changes in the rank order are due to the fact that the original SII-1 values for these countries are very similar, varying from only 0.42 to 0.47. Other countries such as Greece, Spain and Portugal have high sensitivity to the choice of weights but change only 1 or 2 rank order positions. This is because there are much larger differences between them in their original rank order and between these three countries and the countries just ahead of them. Even though the maximum scores for these three countries improve substantially over their original scores, it is still not enough to make a large difference in their rank order.

These analyses of the weighting scheme show that the rank order at the high and low ends is relatively stable and not highly sensitive to the choice of weights. The greatest change is in the middle group of countries (Germany to Norway inclusive) and is due to the close similarity in the original SII scores for these countries. These results suggest that there are no meaningful differences in the rank order scores between the Netherlands, Ireland and France, in particular.

4. Trends

Trends are calculated as the percentage change between the last year for which data are available and the average over the preceding three years, after a one-year lag. The three-year average is used to reduce year-to-year variability; while the one-year lag is used to increase the difference between the average for the three base years and the final year and to minimize the problem of statistical/sampling variability.

The EIS also uses an average trend per country. This is calculated as the weighted average of the trend values for 12 main indicators for which trend data are available. The following weights are used for calculating average country and EU15 trends:

- 1 for indicators 1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 2.2, 4.5 and 4.6
- 0.25 for the two split patent indicators: 2.3.1 and 2.3.2, and 2.4.1 and 2.4.2

The use of weights of 0.25 for the four patent indicators ensures that the weight given to patenting equals 1 and is therefore equivalent to the weight for other indicators, such as for S&E graduates (1.1) and business R&D (2.2).

5. Analysis of Modes of Innovation

This section compares R&D-based versus diffusion-based innovation and the services versus manufacturing sectors.

R&D based versus diffusion:
Countries may differ in their relative performance in "R&D based" innovation versus "diffusion based" innovation. Larger and economically more developed countries might do better on R&D-based innovation as they can benefit from economies of scale in R&D. Smaller or economically less developed countries such as Greece, Portugal and the ACC countries might perform better on innovation diffusion, for example if they successfully adopt new ICT or manufacturing technologies from abroad. In addition, countries that perform well in diffusion may have a lower SII due to the fact that the SII gives greater emphasis to R&D-based innovation: the number of indicators related to R&D-creation is about twice the number of indicators related to diffusion.

Two separate composite indices were constructed to explore possible differences between countries: the R&D-based innovation index and the diffusion innovation index. Figure 4 gives the R&D-based composite index on the vertical axis and the diffusion innovation index on the horizontal axis using the SII-2 indicators that are available for 33 countries. These results must be interpreted cautiously because they include only 2-3 indicators for diffusion and between 4 and 7 indicators for R&D based innovation.

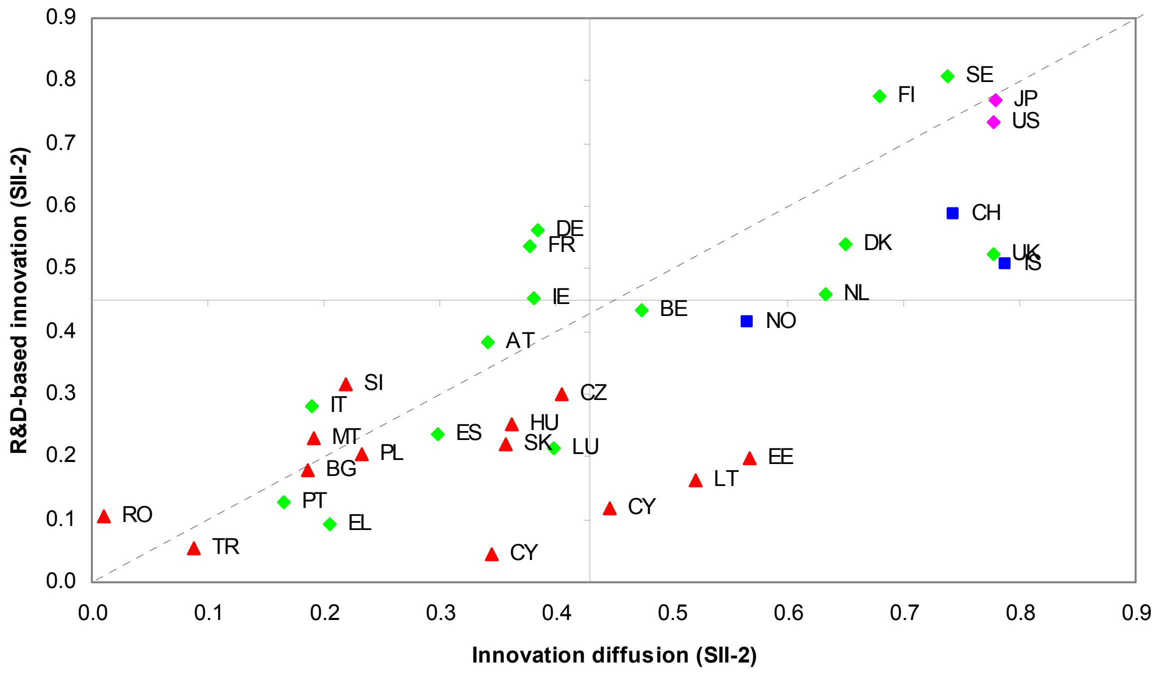
As shown in Figure 4, most of the ACC countries perform much better on innovation diffusion than on the creation of innovation. Only Slovenia, Malta and Romania perform relatively better on the creation of innovation. Figure 4 suggests that, with some notable exceptions, countries with a high rank for R&D-based innovation will also rank high on their overall SII score. Table 5 confirms this by showing a very high significant correlation between the R&D-based innovation index and SII-2.

Table 5. Correlation matrix between R&D-based, innovation diffusion and SII-2

	Diffusion SII-2	R&D-based SII-2	SII-2
Diffusion SII	1		
R&D-based SII	0.772**	1	
SII-2	0.883**	0.980**	1

** Correlation is significant at the 0.01 level (2-tailed).

Figure 4. R&D-based innovation versus innovation diffusion: limited data set

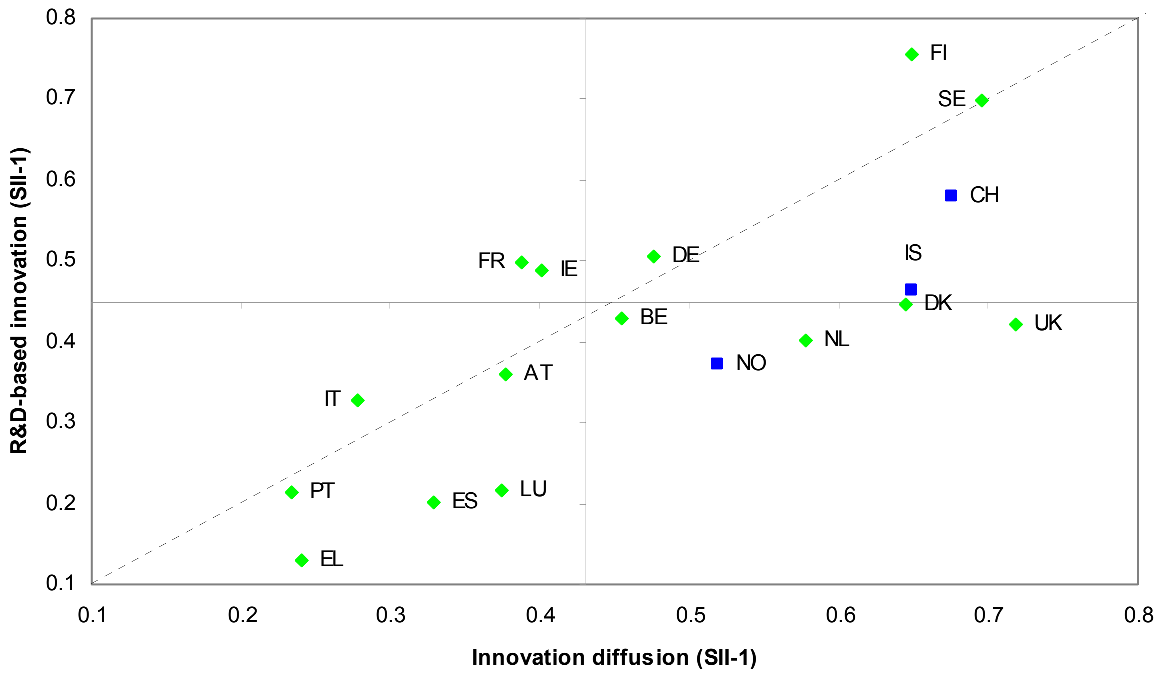


SII-2	BE	DK	DE	EL	ES	FR	IE	IT	LU	NL	AT	PT	FI	SE	UK	US	JP
Diffusion	0.47	0.65	0.38	0.20	0.30	0.38	0.38	0.19	0.40	0.63	0.34	0.17	0.68	0.74	0.78	0.78	0.78
R&D-based	0.44	0.54	0.56	0.09	0.24	0.54	0.45	0.28	0.21	0.46	0.38	0.13	0.77	0.81	0.52	0.73	0.77
# indicators																	
Diffusion	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0
R&D-based	7.0	7.0	7.0	6.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	5.0	4.0

SII-2	CH	IS	NO	BG	CY	CZ	EE	HU	LT	LV	MT	PL	RO	SI	SK	TR
Diffusion	0.74	0.79	0.57	0.19	0.35	0.40	0.57	0.36	0.52	0.45	0.19	0.23	0.01	0.22	0.36	0.09
R&D-based	0.59	0.51	0.42	0.18	0.04	0.30	0.20	0.25	0.16	0.12	0.23	0.20	0.11	0.32	0.22	0.05
# indicators																
Diffusion	3.0	3.0	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0	3.0	3.0	2.0
R&D-based	6.5	7.0	7.0	7.0	7.0	6.5	6.5	7.0	7.0	6.5	5.0	6.0	6.5	7.0	7.0	5.0

The analysis is repeated for the Member States and Associate countries, for which between 4 and 7 indicators are available for diffusion and between 10 and 13 indicators for R&D based innovation. The results are shown in Figure 5. For most countries, there is little change compared to Figure 4 in the relative performance on R&D versus diffusion-based innovation. However, the inclusion of the CIS-indicators for diffusion shifts the relative performance of Sweden, Austria, Germany and Spain towards innovation diffusion. As in Figure 4, most countries perform better in innovation diffusion than in creative innovation. Only Finland, Germany, Ireland, Italy and France perform better in R&D-based innovation than in the diffusion of innovation. Table 6 shows a strong correlation between the R&D and innovation based SIIs, plus a strong correlation with the SII-1.

Figure 5. R&D-based innovation versus innovation diffusion: Full data set



SII-1	BE	DK	DE	EL	ES	FR	IE	IT	LU	NL	AT	PT	FI	SE	UK	CH	IS	NO
Diffusion	0.45	0.64	0.48	0.24	0.33	0.39	0.40	0.28	0.37	0.58	0.38	0.23	0.65	0.70	0.72	0.68	0.65	0.52
R&D-based	0.43	0.45	0.51	0.13	0.20	0.50	0.49	0.33	0.22	0.40	0.36	0.21	0.75	0.70	0.42	0.58	0.46	0.37
# indicators																		
Diffusion	7.0	7.0	6.0	6.0	7.0	6.0	4.0	7.0	6.0	7.0	6.0	7.0	7.0	7.0	6.0	5.0	5.8	6.0
R&D-based	13.0	13.0	12.0	12.0	13.0	13.0	10.0	13.0	10.0	12.0	13.0	13.0	13.0	13.0	12.5	11.5	11.8	13.0

Table 6. Correlation matrix between R&D-based, innovation diffusion and SII-1

	Diffusion SII	R&D-based SII	SII-1
Diffusion SII	1		
R&D-based SII	0.745**	1	
SII-1	0.885**	0.970**	1

** Correlation is significant at the 0.01 level (2-tailed).

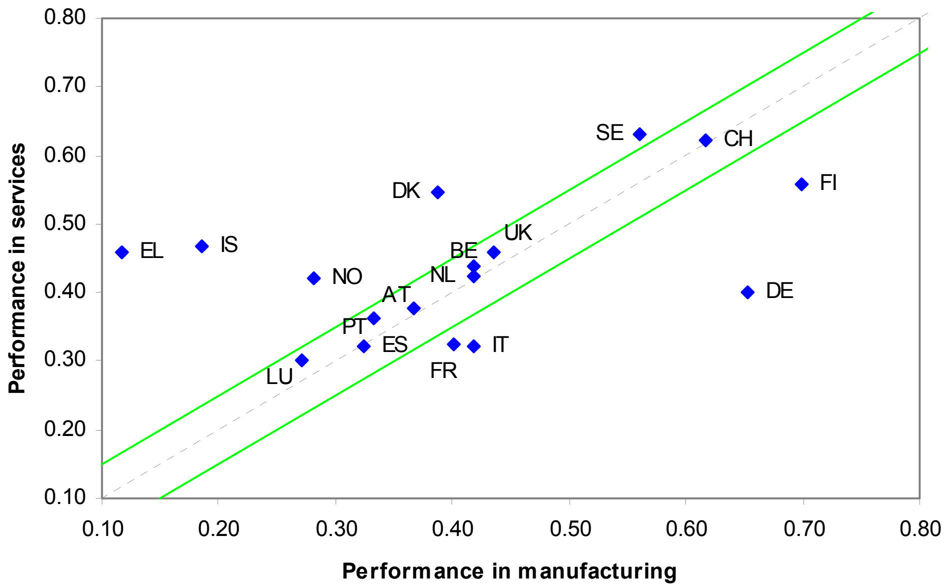
Services versus manufacturing:
The importance of services to overall value-added and employment is an indicator of economic structure of a national innovation system. The relative contribution of services to business R&D is another discriminator. In many EU countries, increasing R&D expenditure in services has driven growth in business R&D as a whole. For the EU-15, the share of services in business R&D has increased from 8% in 1992 to 13% in 1999. In the US, services take up an even bigger share of business R&D, increasing from 24% in 1992 to 34% in 2000.

Japan presents a contrasting picture with a 0.2% share in 1992, increasing to only 2% in 2000.

The latest CIS made valuable new data available on innovation in the service sector. This opened the way to extending research into comparing innovativeness in the service and the manufacturing sectors. Figure 7 demonstrates differences between innovativeness in manufacturing and in services for 14 EU countries, Switzerland, Iceland and Norway[12]. The vertical axis gives a composite index for services and the horizontal axis gives a composite index for manufacturing. Both use re-scaled data for eight indicators. Of note, the index in both cases is relative to the performance of other countries in services and in manufacturing. Therefore, a higher score in one sector does not mean that the country has an absolute level of innovation that is higher in this sector (even if it were possible to develop an indicator for absolute innovation performance in the service and manufacturing sectors).

Countries above the dotted line perform *relatively* better in services compared to other countries, those below perform relatively better in manufacturing. Data availability is good for most countries except for both manufacturing and services for Luxembourg, Switzerland and Iceland and for services for the UK.

Figure 7. Innovation performance in services vs manufacturing



SII	BE	DK	DE	EL	ES	FR	IT	LU	NL	AT	PT	FI	SE	UK	CH	IS	NO
Manufacturing	0.42	0.39	0.65	0.12	0.32	0.40	0.42	0.27	0.42	0.37	0.33	0.70	0.56	0.44	0.62	0.19	0.28
Services	0.44	0.55	0.40	0.46	0.32	0.32	0.32	0.30	0.42	0.38	0.36	0.56	0.63	0.46	0.62	0.47	0.42
Data availability																	
Manufacturing	100%	100%	88%	88%	100%	88%	100%	63%	88%	88%	100%	100%	100%	88%	75%	75%	88%
Services	100%	100%	88%	88%	100%	88%	100%	63%	88%	88%	100%	100%	100%	75%	75%	63%	88%

[12] For Ireland, due to the absence of CIS-3 data, the number of indicators for which separate data for manufacturing and services is available is only 2.

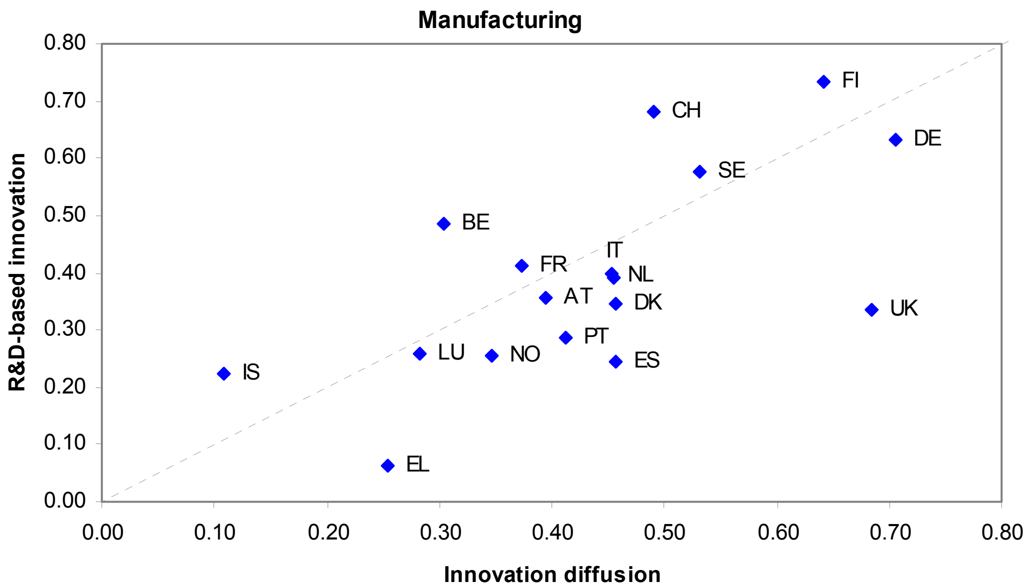
Figure 7 also shows that most countries perform relatively better in services than in manufacturing. However, for several countries the differences between both composite indices is quite small. Those countries lying within the two boundary lines of plus or minus 5% of the central line (showing equal relative performance in manufacturing and services) are assumed to have no significant difference in relative performance between services and manufacturing. Of the remaining countries Sweden, Denmark, Norway, Iceland and Greece show a stronger performance in services, and Finland, Germany, Italy and France show a stronger performance in manufacturing. Greece's relative performance in services is strikingly better than its performance in manufacturing.

Of note, there is a positive correlation (0.451) between performance in manufacturing and services, which is weaker than the correlation between R&D-based and diffusion-based innovation. The positive correlation could be due to spillovers in knowledge and expertise between these major sector groups. However, there is a clear difference between countries that build their innovation performance mainly on services (Greece, Iceland and Denmark), while Germany performs much better in manufacturing.

R&D-based vs innovation diffusion within manufacturing

Figure 8 replicates the results in Figure 5 for the manufacturing sector only. Finland, Switzerland, Sweden, France, Belgium and Iceland perform better in the creation than in the diffusion of innovation in the manufacturing sector. Conversely, the UK's performance is dominated by innovation diffusion.

Figure 8. R&D-based innovation vs innovation diffusion in manufacturing



6. Economic Impact of Innovation

The justification for policy actions to support innovation is that innovation is partly responsible for improvements in the quality of life and in quantitative measures of well-being such as higher GDP per capita, productivity, and economic growth.

Although several different measures of innovation have been used in empirical research, including R&D spending, patenting, and the technological balance of payments, most empirical research has focused on the effect of innovation on productivity, either at the firm, industry or country level. The literature on this issue[13] finds that innovation has a significant effect on productivity, whether measured by R&D spending, patenting or innovation counts. The OECD Growth Project[14] has recently explored the possible sources of divergence in the levels of GDP per capita among OECD countries. Although an individual factor cannot be identified as the main source of growth divergences, innovation and technology are pointed out as significant factors in increased growth performance.

Table 7 provides correlation results between each EIS innovation indicator plus the SII-1 and three macro-economic variables at the national level: 2001 GDP per capita, 2002 labour productivity (per person employed), and the growth in total employment between 1999 and 2001[15]. Since the SII-1 is only available for the 2003 EIS, we do not provide lag time analyses (See the 2002 methodology report for lag time analyses for many of the EIS indicators).

In general, the correlation coefficients between the SII-1, the individual EIS indicators, and the three economic output variables are all quite low. Only two indicators are significantly correlated with GDP per capita, and in both cases the correlation is negative: sales of new-to-market products in services and sales of new-to-firm products in services. Only one indicator is significant and positively correlated with labour productivity: the share of high-tech venture capital investment. And only one indicator is significant and negatively correlated with employment growth: public R&D expenditures. The SII-1 is not correlated with any of the macro-economic variables. These results are not surprising for three reasons. First, very few studies find a correlation between innovation and economic outcomes, when limited to developed countries. Second, the analyses do not adjust for other variables that influence economic outcomes. And third, there is an inadequate lag time between the SII variables and the economic outcomes.

[13] For a review of this literature, see Mairesse, J. and Mohnen, P. (1995). *R&D and productivity: a survey of the econometric literature*, Université du Québec: mimeo; or Cameron, G. (1998) *Innovation and Growth: a survey of the empirical literature* (manuscript).

[14] http://www.oecd.org/subject/growth. See the report: *A new Economy?; The Changing Role of Innovation and Information Technology in Growth*, OECD 2000.

[15] Sources: The data for GDP per capita (PPS), productivity per hour worked and for employment growth are from Eurostat's Structural indicators (http://europa.eu.int/comm/eurostat/). Data for Switzerland are not available in the Eurostat's Structural indicators.

Table 7. The 2003 SII-1 indicators and economic output correlations

	SII-1	Per capita GDP	Labour productivity	Employment growth
SII-1	1.000	.122	.154	-.121
1.1 S&E graduates	.419	-.318	.059	.396
1.2 Tertiary education	.670**	.242	.358	-.173
1.3 Lifelong learning	.759**	.158	-.033	-.224
1.4 Employment in med-high/high-tech manufacturing	.524*	-.158	.097	-.236
1.5 Employment in high-tech services	.886**	.267	.336	-.122
2.1 Public R&D expenditures	.654**	-.257	-.271	-.504*
2.2 Business expenditure on R&D	.868**	.286	.197	.061
2.3.1 EPO high-tech patent applications	.884**	.075	.045	-.114
2.3.2 USPTO high-tech patent applications	.917**	.024	-.027	-.133
2.4.1 All EPO patent applications	.789**	.434	.290	-.076
2.4.2 All USPTO patent grants	.821**	.369	.229	.041
3.1 SMEs innovating in-house (manufacturing)	.382	.240	.257	.325
3.1 SMEs innovating in-house (services)	.320	.476	.289	-.121
3.2 % Manufacturing SMEs in innovation cooperation	.835**	.476	.289	-.121
3.2 % Services SMEs in innovation cooperation	.442	.152	-.091	-.459
3.3 Innovation expenditures in manufacturing	.477	-.154	-.001	.037
3.3 Innovation expenditures in services	.418	-.095	-.187	.078
4.1 High-tech venture capital investment	.158	.388	.560*	.214
4.2 Early stage venture capital	.813**	.309	.086	-.093
4.3.1 'New to market' products – manufacturing	.112	-.169	-.108	.344
4.3.1 'New to market' products – services	-.289	-.644**	-.435	-.176
4.3.2'New to firm' products - manufacturing	.200	-.245	-.171	-.080
4.3.2'New to firm' products – services	-.235	-.562*	-.266	-.269
4.4 Internet access/use	.803*	.442	.275	-.041
4.5 ICT expenditures	.682**	.332	.083	.068
4.6 Percent of manufacturing value-added from high-tech	.072**	-.081	.208	.026
4.7 Volatility manufacturing firms	-.334	-.114	-.287	-.033
4.7 Volatility service firms	-.091	.491	.262	-.630

Notes: * and ** denote significant correlations at the 0.05 and 0.01 levels, respectively.
1: Insufficient data for analysis.

7. Statistical Estimations and Decisions

This section provides statistical details on how the EU means for each indicator are calculated and on the identification of the strengths and weaknesses for each country.

EU15 means: Most EU15 means are calculated and supplied by EUROSTAT, except for indicators 1.1 (S&E graduates) and all CIS-indicators where EUROSTAT could not, due to limited data availability, calculate EU-15 means. As these means are necessary for comparing current performance to the EU-15, weighted averages were calculated for indicator 1.1 and all CIS-indicators.

For indicator 1.1, population data on 20-29 years old was used to:

1) calculate the absolute numbers of S&E graduates per country: (value of indicator 1.1 / 1000) x number of 20-29 years old,
2) and then divide the sum of all S&E graduates by the total number of 20-29 year olds.

For the CIS-indicators, we have experimented with six possible weights to try to get as good an estimate of the EU-15 mean using the CIS-data from the 2001 EIS: GDP, population, total employment, industrial employment, labour force and value-added of industry. Table 8 summarizes these experiments. The 2nd column reproduces the 2001 EIS values for four CIS-indicators: SMEs innovation in-house, SMEs involved in innovation co-operation, innovation expenditures and sales of new-to-market products. Each of the columns (3), (5), (7), (9), (11) and (13) gives the weight for each country using 2000 data for the size of the population, GDP, total employment, industrial employment, labour force and value-added of industry[16]. These weights are simply calculated as the value for each country divided by the total. E.g., the population size (in thousands) for Belgium in 2000 is 10246. Total EU-15 population is 378170. The population weight for Belgium is thus equal to 0.027 (i.e. 10246 divided by 378170). Multiplying per country the indicator value as given in column (2) and the various weights, gives the contribution per country to the EU-15. These contributions are given in columns (4), (6), (8), (10), (12) and (14). To continue our example, for Belgium for 2001 EIS indicator 3.1, the contribution to the EU-15 average equals 0.8 (i.e. Belgium's indicator value of 29.4 multiplied by its population weight of 0.027). For EIS 2001 indicators 3.1 and 3.2 weights are calculated using data for all 15 EU member states, for indicator 3.3 data for only 14 EU member states was used, as CIS-2 data for Luxembourg was not available, and for indicator 4.3 data for only 13 EU member states was used, as CIS-2 data Greece and Luxembourg was not available.

[16] These data were taken from OECD's *Main Science and Technology Indicators*.

Table 8. 2001 EIS CIS-indicator values re-estimated for EU-15 (1)

2001 EIS indicator 3.1: SMEs innovating in-house (manufacturing)

	2001 EIS 3.1	Pop weight	Contri-bution	GDP weight	Contri-bution	Total empl weight	Contri-bution	Indus empl weight	Contri-bution	Lab force weigt	Contri-bution	VA ind weight	Contri-bution
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
BE	29.4	0.027	0.8	0.029	0.8	0.024	0.7	0.022	0.7	0.025	0.7	0.028	0.8
DK	59.0	0.014	0.8	0.020	1.2	0.017	1.0	0.015	0.9	0.016	1.0	0.018	1.1
DE	58.7	0.217	12.8	0.237	13.9	0.231	13.6	0.235	13.8	0.228	13.4	0.240	14.1
EL	20.1	0.029	0.6	0.014	0.3	0.023	0.5	0.026	0.5	0.025	0.5	0.014	0.3
ES	21.6	0.106	2.3	0.071	1.5	0.094	2.0	0.097	2.1	0.102	2.2	0.073	1.6
FR	36.0	0.160	5.8	0.165	6.0	0.144	5.2	0.137	4.9	0.151	5.5	0.162	5.8
IE	62.2	0.010	0.6	0.012	0.7	0.010	0.6	0.011	0.7	0.010	0.6	0.013	0.8
IT	44.4	0.153	6.8	0.136	6.0	0.138	6.1	0.142	6.3	0.135	6.0	0.140	6.2
LU	24.5	0.001	0.0	0.002	0.1	0.002	0.0	0.002	0.0	0.002	0.0	0.003	0.1
NL	51.0	0.042	2.1	0.047	2.4	0.048	2.5	0.048	2.4	0.046	2.3	0.046	2.4
AT	59.1	0.021	1.3	0.024	1.4	0.024	1.4	0.026	1.5	0.022	1.3	0.025	1.5
PT	21.8	0.027	0.6	0.013	0.3	0.029	0.6	0.031	0.7	0.029	0.6	0.012	0.3
FI	27.4	0.014	0.4	0.015	0.4	0.014	0.4	0.013	0.4	0.015	0.4	0.015	0.4
SE	44.8	0.023	1.0	0.030	1.4	0.025	1.1	0.022	1.0	0.025	1.1	0.028	1.3
UK	35.8	0.155	5.6	0.182	6.5	0.175	6.3	0.174	6.2	0.168	6.0	0.180	6.5
EU	44.0	1.000	41.4	1.000	43.0	1.000	42.1	1.000	42.1	1.000	41.8	1.000	43.1

2001 EIS indicator 3.2: SMEs involved in innovation co-operation (manufacturing)

	2001 EIS 3.2	Pop weight	Contri-bution	GDP weight	Contri-bution	Total empl weight	Contri-bution	Indus empl weight	Contri-bution	Lab force weigt	Contri-bution	VA ind weight	Contri-bution
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
BE	8.9	0.027	0.2	0.029	0.3	0.024	0.2	0.022	0.2	0.025	0.2	0.028	0.2
DK	37.4	0.014	0.5	0.020	0.7	0.017	0.6	0.015	0.6	0.016	0.6	0.018	0.7
DE	14.7	0.217	3.2	0.237	3.5	0.231	3.4	0.235	3.5	0.228	3.4	0.240	3.5
EL	6.5	0.029	0.2	0.014	0.1	0.023	0.2	0.026	0.2	0.025	0.2	0.014	0.1
ES	7.0	0.106	0.7	0.071	0.5	0.094	0.7	0.097	0.7	0.102	0.7	0.073	0.5
FR	12.0	0.160	1.9	0.165	2.0	0.144	1.7	0.137	1.6	0.151	1.8	0.162	1.9
IE	23.2	0.010	0.2	0.012	0.3	0.010	0.2	0.011	0.3	0.010	0.2	0.013	0.3
IT	4.7	0.153	0.7	0.136	0.6	0.138	0.6	0.142	0.7	0.135	0.6	0.140	0.7
LU	9.6	0.001	0.0	0.002	0.0	0.002	0.0	0.002	0.0	0.002	0.0	0.003	0.0
NL	13.8	0.042	0.6	0.047	0.6	0.048	0.7	0.048	0.7	0.046	0.6	0.046	0.6
AT	12.9	0.021	0.3	0.024	0.3	0.024	0.3	0.026	0.3	0.022	0.3	0.025	0.3
PT	4.5	0.027	0.1	0.013	0.1	0.029	0.1	0.031	0.1	0.029	0.1	0.012	0.1
FI	19.9	0.014	0.3	0.015	0.3	0.014	0.3	0.013	0.3	0.015	0.3	0.015	0.3
SE	27.5	0.023	0.6	0.030	0.8	0.025	0.7	0.022	0.6	0.025	0.7	0.028	0.8
UK	15.7	0.155	2.4	0.182	2.9	0.175	2.8	0.174	2.7	0.168	2.6	0.180	2.8
EU	11.2	1.000	12.1	1.000	13.0	1.000	12.5	1.000	12.4	1.000	12.4	1.000	12.9

2001 EIS indicator 3.3: Innovation expenditures (manufacturing)

	2001 EIS 3.3	Pop weight	Contri-bution	GDP weight	Contri-bution	Total empl weight	Contri-bution	Indus empl weight	Contri-bution	Lab force weigt	Contri-bution	VA ind weight	Contri-bution
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
BE	2.1	0.027	0.1	0.029	0.1	0.024	0.1	0.022	0.0	0.025	0.1	0.028	0.1
DK	4.8	0.014	0.1	0.020	0.1	0.017	0.1	0.015	0.1	0.016	0.1	0.018	0.1
DE	3.9	0.218	0.8	0.238	0.9	0.232	0.9	0.236	0.9	0.229	0.9	0.241	0.9
EL	1.6	0.029	0.0	0.014	0.0	0.024	0.0	0.026	0.0	0.025	0.0	0.014	0.0
ES	2.4	0.106	0.3	0.071	0.2	0.094	0.2	0.097	0.2	0.102	0.2	0.073	0.2
FR	3.9	0.160	0.6	0.166	0.6	0.144	0.6	0.137	0.5	0.152	0.6	0.163	0.6
IE	3.3	0.010	0.0	0.012	0.0	0.010	0.0	0.011	0.0	0.010	0.0	0.013	0.0
IT	2.6	0.153	0.4	0.137	0.4	0.138	0.4	0.142	0.4	0.135	0.4	0.141	0.4
LU	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
NL	3.8	0.042	0.2	0.047	0.2	0.049	0.2	0.048	0.2	0.046	0.2	0.047	0.2
AT	3.5	0.021	0.1	0.024	0.1	0.024	0.1	0.026	0.1	0.022	0.1	0.025	0.1
PT	1.7	0.027	0.0	0.014	0.0	0.029	0.1	0.031	0.1	0.029	0.0	0.012	0.0

FI	4.3	0.014	0.1	0.015	0.1	0.014	0.1	0.013	0.1	0.015	0.1	0.015	0.1
SE	7.0	0.023	0.2	0.030	0.2	0.026	0.2	0.022	0.2	0.025	0.2	0.029	0.2
UK	3.2	0.155	0.5	0.183	0.6	0.175	0.6	0.174	0.6	0.168	0.5	0.181	0.6
EU	3.7	1.000	3.3	1.000	3.5	1.000	3.4	1.000	3.3	1.000	3.4	1.000	3.5

2001 EIS indicator 4.3: Sales of new-to-market products (manufacturing)

	2001 EIS 4.3	Pop weight	Contri-bution	GDP weight	Contri-bution	Total empl weight	Contri-bution	Indus empl weight	Contri-bution	Lab force weigt	Contri-bution	VA ind weight	Contri-bution
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
BE	2.6	0.028	0.1	0.029	0.1	0.025	0.1	0.023	0.1	0.026	0.1	0.029	0.1
DK	5.1	0.015	0.1	0.020	0.1	0.017	0.1	0.016	0.1	0.017	0.1	0.019	0.1
DE	7.1	0.224	1.6	0.241	1.7	0.237	1.7	0.242	1.7	0.235	1.7	0.245	1.7
EL	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
ES	9.8	0.109	1.1	0.072	0.7	0.096	0.9	0.099	1.0	0.105	1.0	0.074	0.7
FR	7.9	0.165	1.3	0.168	1.3	0.148	1.2	0.141	1.1	0.156	1.2	0.165	1.3
IE	8.4	0.010	0.1	0.012	0.1	0.010	0.1	0.011	0.1	0.010	0.1	0.013	0.1
IT	13.5	0.157	2.1	0.139	1.9	0.142	1.9	0.146	2.0	0.139	1.9	0.143	1.9
LU	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
NL	6.9	0.043	0.3	0.048	0.3	0.050	0.3	0.049	0.3	0.047	0.3	0.047	0.3
AT	5.6	0.022	0.1	0.025	0.1	0.025	0.1	0.027	0.2	0.023	0.1	0.025	0.1
PT	7.2	0.028	0.2	0.014	0.1	0.030	0.2	0.032	0.2	0.030	0.2	0.013	0.1
FI	7.3	0.014	0.1	0.015	0.1	0.014	0.1	0.014	0.1	0.015	0.1	0.015	0.1
SE	6.9	0.024	0.2	0.031	0.2	0.026	0.2	0.023	0.2	0.026	0.2	0.029	0.2
UK	6.7	0.160	1.1	0.185	1.2	0.179	1.2	0.179	1.2	0.172	1.2	0.183	1.2
EU	6.5	1.000	8.3	1.000	8.0	1.000	8.1	1.000	8.2	1.000	8.1	1.000	8.1

Summing up the contributions of the different countries gives an estimate for the EU-15 average. E.g., for 2001 EIS indicator 3.1, summing up the contributions which were derived using population weights, gives an estimate of 41.4 for the EU-15. The real EU-15 value however was 44.0. Table 9 compares these estimated and real values by first dividing the real value by the estimated value. These ratios are given in rows (1) to (4). For indicators 3.1 and 3.3 all weights underestimate the real value by respectively 4% and 9%. For indicators 3.2 and 4.3 all weights overestimate the real value by respectively 11% and 20%.

Table 9. 2001 EIS CIS-indicator values re-estimated for EU-15 (2)

		Pop weight	GDP weight	Total empl weight	Indus empl weight	Lab force weigt	VA ind weight
(1)	3.1	1.06	1.02	1.05	1.04	1.05	1.02
(2)	3.2	0.93	0.86	0.90	0.90	0.90	0.87
(3)	3.3	1.11	1.07	1.10	1.11	1.10	1.07
(4)	4.3	0.78	0.81	0.80	0.80	0.80	0.80
				Squared differences			
(5)	3.1	0.004	0.001	0.002	0.002	0.003	0.000
(6)	3.2	0.006	0.020	0.011	0.009	0.010	0.018
(7)	3.3	0.012	0.004	0.009	0.011	0.010	0.005
(8)	4.3	0.047	0.037	0.040	0.042	0.041	0.038
(9)	SUM	0.0682	0.0612	0.0628	0.0641	0.0636	0.0615

Rows (5) – (8) in Table 9 give the squared values of the ratios minus 1 in rows (1) to (4). The sum of these - the sum of squared differences - is used as a proxy for determining how good a specific weights is able to reproduce the real CIS-2 data for the EU-15. Row (9) shows that the weight giving the smallest error as measured by the sum of squared differences is GDP.

For the 2003 EIS, GDP weights were thus used to calculate estimates for the EU-15 means for the five CIS-indicators.

National strengths and weaknesses: The EIS report lists the main strengths and weaknesses, in terms of either trend or current indicator performance. Only current indicator values and trend results more than 20% above or below the EU mean are taken into account. These are then ranked in descending/ascending order to determine the three best or worst performing indicators. For determining best and worst trends, trend results have first been re-scaled. Additional details are given in Technical Paper No 2.

Appendix A. Correlation matrix between the EIS indicators for EU Member States plus Switzerland, Iceland and Norway

	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3.1	2.3.2	2.4.1	2.4.2	3.1MAN	3.1SER	3.2MAN	3.2SER	3.3MAN	3.3SER	4.1	4.2	4.3.1MAN	4.3.1SER	4.3.2MAN	4.3.2SER	4.4	4.6	4.6	4.7MAN	4.7SER
1.1	**1**																											
1.2	.475	**1**																										
1.3	.184	.631**	**1**																									
1.4	.326	.197	.045	**1**																								
1.5	.484**	.738**	.795**	.334	**1**																							
2.1	.179	.373	.650**	.118	.627**	**1**																						
2.2	.119	.507*	.589*	.377	.719**	.531*	**1**																					
2.3.1	.287	.623**	.622**	.377	.704**	.583*	.776**	**1**																				
2.3.2	.247	.548*	.699**	.364	.771**	.698**	.919**	.905**	**1**																			
2.4.1	-.089	.553*	.522*	.471*	.630**	.370	.821**	.827**	.760**	**1**																		
2.4.2	-.050	.429	.549*	.470*	.610**	.373	.897**	.786**	.791**	.903**	**1**																	
3.1MAN	-.348	.057	.109	.374	.164	.225	.401	.260	.246	.483*	.573*	**1**																
3.1SER	-.393	-.054	.186	.048	.094	.292	.454	.205	.274	.421	.561*	.818**	**1**															
3.2MAN	.386	.704**	.614*	.278	.746**	.586*	.751**	.815**	.800**	.748**	.677**	.158	.210	**1**														
3.2SER	.145	.378	.417	-.104	.346	.577*	.451	.684**	.571*	.477	.322	-.158	.183	.689**	**1**													
3.3MAN	.183	.118	.056	.484*	.251	.089	.552*	.485	.536*	.477	.322	.393	.247	.202	.130	**1**												
3.3SER	.117	.074	.250	.121	.329	.286	.617**	.411	.604*	.379	.482	.036	.202	.152	.228	.654**	**1**											
4.1	.011	-.114	-.219	.368	.142	.135	.130	.080	.030	.172	.107	.458	.295	.084	-.093	.213	-.050	**1**										
4.2	.272	.608**	.660**	.240	.756**	.624**	.844**	.851**	.919**	.674**	.636**	-.033	.045	.830**	.645**	.324	.517*	-.120	**1**									
4.3.1MAN	.090	-.139	-.042	.294	-.102	-.095	-.037	.290	.114	.031	-.025	-.001	-.195	.240	.157	.023	-.318	.203	.107	**1**								
4.3.1SER	.072	-.274	-.400	-.003	-.454	-.200	-.278	-.009	-.072	-.334	-.318	-.371	-.423	-.254	.054	.187	.080	-.284	-.129	.369	**1**							
4.3.2MAN	-.161	-.147	-.208	.608**	-.035	.077	.239	.398	.309	.375	.271	.214	.043	.115	.165	.342	.266	.168	.221	.414	.463	**1**						
4.3.2SER	.042	-.183	-.484*	.146	-.397	-.266	-.148	-.071	-.063	-.177	-.109	-.218	-.299	-.210	.005	.314	.176	-.220	-.112	.071	.902**	.472	**1**					
4.4	-.001	.543*	.762**	.199	.852**	.634**	.792**	.632**	.745**	.746**	.783**	.331	.401	.721**	.467	.111	.339	.130	.757**	-.145	-.593*	.069	-.525*	**1**				
4.5	-.041	.351	.697**	.087	.629**	.492*	.744**	.465	.658**	.608**	.795**	.438	.519*	.515*	.145	.361	.444	-.061	.540*	-.354	-.586*	-.248	-.400	.737**	**1**			
4.6	.760**	.467	.483*	.541*	.677**	.392	.415	.533*	.500**	.311	.419	.283	.179	.734**	.295	.473	.154	.243	.378	.401	-.085	.089	-.102	.377	.314	**1**		
4.7MAN	.293	-.060	.105	-.185	-.262	-.275	-.595	-.350	-.479	-.516	-.568	-.511	-.509	-.347	-.357	-.637*	-.526	-.435	-.430	.221	-.221	-.513	-.576	-.501	-.284	-.053	**1**	
4.7SER	.211	.267	.330	.022	.205	-.242	-.348	-.260	-.297	-.192	-.259	-.545	-.792*	.050	-.215	-.703*	-.658	-.442	-.098	.062	-.501	-.556	-.531	.047	.030	.105	.591	**1**

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed)