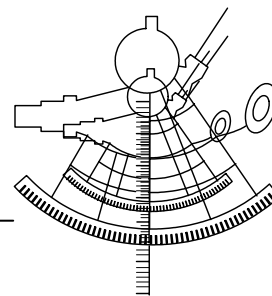


# European Trend Chart on Innovation

---



## 2002 European Innovation Scoreboard Technical Paper No 6 Methodology Report

December 20, 2002



## 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, Liechtenstein, Lithuania, Norway, Poland, Romania, Slovak Republic and Slovenia. The Trend Chart website ([www.cordis.lu/trendchart](http://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, Catalina Bordoy and Hugo Hollanders of MERIT ([www.merit.unimaas.nl](http://www.merit.unimaas.nl)) and Xavier Duran and Pari Patel of SPRU ([www.sussex.ac.uk/spru/](http://www.sussex.ac.uk/spru/)). The information contained in this report has not been validated in detail by either the Member States or the European Commission.

**Contact:** Anthony Arundel: [a.arundel@merit.unimaas.nl](mailto:a.arundel@merit.unimaas.nl) with a copy to the Trend Chart officer at the European Commission ([peter.loewe@cec.eu.int](mailto:peter.loewe@cec.eu.int)).

This document originates from the European Commission's "European Trend Chart on Innovation" (Enterprise Directorate-General). Copyright of the document belongs to the European Commission. Neither the European Commission, nor any person acting on its behalf, may be held responsible for the use to which information contained in this document may be put, or for any errors which, despite careful preparation and checking, may appear.



## European Innovation Scoreboard

The European Innovation Scoreboard (EIS) was developed at the request of the Lisbon European Council in 2000<sup>1</sup>. 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 EIS contains 17 main indicators, selected to summarize the main drivers and outputs of innovations. These indicators are divided into four groups: Human resources for innovation (5 indicators); the creation of new knowledge (3 indicators of which one is divided into EPO and USPTO patents); the transmission and application of knowledge (3 indicators); and Innovation finance, outputs and markets (6 indicators).

The EIS complements the *Enterprise Policy Scoreboard*<sup>2</sup> and other benchmarking exercises of the European Commission. It mainly uses Eurostat data, or private data of sufficient reliability if official data is not available. Six indicators are drawn from the European Commission's Structural indicators.

All indicators have been updated based on data availability as of September 15, 2002. Four indicators could not be updated due to delays in the execution of the third Community Innovation Survey<sup>3</sup>. As a result, the 2002 EIS does not provide trend results for these indicators and it does not contain a summary innovation index similar to the one offered in 2001. Subject to the availability of new CIS data, the 2003 EIS is expected to offer again an updated composite innovation index and a comparison between the index and average trends for each country, which was one of the most interesting features of the 2001 EIS.

The EIS is complemented by six technical papers:

- (1) Technical Paper No 1: Member States and Associate Countries  
Detailed results for current and trend data, innovation leaders, relative strengths and weaknesses per country, convergence and divergence analysis between member states and different groups of member states, and country pages with trend diagrams and main policy changes.
- (2) Technical Paper No 2: Candidate Countries  
Detailed results for current and trend data, innovation leaders, relative strengths and weaknesses per country, and country pages with both current and trend graphs.
- (3) Technical Paper No 3: EU Regions  
Detailed results for currently available data, leading regions, two tentative composite innovation indicators, indicator graphs, and preliminary steps towards the 2003 regional scoreboard.
- (4) Technical Paper No 4: Indicators and Definitions  
Full definitions and graphs for all indicators.
- (5) Technical Paper No 5: Thematic Scoreboard "Lifelong Learning for Innovation"  
Prototype of a complementary scoreboard on "Lifelong Learning for Innovation".
- (6) Technical Paper No 6: Methodological Report  
Overview of five different methods for constructing composite indices, and review of the similarities and differences between the EIS and other European Commission scoreboards.

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

---

<sup>1</sup> 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.

<sup>2</sup> SEC(2002) 1213.

<sup>3</sup> These are indicators 3.1, 3.2, 3.3 and 4.3.

## Table of Content

1. Introduction.....	2
2. Composite Innovation Indices .....	2
2.1. Methods for calculating composite indices.....	2
2.2 Rank order results .....	6
2.3 Changes over time.....	7
2.4 Composite indices by innovation category .....	9
2.5 Weighting indicators.....	11
2.6 Conclusions.....	13
3. Comparison with other Commission Scoreboards.....	16
3.1 Similarities and differences.....	16
3.2 Reasons for the similarities .....	17
3.2.1 EIS and the Research Scoreboard.....	19
3.2.2 EIS and the Enterprise Scoreboard.....	19
3.2.3 EIS and Eurostat’s Structural Indicators.....	20
3.3 Room for Improvement?.....	20
4. Looking at Other Scoreboards .....	22
4.1 Introduction.....	22
4.2 General Characteristics of the Scoreboards .....	23
4.3 Conceptual Framework.....	24
4.4 Comparing Indicators .....	26
4.5 Construction of a Summary Index .....	29
4.6 Comparing Recommendations for Innovation Policy.....	30
4.7 Conclusions.....	32
5. Economic Impact of Innovation.....	34
6. Definition and Sources for the EIS Indicators .....	38
Appendix A. Correlation matrix between the EIS indicators for the EU Member States.....	46
Appendix B. Summaries Of Differences Between ISB And Other Scoreboards.....	47

## 1. Introduction

---

This report looks at several methodological issues involving the European Innovation Scoreboard (EIS). Section 2 below evaluates different methods of calculating a composite innovation index<sup>4</sup>. Most of the analyses use the 2001 EIS because a composite index was not calculated for 2002, due to a lack of updated data for the four indicators from the Community Innovation Survey. The European Commission has developed two other scoreboards for entrepreneurship and research. Section 3 compares these two scoreboards with the EIS. Section 4 examines the similarities and differences between the EIS and 6 other scoreboards that are based on innovation indicators. Section 5 provides a brief evaluation of the macro-economic relationship between innovation and economic growth, productivity and GDP. These preliminary analyses will be expanded in 2003. Finally, Section 6 provides full definitions for all indicators in the EIS.

## 2. Composite Innovation Indices

---

The advantage of a composite index is that a single number summarizing the relative standing of a nation can attract attention and build political support for appropriate policies. For these reasons, the 2001 EIS included a “Summary Innovation Index” (SII). This index was very successful in attracting the attention of the media and policy makers. However, it also attracted some criticism over its ability to accurately summarize national innovative capabilities in a single number. This accuracy partly depends on two choices in the design of a composite index: the method of calculation and the weights or contribution of each indicator to the composite index.

### 2.1. Methods for calculating composite indices

---

All methods of calculating a composite index must address two issues:

1. Convert different units of measurement into the same unit.
2. Develop a rule for treating interval level data, particularly when there are outliers (values that differ substantially from the mean).

The first problem is relatively simple to solve and can be met by using percentages or standardized values such as z scores. The more difficult choice is how to treat interval data. Even if we weight each indicator so that it contributes equally to the composite index, the method of treating interval data can give greater *de facto* weights to high values of an indicator. The severity of this problem increases when there are large outliers. It is possible to calculate a composite index so that it is insensitive to outliers that differ substantially from the mean, but most of these methods are statistically more complex and less transparent than other methods.

---

<sup>4</sup> Part of this section draws on a MERIT project for DG Research, *Methodological Review of DG Research's Composite Indicators for the Knowledge-Based Economy*, June 2002.

Does it matter if outliers give *de facto* greater weight to some indicator values than to others? The answer to this question partly depends on how innovative capabilities work. For example, assume that country *A* does extremely well in public R&D so that this indicator is an outlier, but very poorly in all other innovation indicators. In contrast, country *B* has an average performance in all indicators. A composite index that is sensitive to outliers could rate *A* higher than *B*, while an index that is not sensitive to outliers could rate *B* higher than *A*.

Current theories of innovation stress that innovation is an interconnected process, requiring a wide range of capabilities and inputs. If true, the fact that *A* does poorly on most indicators should substantially reduce the efficiency and impact of public R&D, resulting in poor innovative outcomes. Country *B* should do better than country *A*, and consequently the method for calculating a composite index should minimize the effect of outliers.

Optimally, we would like to have a composite indicator that is simple to understand and which is unaffected by outliers. The SII used in the 2001 EIS meets these requirements. The SII uses the simplest method possible: the percentage of indicators that are ‘above average’ minus the percentage that are below average. In order to adjust for sampling variation, all indicators within plus or minus an arbitrarily selected threshold of 20% of the EU average are counted as ‘average’ and do not influence the SII<sup>5</sup>. The SII is adjusted to vary between a maximum of +10 and a minimum of –10.

One of the main criticisms of the SII is that it converts interval level data into ordinal level data, resulting in a loss of information. Whether or not this feature is a problem depends on how the SII compares to other methods of constructing a composite index. The basic question is if other methods of calculating a composite index give substantially different results.

Table 1 describes the SII plus four other methods of constructing a composite index. The four other methods were identified from a review of published studies that developed composite indices for innovation, economic, or environmental goals. Some of the differences in the methods are minor. For example, method 4 is a re-scaled version of method 3, while method 5, or the “best performance method”, is a special case of method 4.

In some cases the differences between methods are based on what they assume about innovative processes. For example, method 5 implicitly assumes that the lowest attainable value is zero while the maximum possible value is observed within the dataset. Conversely, method 3 implicitly assumes that both the minimum and maximum values can reach the theoretical maximum (or minimum). The advantage of method 5 is largely due to its stress on an optimum level for most innovation indicators that is substantially below the theoretical maximum. For example, business R&D intensities could theoretically approach 100%, but this would be economically disastrous and enormously inefficient.

---

<sup>5</sup> The DG Enterprise scoreboard follows a conceptually similar approach to identify member state’s strengths and weaknesses, although it does not provide a composite index.

**Table 1. Five methods for calculating a composite innovation index**

	<b>Advantages</b>	<b>Disadvantages</b>
<p>1. Number of indicators above the mean minus the number below the mean (SII).</p> $CI_i^t = \frac{y_i^t}{\sum_{j=1}^m q_j}, \text{ where}$	<p>Simplest method, unaffected by outliers either below or above the mean.</p> $y_i^t = \# \left\{ j \text{ s.t. } \frac{x_{ij}^t}{x_{EUj}^t} > 1 + p \right\} - \# \left\{ j \text{ s.t. } \frac{x_{ij}^t}{x_{EUj}^t} < 1 - p \right\}$	<p>Loss of interval information, leaving only ordinal level data for each indicator; arbitrary nature of the thresholds.</p>
<p>2. Summing percentage differences from the mean</p> $CI_i^t = \frac{\sum_{j=1}^m q_j y_{ij}^t}{\sum_{j=1}^m q_j},$ <p>where</p>	<p>Simple to construct.</p> $y_{ij}^t = \frac{x_{ij}^t}{x_{EUj}^t}$	<p>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.</p>
<p>3. Standardized values (z scores) for each indicator</p> $CI_i^t = \frac{\sum_{j=1}^m q_j y_{ij}^t}{\sum_{j=1}^m q_j}, \text{ where}$	<p>Maintains interval level information.</p> $y_{ij}^t = \frac{x_{ij}^t - x_{EUj}^t}{\sigma_{EUj}^t}$	<p>Variables with a large variance have a <i>de facto</i> greater weight; index sensitive to both positive and negative outliers.</p>
<p>4. Re-scaled values. The re-scaled scores vary within the identical range for each indicator (0 to 1).</p> $CI_i^t = \frac{\sum_{j=1}^m q_j y_{ij}^t}{\sum_{j=1}^m q_j}, \text{ where}$	<p>Maintains interval level information, lowest sensitivity to outliers of the methods that maintain interval level data.</p> $y_{ij}^t = \frac{x_{ij}^t - \min(x_j^t)}{\text{range}(x_j^t)}$	<p>Statistically more complex than other methods.</p>
<p>5. Best performance. (Special case of Method 4)</p> $CI_i^t = \frac{\sum_{j=1}^m q_j y_{ij}^t}{\sum_{j=1}^m q_j}, \text{ where}$	<p>Maintains interval level information. Simpler version of method 4. <math>y_{ij}^t = \frac{x_{ij}^t}{\text{Max}(x_j^t)}</math></p>	<p>Sensitive to positive outliers.</p>

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.

There are also variations for each of the methods given in Table 1. For example, the Environmental Performance Index<sup>6</sup> of the World Economic Forum uses a re-scaled percentage method. In any case, the best alternatives to the SII are likely to use re-scaling to reduce sensitivity to one or two outliers.

In terms of the method of calculation, the ‘gold’ standard is Method 4, based on re-scaled values, because it uses interval level data while minimizing sensitivity to outliers. However, it is statistically complex compared to the alternatives and more difficult to link to assumptions about innovation processes. This makes it less transparent.

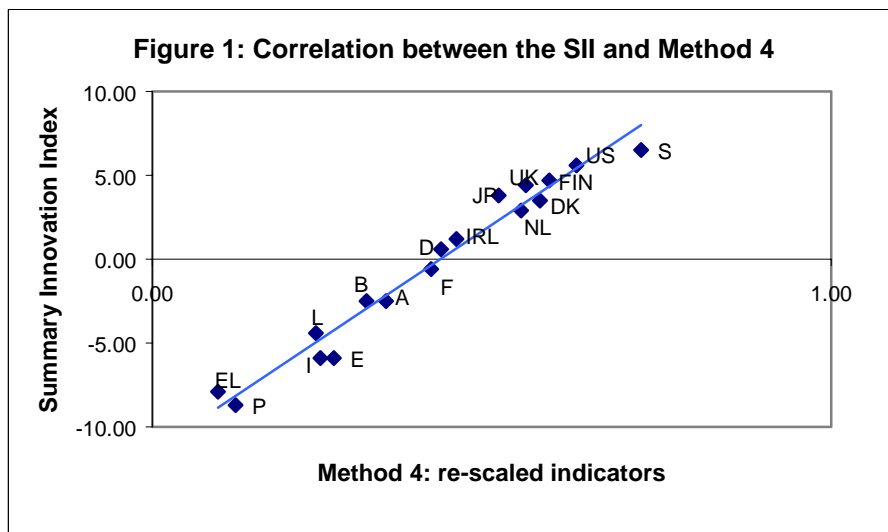
Do the different methods of calculating a composite index give different results? Table 2 gives the R<sup>2</sup> values from correlations between each of the five methods of constructing a composite index. All five methods use the identical 2001 EIS data for 17 countries (15 EU countries and the US and Japan). As shown in Table 2, all methods produce very similar results, with R<sup>2</sup> values ranging from 0.89 between Methods 2 (percentage differences from the mean) and 4 (re-scaled values), to 0.99 between Methods 3 (z-values) and 4 and between methods 4 and 5 (best performance). Also, the SII is highly correlated with the other four methods, especially with methods 4 and 5. To further illustrate the strong correlation between the different composite indices, Figure 1 graphs the correlation between Method 4 and the SII<sup>7</sup>. These results suggest that all five methods generate very similar composite indices.

**Table 2. Correlation matrix (R<sup>2</sup> values) for five methods for calculating a composite innovation index (2001 EIS)**

	SII	Method 2 (% difference from mean)	Method 3 (Z-values)	Method 4 (Re-scaled values)	Method 5 (Best performance)
SII	1				
Method 2	0.89	1			
Method 3	0.95	0.92	1		
Method 4	0.97	0.89	0.99	1	
Method 5	0.97	0.93	0.98	0.99	1

<sup>6</sup> World Economic Forum, Pilot Environmental Performance Index, Yale Centre for Environmental Law and Policy, 2002.

<sup>7</sup> Unlike the unscaled z score method, in which the composite index can vary from a negative to a positive number, all of the values of the re-scaled values are positive. This is due to re-scaling the original indicators so that each indicator has an equal range. In this case, the range is between 0 and 1, but it is possible to select a range that would run from -1 to +1.



## 2.2 Rank order results

The most common interpretation of a composite index is based on their rank order – which country is first, second, third, etc. in terms of innovativeness. For this reason, we also evaluated the effect of the method of calculating the innovation index on the rank order of the innovativeness of each country. Table 3 gives the rank orders generated by the SII and three other methods of computing the innovation index. Although the SII generates two sets of ties in the rank orders (Italy and Spain fall in position 3; Austria and Belgium fall in position 5), these have been adjusted to optimize the match with the re-scaled ranking.

For 17 countries, the maximum possible number of changes in the rank order is 144 units<sup>8</sup>, with a 1 unit change equal to a change in one position, such as from fourth to fifth place. The maximum number of changes for a single country is 16 units, for example if Portugal shifted from last to first place.

All rank orders between the four methods are very similar. There are only 12 unit changes between the SII and Method 4, 10 unit changes between the SII and Method 5, and 18 unit changes between the SII and Method 3<sup>9</sup>. For a single country, the maximum observed number of unit changes in the rank order compared to the SII is two. For example, Japan changes from position 13 in the SII to position 11 using Method 4<sup>10</sup>.

<sup>8</sup> For 17 countries, the maximum number of changes occurs when the country which was in the first place (rank order=17) in one year shifts to the last one (rank order=1) in the next one; when the country with rank order 16 in one year shifts to position 2 in the next one; when the country with rank order 15 shifts to rank order 3; and so on. By adding up the number of changes in the position for each country (i.e. (17-1)+(16-2)+(15-3)+...) one obtains 144.

<sup>9</sup> The number of unit changes between the SII and method 2 (not included in the table) is 22.

<sup>10</sup> The maximum number of unit changes between all of the methods is three, which occurs for Japan in a comparison between methods 4 and 3 (Japan is in position 11) and method 5 (Japan is in position 14).

These comparisons show that the simple SII provides rank order results that are very comparable to the more complex statistical methods used in Methods 3, 4 and 5. Moreover, as Table 3 reveals, independently of the method used, one can always identify three groups of countries: a group which always ranks in the top places (Sweden, US, Finland), a second group which ranks in the bottom places (Portugal, Greece, Spain and Italy), and a third group which ranks in the middle (Belgium, Austria, France, and Germany). A few other countries are slightly more sensitive to the choice of method for calculating the composite index (Denmark, the UK, Ireland).

**Table 3. Rank order of four methods of calculating a composite index (1 = least innovative and 17 = most innovative)**

	SII	Re-scaled (Method 4)	Z scores (Method 3)	Best performance (Method 5)
Portugal	1	2	2	2
Greece	2	1	1	1
Spain	3	5	5	5
Italy	4	4	4	4
Luxembourg	5	3	3	3
Belgium	6	6	6	6
Austria	7	7	7	7
France	8	8	9	8
Germany	9	9	10	9
Ireland	10	10	8	10
Netherlands	11	12	13	11
Denmark	12	14	14	13
Japan	13	11	11	14
UK	14	13	12	12
Finland	15	15	15	15
US	16	16	16	16
Sweden	17	17	17	17
<i>Total unit changes compared to the SII</i>		12	18	10

Notes: light grey = one unit change in the rank order compared to the SII. Darker grey = two unit change in the rank order.

### 2.3 Changes over time

A robust composite index must also be useful for looking at changes over time. In order to explore these effects, we computed the composite index using the SII, method 4 (the ‘gold’ standard, and method 5 (best performance index) for 2001 and 2002. To maintain

comparability, the four CIS indicators (i.e., category 3 indicators and indicator 4.3) have been excluded from both the 2001 and 2002 results.

We expect changes in the rank order among countries from two factors: real changes between countries that have developed over time, and changes that are an artifact of the calculation method.

Table 4 reports the rank orders for 2001 and 2002 using the three methods. The SII and the re-scaled method have almost the same number of units in the change of the rank order, whereas Method 5 presents twice the number of unit changes as the SII. Denmark improves 3 places in 2002 when using the best performance method, whereas it only increases one position with the SII and there is no difference with Method 4. This increase in the rank order for Denmark is basically due to the increase in the venture capital indicator (which increased by more than 600% between 2001 and 2002), and in the number of S&E graduates (which increased by 76% over the same period). The same indicators explain also the increase of three units in the rank order for Finland using the best performance method.

**Table 4. Effects of the calculation method on changes over time**

Rank	SII		Re-scaled (Method 4)		Best performance (Method 5)	
	2001	2002	2001	2002	2001	2002
1	P	P	GR	GR	P	GR
2	GR	GR	P	P	GR	P
3	I	E	I	I	I	I
4	E	I	L	E	L	E
5	L	L	E	A	E	A
6	A	A	A	L	A	L
7	F	D	B	D	F	D
8	D	IRL	D	F	IRL	F
9	B	F	IRL	IRL	D	B
10	IRL	B	F	B	B	IRL
11	DK	NL	J	NL	DK	NL
12	NL	DK	DK	DK	UK	J
13	J	US	NL	J	NL	UK
14	UK	UK	UK	UK	FIN	DK
15	US	J	US	US	SWE	US
16	FIN	FIN	FIN	SWE	J	SWE
17	SWE	SWE	SWE	FIN	US	FIN
<i>Total unit changes</i>	14		15		28	

The largest differences over time are for Japan, which also shows a change in direction depending on the method used. The rank order for Japan *falls* 4 places with the best performance method and *increases* two places with the other two methods. The reason for this switch in direction is that the best performance method only considers the maximum value of the original indicators to compute the corresponding transformed indicators, whereas the re-scaled method considers also the minimum value and the range. This makes method 5 more sensitive to outliers and also more volatile over time. An example is given in Table 5, which shows the transformed indicators for indicator 1.1 for Japan, computed according to methods 4 and 5. Since the percentage increase in 2002 of the original indicator is lower than the percentage increase of the maximum value, the best performance indicator falls. On the contrary, the decrease in the minimum value more than compensates the increase in the maximum value, and as a result the re-scaled indicator increases.

**Table 5. Transformed values of indicator 1.1 for Japan**

	2001	2002	Transformed values			
			Method 4		Method 5	
			2001	2002	2001	2002
Original indicator 1.1	11	12.5				
Maximum	17.8	23.2	0.48	0.5	0.62	0.54
Minimum	4.7	1.8				
Range	13.1	21.4				

## 2.4 Composite indices by innovation category

Table 6 provides the rank order of each country, using the SII and method 4, within each of the four categories of innovation indicators: 1) human resources, 2) knowledge creation, 3) the transmission and application of new knowledge, and 4) innovation finance, outputs and markets. The 2001 EIS data are used. There is little difference between the SII and Method 4 for both categories 1 and 2, with respectively 10 and zero unit differences in the rank order.

As these examples show, Method 4 is more sensitive to outliers than the SII, which is due to the fact that the former maintains interval level information. The number of outliers is especially large within category four indicators, which, together with the fact that method 4 is more sensitive to outliers than the SII, explains the differences in the rank orders between the two methods. These results also show that the differences in the rank orders of the composite index using all 17 indicators can be partly traced back to outliers among the category 4 indicators.

**Table 6. Rank orders by category**

Rank	Category 1 <i>Human resources</i>		Category 2 <i>Knowledge creation</i>		Category 3 <i>Transmission and application of new knowledge</i>		Category 4 <i>Innovation finance, output and markets</i>	
	SII	Re-scaled	SII	Re-scaled	SII	Re-scaled	SII	Re-scaled
1	P	P	GR	GR	B	P	DE	I
2	GR	GR	P	P	E	GR	P	GR
3	L	I	L	L	GR	E	I	DE
4	I	L	E	E	P	L	F	J
5	E	A	I	I	I	B	G	F
6	A	E	IRL	IRL	L	I	A	A
7	NL	B	A	A	F	UK	E	P
8	B	NL	B	B	FIN	F	L	L
9	DE	DE	UK	UK	A	FIN	B	E
10	F	F	DK	DK	NL	NL	DK	IRL
11	US	IRL	F	F	UK	A	J	B
12	IRL	DK	DE	DE	DE	DE	IRL	FIN
13	DK	US	NL	NL	IRL	IRL	FIN	DK
14	J	J	US	US	SW	SW	UK	UK
15	FIN	FIN	J	J	DK	DK	NL	US
16	SWE	SWE	SWE	SWE	n.a	n.a.	SWE	NL
17	UK	UK	FIN	FIN	n.a	n.a	US	SWE
<i>Total units change</i>		10		0		20		34

## 2.5 Weighting indicators

---

How to weight the indicators in a composite index is essentially an unsolvable problem unless we have a measure of the latent, underlying phenomena that we want to measure. Under these conditions, we can run a regression analysis, with suitable lag times, in which the indicators are the independent variables and the measure of the latent phenomena is the dependent variable. The regression coefficients are then used as the weights. In this case, the purpose of the exercise would change. Instead of trying to estimate the composite index (which as the dependent variable would be known), we would want to know how much each indicator contributed to the composite index. This information could be used to determine the policy importance of each indicator.

Except for one study<sup>11</sup>, 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’<sup>12</sup>. The rationale for this is that it is impossible to carefully calculate weights without a measure of the latent phenomena. We can only make educated guesses at what the weights might be. However, a few of the critics of the SII suggested that Principal Component Analysis (PCA) could be used to compute appropriate weights for the constituent indicators.

PCA is a statistical technique that linearly transforms an original set of variables into a substantially smaller set of uncorrelated variables that represents most of the information in the original set of variables (Dunteman 1989<sup>13</sup>). This technique allows one to analyze the interactions among variables and determine the existence of redundancies in a given data set.

---

<sup>11</sup> The study by Porter and Stern (*The New Challenge to America’s Prosperity: Findings from the Innovation Index*. Council on Competitiveness, Washington DC, 1999) claims to identify a latent measure of innovativeness. Their study uses international patenting as the measure of innovativeness and regresses several indicators against it. The quality of their method is based on whether or not patents, by themselves, are an accurate output measure for innovativeness. We think that the evidence is against them, both because patents only capture one of many aspects of innovation and because patents are an intermediate rather than a final output measure for innovative activities.

<sup>12</sup> The State New Economy Index 2000 (Progressive Policy Institute; <http://www.neweconomyindex.org>) uses weights of both 0.5 and 0.75.

<sup>13</sup> George H. Dunteman, 1989. *Principal components analysis*. SAGE publications, Number 07-069.

In general, the purpose of using PCA is to reduce the dimensionality of the original data set while keeping most of the information contained in it. More specifically, PCA generates a series of new variables (principal components) that are linear combinations of the original variables, with the first principal components explaining most of the variance in the original variable set. In the context of elaborating composite indices, PCA may have two uses: on one hand, find appropriate weights for the constituent indicators, and, on the other hand, identify a subset of indicators that represent the total set of indicators.

Note that the goals of PCA and of constructing a composite index are in fact the same: to obtain a new variable that summarises the information contained in a given set of variables (indicators). For that reason, PCA could be used to develop appropriate weights for the constituent indicators. However, PCA is a statistical technique and, as such, it uses statistical measures, mainly the variance explained by a set of variables and the correlations between these variables. Hence, the weights produced from PCA will be based on these statistical measures and not on the influence of each variable (indicator) on what we are trying to measure. In the case of the Innovation Scoreboard the appropriate weights for the 17 indicators in the SII should correspond to the contribution of each indicator to innovation performance. These weights should then be based on a subjective assessment of the value of each indicator for the outcome of interest.

### **Key indicators**

One application of PCA is to use it to select a subset of indicators to represent the total set of variables. The correlation matrix (see Appendix A) of the set of eighteen indicators (two indicators for patenting) reveals high correlations (correlation coefficients higher than 0.7) between the indicators, suggesting that we can represent the variation in the total set of indicators by a much smaller set of indicators. Of note, only the *internal structure* of the data is considered in selecting the subset of variables. Other criteria, such as the effectiveness of each indicator in predicting a dependent variable, or, in our case, the *Summary Innovation Index*, are not used.

PCA was applied to the set of eighteen indicators for the fifteen EU countries (using 2001 data) and the following subset of six ‘key’ indicators was selected<sup>14</sup>:

- 1.1. New S&E graduates (% of 20 – 29 age class)
- 2.3a EPO high tech patent applications (per million population)
- 2.3b USPTO high tech patent applications (per million population)
- 3.1. SMEs innovating in-house (% of manufacturing SMEs)
- 4.2. New capital raised on stock markets

---

<sup>14</sup> Since the variables (indicators) are not in the same metric and the variances differ widely from one another, PCA was conducted using standardized variables (zero mean and unit variance).

#### 4.3. ‘New to market’ products (% of total sales by manufacturing firms from innovative products).

These indicators explain 96.9% of the total variation<sup>15</sup>. Therefore, this analysis produces a subset of key indicators that represent most of the information contained in the whole set of indicators.

These results suggest that the EIS could be altered to simply include these six indicators. However, even though six indicators explain most of the variance, these indicators do not provide enough information on the different factors that are linked to building innovative capabilities at the national level. The complete list of 17 indicators is useful for the design of appropriate policies and can help to identify national strengths and weaknesses.

## 2.6 Conclusions

---

The results of the above analyses show that all methods for calculating a composite innovation index (using all 17 indicators) produce similar results, even though outliers are treated differently. This result is encouraging and shows that the indices are comparatively robust. It simply does not matter much which method of calculation is used. The choice can then be based on both simplicity and ease of understanding and on insensitivity to outliers.

However, there are small differences by method in the rank order of a few countries by one or two units. Introducing changes over time or limiting the index to a single category can increase differences in the rank order. In addition to the choice of the calculation method, other research (results not given here) has shown that these small differences in the rank order can be caused by minor changes in the choice or definition of the indicators, or due to one or two indicators (as shown in section 2.3 for Japan). The important lesson to be drawn is that *small differences in the rank order of a composite index are meaningless*. This creates a problem for presenting the results. The 2001 SII attracted substantial media attention due to the fact that a single indicator is much simpler to present than complex tables. Yet, if small differences in a composite index are due to minor, erratic variations, or to differences in the calculation method, we cannot conclude that there is any real difference in two countries with a similar composite index – such as the 2001 SII of 4.7 for Finland and 4.4 for the UK.

The presentation of a composite index for innovation must therefore emphasize this fact. Perhaps it would help if the countries were combined into simple groups, such as leaders,

---

<sup>15</sup> The amount of variation explained by a subset of variables is defined as the sum of their variances and the variation they explain in each of the discarded variables. Since the variance of a standardized variable is equal to one, the amount of variation explained is equal to  $n_r + \sum_{i=1}^d R_{i,r}^2$ , where  $n_r$  is the number of retained variables and  $R_{i,r}^2$  is the squared multiple correlation of the  $i$ th discarded variable with the  $r$  retained variables.

followers, and laggards. This would be possible if the countries clump together with gaps between each group.

A major reason why each method of calculation produces similar results is due to consistency between innovative indicators: countries with a high index score do very well on almost all indicators, countries with a moderate index score have average results for most indicators, and countries with a low index score do poorly on almost all of them. Therefore, changing the method of calculation does not alter the composite index or rank order by very much. In addition, these characteristics mean that changing the weights are unlikely to have much of an effect either. As an example, both the Joint Research Centre and the OECD have recently explored the effect of several thousand iterations of randomly assigned weights for a Technology Achievement Index and an Innovation Index<sup>16</sup>. The OECD analyses find a reasonable correlation between the Innovation Index with predefined weights and the average of the randomly assigned weights. In addition, the confidence bands for 90% of the randomly estimated composite indices place each of 26 countries in a similar rank order. The JRC uses the method to identify a few countries where the weighting scheme has a large effect on the index (wider uncertainty bounds). This occurs in a few countries with a mix of indicators ranging from well above to well below the average. With a few exceptions, these results suggest that innovation is an interconnected process, as proposed by current innovation theory.

The summary innovation index results for changes over time and for each innovation category show larger differences between each method of calculation. The analyses of the changes between 2001 and 2002 show that the best performance method is more sensitive to positive outliers, created by volatility over time. Of greater concern is that the change in the rank order of a country over time can move in opposite directions, depending on the method of calculation. The results by innovation category show that some of the volatility can be traced to a few indicators. Their effect is magnified when the composite index is based on only a few indicators. This suggests that composite indices should not be developed for sub-categories that contain a small number of indicators with a large degree of variation.

At this time, there is no solution to the weighting issue because we lack a dependent variable for innovation processes that we could use to test the relative contribution of each indicator. PCA analysis is useful in identifying key indicators, but it does not provide a solution to the weighting problem. The fact that leading countries do well and lagging countries do poorly on most indicators suggests that different weighting schemes will not have much of an impact on the results. This conclusion is supported by the OECD and JRC experiments using randomized weighting schemes. The greatest differences are likely to be observed among a few countries, such as Germany and France, which do well on some indicators and poorly on

---

<sup>16</sup> Applied Statistics Group, Joint Research Centre of the European Commission, Report on Current Methodologies and Practices for Composite Indicator Development, June 2002; OECD, Draft Working Paper, Composite Indicators of Country Performance: A Critical Assessment, November 2002.

others. Higher weights on indicators for which Germany does well (Business R&D and EPO patents) and lower weights on indicators where Germany does poorly (lifelong learning and venture capital) would improve Germany's score on a composite index. In the 2003 EIS, we will experiment with different weighting schemes in order to identify countries whose composite index is sensitive to different weighting schemes.

### 3. Comparison with other Commission Scoreboards

---

The European Commission has developed several collections of indicators (or scoreboards) for addressing specific policy areas. In addition to the EIS, these include DG Research's *Indicators for Benchmarking of National Research Policies*<sup>17</sup> (hereafter referred to as the Research Scoreboard) and DG Enterprise's *Enterprise Policy Indicators*<sup>18</sup> (hereafter referred to as the Enterprise Scoreboard).

Each of the Commission's scoreboards serves a different purpose. The EIS measures the innovative capabilities of European countries in both the public and private sectors. The goal of the Enterprise Scoreboard is to measure factors that are "key contributors to enterprise growth, performance, and presumably competitiveness". Finally, the Research Scoreboard focuses on benchmarking national research policies.

The EIS contains 17 indicators (the two variants of the patent indicator count as one indicator), the Research Scoreboard has 17 indicators, and the Enterprise Scoreboard has 21 indicators. All three scoreboards draw on some of Eurostat's Structural Indicators but they also contain other indicators, or variations of the Structural Indicators. In addition, the EIS contains some indicators that are identical or similar to those in the Research and Enterprise Scoreboards.

These areas of overlap between the three scoreboards raise questions about why we need three different but similar scoreboards. This section evaluates the similarities and differences between the three scoreboards, the reasons for the similarities, and suggests a few improvements in their production.

#### 3.1 Similarities and differences

---

Table 7 gives the number of indicators in the Research and Enterprise Scoreboards that are identical or similar to the indicators in the EIS. For example, 7 (41%) of the Research Scoreboard indicators are not found in the EIS, while 1 indicator is identical to an EIS indicator. The remaining nine indicators measure similar factors, although they differ in the exact definition of the indicator. For example, one Research Scoreboard indicator uses medium-high and high technology value added, while the EIS indicator is limited to high technology value-added. The latter is a subset of the former indicator. Similarly, the Research Scoreboard gives the percentage of all firms that innovate, while the EIS use the percentage of manufacturing SMEs that innovate. Although conceptually similar, these differences in how each indicator is defined can result in large differences in the actual values of the indicator.

---

<sup>17</sup> DG Research, *Towards a European Research Area: Key Figures 2001*, European Commission, Brussels, 2001.

<sup>18</sup> DG Enterprise (Unit A5), *A Pocketbook of Enterprise Policy Indicators*, European Commission, Luxembourg, 2001.

**Table 7. Comparison between the EIS and the Research and Enterprise Scoreboards**

Occurrence in EIS	Enterprise		Research	
Identical	24%	5	6%	1
Similar but different	19%	3	53%	9
Not found in EIS	57%	13	41%	7
<i>Total</i>	<i>100%</i>	<i>21</i>	<i>100%</i>	<i>17</i>

Table 8 provides the opposite perspective to that of Table 7. It gives each indicator in the EIS and notes which indicators in the Research and Enterprise Scoreboards are identical (\*\*\*) , similar (+), or not at all related (blank). The last column of Table 8 shows which EIS indicators are identical to or similar to Eurostat’s Structural Indicators. The footnotes describe the differences between the EIS indicators and those of the other Scoreboards. In total, 59% of the 18 EIS indicators are identical to or similar to an indicator in the Research Scoreboard, compared to a 45% overlap between the EIS and the Enterprise Scoreboard.

### 3.2 Reasons for the similarities

There are two explanations for the similarities between the scoreboards. First, many indicators are conceptually related to several outcomes. For example, research drives some types of innovation, which in turn can influence enterprise performance. Therefore, all three scoreboards contain similar (although not always identical) indicators for public and private R&D and for patenting. Second, there are a limited number of good quality indicators that are available for most EU countries. This means that all scoreboards must draw on the same set of indicators. The result is that each scoreboard often has to use an indicator that is not perfectly suited to its goals. For example, both the EIS and the Research Scoreboard include an indicator for employment in high technology services, but both have to make compromises.

The EIS, with a focus on innovation, limits the high technology services employment indicator to three high technology service sectors. The indicator ranges from a low of 1.2% of total employment in Portugal to a high of 4.8% in Sweden. However, an ideal version of this indicator would capture high-skilled employment in other service sectors, such as banking and retail. Unfortunately, this type of data is not available. Faced with a similar problem, DG Research adopts a much broader definition of ‘knowledge-intensive services’ that includes sectors in which a large fraction of employees only have low-level skills. As a result, the indicator ranges from a low of 19% of total employment in Portugal to a high of 45% in Sweden.

<b>Table 8. Similarities between the EIS indicators and other EC indicators</b>			
<b>Innovation Scoreboard (EIS)</b>	<b>Enterprise 2001</b>	<b>Research 2001</b>	<b>Structural Indicators</b>
S&E graduates / 20 - 29 year age class		+ R1	***
Percent 25-64 year olds w tertiary education	***		
Percent 25-64 year olds in educational training	***		***
Share workforce in med/high-tech manuf.		+ R2	
Share workforce in high-tech services		+ R3	
Public R&D/GDP	***	+ R4	*** S1
Business R&D/GDP	***	+ R5	*** S1
High-tech EPO patents per capita	***	+ R6	+ S2
High-tech USPTO patents per capita		+ R7	+ S3
Percent SMEs innovating in-house			
Percent Manuf. SMEs in innovation co-operation		+ R8	
All innovation expenditures/sales			
High-tech venture capital /GDP	+ E1	+ R9	+ S4
New capital raised /GDP			+ S5
New-to-market product sales/all sales			
Percent households with internet access	+ E2		***
ICT expenditure/GDP	+ E3		***
High-tech manuf. value-added/all manuf v-added		+ R10	

\*\*\* = identical, + = similar. Notes: The definition of the EIS for 2002 is compared to the 2001 definitions of the Enterprise and Research scoreboards and to the 2002 definitions of the Structural Indicators. In contrast, data comparisons are based on the 2001 versions of the three scoreboards.

E1. All venture capital versus high technology venture capital in the EIS.

E2. Percent of households with broadband access versus all households with home access in the EIS.

E3. The enterprise scoreboard appears to use the same indicator as the EIS, but the data differ slightly, possibly because different years are used.

R1. Percent of new science and technology PhDs among 25 to 34 year olds versus percent of Science and engineering post-secondary graduates out of 20 to 29 year olds.

R2. The research scoreboard uses high-tech manufacturing.

R3. The research scoreboard uses a broad definition of knowledge intensive services that includes all health sector workers etc, while the EIS is limited to three high technology business sectors.

R4. Share of the government budget allocated to R&D versus non-BERD R&D as a percentage of GDP in the EIS.

R5. BERD as a percentage of industrial output versus BERD as a percentage of GDP in the EIS.

R6. All EPO patents versus high technology patents in the EIS.

R7. All USPTO patents versus high technology patents in the EIS.

R8. Percent of all firms involved in innovation cooperation versus the percent of manufacturing SMEs in the EIS.

R9. All venture capital versus high technology venture capital in the EIS

R10. The research scoreboard includes medium-high technology industries versus high tech industries only in the EIS. Also, whereas the EIS takes total manufacturing value added as the denominator, the research scoreboard takes total GDP.

S1: The definitions for the Structural indicators on R&D were changed on October 2002: COM(2002): 551. The new definitions disaggregate R&D expenditures according to source of finance. The data used in this analysis still reflects the old definition which disaggregated expenditures according to sector of spending.

S2. All EPO patents versus high technology patents in the EIS.

S3. All USPTO patents versus high technology patents in the EIS.

S4. All venture capital versus high technology venture capital in the EIS

S5. Total new capital raised versus only capital raised by new firms or by firms on parallel markets in the EIS.

Some of the differences between the EIS and the other two scoreboards is also due to the internal structure and goals of the EIS. The EIS tries to cover all aspects of innovation, which includes innovation as a creative activity, such as the development and manufacture of ICT, and innovation as diffusion, such as the adoption of ICT and other new technology by other firms. Some indicators are shifted towards one of these two types of innovation to limit the amount of overlap *within* the EIS indicators. For example, the indicators for innovation and cooperation rates among firms only use SMEs, since almost all large firms are both innovative and involved in innovation cooperation. This shifts the indicator towards capturing diffusion rather than creative activities. In contrast, the Research Scoreboard uses the percent of all firms involved in innovation cooperation because its focus is on innovation as a creative activity, where large firms are more active than SMEs.

### *3.2.1 EIS and the Research Scoreboard<sup>19</sup>*

The higher level of overlap between the EIS and the Research Scoreboard than between the EIS and the Enterprise Scoreboard is due to the closer proximity between research and innovation than between innovation and enterprise growth, performance and competitiveness. However, the high level of overlap between the EIS and the Research Scoreboard is misleading, since many of the definitions are very different, resulting in very different actual values for similar indicators.

Some of the differences between similar indicators in the EIS and Research Scoreboard are due to different goals. For example, the EIS uses the percentage of all Science and Engineering (S&E) post-secondary graduates as an indicator of human resources. This includes diploma, bachelor, masters, and PhD degrees. A broad definition of S&E graduates is used because many of these skill levels, such as ICT technicians, will be important to the diffusion of new technology. In contrast, the comparable indicator in the Research Scoreboard is limited to PhD graduates because this scoreboard focuses on the creation of new technology. Similarly, the Research Scoreboard uses the percentage of all firms that cooperate as a measure of scientific and technological productivity, whereas the EIS limits the indicator to SMEs as a measure of diffusion, as noted above.

### *3.2.2 EIS and the Enterprise Scoreboard*

In total, 45% of the 18 EIS indicators are identical or similar to one of the 21 indicators in the Enterprise Scoreboard. The latter divides the 21 indicators into seven categories with three indicators each: access to finance, administrative and regulatory environment, well-

---

<sup>19</sup> For 2002, DG Research has been experimenting with different methods of constructing a composite index for two measures: investment in a knowledge-based economy and performance in the transition towards a knowledge-based economy. Five indicators are proposed for investment: S&E researchers per capita, new PhDs, total R&D expenditures, total education expenditures, and IT expenditures. Three indicators are proposed for performance: patenting, publications, and employment in high technology sectors. At this time, it is not possible to assess the overlap between the EIS and the 2002 Research Scoreboard because the final indicators to include in the latter have not been chosen or fully defined.

functioning markets, innovation, entrepreneurship, human capital, and access to IT. There is no overlap between the Innovation and Enterprise Scoreboards for three of the seven categories (administrative and regulatory environment, well-functioning markets, and entrepreneurship). In contrast, all three of the innovation indicators in the Enterprise Scoreboard occur in the EIS, and two of the three human capital indicators. The Enterprise Scoreboard includes innovation and human capital indicators because both can influence performance, while the EIS includes both because they are essential components of innovation.

### 3.2.3 EIS and Eurostat's Structural Indicators

Eurostat's Structural Indicators provide a source of high-quality data for all three Scoreboards. The question here is why the EIS does not use the Structural Indicator's version of four indicators: two for patenting and two for innovation finance. The reason is that the Structural Indicators are not fully focused on innovation. The two patent indicators include all patent classes, many of which are used by sectors that only patent a small percentage of their innovations. In these sectors, patent use could be a better measure of appropriation conditions and competitive strategies than of innovation. The two finance indicators include all types of finance, such as venture capital for retail and tourism, which together account for the majority of venture capital. Again, the EIS versions of these two indicators focus more closely on higher-level innovative activities.

## 3.3 Room for Improvement?

---

Although much of the overlap between the three scoreboards is inevitable, there is room for improvement if there is greater coordination between the three. For example, the Research Scoreboard could focus more closely on research inputs, the EIS on innovation as diffusion and measures of innovation outputs, and the Enterprise Scoreboard on regulatory, entrepreneurial, and market conditions. The justification for this approach is that all three scoreboards cover factors that influence the economic performance and competitiveness of European economies. For this reason, the three scoreboards are inherently linked. One option is to fully recognize these linkages and construct modules of indicators for each of the main 'themes' (as described in the Research Scoreboard), 'categories' (as in the EIS), or 'areas' (as in the Enterprise Scoreboard) and then to share modules when constructing composite indices. Table 9 provides an outline of the current themes, categories and areas of each scoreboard. The left hand column gives the main underlying themes. The information under each scoreboard gives the name of the theme, category or area that contains at least one indicator of relevance to the main themes.

The shaded cells in Table 9 indicate 'core areas' that could be the main responsibility of each scoreboard, with other indicators obtained as modules. For example, the core area of the EIS could be to develop indicators for innovation as diffusion plus innovation outputs. Indicators for human resources and creative innovation would still be included in the EIS, but they

would be obtained as modules from DG Research. This would require a few adjustments to the existing structure of each theme in each scoreboard. For example, the EIS includes indicators on high technology employment within the human resources category. These two indicators would need to be shifted to innovation outputs. Similarly, DG Enterprise would need to develop indicators for innovation finance that focuses on innovation, in addition to its broader indicators that cover all types of finance.

**Table 9. Thematic coordination between the three scoreboards**

Main Themes	Definition of theme in each scoreboard		
	DG Research	EIS	DG Enterprise
Human resources	Human resources in R&D and attractiveness of S&T professions	Human resources	Human capital
Creative innovation	1. Public and private investment in R&D 2. Scientific and technological productivity	Creation of new knowledge	Innovation
Innovation as diffusion		Transmission and application of new knowledge	
Innovation outputs	Impact of R&D on economic competitiveness and employment	Innovation finance, outputs and markets	Access to IT
Finance		Innovation finance, outputs and markets	Access to finance
Administrative and regulatory environment			Administrative and regulatory environment
Entrepreneurship			Entrepreneurship
Well-functioning markets			Well-functioning markets

Of note, coordination between the different scoreboards would reduce some of the fine-tuning of related indicators that improves the fit between these indicators and the goals of each scoreboard.

## 4. Looking at Other Scoreboards

---

### 4.1 Introduction

---

The purpose of this section is to examine the similarities and differences between the TrendChart Innovation Scoreboard (ISB) and other scoreboards that are based on innovation indicators. It excludes other European Commission Scoreboards as these were considered in Section 3, and those scoreboards where there are no comparisons across countries or regions (e.g. French Tableau du Bord).

The report identifies 6 scoreboards, which are compared to the ISB:

- *UK Competitiveness Index (UKCI)*, DTI (2002).  
<http://www.dti.gov.uk/opportunityforall/indicators2/index.htm>
- *Index of Massachusetts Innovation Economy (IMIE)*, Massachusetts Technology Collaborative (2001)  
<http://www.mtpc.org/2001index/about.htm>
- *Science, Technology and Innovation Scoreboard (STIS)*, OECD (2001)  
<http://www.oecd.org/EN/document/0,,EN-document-571-nodirectorate-no-15-17270-18,00.html>
- *New Economy Index (NEI)*, Atkinson and Gottlieb (2001).  
<http://www.neweconomyindex.org/>
- *Global Entrepreneurship Monitor (GEM)*, (Reynolds, et al , 2001)  
<http://www.gemconsortium.org/download.asp?fid=164>
- *US Innovation Index (USII)*, (Porter and Stern, 2001)  
<http://www.compete.org/pdf/index.pdf>

The aim is to look for similarities and differences between these scoreboards along the following dimensions:

- General characteristics and conceptual framework
- Indicators chosen and data sources
- Construction of a Summary index
- Innovation policy recommendations

This section contains a summary of the main results of the comparisons. Appendix B takes a more detailed look at the ISB and each of the scoreboards in turn.

## 4.2 General Characteristics of the Scoreboards

---

While there are important differences in their precise purpose, all the Scoreboards share one common belief, namely that innovation is one of the key drivers of economic performance. The aim of the *UK Competitiveness Index (UKCI)* is to compare economic performance of the UK with the G7 countries. At the core of the comparison are a number of indicators related to innovation. The analysis is used as a key tool in assessing the progress that the UK economy is making towards closing the productivity gap with its major competitors. The *Index of the Massachusetts Innovation Economy (IMIE)* is explicitly based on the premise that innovation is a critical factor in economic growth. It compares the economic performance of Massachusetts with that of other leading US States (e.g. California, Colorado, Connecticut, Minnesota, New Jersey, and New York) in nine ‘high-tech clusters’ (or broad industry groups). The main aim is to examine how well the Massachusetts economy is able to turn innovation resources into tangible products and services. The *OECD Science Technology and Industry Scoreboard (STIS)* brings together the most complete and latest internationally comparable science, technology and industrial data in order to analyse trends towards the knowledge-based economy. Its purpose is to provide easy access to a large number of policy relevant indicators (more than 100) and highlight some of the structural shifts within OECD countries.

At the heart of the *New Economy Index (NEI)* is the observation that modern technologies, and particularly IT, have changed industrial and occupational structures, and hence the necessity to develop a scoreboard that measures performance of regions and economies in progressing towards the new economic order. The *Global Entrepreneurship Monitor (GEM)* aims to enhance our understanding of the role of entrepreneurship in national economic growth. While acknowledging innovation as being crucial in producing economic growth and well-being, *GEM* emphasises the role of entrepreneurship in this process. Thus it aims to measure differences in the level of entrepreneurial activity between countries, how far these are associated with economic growth and a variety of national characteristics, including innovative activities. The focus of the *US Innovation index (USII)* is on benchmarking *national innovative capacity*, defined “as the ability of a country to produce commercially relevant innovations”. This capacity is measured by an index constructed on the basis of a variety of innovation indicators.

Thus there are important differences in the purpose of each of the scoreboards: some aim to provide an overview of competitive performance of the whole economy, while others are focused on knowledge intensive industries. Some focus only on innovation and others on some specific aspect of innovation – such as entrepreneurship. However they all share a strong emphasis on innovation as the key to economic growth and structural change. These differences in purpose partly explain the differences in indicators chosen (see section 4.4).

**Table 10 Summary of General Characteristics of Scoreboards**

	Type of activity being analysed	Unit of Comparison	Inclusion of Policy Recommendations	New Data or Compilation of Existing Indicators	Number of Indicators	Aggregate Index
<i>ISB</i>	Innovation	EU Countries, US and Japan	No	Compilation	17	Yes
<i>UKCI</i>	Competitiveness - economic performance	G7 Countries	No	Compilation	45 Innovation 76 Full	No
<i>IMIE</i>	Performance in high-tech clusters	7 Leading US States	No	Compilation	37	No
<i>STIS</i>	Knowledge-based economy	OECD Countries	No	Compilation	102	No
<i>NEI</i>	New Economy: Performance in IT and associated changes	States and Metropolis	Yes	Compilation	16 Metropolis; 21 State	Yes
<i>GEM</i>	Entrepreneurship	Countries	Yes	Compilation and new indicators	23 Innovation; 56 Full	No
<i>USII</i>	Innovative capacity	Countries	Yes	Compilation	16	Yes

Table 10 shows that there are a number of other differences in the general characteristics of the Scoreboards. The number of indicators chosen as the basis of the comparisons varies between 16 and 102. The unit of analysis varies between country (5 out of the 7 scoreboards) and region (state or metropolis). Moreover while all scoreboards are aimed at offering policy makers and analysts a wide-ranging set of indicators on a specific subject, most of these are based on existing data sources and are not concerned with compiling new data (the main exception being GEM). A number of scoreboards contain indicators from ad-hoc (one-off) studies. In addition to the *ISB*, two of the scoreboards include an aggregate index, the construction and interpretation of which is discussed in Section 4.5. Some scoreboards include broad policy discussions/recommendations and these are discussed further in Section 4.6 below.

### 4.3 Conceptual Framework

There is a general conceptual framework (either explicit or implicit) underlying some of the scoreboards. Although they do not use the same categories, they can be characterised under the input/resources – process – output/performance framework. Table 11 classifies each scoreboard's headings into this underlying framework.

**Table 11 Correspondence between Input-Process-Output framework and the Scoreboard sections**

	<b>Inputs</b>	<b>Processes</b>	<b>Outputs</b>
<b>ISB</b>	Human Resources	Knowledge creation Transmission & application of knowledge	Innovation finance, outputs and markets
<b>UKCI</b>	Human Capital Physical Capital Finance ICTs Science & Technology	Commercialisation Knowledge transfer Receptiveness to foreign ideas Entrepreneurship	Productivity Employment Trade Specialisation in Knowledge based industries
<b>IMIE</b>	Human Technology Investment Infrastructure	Idea generation Technology commercialisation Entrepreneurship Business innovation	Quality of Jobs High Wages Exports
<b>STIS</b>	Knowledge base Information economy International integration		Economic growth and performance
<b>NEI</b>	Knowledge jobs Technological innovation Economic dynamism and competition Digital economy		Economic Growth and Productivity
<b>GEM</b>	Entrepreneurship Venture capital Research and technological development		Economic growth and performance
<b>USII</b>	Innovation infrastructure and linkages to Cluster specific conditions		Productivity and economic growth

The *ISB*, *UKCI*, and *IMIE* explicitly use this framework, whereas *USII* uses innovation infrastructure-clusters-linkages as the basic conceptual categories. However, in *USII* innovation infrastructure includes some of the same elements outlined under inputs (human capital, physical capital, knowledge resources etc.) in *ISB*, *UKCI* and *IMIE*, and the concept of linkages includes some key elements of transmission and application of knowledge. The conceptual framework for *GEM* is different, with a strong emphasis on the role of entrepreneurship in economic growth, and its relationship with research and technological development as well as various other national characteristics (such as education/gender/industry). The *STIS* also includes elements of this framework, but pays considerable attention to ICTs as infrastructure *resources* and international integration under *innovation processes*. However *STIS* also includes other indicators under these two headings that cannot easily be categorised as resources-processes-outputs. Finally, the *NEI* approach, although including some resources-processes indicators such as technological innovation, is focused on more general processes affecting structural change.

All scoreboards share a common understanding that human resources are one of the key inputs to the innovation process and hence include these under a separate heading. However this does not mean that they include the same indicators under this heading (see below). In some cases there are differing views on whether a particular indicator should be included under the heading of resource or process. For example, the *UKCI* includes R&D as part of the S&T infrastructure under the heading of resources, while the *ISB* considers R&D as part of knowledge creation, under processes.

A number of scoreboards include an extensive, separate section on ICTs or the digital economy under the heading of resources or processes. This focus is probably due to the widespread belief that the ‘knowledge economy’ is dependent on high levels of investment in ICTs and on their application.

#### 4.4 Comparing Indicators

---

In Sections 4.2 and 4.3 we have shown that although there are important differences in the purpose of each of the scoreboards, they share broadly similar overall conceptual framework, with a strong emphasis on the role of innovation. This section is concerned with the precise indicators chosen within *ISB* and how they compare with those chosen in other scoreboards (Table 12). The purpose is to highlight the similarities and differences between the scoreboards and to reflect on the type of activity being measured.

As highlighted above one of the key points of similarity between all the scoreboards is the emphasis on the scale and quality of human capital as one of the key determinants of innovation performance and hence economic growth. Moreover as shown in Table 2 there is also a near unanimous verdict on the indicator best suited to measure this<sup>20</sup>: *% of Population with tertiary education*. This indicator is used as a proxy measure for the availability of high-level skills within the workforce. However one of the major problems with this measure is that it does not capture a whole range of intermediate level technical skills which are crucial in a number of areas of manufacturing, and now increasingly, services. Some analysts have argued that differences in such skills are also important determinants of international differences in productivity and product quality<sup>21</sup>. The *ISB* and *UKCI* partly correct for this bias by including an indicator for life long learning. Another way of correcting for this would be to include an indicator of the proportion of the population that has completed upper secondary schooling as in *STIS*. However this indicator would not be sufficient on its own as it does not control for differences in the quality of schooling.

---

<sup>20</sup> The variants being *Share of GDP spent in secondary and tertiary education* (USII; Source: World Bank) and *Gross enrolment in tertiary education* (GEM; Source: not indicated)

<sup>21</sup> Prais, S. (1993) *Economic Performance and Education: the Nature of Britain's Deficiencies* Discussion Paper No. 52, National Institute of Economic and Social Research, London.

**Table 12 Number of other scoreboards that use each ISB indicator**

No	ISB Indicator	Number of scoreboards using similar indicator	Shared/similar Indicator	Source
1.1	New S&E graduates (% of 20-29 years age class)	2/6	New S&E graduates	Eurostat Labor Force Survey OECD Education at glance American Association of Engineers; NSF
1.2	Population with tertiary education (% of 24-64 years age class)	6/6	Population with tertiary education Share of GDP spent in secondary and tertiary education Gross enrolment in tertiary education	Eurostat Labour Force survey OECD Education survey US Census Bureau World Bank
1.3	Life long learning (% of 24-64 years age class)	1/6	Participation in long-life learning	Eurostat Labour Force survey OECD report on International Adult Literacy Survey
1.4	Employment in medium/high tech manufacturing (% of total workforce)	1/6	Employment in high-tech	Eurostat Labour Force surveys, Collaborative Economics, US Census Bureau
1.5	Employment in medium/high tech services (% of total workforce)	1/6		
2.1	Public R&D (GERD-BERD) (% of GDP)	4/6	Government R&D per worker in 1990 PPP dollars Federal R&D per 1.000 people Academic R&D divided by workforce	OECD Main S&T indicators NSF
2.2	Business R&D (BERD) (% of GDP)	4/6	R&D funded by industry per worker in 1990 PPP \$ R&D funded by industry per worker Industry R&D divided by workforce	OECD Annual Business Enterprise Standard & Poor's Compustat NSF
	Total R&D	2/6	Total R&D as a % of GDP Total R&D personnel per 1,000 people Aggregate R&D in millions of PPP dollars	Sources not indicated OECD S&T indicators
2.3.a	High-tech EPO patents (per million population)	6/6	EPO patent applications per million population	EPO
2.3.b	High-tech USPTO patents (per million population)		USPTO patent applications per million population Patent applications & grants per million population Share of each country in EPO applications Patent applications divided by BERD Utility patents issues to firms or individuals divided by 1.000s of workforce Patents USPTO and one additional patent office	USPTO USPTO OECD Patent database OECD Patent database USPTO CHI database
3.1	SMEs innovating in-house (% of manufacturing SMEs)	0/6	% of enterprises that bring new products/services to market or develop new process technology ;	
3.2	SMEs innovating through co-operation (% of manufacturing SMEs)	0/6	% of enterprises that considered as very important each source of information for innovation from CIS	
3.3	Innovation expenditures (% of all manufacturing turnover)	2/6	% of innovation expenditures of turnover	EU Community Innovation Survey
4.1	High-tech venture capital investment (% of GDP)	5/6	Venture capital as a % of GDP Number and value of venture capital investments Share of high tech sectors in total venture capital Venture capital by country of management and destination Number of companies funded and value of funding	European Private Equity and Capital Venture Association PricewaterhouseCoopers, LLP, Venture One EVCA, NVCA, CVCA, Asian Venture Capital Journal
4.2	Capital raised on parallel markets plus new firms on main markets (% of GDP)	3/6	Capitalisation of parallel markets as a % of GDP Stock market capitalisation per £ of GDP Number and value of IPOs Number of IPOs per 10 billion dollars of Metropolitan Product	International federation of Stock Exchanges Andersen Securities & Exchange Commission and Standard & Poor
4.3	Sales of new to market products (% of all manufacturing turnover)	2/6	Share of manufacturing turnover of new or improved products/processes	EU Community Innovation Survey
4.4	Home internet access (% of all households)	2/6	% of households with access to home computers % of households with access to internet computers % individuals using internet from any location % of adults with internet access at work	OECD ICT database Scarborough Research
4.5	Share of ICT markets as a percent of GDP	2/6	ICT expenditure as % of GDP	OECD
4.6	Share of manufacturing value-added in high tech industries	3/6	high tech industries as % of business values added High tech exports as a % of manufactured exports	OECD No sources indicated

There is little agreement on the other *ISB* indicators of *Human Resources*. Some of the scoreboards include a range of different indicators under this category, such as those related to:

- management skills;
- skilled migrants;
- schools infrastructure and quality.

All scoreboards include some form of indicators on *R&D* and *Patenting*. As for *R&D* there are a number of variations according to breakdown by source of funding and sector of performance (with Government and Business sectors most frequently used). There are also different methods for controlling for differences in the size of countries or regions using GDP, workforce or population. Indicators based on patenting include variations in the definition of a patent being counted. First, some scoreboards count *patent applications* while other count *patent grants*. Second, some scoreboards count patents from a single patent office (most frequently USPTO or EPO), and others count only patents that have been granted by the three main patent offices (USPTO, EPO, and Japan). Finally, there is also variation in the metric used to control for differences in size (Patents relative to million of people, workforce, BERD, GDP). *ISB* is the only scoreboard that includes an indicator based on high technology patenting. All others are based on total patenting. This broad similarity in the inclusion of *R&D* and patenting measures suggests that there is now general agreement on their quality as innovation indicators. Most scoreboards also include both these measures, recognising their complementarity in terms of the type of innovative activities they are capturing.

Another set of indicators common to all but one of the scoreboards are those based on *venture capital*. The underlying rationale for their inclusion is the observation that one of the main barriers to innovation is the ability to raise adequate funding, particularly at the start-up and early expansion phases of a high-technology firm. One key way to alleviate this constraint is by the provision of venture capital funding. There are a number of variations in the precise indicator used to measure this activity in each scoreboard. Some control for differences in size, while others use the total value of venture capital investment. Some only include the value of venture capital investment in high-tech sectors, while others use this as a percentage of all venture capital.

Most of the venture capital indicators are based on data gathered by venture capital associations (e.g. European or North American Venture Capital Associations) or private firms (PriceWaterhouse Cooper). The main problem with these data is the lack of information on how they are collected, and hence no easy way of assessing the comprehensiveness of coverage. Their popularity may be explained by the fact that they are the most readily available data covering a large number of countries rather than a proper assessment of their quality.

There is one important policy area under the heading of *transmission and application of knowledge* that is not yet covered by *ISB*, but receives prominent attention in some of the scoreboards, namely the interaction between publicly funded science base and industrial application. The following indicators are included under this category:

- Share of scientific publications with joint academic and industry co-authors in total scientific publications (*UKCI*).
- Royalties for university licensing (*IMIE*).
- University inventions disclosed per million people (*IMIE*).

Of these three only the first is potentially available for EU countries, and hence eligible for inclusion in the *ISB*.

#### 4.5 Construction of a Summary Index

---

The *ISB* contains a summary innovation index that provides a single composite index of the innovative capability of the EU countries plus the US and Japan. Only two out of the 6 scoreboards being compared in this report contain a summary index: *NEI* and *USII*. In both cases the index is constructed to provide a simple comparison between states and countries. The other 4 scoreboards do not even contain a discussion of the desirability or otherwise of such an index.

The *NEI* Summary Index is calculated as follows. The first step involves the transformation of the raw value of each indicator for each state by calculating the standard deviation from the mean (based on the values of all the states). In other words the index is calculated on the basis of standardised scores (transformed into positive values by adding a constant) which measure the magnitude of the differences between the states in each indicator. The second step involves the aggregation of these standardised scores for each of 5 categories (Knowledge jobs, Globalisation, Economic Dynamism and Competition, Transformation to a digital economy, Technological Innovation capacity), for each state using an arbitrary set of weights (see Appendix B). The main consideration in the construction of the weights is to avoid any undue influence of indicators that may be highly correlated within each of the 5 categories. The final step in calculating the index is the aggregation of each state's adjusted scores in each indicator category and then dividing that total by the sum of the highest score achieved by any state in each category. In other words the final score is a percentage of the total score a state would have achieved if it had finished first in each category.

This method of constructing an innovation index suffers the same problems as other such methods, namely that it involves a number of arbitrary decisions. In the case of *NEI* these are in relation to the number of indicators per category as well as the weights attached to each indicator. The various reports on *NEI* do not contain any sensitivity analysis of how different weighting structures affect the overall rankings.

The methodology for constructing *USII* innovation index proceeds in two stages. The first step consists of establishing a causal relationship between innovation and a set of independent variables, using a time-series cross-section regression model. The resulting coefficients are then used as weights to aggregate each of the independent variable by country by year to form an index. The crucial part of the whole exercise is the choice of the dependent (innovation output) variable and a set of independent variables (determinants of innovation). In the *USII* the former is simply based on international patenting, and the independent variables are chosen from a large number of candidates on the basis of ‘goodness of fit’. This process results in 8 variables which best explain the evolution of international patenting over time and across sector (see Appendix B for details). The coefficients from this last step are applied to country specific variables over time to construct the index.

This method for constructing an innovation index overcomes the problems of assigning arbitrary weights but introduces other difficulties. The main one being that aggregate country level patenting is a biased indicator of innovation performance. There are major differences in the propensity to patent the results of innovative activity amongst countries, technologies and industries. This means that the stronger performance of some countries maybe a reflection of the composition of their economies or other sources of the differences in the propensity to patent.

#### **4.6 Comparing Recommendations for Innovation Policy**

---

As far as policy analyses are concerned the scoreboards can be divided into two groups. The first group consists of those simply documenting trends in innovation or economic performance over a given period of time: *UKCI*, *IMIE* and *STIS*. The analysis contained in these scoreboards only goes as far as suggesting that a particular country or region is relatively strong or weak in relation to a specific theme such as Human Resources for innovation or Knowledge Creation, without elaborating what this means for polices. The second group of scoreboards contains a much wider discussion of policies, including some specific policy recommendations: *NEI*, *GEM*, and *USII*. However sometimes it is difficult to judge how the policy recommendations relate to the analysis contained in a particular scoreboard.

The *UKCI* contains a thorough discussion of UK position in relation to a set of factors affecting economic performance. Thus for example it shows that basic skills, vocational qualifications, and management skills are generally lower in the UK than in most of other EU countries. Moreover, the UK science base is strong but there are weaknesses in R&D. This information is used “in the DTI<sup>22</sup> to inform policy analysis including policies aimed at meeting the joint HM Treasury and DTI target for reducing the productivity gap”<sup>23</sup>. Hence

---

<sup>22</sup> Department of Trade and Industry

<sup>23</sup> See *UKCI* (2002), p.3.

there would appear to be a strong commitment on the part of the UK government to take this analysis seriously. But there is no discussion in the Scoreboard as to what precise policies are implemented on the basis of such diagnoses.

The *IMIE* is simply concerned with charting the progress of the Massachusetts economy, without any discussion of the policy implications of the main findings. Thus for example it shows that Massachusetts continues to be relatively strong in some resources such as R&D investment and venture capital, but faces a chronic long-term shortage of human resources, as outward migration has increased and school infrastructure is deficient in promoting interest in S&E amongst students. However there is no discussion of the types of policies that would discourage outward (or encourage inward) migration.

*STIS* contains the most comprehensive collection of indicators showing some of the main features of structural change and innovation performance within OECD countries. As the information in the Annex shows many of the findings are policy relevant. However *STIS* does not contain any discussion of what the findings mean for national or supra-national policy makers.

Unlike the 3 scoreboards discussed so far, the *NEI* contains an extensive discussion of specific policies that would need to be implemented in order for states to “get better” in the New Economy. For example it recommends that state governments should take the following actions:

- Change policy goal from employment growth to growth of per capita income.
- Create a forum consisting of key leaders in business, government, labour and civic groups and academia to build widespread consensus for action.
- Change business incentive schemes.
- Co-invest in the skills of the workforce.
- Co-invest in an infrastructure for innovation (e.g. public sector research organisations).
- Support industry clusters.
- Boost quality of life.
- Help more regions within a state to succeed in the New Economy.

While all these recommendations are laudable, most of them have very little to do with the analysis based on the indicators presented in the *NEI*. The main exception to this is the recommendation to change the policy goal from employment growth to growth of per capita income. This is based on the observed high, positive and statistically significant correlation between per capita income and *NEI* ranking, and the low and negative correlation between employment growth and the ranking.

*GEM* contains a wide ranging set of policy implications most of which are based on a series of cross-tabulations between a number of indicators of entrepreneurship and national characteristics such as educational attainments, age and sex. For example one

recommendation is to *facilitate greater levels of female participation in entrepreneurship*. This is based on the observation that the proportion of women entrepreneurs is half that of men. However other policy prescriptions are not based on the available data within *GEM*. An example is the prescription to *enhance education* as “those with limited education are less likely to participate in entrepreneurial activity”. The main problem with this policy is that at the very least it needs some qualification, as the analysis contained in *GEM* shows that around 62% of those active in entrepreneurship have not completed more than secondary education. Thus providing educational opportunities beyond the secondary level is not necessarily going to lead to increasing levels of entrepreneurship.

The *USII* contains an extensive discussion of the implications for US policy makers of its main findings, based on comparing the Innovation Index for 9 countries over more than 20 years. The analysis shows that the US has been consistently near the top of the rankings throughout the period, but other countries such as Japan, Germany and some of the Scandinavian countries have been catching up. Most of the policy prescriptions however, are based on the fact that if the index is projected forward a number of years, then there would be a dramatic fall in the US ranking. This decline in the US position is explained by examining the trends in some of the underlying variables that are used to construct the index. In particular the analysis shows the following patterns:

- a decline in the growth rate of R&D funding and employment
- flat or declining spending on education as a percentage of GDP
- a fall in international openness
- slow growth in GDP per capita at least through the early 1990s.

This diagnosis leads to a number of policy prescriptions including increasing federal support for R&D and increasing investment in all forms of education. The main problem with this analysis is that it is based on projecting forward on the basis of the past trends in underlying variables that make up the index. However as the R&D data shows, the second half of the 1990s were a period when there was a great revival in US R&D expenditures. This could not be attributed to the above recommendations as *USII* only appeared in 1999.

## 4.7 Conclusions

---

There are a number of similarities between the *ISB* and other scoreboards discussed in this report. They are all based on a framework that has a strong emphasis on innovation as the key driver of economic growth and structural change. Moreover they all share a common understanding that human resources are one of the key inputs to the innovation process and hence are included under a separate heading. At the same time there are some important differences between *ISB* and the other scoreboards, arising from their different goals and limitations of data availability.

All the scoreboards provide a good overview of trends in innovation or economic performance over a given period of time. They show that a particular country or region is relatively strong or weak in relation to a number of different factors underlying such performance. However only 3 out of the 6 scoreboards contain a discussion of policy implications of their main findings, including some specific policy recommendations. In most cases it is difficult to judge how such recommendations relate to the analysis of the indicators contained in a particular scoreboard. This suggests that the data contained in most scoreboards is not suitable for detailed policy analysis and is of little help in the design of specific policy measures.

## 5. 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.

The link between innovation and growth has been extensively explored from both a theoretical and an empirical perspective. 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<sup>24</sup> finds that innovation has a significant effect on productivity, whether measured by R&D spending, patenting or innovation counts. The OECD Growth Project<sup>25</sup> 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.

Tables 13 through 15 provide correlation results between the 17 innovation indicators plus the SII and three macro-economic variables at the national level: 2000 GDP per capita (Table 13), 2001 hourly productivity (Table 14) and the growth in total employment between 2000 and 2001 (Table 15)<sup>26</sup>. We use two, three, and five-year time lags when possible, to allow adequate time for innovation activities to influence macro-economic conditions. Of note, none of the correlations using the SII are statistically significant, while only a few of the correlations for individual indicators are significant.

The very low number of significant correlations is partly due to two limitations, the simplicity of the analysis, which does not control for the effect of other variables, and limitations with the innovation indicators themselves. First, macro-economic variables such as GDP and labour productivity are based on many factors other than innovation, such as capital investment and existing capital stocks. Including other factors in the analysis is beyond the scope of this project – our main purpose here is to identify any major patterns that might be visible, even without controlling for other variables. Second, the EIS indicators are imperfect measures of all innovative activities at the national level. They are weak on innovation as diffusion, which could be the mechanism followed by some countries, such as Italy, to innovate. This could explain why Sweden, characterized by a high innovative capability, and

---

<sup>24</sup> 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).

<sup>25</sup> <http://www.oecd.org/subject/growth>. See the report: *A new Economy?; The Changing Role of Innovation and Information Technology in Growth*, OECD 2000.

<sup>26</sup> Sources: The data for productivity per hour worked and for employment growth are from Eurostat's structural indicators (<http://europa.eu.int/comm/eurostat/>). GDP per capita (PPS) data is from the OECD.

Italy, with a low innovative capability, both have similar per capita GDP. The EIS indicators also *intentionally* focus on innovation in high technology manufacturing sectors, whereas between 60% and 70% of economic activity in the countries covered by the EIS is in the service sectors.

Table 13 shows the correlations between the innovation indicators and GDP per capita. In general, the correlation coefficients are all quite low. Only two indicators are significant and positively correlated with GDP per capita: the percentage of the working-age population with tertiary education (only for a two-year lag) and business expenditure on R&D (for both a three and five year lag).

**Table 13. Correlations between innovation indicators and 2000 GDP per capita**

	2 year lag	3 year lag	5 year lag
SII	0.31	<sup>-1</sup>	-
1.1 S&E graduates	-0.06	-0.20	0.01
1.2 Tertiary education	0.59*	0.25	0.13
1.3 Lifelong learning	0.246	0.05	0.17
1.4 Employment in med-high/high tech manufacturing	-0.17	-0.14	-0.14
1.5 Employment in high-tech services	0.27	0.23	0.09
2.1 Public R&D expenditures	0.025	0.35	0.41
2.2 Business expenditure on R&D	0.26	0.58*	0.59*
2.3.1 EPO high-tech patent applications	0.01	0.10	0.07
2.3.2 USPTO high-tech patent appl.	0.26	0.25	0.27
3.1 SMEs innovating in-house <sup>2</sup>	-	0.20	-
3.2 % manuf. SMEs in innovation cooperation <sup>2</sup>	-	0.20	-
3.3 Innovation expenditures <sup>2</sup>	-	0.50	-
4.1 High-tech venture capital investment	0.15	-	-
4.2 New capital raised on stock markets	0.16	-	-
4.3 'New to market' products <sup>2</sup>		-0.29	-
4.4 Home internet access	0.19	-	-
4.5 ICT expenditures	0.43	0.47	0.47
4.6 Percent of manuf. value-added from high-tech		0.09	-

Notes: \* and \*\* denote significant correlations at the 0.05 and 0.01 levels, respectively.

1: Insufficient data for analysis.

2. The lag time for indicators 3.1, 3.2, 3.3 and 4.3 varies by country between two years for the Netherlands, Greece and Spain and four years for all other EU countries.

Although not significant, three results suggest possible connections between innovative activities and per capita GDP. First, the trend in the correlation for public R&D increases with the number of lag years, suggesting that public R&D could increase GDP per capita, but that it takes much longer than private R&D to have an effect. This is plausible, since publicly-funded R&D is often farther from commercialization than private R&D. Furthermore, one of the main outputs of the public research sector are trained scientists in leading edge research.

These individuals could be employed by the private sector once they finish their studies. Second, although the employment share in medium-high and high technology manufacturing is always negative. This could be due to lower average incomes in this sector than in alternatives, such as finance. Third, although not significant, the correlation coefficients for ICT investment are comparatively high. This variable could be significant if the number of observations (countries) was larger.

Table 14 gives the correlation results for hourly labour productivity in 2001. The correlations between the innovation indicators and hourly productivity are all very small, no matter the time lag is used. Only the indicator for new capital raised on stock markets is significant and positively correlated with productivity when a two-year lag is used. Possibly new capital tends to go into more productive investment, but there is not enough information on this result to make reliable conclusions.

**Table 14. Correlations between innovation indicators and 2001 hourly productivity**

	2 year lag	3 year lag	5 year lag
SII	- <sup>1</sup>	0.00	-0.04
1.1 S&E graduates	-0.14	-0.12	-0.14
1.2 Tertiary education	0.00	0.15	0.10
1.3 Lifelong learning	-0.05	0.11	-0.11
1.4 Employment in med-high/high tech manufacturing	-0.14	-0.17	-0.17
1.5 Employment in high-tech services	0.39	0.19	0.14
2.1 Public R&D expenditures	0.80	-0.17	-0.02
2.2 Business expenditure on R&D	0.24	-0.34	0.18
2.3.1 EPO high-tech patent applications	-0.02	-0.06	-0.10
2.3.2 USPTO high-tech patent appl.	-0.18	-0.17	-0.19
3.1 SMEs innovating in-house <sup>2</sup>	-	0.15	-
3.2 % manuf. SMEs involved in innovation cooperation <sup>2</sup>	-	0.05	-
3.3 Innovation expenditures <sup>2</sup>	-	0.30	-
4.1 High-tech venture capital investment	0.11	0.05	-
4.2 New capital raised on stock markets	0.59*		-
4.3 'New to market' products <sup>2</sup>	-	-0.11	-
4.4 Home internet access	0.09	0.12	-
4.5 ICT expenditures	0.28	0.15	-
4.6 Percent of manuf. value-added from high-tech	0.19	-	-

Notes: \* and \*\* denote significant correlations at the 0.05 and 0.01 levels, respectively.

1: Insufficient data for analysis.

2: The lag time for indicators 3.1, 3.2, 3.3 and 4.3 varies by country between two years for the Netherlands, Greece and Spain and four years for all other EU countries.

Table 15 gives the results for employment growth for 2001. The analyses are likely to be very problematic, because so many other factors will influence employment growth, including

demographics, immigration, and taxation policy. There is only one positive and significant relationship between the innovation indicators and employment growth: for new capital raised on stock markets. This is a plausible relationship, because this capital should be invested in new firms, production, or research.

**Table 15. Correlations between innovation indicators and employment growth (2000 to 2001)**

	2 year lag	3 year lag	5 year lag
SII	- <sup>1</sup>	-0.12	-0.18
1.1 S&E graduates	-0.40	-0.60	-0.50
1.2 Tertiary education	-0.10	0.13	-0.02
1.3 Lifelong learning	-0.15	-0.18	-0.16
1.4 Employment in med-high/high tech manufacturing	-0.39	-0.42	-0.45
1.5 Employment in high-tech services	0.17	-0.01	-0.13
2.1 Public R&D expenditures	-0.33	-0.29	-0.17
2.2 Business expenditure on R&D	-0.03	-0.19	-0.06
2.3.1 EPO high-tech patent applications	-0.09	-0.11	-0.15
2.3.2 USPTO high-tech patent appl.	-0.23	-0.20	-0.17
3.1 SMEs innovating in-house <sup>2</sup>	-	-0.25	-
3.2 % Manuf. SMEs in innovation cooperation <sup>2</sup>	-	-0.16	-
3.3 Innovation expenditures <sup>2</sup>	-	0.07	-
4.1 High-tech venture capital investment	0.28	0.27	-
4.2 New capital raised on stock markets	0.77**	-	-
4.3 'New to market' products <sup>2</sup>	-	0.44	-
4.4 Home internet access	-0.01	0.04	-
4.5 ICT expenditures	0.18	0.11	-
4.6 Percent of manuf. value-added from high-tech	0.33	-	-

Notes: \* and \*\* denote significant correlations at the 0.05 and 0.01 levels, respectively.

1: Insufficient data for analysis.

2. The lag time for indicators 3.1, 3.2, 3.3 and 4.3 varies by country between two years for the Netherlands, Greece and Spain and four years for all other EU countries.

## 6. Definition and Sources for the EIS Indicators

---

### 1.1 New S&E graduates (% of 20-29 years age class)

**Definition:** The reference population is all age classes between 20 and 29 years inclusive. Tertiary graduates in Science & Engineering (S&E) are defined as all post-secondary education graduates (ISCED classes 5a and above) in life sciences (ISC42), physical sciences (ISC44), mathematics and statistics (ISC46), computing (ISC48), engineering and engineering trades (ISC52), manufacturing and processing (ISC54) and architecture and building (ISC58). Due to a change in definition a comparison with the 2001 Scoreboard results is not possible. This indicator is identical to Structural indicator 2.4: Science and technology graduates.

**Interpretation:** The indicator is a measure of the supply of new graduates with training in Science & Engineering (S&E). Due to problems of comparability for educational qualifications across countries, this indicator uses broad educational categories. This means that it covers everything from graduates of one-year diploma programmes to PhDs. A broad coverage can also be an advantage, since graduates of one-year programmes are of value to incremental innovation in manufacturing production and in the service sector.

### 1.2 Population with tertiary education (% of 25-64 years age classes)

**Definition:** The percentage of the total working age population (25-64 years age classes) with some form of post-secondary education (ISCED 5 and 6).

**Interpretation:** This is a general indicator of the supply of advanced skills. It is not limited to science and technical fields because the adoption of innovations in many areas, particularly in the service sectors, depends on a wide range of skills. Furthermore, it includes the entire working age population, because future economic growth could require drawing on the non-active fraction of the population. International comparisons of educational levels however are notoriously difficult due to large discrepancies in educational systems, access, and the level of attainment that is required to receive a tertiary degree. Therefore, differences among countries should be interpreted cautiously.

### 1.3 Participation in life-long learning (% of 25-64 years olds)

**Definition:** The reference population is all age classes between 25 and 64 years inclusive. A reference period of four weeks has been chosen in order to avoid distortion of information due to recall problems. The reference period is the last four weeks preceding the survey, except for France, the Netherlands (until 1999) and Portugal for which information is collected only if education or training is under way on the date of the survey. Education includes initial education, further education, continuing or further training, training within the company, apprenticeship, on-the-job training, seminars, distance learning, evening classes, self-learning, etc. as well as other courses followed for general interest: language, data-processing, management, art/culture, health/medicine courses. Before 1998, education was related only to education and vocational training which was relevant for the current or possible future job of the respondent. This indicator is identical to Structural indicator 1.7.

**Interpretation:** A central characteristic of a knowledge economy is continual technical development and innovation. Under these conditions, individuals need to continually learn

new ideas and skills - or to participate in life-long learning. All types of learning are valuable, since it prepares people for “learning to learn”. The ability to learn can then be applied to new tasks with social or economic benefits. The limitation of the indicator to a brief window of four weeks could reduce comparability between countries due to differences in adult education systems. Little is known at this time about such differences, but differences in the timing of national holidays, preferred times for adult education courses, the average length of adult courses, and other unknown factors could influence the results and reduce comparability. Technical Paper N° 5 of the 2002 EIS further elaborates on the issue of “Lifelong Learning for Innovation”.

#### *1.4 Employment in medium-high and high-tech manufacturing (% of total workforce)*

Definition: The medium-high and high technology sectors include chemicals (NACE 24), machinery (NACE 29) office equipment (NACE 30), electrical equipment (NACE 31), telecom equipment (NACE 32), precision instruments (NACE 33), automobiles (NACE 34), and aerospace and other transport (NACE 35). The total workforce includes all manufacturing and service sectors.

Interpretation: The percentage of employment in medium-high and high technology manufacturing sectors is an indicator of the share of the manufacturing economy that is based on continual innovation through creative, inventive activity. The use of total employment gives a better indicator than using the share of manufacturing employment alone, since the latter will be affected by the hollowing out of manufacturing in some countries.

#### *1.5 Employment in high-tech services (% of total workforce)*

Definition: This indicator focuses on three leading edge sectors that produce high technology services: post and telecommunications (NACE 64); information technology including software development (NACE 72); and R&D services (NACE 73). The total workforce includes all manufacturing and service sectors.

Interpretation: The high technology services both provide services directly to consumers, such as telecommunications, and provide inputs to the innovative activities of other firms in all sectors of the economy. The latter can increase productivity throughout the economy and support the diffusion of a range of innovations, particularly those based on ICT.

#### *2.1 Public R&D expenditures (GERD - BERD) (% GDP)*

Definition: The indicator is the percentage of GDP due to public R&D spending. The latter is defined as the difference between total R&D expenditures (GERD) and business enterprise expenditures (BERD). It thus includes higher education expenditure in R&D (HERD), government expenditure in R&D (GORD) and private non-profit expenditure in R&D (PNRD). Note that this definition has changed compared to the 2001 EIS as it now also includes private non-profit expenditure in R&D (PNRD). This indicator was identical to the initial Structural indicator 2.2: R&D expenditure. The definition of Structural indicator 2.2 was changed in October 2002: the R&D indicators are now disaggregated by source of finance rather than the sector carrying out the R&D expenditure. This change in definition could, due to time constraints, not be taken into account in the 2002 EIS.

**Interpretation:** In addition to the production of basic and applied knowledge in universities and higher-education institutions, publicly funded research offers several other outputs of direct importance to private innovation: trained research staff and new instrumentation and prototypes.

## 2.2 Business expenditure on R&D (BERD) (% GDP)

**Definition:** This indicator measures the R&D expenditure (from all sources of funding) of the business sector (manufacturing and services) as a percentage of GDP. This indicator was identical to the initial Structural indicator 2.2: R&D expenditure. The definition of Structural indicator 2.2 was changed in October 2002 : the R&D indicators are now disaggregated by source of finance rather than the sector carrying out the R&D expenditure. This change in definition could not, due to time constraints, be taken into account in the 2002 EIS.

**Interpretation:** The indicator captures the formal creation of new knowledge within firms. It is particularly important in the science-based sectors (pharmaceuticals, chemicals and some areas of electronics) where most new knowledge is created in or near R&D laboratories.

### 2.3.1 EPO high-tech patent applications (per million population)

**Definition:** The indicator is defined as the number of patent applications (reference year is year of filing) at the EPO in high-technology patent classes per million population. The national (and regional) distribution of the patent applications is assigned according to the address of the inventor. The high technology patent classes include pharmaceuticals, biotechnology, information technology, and aerospace. The following IPC subclasses are included:

- B41J: typewriters; selective printing mechanisms, i.e. mechanisms printing otherwise than from a form; correction of typographical errors
- G06C: digital computers in which all the computation is effected mechanically
- G06D: digital fluid-pressure computing devices
- G06E: optical computing devices
- G06F: electric digital data processing
- G06G: analogue computers
- G06J: hybrid computing arrangements
- G06K: recognition of data; presentation of data; record carriers; handling record carriers
- G06M: counting mechanisms; counting of objects not otherwise provided for
- G06N: computer systems based on specific computational models
- G06T: image data processing or generation, in general
- G11C: static stores
- B64B: lighter-than-air aircraft
- B64C: aeroplanes; helicopters
- B64D: equipment for fitting in or to aircraft; flying suits; parachutes; arrangements or mounting of power plants or propulsion transmissions
- B64F: ground or aircraft-carrier-deck installations
- B64G: cosmonautics; vehicles or equipment therefore
- C12M: apparatus for enzymology or microbiology
- C12N: micro-organisms or enzymes; compositions thereof; propagating, preserving, or maintaining micro-organisms; mutation or genetic engineering; culture media

- C12P: fermentation or enzyme-using processes to synthesize a desired chemical compound or composition or to separate optical isomers from a racemic mixture
- C12Q: measuring or testing processes involving enzymes or micro-organisms
- H01S: devices using stimulated emission
- H01L: semiconductor devices; electric solid state devices not otherwise provided for
- H04B: transmission
- H04H: broadcast communication
- H04J: multiplex communication
- H04K: secret communication; jamming of communication
- H04L: transmission of digital information, e.g. telegraphic communication
- H04M: telephonic communication
- H04N: pictorial communication, e.g. television
- H04Q: selecting
- H04R: loudspeakers, microphones, gramophone pick-ups or like acoustic electromechanical transducers; deaf-aid sets; public address systems
- H04S: stereophonic systems

Interpretation: This indicator complements indicator 2.2 on business R&D in that patenting captures new knowledge created anywhere within a firm and not just within a formal R&D laboratory. The indicator also measures specialisation of knowledge creation in fast-growing technologies.

#### *2.3.1A EPO patent applications (per million population)*

Definition: The indicator is defined as the number of all patent applications at the EPO per million population. The national (and regional) distribution of the patent applications is assigned according to the address of the inventor. This indicator is used for the Candidate countries as an alternative for indicator 2.3.1 as the numbers for high-technology EPO patent applications are too small.

Interpretation: This indicator complements indicator 2.2 on business R&D in that patenting captures new knowledge created anywhere within a firm and not just within a formal R&D laboratory.

#### *2.3.2 USPTO high-tech patent applications per million population*

Definition: The indicator is defined as the number of patent applications at the US Patent and Trade Mark Office (USPTO) in high-technology patent classes, per million population. The high technology patent classes are the same as those for indicator 2.3.1.

Interpretation: Indicator 2.3.1 on EPO patent applications favours European versus American and Japanese firms. The present indicator provides the equivalent for American firms and measures US patenting activity by European inventors.

#### *3.1 SMEs innovating in-house (% of manufacturing SMEs)*

Definition: Innovative manufacturing firms are defined as those who introduced new products or processes either:

2. In-house or
3. In combination with other firms

Note: This indicator does not include new products or processes developed by other firms (option 1 in the CIS questionnaires; compare question 2 in the CIS 2 questionnaire and question 2.1 in the CIS 3 questionnaire). Only SMEs with 20-249 employees are taken into account in CIS 2. Small and medium-sized enterprises (SMEs) are characterised as those enterprises with 20-249 employees.

Interpretation: The CIS defines innovative manufacturing firms quite broadly as those who introduced new products or processes developed by 1) other firms, 2) in house, or 3) in combination with other firms. The present indicator is more focused in two respects. It is limited to SMEs because almost all large firms innovate and because countries with an industrial structure weighted to larger firms would tend to do better. And it is limited to firms with in-house innovative activities that either develop product or process innovations themselves or in combination with other firms.

### *3.2 Manufacturing SMEs involved in innovation co-operation*

Definition: The indicator is the percentage of all manufacturing SMEs (including non-innovators) with 20 or more employees that had any co-operation agreements on innovation activities with other enterprises or institutions in the three years before the survey (compare question 11 in the CIS 2 questionnaire and question 8.1 in the CIS 3 questionnaire).

Interpretation: Complex innovations, particularly in ICT, often depend on the ability to draw on diverse sources of information and knowledge, or to collaborate on the development of an innovation. This indicator measures the flow of knowledge between public research institutions and firms and between firms and other firms. The indicator is limited to SMEs because almost all large firms are involved in innovation co-operation. This indicator also captures technology-based small manufacturing firms, since most are involved in co-operative projects. However, the indicator will miss high-technology firms with no product sales, such as many biotechnology firms, because these firms are assigned to the service sector.

### *3.3 Innovation expenditures (% of all turnover in manufacturing)*

Definition: This indicator includes all manufacturing firms with 20 or more employees. Innovation expenditures includes the full range of innovation activities: in-house R&D, extramural R&D, machinery and equipment linked to product and process innovation, spending to acquire patents and licenses, industrial design, training, and the marketing of innovations. Total innovation expenditure by all firms in each country is divided by total turnover. This includes firms that do not innovate, whose innovation expenditures are zero by definition (compare question 6 in the CIS 2 questionnaire and question 4.1 in the CIS 3 questionnaire).

Interpretation: Several of the components of innovation expenditure, such as investment in equipment and machinery and the acquisition of patents and licenses, measure the diffusion of new production technology and ideas. Overall, the indicator measures total expenditures on many different activities of relevance to innovation. The indicator partly overlaps with indicator 2.2 on R&D expenditures. A better version would exclude R&D, but concerns over data reliability have prevented this option.

#### 4.1 High-tech venture capital investment (% of GDP)

**Definition:** The percentage of GDP due to venture capital in high technology firms active in the following sectors: computer related fields, electronics, biotechnology, medical/health, industrial automation, financial services. Venture capital is the sum of early stage capital (seed and start-up) plus expansion capital.

The data for this indicator were taken from EVCA's "Mid-Year Survey of Pan-European Private Equity & Venture Activity". More recent data for high-tech venture investments including replacement and buyout capital are available in EVCA's "Yearbook: Annual Survey of Pan-European Private Equity & Venture Capital Activity". The Yearbook however does not provide disaggregated data to calculate high-tech venture capital investments according to the EIS definition and these data have thus not been used.

**Interpretation:** One of the main barriers to innovation is the ability of new technology-based firms to raise adequate funding. This indicator measures the supply of private venture capital to these firms. The total supply of capital will be higher because of bank and private-placement financing. The main disadvantage is that there are many alternative methods of financing new technology-based start-up firms that are not covered by this indicator. Firms can also go abroad to raise venture capital. An additional concern is the lack of information on the accuracy of the venture capital data.

#### 4.2 New capital raised on stock markets (% of GDP)

**Definition:** This indicator is the amount of new capital raised by domestic firms on domestic stock markets as a percentage of GDP. It excludes investment funds and unit trusts. And, in order to focus the indicator on new innovative firms, the indicator excludes capital raised by existing firms on the main stock exchanges. Three types of new capital are included:

- capital raised by newly admitted firms to the main stock exchanges
- capital raised on parallel markets by already listed firms
- capital raised on parallel markets by newly admitted firms.

The focus on new capital that is probably raised by innovative firms in high technology sectors differentiates this indicator from the Structural indicator "Capital raised on stock markets", which includes all capital raised on stock markets, including capital raised on the main markets. Parallel stock exchanges focus on high technology sectors.

**Interpretation:** New capital is a major source of investment for many firms, but particularly for fast growing firms in high technology sectors. The indicator is strongly influenced by volatility in capital markets: it includes stocks that have little to do with technology. Firms raising capital in foreign markets will distort the results.

#### 4.3 'New to market' products (% of sales by manufacturing firms)

**Definition:** The amount of product sales (or total turnover), by manufacturing firms with more than 20 employees, from innovations that are new to the firm's market. These are limited to products that are both new to the firm itself and new to the firm's market. (compare question 5 in the CIS 2 questionnaire and question 1.4 in the CIS 3 questionnaire).

**Interpretation:** This is a direct output measure of innovation that is not distorted by market speculation (as would the market value of a firm). The product must be new to the firm, which in many cases will also include innovations that are world-firsts. The main disadvantage is that there is some ambiguity in what constitutes a ‘new to market’ innovation. Smaller firms or firms from less developed countries could be more likely to include innovations that have already been introduced onto the market elsewhere.

#### *4.4 Home internet access (% of all households)*

**Definition:** Percentage of households who have internet access at home. All forms of use are included. Population considered is equal to or over 15 years old. This indicator is identical to Structural indicator 2.3: Level of internet access.

**Interpretation:** Internet use by the domestic population is a measure of the ability to access an enormous wealth of data on-line, including business-to-consumer e-commerce and government-to-citizen online services. In the future, much more sophisticated measures of internet use will be needed. Better data is needed on what the internet is used for and if the population is aware of several efficiency enhancing uses.

#### *4.4A Internet access (% of population)*

**Definition:** Percentage of population with any form of internet access. All forms of use are included. Population considered is equal to or over 15 years old. This indicator is used for the Candidate countries as an alternative for indicator 4.4 due to better data availability.

**Interpretation:** Internet use by the domestic population is a measure of the ability to access an enormous wealth of data on-line, including business-to-consumer e-commerce and government-to-citizen online services. In the future, much more sophisticated measures of internet use will be needed. Better data is needed on what the internet is used for and if the population is aware of several efficiency enhancing uses.

#### *4.5 ICT expenditures (% of GDP)*

**Definition:** This indicator measures total expenditures on Information and Communication Technology (ICT) as a percentage of GDP. ICT includes office machines, data processing equipment, data communication equipment, and telecommunications equipment, plus related software and telecom services. This indicator is identical to Structural indicator 2.7.

**Interpretation:** ICT is a fundamental feature of knowledge based economies and the driver of current and future productivity improvements. An indicator for ICT investment is crucial for capturing innovation in knowledge-based economies, particularly due to the diffusion of new IT equipment, services, and software. One disadvantage of this indicator is that it is ultimately obtained from private sources (IDC), with a lack of good information on the reliability of the data. Another disadvantage is that some expenditures are for final consumption and may have few productivity or innovation benefits. It would be preferable to have data on ICT investment rather than ICT expenditure, but reliable investment data are not yet available.

#### *4.6 Percent of manufacturing value-added from high technology*

Definition: The percentage of total value added in manufacturing in four high technology industries: pharmaceuticals (NACE 24.4), office equipment (NACE 30), telecommunications and related equipment (NACE 32), and aerospace (NACE 35.3).

Interpretation: Value-added is the best measure of manufacturing output, whereas other indicators such as total production can be biased by ‘screwdriver’ plants with little value-added. The requirement for good data on value added creates a lag of two or more years longer than for GDP and other economic data. The main disadvantage of the main indicator is that a hollowing-out of manufacturing, as in the UK, can lead to relatively good results, if low and medium technology industries no longer survive.

#### *4.6A Stock of inward FDI (% of GDP)*

Definition: The indicator is defined as the stock in inward Foreign Direct Investment (FDI) as a percentage of GDP. UNCTAD defines FDI “as an investment involving a long-term relationship and reflecting a lasting interest and control by a resident entity in one economy (foreign direct investor or parent enterprise) in an enterprise resident in an economy other than that of the foreign direct investor (FDI enterprise or affiliate enterprise or foreign affiliate). FDI implies that the investor exerts a significant degree of influence on the management of the enterprise resident in the other economy. Such investment involves both the initial transaction between the two entities and all subsequent transactions between them and among foreign affiliates, both incorporated and unincorporated.” This indicator is used for the Candidate countries as an alternative for indicator 4.6.

Interpretation: The inflow of FDI steers production towards higher value-added goods, or increases production efficiency. Both can depend on the transfer of foreign technology and provide a potential for conducting industrial research in the host country. Stock data are a better proxy for the rate of penetration of FDI and also neutralize large variations in annual inflows.

## Appendix A. Correlation matrix between the EIS indicators for the EU Member States

	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3a	2.3b	3.1	3.2	3.3	4.1	4.2	4.3	4.4	4.5	4.6
1.1	1																	
1.2	.332	1																
1.3	.069	.704**	1															
1.4	.279	.410	.302	1														
1.5	.397	.742**	.746**	.417	1													
2.1	.016	.597*	.631*	.406	.636*	1												
2.2	.222	.773**	.662**	.666**	.809**	.767**	1											
2.3a	.101	.703**	.586*	.360	.562*	.780**	.668**	1										
2.3b	.071	.804**	.795**	.478	.725**	.884**	.892**	.873**	1									
3.1	-.017	.102	.262	.579*	.424	.264	.291	.111	.191	1								
3.2	.123	.611*	.722**	.368	.777**	.462	.633*	.408	.594*	.586*	1							
3.3	.139	.585*	.705**	.524	.799**	.762**	.880*	.477	.769**	.494	.780**	1						
4.1	.344	.759**	.731**	.372	.698**	.473	.652*	.459	.675**	.016	.328	.464	1					
4.2	-.355	.153	.202	-.308	-.056	.049	-.278	-.033	-.019	.075	.200	-.027	-.059	1				
4.3	.088	-.475	-.299	.020	-.245	-.232	-.295	-.204	-.305	-.060	-.339	-.141	-.338	-.085	1			
4.4	-.055	.585*	.856**	.218	.796**	.646*	.652*	.528*	.690**	.523*	.746**	.752**	.617*	.234	-.367	1		
4.5	-.027	.293	.503	-.204	.135	.439	.331	.097	.402	-.307	.150	.435	.420	.290	-.225	.317	1	
4.6	.517	.413	.290	.122	.696*	-.017	.542	.135	.295	.209	.494	.498	.405	-.410	-.251	.411	.044	1

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

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

## Appendix B. Summaries Of Differences Between ISB And Other Scoreboards

---

### 1. UK Competitiveness Indicators

#### Differences in purpose

The aim of the UK Competitiveness Index (UKCI) (DTI, 2001) is to compare economic performance of the UK with the G7 countries. A large number of indicators in the Index are related to Innovation. It is mainly used to inform policy analysis at DTI and HM Treasury.

#### Differences in sources of indicators and indicators chosen and reasons

The UKCI is organised in four main sections: business environment (macroeconomic, competition, labour market, institutions, quality of life), resources (human capital, physical capital, finance, ICTs, S&T), innovation process (technology commercialisation, knowledge transfer, receptiveness to foreign ideas, entrepreneurship), results (GDP pc, productivity, employment, specialisation in trade, composition of the economy).

The main sections of the ISB conceptually coincide with UKCI sub-sections as follows:

- Human resources ~ human capital, but the indicators chosen by the ISB make emphasis on human resources in S&T fields while the UKCI is broader by including adult literacy and numeracy and management skills.
- Knowledge creation ~ S&T and knowledge commercialisation, where both scoreboards include almost identical indicators (UKCI uses one additional indicator on scientific publications).
- Transmission and application of knowledge ~ technology commercialisation, where both scoreboards include broadly similar indicators (ISB differentiates between innovation through in-house and collaboration).
- Innovation finance, output and markets ~ finance, technology commercialisation, ICTs and output (share of output in knowledge based industries), where both scoreboards include almost identical indicators (ISB emphasises on home access to internet while UKCI emphasises business access to internet).

Additionally, the UKCI also explores other innovation areas like:

- Knowledge transfer (university licensing and start-ups)
- Receptiveness to foreign ideas (international alliances and technological alliances)
- Entrepreneurship (entry, exit, growth, attitude toward risk)

In summary, although both scoreboards have different purposes, are conceptually organised in different ways, there is high degree of similarity between conceptual categories used and the indicators used to measure these conceptual categories. For example, knowledge creation in the ISB is conceptually very similar to S&T in the UKCI and both use almost identical indicators. The only exception is UKCI's

*technology commercialisation* concept that groups indicators from ISB's knowledge creation (patents), transmission and application of knowledge (innovation expenditure and proportion of innovative firms), and innovation finance, output, and markets (share of sales of new products).

The indicators used by the UKCI in the innovation process section that are shared by the ISB are identified in table 1.A and other relevant indicators used by the UKCI that are not shared by the ISB are identified in table 1.B.

### **Differences in methodology for summary indices**

No summary index is suggested.

### **Recommendations for innovation policy**

The UKCI information is used to set up a diagnosis, but says little about past, actual, or new policies and its effects. The following is a summary of the main diagnosis provided in the report.

#### *Resources:*

- Basic skills, vocational qualifications, and management skills are generally lower than in most of other EU countries and only long life learning is at the EU average.
- Investment from private and public sector is among the lowest in EU.
- Access to venture capital is relatively high, particularly, in the final stages, and also to parallel markets required to exit.
- ICTs are relatively frequently used and owned, but e-commerce has not taken off relatively to other EU competitors and the US.
- Excellent science base but low government and private R&D investment.

#### *Innovation process:*

- Services industry is doing well in using knowledge to offer novel products/processes but manufacturing is lagging compared to other EU countries
- High degree of openness to foreign ideas, high R&D foreign investment, and international technology alliances.
- Risk aversion dominates the population and relatively low social recognition to entrepreneurs.

#### *Results:*

- Low labour productivity growth when compared to the rest of G7
- Knowledge based industries are growing and the UK is a leading exporter in these amongst all G7 countries.

**Table 1.A Indicators shared by ISB and UKCI**

No	ISB Indicator	Shared/similar Indicator	Source
<b>1. Human Resources</b>			
1.1	New S&E graduates (% of 20-29 years age class)	×	
1.2	Population with tertiary education (% of 25-64 years age class)	Distribution of population between 24-65 years by highest completed level of education (below upper secondary, upper secondary, post-secondary non-tertiary, BA/BS, MA/MS+PhD)	OECD Education at glance
1.3	Lifelong learning (% of 25-64 years age class)	Average hours of continuing education and training per person between 24-65	OECD Final report of the international adult literacy survey: literacy in the information age
1.4	Employment in medium/high-tech Manufacturing (% of total workforce)	×	
1.5	Employment in high-tech services (% of total workforce)	×	
<b>2. Knowledge creation</b>			
2.1	Public R&D (GERD-BERD) (% of GDP)	Government R&D per worker in 1990 PPP dollars	OECD Main S&T indicators
2.2	Business R&D (BERD) (% of GDP)	R&D funded by industry per worker in 1990 PPP dollars	OECD Annual business enterprise R&D
2.3.a	High-tech EPO patents (per million population)	EPO Patent applications per million of population	Data EPO
2.3.b	High-tech USPTO patents (per million population)	USPTO Patent grants per million of population	Data from USPTO
<b>3. Transmission and application of knowledge</b>			
3.1	SMEs innovating in-house (% of manufacturing SMEs)	% of enterprises that bring new products/services to market or develop new process technology & % of enterprises that considered as very important each source of information for innovation from CIS	EU Community innovation survey
3.2	SMEs innovating through co-operation (% of manufacturing SMEs)		
3.3	Innovation expenditures (% of all manufacturing turnover)	Identical	
<b>4. Innovation finance, output, and markets</b>			
4.1	High-tech venture capital investment (% of GDP)	% venture capital (by seed, start-up, early stage) per £ of GDP, not only high-tech venture capital	European Private Equity and Capital Venture Association
4.2	Capital raised on parallel markets plus new firms on main markets (% of GDP)	Capitalisation of parallel markets as % of GDP & Stock market capitalisation per £ of GDP	International Federation of Stock Exchanges
4.3	Sales of new to market products (% of all manufacturing turnover)	Share of manufacturing turnover of new or improved products/processes	EU Community innovation survey
4.4	Home internet access (% of all households)	×	
4.5	Share of ICT markets as a percent of GDP	×	
4.6	Share of manufacturing value-added in high tech sectors	% value added (by services, communication services, medium & high tech manufacturing) per £ of business value added	OECD

**Table 1.B. Indicators included in UKCI and not included in ISB**

UKCI section	UKCI concept	Indicators	Source	
Resources	Human capital	Average score of business executive perceptions of quality of management	International Institute for Management Development	
	Physical capital	Business investment per worker	OECD Business sector database	
		% government expenditure in investment per £ GDP	OECD Business sector database	
		Public and private investment in transport	Not available	
	Finance	Number of companies incorporated in parallel markets	International Federation of Stock Exchanges	
	ICTs	% of businesses connected to internet (by business size)	DTI Consultancy report “Moving into the information age: international benchmarking study” by Romtec Plc	
		% of adoption of e-commerce by businesses	DT Consultancy report “Moving into the information age: international benchmarking study” by Romtec Plc	
		B2B sales per £ of GDP	Merrill Lynch Benchmarking the new economy: Europe in a global context	
		B2C sales per £ of GDP	Merrill Lynch Benchmarking the new economy: Europe in a global context	
		Reason for not adopting or further developing e-commerce: IT skills shortage	DTI Consultancy report “Moving into the information age: international benchmarking study” by Romtec Plc	
	S&T	Papers per head	Institute for Scientific Information ISI Science citation index	
		Citations per head	Institute for Scientific Information ISI Science citation index	
		Business enterprise R&D intensity by industry	OECD Annual business enterprise R&D	
	Innovation process	Commercialisation	% of enterprises that bring new products/processes	EU Community Innovation Survey
			% of enterprises that bring new products/processes to market	EU Community Innovation Survey
Knowledge transfer		University licensing to start-ups and value of royalties	Higher Education Funding Council for England Industry-academy links report (No international or regional comparisons)	
		Number of papers with joint partner (university-industry) publishing	SPRU UK corporate research collaboration (No international or regional comparisons)	
Receptiveness to foreign ideas		% of industrial R&D accounted for by foreign affiliates	OECD Activity of foreign affiliates database	
		Technological alliances per million of population	MERIT	
Entrepreneurship		Business start-ups	Global Enterprise Monitor GEM Report (Babson College (US) and LBS (UK) alliance)	
		Direct registration cost and time taken to set up a business	EC Benchmarking enterprise policy	
		% of listed businesses which have more than doubled sales growth in the last five years	Merrill Lynch Benchmarking the new economy: Europe in a global context	
		% of entrepreneurs giving affirmative responses to statements about starting new businesses as a respectable occupation and about willingness to start a new business	Global Enterprise Monitor GEM Report (Babson College (US) and LBS (UK) alliance)	
Results	Productivity	GDP per worker	OECD Economic outlook database	
		Growth of GDP per worker	OECD Economic outlook database	
	Specialisation in knowledge based industries	% exports by medium/high tech exports	IMF Balance of payments statistics yearbook and UN Comtrade database	
		% of manufacturing value added by finance services, communication services, and medium/high tech manufacturing	OECD S&T and industry scoreboard	

## 2. Index of the Massachusetts Innovation Economy

### Differences in purpose

The Index of the Massachusetts Innovation Economy (IMIE) (Massachusetts Collaborative, 2001) is explicitly based on the premise that innovation is a critical factor in the growth of the state's economy. It compares the economic performance of the Massachusetts with that of other leading US States such as California, Colorado, Connecticut, Minnesota, New Jersey, New York in nine industry clusters.

### Differences in sources of indicators and indicators chosen and reasons

The IMIE is organised in three main sections: results (job growth, rising average wages, export value), innovation processes (dynamic interactions like idea generation, commercialisation, entrepreneurship, and business innovation), resources (human, technology, investment, infrastructure).

The main sections of the ISB conceptually coincide with the sections of the IMIE as follows:

- Human resources ~ IMIE includes migration, education infrastructure, students intention to do S&E degrees, and SAT scores.
- Knowledge creation ~ technology resources (R&D spending) and idea generation (patenting).
- Transmission and application of knowledge ~ technology commercialisation (university licensing and FDA approvals), points to a similar concept but uses a different indicator.
- Innovation finance, output and markets ~ investment resources (venture capital), entrepreneurship (new business incorporations, SBIR awards, IPOs, mergers & acquisitions, NASDAQ firm's value, fast growth companies) and infrastructure resources (e-commerce companies, median price single family owned house). It is important to note that the concept of infrastructure resources in IMIE also includes general welfare and living conditions measured by house prices (living conditions in NY are not as nice as in the suburbs)

In summary, since both scoreboards have similar purposes, they are conceptually organised in similar ways. However, they use different sets of indicators. For example, human resources are measured with more indicators in the IMIE than in the ISB, and in consequence the IMIE has the opportunity to explore other dimensions like migration and student intention to do S&E degrees, not explored by the ISB.

The indicators chosen for the IMIE meet the following criteria:

- Derived from objective and reliable data sources
- Statistically measurable on an-going basis
- Bellwethers that reflect the fundamentals of economic vitality
- Understood and accepted by the community
- Measure conditions in which there is an active public interest

The industry clusters on which the comparisons are based are as follows: defence, textiles & apparel, computer & communication hardware, diversified industrial support, healthcare technology, financial services, innovation services, and software & communication services and postsecondary education,. These industries account for more than 25% non-governmental employment and 38% of total payroll of Massachusetts, and on average pay 67,306 dollars per annum to each worker, which is 34% higher than the rest of Massachusetts.

The indicators used by the IMIE in the innovation process section that are shared by the ISB are identified in table 2.A and other relevant indicators used by the IMIE that are not shared by the ISB are identified in table 2.B.

**Table 2.A. Indicators shared by ISB and IMIE**

No	ISB Indicator	Shared/similar Indicator	Source
<b>1. Human Resources</b>			
1.1	New S&E graduates (% of 20-29 years age class)	New engineering and computer sciences graduates by degree level	Information provided by American Association of Engineering Societies
1.2	Population with tertiary education (% of 25-64 years age class)	Population without a high school diploma	US Census Bureau
		Population with college degree	US Census Bureau
1.3	Lifelong learning (% of 25-64 years age class)	×	
1.4	Employment in medium/high-tech Manufacturing (% of total workforce)	Employment & employment growth in industry clusters	Collaborative Economics & Regional Financial Associates
1.5	Employment in high-tech services (% of total workforce)		
<b>2. Knowledge creation</b>			
2.1	Public R&D (GERD-BERD) (% of GDP)	Federal R&D per 1.000	National Science Foundation
2.2	Business R&D (BERD) (% of GDP)	R&D funded by industry per worker	Standard & Poor's Compustat of Publicly-Traded Companies
2.3.a	High-tech EPO patents (per million population)	Patent application and grants per million of population	Information provided by USPTO
2.3.b	High-tech USPTO patents (per million population)	×	
<b>3. Transmission and application of knowledge</b>			
3.1	SMEs innovating in-house (% of manufacturing SMEs)	×	
3.2	SMEs innovating through co-operation (% of manufacturing SMEs)	×	
3.3	Innovation expenditures (% of all manufacturing turnover)	×	
<b>4. Innovation finance, output, and markets</b>			
4.1	High-tech venture capital investment (% of GDP)	No. & value of venture capital investments	Information provided by PricewaterhouseCoopers, LLP, and Venture One
4.2	Capital raised on parallel markets plus new firms on main markets (% of GDP)	No. & value of IPOs	Information provided by Andersen
4.3	Sales of new to market products (% of all manufacturing turnover)	×	
4.4	Home internet access (% of all households)	×	
4.5	Share of ICT markets as a percent of GDP	×	
4.6	Share of manufacturing value-added in high tech sectors	×	

**Table 2.B. Indicators included in IMIE and not included in ISB**

Section	Topic	Indicators per State	Source	
Results	No relevant indicators. All indicators chosen are economic output or welfare, not innovation output			
Innovation process	Ideas generation	No. inventions disclosed by universities, non-profit research organisations or hospitals	AUTM survey	
		No. new patents applied for by universities, non-profit research organisations or hospitals	AUTM survey	
	Technology commercialisation	No. licenses issued by universities, non-profit research organisations or hospitals	AUTM survey	
		Value of gross licensing income by universities, non-profit research organisations or hospitals	AUTM survey	
		No. FDA approval applications for advanced medical devices	Information provided by FDA	
	Entrepreneurship	No. new businesses incorporation	Information provided by Massachusetts Secretary of the Commonwealth's Office	
		No. SBAIR awards by phase of award	Information provided by Small Business Administration	
		Value of SBAIR awards per 100.000 population	Information provided by Small Business Administration	
		No. Merger & Acquisitions (M&As)	Information provided by Andersen	
		Value of M&As	Information provided by Andersen	
		Annual average growth rate of NASDAQ companies market value	NASDAQ Exchange	
		Annual average growth rate of market capitalisation (Securities and Exchange commission (SEC))	NASDAQ Exchange	
		No. publicly-traded fast grow companies	Standard & Poor's Compustat of Publicly-Traded Companies	
	Business innovation	No. corporate headquarters (as anchor for R&D and business strategy)	Information provided by infoUSA.com	
		No. Fortune 500 companies	Fortune 500	
	Resources	Human	International in-migration	Statistics of Income Division, Internal Revenue Service (equivalent to Inland Revenue) and Census Bureau
			Domestic out-migration	Statistics of Income Division, Internal Revenue Service (equivalent to Inland Revenue) and Census Bureau
Net migration			Statistics of Income Division, Internal Revenue Service (equivalent to Inland Revenue) and Census Bureau	
Average SAT scores			College Board, SAT Program Summary Reporting Services	
% of Massachusetts engineering still living in Massachusetts			Information compiled by Massachusetts Technology Collaboration from a sample of universities	
% of schools with access to internet from one or more classrooms			Education Weeks's Technology Counts	
% of schools with access to internet from one or more classrooms			Education Weeks's Technology Counts	
% of schools with access to internet through high-speed connection			Education Weeks's Technology Counts	
% of students taking SAT and intending to major in engineering			College Board, SAT Program Summary Reporting Services	
Technology resources		R&D in health per 1.000	Department of Health and Human Services	
Infrastructure		Employment generated e-commerce companies & the value of venture capital attracted by them (maximise supplier-producer relationships and shared infrastructure)	No. & employment from The Massachusetts Directory of High Tech Companies. Venture capital information was provided by PricewaterhouseCoopers, LLP, and Venture One	
		Median price of single-family homes (is a critical factor in the cost of living, the State's ability to retain and attract new residents)	Federal Housing Finance Board	
		% of home ownership	US Census Bureau	

## **Differences in methodology for summary indices**

No summary IMIE index is suggested.

## **Recommendations for innovation policy**

The IMIE information is used to set up a diagnosis, and identify trends, weaknesses and strengths of the different States. However, it says little about past, actual, or new policies and their effects. For example, the report points to shortages of human resources as an important policy issue but no suggestion on how to prevent out-migration and promote in-migration are put forward. The following is a summary of the main diagnosis provided in the report.

### *Results:*

There has been a general slowdown in growth for the Massachusetts State economy that is also observed in each of the nine industry clusters analysed. Additionally, in six of these industry clusters employment growth was lower in Massachusetts than in any of the other States, while employment in computers & communications hardware, diversified industrial support, and financial services clusters grew more than in other States.

### *Innovation process:*

- Advantages in patenting have been eroded by catching-up from Connecticut and Minnesota. The State is mostly active in health care, transportation and aerospace industry patenting.
- Strong growth of invention disclosures, new technology licenses, royalties, new business incorporations and SBIR awards relative to other new economy States and the US as a whole, while the number of IPOs and NASDAQ market capitalisation's showed the opposite.

### *Resources:*

Massachusetts continues to be relatively strong in capital resources such as R&D investment and venture capital, but faces a chronic long-term shortage of human resources since out migration increased and school infrastructure is deficient and does not promote interest in S&E to its students.

### **3. Science, Technology and Industry Scoreboard**

#### **Differences in purpose**

The purpose of the Science Technology and Industry Scoreboard (STIS) (OECD, 2001) is to bring together the most complete and latest internationally comparable data in order to analyse trends in the knowledge-based economy.

#### **Differences in sources of indicators and indicators chosen and reasons**

The STIS is organised in four main sections: knowledge base (R&D financing and performance, human resources, innovation expenditure and performance, scientific publications and patents), information economy (investment and expenditure in ICT; skills and occupations; infrastructure; access, price and use of internet; and size, growth, international trade & cross-border merger & acquisitions and alliances), international integration of economic activity (international trade and exposure to international competition, foreign direct investment, internationalisation of industrial R&D, international alliances, cross-border ownership of inventions, international co-operation in S&T, and technology balance of payments), economic growth and performance (income and productivity, economic structure, international trade and comparative advantage).

The main part of the ISB conceptually coincides with the first section of the STIS, as follows:

Human resources, knowledge creation & transmission and application of knowledge ~ knowledge base, similar concepts but since the STIS is more extensive it includes a more detailed section on R&D, detailed statistics on students and researchers growth and international mobility. Additionally, for some indicators, such as S&T graduates, STIS uses S&E employment growth in addition to S&T employment as a share of labour force.

The ISB also includes under innovation finance, output and markets two indicators used by the STIS in the extensive information economy section and one indicator from the detailed economic growth and performance section. There is an extensive analysis of internationalisation of innovation in STIS, a topic not addressed in ISB.

In summary, the ISB is similar to the knowledge base STISs section while including some indicators from the information economy and economic growth and performance sections. The STIS is, however, much more extensive and also includes a section, not included in the ISB, on international processes and outputs.

The indicators used by the STIS in the innovation process section that are shared by the ISB are identified in table 3.A and other relevant indicators used by the STIS that are not shared by the ISB are identified in table 3.B.

**Table 3.A. Indicators shared by ISB and STIS**

No	ISB Indicator	Shared/similar Indicator	Source
<b>1. Human Resources</b>			
1.1	New S&E graduates (% of 20-29 years age class)	S&E employment average growth rate S&E employment as a share of the labour force	OECD, Labour Force Survey
1.2	Population with tertiary education (% of 25-64 years age class)	Share of population aged 24-64 with at least upper secondary education Expenditure per student for tertiary education level in millions of PPP dollars	OECD, Education database
1.3	Lifelong learning (% of 25-64 years age class)	×	
1.4	Employment in medium/high-tech Manufacturing (% of total workforce)	×	
1.5	Employment in high-tech services (% of total workforce)	×	
<b>2. Knowledge creation</b>			
2.1	Public R&D (GERD-BERD) (% of GDP)	Identical	
2.2	Business R&D (BERD) (% of GDP)	Identical	
2.3.a	High-tech EPO patents (per million population)	Share of countries in EPO patent applications Number of EPO patent applications per million of population Number of EPO patent applications divided by BERD	OECD Patent database
2.3.b	High-tech USPTO patents (per million population)		
<b>3. Transmission and application of knowledge</b>			
3.1	SMEs innovating in-house (% of manufacturing SMEs)	×	
3.2	SMEs innovating through co-operation (% of manufacturing SMEs)	×	
3.3	Innovation expenditures (% of all manufacturing turnover)	Identical	
<b>4. Innovation finance, output, and markets</b>			
4.1	High-tech venture capital investment (% of GDP)	Investment in venture capital as a percentage of GDP Share of high-technology sectors in total venture capital Venture capital by country of management and destination	EVCA, NVCA, CVCA, Asian Venture Capital Journal
4.2	Capital raised on parallel markets plus new firms on main markets (% of GDP)	×	
4.3	Sales of new to market products (% of all manufacturing turnover)	Share of firms introducing new or technologically improved products or processes on the market	OECD STI/EAS division
4.4	Home internet access (% of all households)	Percentage of households with access to home computers Percentage of households with access to internet computers Individuals using internet from any location	OECD ICT database
4.5	Share of ICT markets as a percent of GDP	ICT expenditure as a percentage of GDP	OECD based on World IT and Services Alliance (WITSA)/International Data Corporation (IDC)
4.6	Share of manufacturing value-added in high tech sectors	Share of ICT value added in business sector by manufacturing/services	OECD estimates based on National Accounts

**Table 3.B. Indicators included in STIS and not included in ISB**

Section	Topic	Indicator per country	Source
Knowledge base	Investment in knowledge	Business R&D + software R&D + higher education R&D	OECD, National Accounts, MSTI, Education, and International Data Corporation databases
	R&D financing and performance	R&D expenditures by performing sector as percentage share of total in 1999	OECD MSTI database
	Research performed by government and higher education	Reserachers per 10.000 labour force	OECD R&D and MSTI databases
	Business R&D by industry and size class	R&D growth by industry Share of business R&D by technology intensity Share of business R&D by size class of firms Share of government financed business R&D by size class	OECD ANBERD database and STI/EAS division
	R&D in selected ICT industries and ICT patents	Business R&D in selected ICT manufacturing industries* as percentage of GDP ICT patents** as percentage of total national patents filed at EPO for priority year 1997	OECD ANBERD and Patent database
	Collaborative efforts between business and public sector	Share of businesses in funding research performed by government and higher education Share of firms with co-operation agreements with government or higher education	OECD R&D database and STI/EAS division
	Public funding of biotechnology R&D and biotechnology patents	Public funding of biotechnology*** in millions of PPP dollars Biotechnology as a percentage of government budget appropriations or outlays on R&D Biotechnology patents**** as a percentage of total national patents filed at EPO for priority year 1997	Government budget appropriations or outlays on R&D, European Comission (Inventory of Public Biotechnology R&D programmes in Europe, 2000), OECD Patent database
	Environmental R&D in government budget	Environmental R&D in the government budget as a percentage of civil government budget appropriations and outlays on R&D	OECD R&D database
	Health related R&D	Health R&D in the government budget as a percentage of civil government budget appropriations and outlays on R&D R&D expenditure in the pharmaceutical industry as a percentage of GDP and BERD	OECD R&D and ANBERD databases
	Basic research	Basic research as a percentage of GDP by sector of performace Breakdown of R&D by type of research as a percentage of GDP	OECD R&D database
	Defence research	Defence R&D in the government budget as a percentage of civil government budget appropriations and outlays on R&D	Government budget appropriations or outlays on R&D
	Tax treatment	Rate of tax subsidies for 1 US dollars of R&D SME/Large firms	OECD STI/EAS division
	Trends in researchers	Researchers per 10.000 labour force Avergae annual growth rate of business researchers	OECD MSTI database
	International mobility of human capital	Non-US citizens with S&E doctorates in US Relative share of non-national human resources in S&T employment in European Union	NSF, SESTAT database OECD from Eurostat Labour Force survey
	International mobility of students	Foreign students in university level education as a percentage of total enrolment Distribution of university level foreign students by field of study Distribution of foreign students in OECD countries by host country	OECD Education database
	Patent families	Share of countries in triadic patent families***** Number of patents in triadic patent families per million of population Number of patents in triadic patent families divided by BERD	Patent database
Scientific publications	Scientific and technical articles per million population Distribution of scientific and technical articles by field	NSF S&E indicators	
Information economy	Investment in ICT	Percentage of non-residential gross fixed capital formation in ICT*****, business sector Price indexes for ICT products national deflators Price indexes for ICT products, harmonised deflators	OECD STI/EAS estimates based on National Accounts and STAN database
	Occupations & skills	Share of high and low skills within ICT related occupations in the EU and US*****	OECD Eurostat Labour Force Survey and US Current Population Survey

	Infrastructure for the information economy	Access paths per 100 inhabitants by fixed/mobiles Number of DSL and cable modem lines per 100 inhabitants	OECD Communications outlook and telecommunications database
	Internet infrastructure	Number of internet hosts per 1.000 inhabitants (global top level domains adjusted to country of location) Web sites per 1.000 inhabitants	OECD Communications outlook
	Internet use and hours spent on-line	Number of internet subscribers per 100 inhabitants Graph where axis are (y) number of on-line and internet hosts and (x) average on-line time per month multiplied by internet subscriber penetration rate	OECD Telecommunications database and Netzier (www.netzier.com)
	Internet access by enterprise size and industry	Internet penetration by enterprise size class Internet penetration by industry Businesses with internet and web sites	OECD ICT database
	Internet and electronic commerce	Number of secure web servers per million of inhabitants Internet/web purchases and sales as a share of total purchases and sales by enterprise size class Percentage of individuals using and ordering goods and services over the internet	OECD ICT database
	Price of internet access and use	Price of leased lines Price for 40 hours of internet use at peak times in PPP dollars by fixed/mobile/ISP charge Graph where axis are (y) internet hosts per 1.000 inhabitants and (x) average price for 20 hours internet access in PPP dollars	OECD estimates based on National Accounts
	Contribution of ICT sector to employment	Share of ICT employment in business sector employment by manufacturing/services	OECD estimates based on National Accounts
	Contribution of ICT sector to international trade	Share of ICT manufacturing trade in total goods trade ICT trade balance as percentage of GDP	OECD ITCS database
	Cross-border mergers, acquisitions and alliances in the ICT sector	Percentage of ICT merger and acquisitions taking place within and across regions by acquirer and target area Ratio ICT cross-border merger and acquisitions to total cross-border merger and acquisitions Ratio ICT cross-border alliances to total cross-border alliances Ratio of cross-border ICT alliances to all ICT alliances divided by the same ratio for the whole economy	Thomson Financial
International integration of economic activity	Foreign direct investment flows	Average inward and outward FDI flows as a share of GDP Cumulative net FDI flows in billions of US dollars	OECD International Direct Investment database
	Cross-border mergers and acquisitions	Number mergers and acquisitions and total deal value in billions of US dollars Average inward mergers and acquisitions Average outward mergers and acquisitions	Thomson Financial
	Activity of foreign affiliates	Share of foreign affiliates in manufacturing/services turnover and employment Export and imports as a share of turnover of foreign affiliates in manufacturing/services Graph where axis are (y) growth rate employment/turnover of foreign affiliates and (x) growth rate of employment/turnover of national firms manufacturing/services	OECD AFA and FATS database
	Internationalisation of industrial R&D	Graph where axis are (y) share of foreign affiliates turnover and (x) share of foreign affiliates in manufacturing R&D expenditures Graph where axis are (y) R&D expenditure as a share of domestic product by foreign affiliates and (x) R&D expenditure as a share of domestic product by national firms	OECD AFA database
	International strategic alliances	Number of cross-border and domestic alliances Distribution of cross-border strategic alliances by industry	Thomson Financial
	Cross-border ownership of inventions	Share of patent applications to the EPO owned by foreign residents in total patents invented domestically Share of patent applications to the EPO invented abroad in total patents owned by country residents	Patent database
	International cooperation in S&T	Percentage of scientific publications with a foreign co-author Percentage of patent applications to the EPO with foreign co-inventors	NSF S&E indicators and OECD Patent database

	Technology balance of payments	Average technology payments and receipts as a percentage of GDP Technology balance as a percentage of GDP	OECD TBP database
Economic growth & performance	Differences in income and productivity	Percentage gap with respect to US GDP per capita Percentage gap with respect to US GDP per hour worked Percentage gap with respect to US labour utilisation Trend growth in GDP per hour worked Trend growth in multifactor productivity growth Average labour productivity growth by industry	OECD National Accounts, Economic outlook
	Technology and knowledge industries	Share of total gross value added by industry	OECD STAN and National Accounts
	Structure of economy	Share of value added in top six and bottom six countries for agriculture/construction/wholesale/transport/finance/community services	OECD STAN and National Accounts
	International trade by technology intensity	Value of manufacturing trade by technology intensity Distribution of manufacturing trade by technology intensity	OECD STAN databases
	International trade in high and medium-high technology industries	Share of high and medium-high technology industries in manufacturing exports Annual average growth rate of exports in high and medium-high technology industries Graph where axis are (y) R&D intensity and (x) high tech exports divided by total manufacturing exports	OECD STAN and ANBERG databases
	Comparative advantage by technology intensity	Contribution to manufacturing trade balance***** by technology intensity Change in the contribution to manufacturing trade balance by technology intensity	OECD STAN database

R&D is always understood as Expenditure in R&D

\* Office & computing machinery (30); Radio, TV and communication equipment (32); Medical, precision and optical instruments, watches and clocks (33); Post and communication services (64); Computer and related activities services (72) (ISIC rev. 3 2 digits)

\*\* Computing, calculating & counting (G06); Information storage (G11); Electric communication technique (H04)

\*\*\* Biotechnology industries includes: 1) DNA (the coding): genomics, pharmaco-genetics, gene probes, DNA sequencing/synthesis/amplification, genetic engineering; 2) Proteins and molecules (the functional blocks): protein/petide sequencing/synthesis, lipid/protein engineering, proteomics, hormones and growth factors, cell receptors/signalling/pheromones; 3) Cell and tissue culture and engineering: cell/tissue culture, tissue engineering, hybridisation, cellular fusion, vaccine/inmune stimulants, embryo manipulation; 4) Process

biotechnology:bioreactors, fermentation, bioprocessing, bioleaching, bio-pulping, bio-bleaching, bio-desulphurisation, bioremediation and biofiltration; 5) Su-cellular organisms: gener therapy, viral vectors

\*\*\*\* Apparatus for enzymology or icrobiology (C12M); Microorganisms, or enzymes, propagating, preserving, or maintaining microorganisms, mutationor genetic engineering (C12N); Fermentation or enzyme using (C12P); Measuring or testing processes involving enzymes or micro-organisms, compositions or test papers therefor, processes for preparing such compositions, condition-responsive control in microbiological or enzymological processes (C12Q); Processes using enzymes or microorganisms to treat textiles or to clean solid surfaces or materials (C12S).

\*\*\*\*\* Venture capital includes seed capital (provided to research, assess and develop initial concept), start-up (product development and initial marketing), and expansion (increased production capacity, market or product development, working capital)

\*\*\*\*\* Family patent is a set of patents generated when a priority application is extended to other offices. The statistics collected by OECD correspond to data from EPO, USPTO, and Japanese Patent Office

\*\*\*\*\* ICT is defined as computer and office equipment, communications equipment, software, including purchased and own account

\*\*\*\*\* EU High skills are defined as International Standard Classification of Occupations (ISCO-88) classes include computing professionals (213), computing associate professionals (312), optical and electronic equipment operators (313) and low skills are defined as electrical and electronic equipment mechanics and filters. US skills include computer systems analysts and scientists (64), operations and systems researchers and analysts (65), computer programmers (229), tool programmers, numerical control (233), electrical and electronic technicians (213), broadcast equipment operators (228), computer operators (308), and peripheral equipment operators (309) while low skills include data processing equipment repairers (525), electrical power installers and repairers (577), telephone line installers and repairers (527), telephone installers and repairers (529), electronic repairers, communications and industrial equipment (523)

\*\*\*\*\* Contribution to trade is the difference between the actual trade balance of industry j and the aggregate trade balance weighted by the participation of industry j in aggregate trade

## Differences in methodology for summary indices

No summary STIS index is suggested.

## Recommendations for innovation policy

The STIS information is used to describe processes taking place in the past, by identifying trends, and pointing weaknesses and strengths. However, it says little about past, actual, or new policies and their effects. The following are the main trends highlighted by the report:

- Indicators show that knowledge-intensity of OECD economies (as measured by investment in knowledge (defined as total R&D, software and higher education)) is increasing and the US, Korea, Sweden and Finland are leading ~ OECD average is close to 5% (or 10% when all education is included). Specifically, ICTs have shown important relative growth within investment in knowledge.
- S&T human resources and R&D increased during the 1990s in the whole OECD area, with the largest increases in the US, Ireland and the Nordic countries.
- The major source of funding for new technology based firms is venture capital, even though it has slowed down. The lion share of funding is allocated to new development of ICTs while funding for biotechnology is growing strongly.
- The role of business in R&D is increasing. It accounts for 60% of total R&D within the OECD countries (i.e., OECD average) and for most of ICT R&D.
- The role of public R&D funding remains important with increasing volumes of funds devoted to basic R&D since early 1980s in almost all countries. The importance of defence R&D is reducing, but it still represents a high proportion of total government R&D in the US, UK and France. Finally government support for health related R&D, particularly biotechnology, rose rapidly.
- Knowledge flows within and across economies have taken on greater importance though collaborative projects between universities, research institutions, and firms funded privately and publicly.
- Collaborative research projects between business-research institutes and higher education is increasing, with firms engaged in such projects generating almost 10% of total EU employment.
- Research collaborations across countries are increasing. They account for more than a quarter of scientific publications and 7% of patenting activity in OECD area. However, there are important country differences in these trends. While small European countries have highly internationalised S&T bases, Japan's S&T base collaborates little with scientists and engineers from other countries.
- Ownership of technology is also becoming international. The number of inventions owned by foreigners in each country is increasing, particularly in Canada, UK and Switzerland where US nationals and companies own important proportions of all inventions, while it continues to be low in Japan and Korea.
- Inward flows of students and researchers are concentrated in few countries, particularly US, UK and Germany, although some small OECD countries also show high levels of foreign S&E human resources.
- Trade in goods and services, particularly international financial services, FDI, mergers and acquisitions, and turnover under foreign control have increased rapidly in almost all countries. However, the balances are not homogeneous. For instance, while

in Germany and the UK outward FDI greatly exceeds inward FDI, in Austria, Hungary and Spain the situation is reversed.

- ICTs are diffusing rapidly especially amongst the Nordic countries, with Korea, US and Canada following closely behind.
- Personal computers have spread faster in northern European countries than in southern European countries.
- Internet use by households is soaring everywhere, except in the poorest segments of society where its spread is constrained by low incomes and high costs. When the Internet is used, it is mostly to look for information. On the other hand the propensity to carry out electronic commerce varies highly between countries and industries but remains low in general.
- Internet use by business is soaring so that in the Nordic countries almost 80% of businesses with more than 10 employees have access to internet and more than 40% of the employees use the Internet on a daily basis. Furthermore, the value of Internet services may already be achieving levels close to one third of sales of electronics.
- High-tech manufacturing and services are expanding together with high-tech trade.
- On average high-tech services account for 17% of total Business R&D, but there are important differences between countries. For instance, in Norway and the US more than 30% of total business R&D is executed by high-tech services, while in Germany or France this percentage is less than 10%.
- ICTs sector is making a substantial contribution to turnover, value added, and employment growth in almost all countries.
- Multi-factor productivity has increased rapidly in some countries since mid 1990s: Ireland, Finland, Australia, Canada and the US.
- Patenting activity is also increasing especially in Switzerland, US, Sweden, and Japan.

## 4. New Economy/State/Metropolitan Index

### Differences in purpose

The New Economy Index (NEI) (Atkinson and Gottlieb, 2001) is based on the observation that modern technologies, and particularly IT, have changed industrial and occupational order and promoted trends of globalisation. Thus, it is necessary to develop a scoreboard that measures performance of economies to the new economic order. The initial index was developed in 1998 to measure these changes at aggregate level in the US during the past two decades. Then an adapted version was built to compare performance of different States in the US in 1999 and 2002. Finally, it was also adapted to compare performance of several cities in the US in 2001. Since the main purpose of this summary is to compare the ISB with other comparative scoreboards, it will be based only on the metropolitan and states new economy indexes, and whenever necessary it will point out differences between the two indexes.

### Difference in sources of indicators and indicators chosen and reasons

The NEI is organised in five main sections: knowledge jobs (jobs held by managers, professionals and technicians, and educational attainment of the workforce), globalisation (export orientation of manufacturing), economic dynamism and competition (fast growing gazelle companies, rate of economic “churn”, and IPOs), transformation to a digital economy (adults on line, dot.com’s, share of students using computers in school, internet backbone capacity, broadband telecommunication services), and technological innovation capacity (high-tech jobs, S&E graduates, patents, R&D, venture capital).

The main sections of the ISB conceptually coincide with the sections of the NEI as follows:

- Human resources and knowledge creation ~ Technological innovation capacity is similar to knowledge creation. Additionally, Knowledge jobs section includes workforce education that is similar to population with tertiary education in the ISB.
- Some indicators in the other four NEI sections are similar to some indicators included in the Innovation finance, output and market section of ISB.

However, clear conceptual differences also exist between the NEI and ISB:

- NEI does not include any section or indicator similar to Transmission and application of knowledge
- ISB’s Innovation finance, output and markets section is (i) less extensive on ICTs technologies than the NEI’s section on Digital economy and (ii) does not include a characterisation of competitive conditions of markets as NEI’s section on Economic dynamism and competition. Additionally Globalisation issues are not included in the ISB

The indicators used by the NEI that are shared by the ISB are identified in table 4.A and other relevant indicators used by the NEI that are not shared by the ISB are identified in table 4.B.

**Table 4.A. Indicators shared by ISB and NEI**

No	ISB Indicator	Shared/similar Indicator	Source
<b>1. Human Resources</b>			
1.1	New S&E graduates (% of 20-29 years age class)	S&E degrees granted divided by total workforce	NSF, CASPAR database and Bureau of Economic Analysis, Regional Economic Information System
1.2	Population with tertiary education (% of 25-64 years age class)	Weighted average of proportion with highschool (0.5), with college (1), or with graduate (2) degree (value of weights used). Additionally, the State index includes a measure based on this weighted score but adjusted to differences in educational levels between the aggregate and the manufacturing sector	Bureau of Labour Statistics, Current Population Survey and Bureau of Economic Analysis, Regional Economic Information System
1.3	Lifelong learning (% of 25-64 years age class)	×	
1.4	Employment in medium/high-tech Manufacturing (% of total workforce)	High-tech employment divided by total workforce	US Census Bureau, County Business Patterns and Bureau of Economic Analysis, Regional Economic Information System
1.5	Employment in high-tech services (% of total workforce)		
<b>2. Knowledge creation</b>			
2.1	Public R&D (GERD-BERD) (% of GDP)	Academic R&D divided by total workforce (Metropolitan & nation index )	NSF, CASPAR database and Bureau of Economic Analysis, Regional Economic Information System
2.2	Business R&D (BERD) (% of GDP)	Industry R&D divided by total workforce (State & nation index)	NSF, CASPAR database and Bureau of Economic Analysis, Regional Economic Information System
2.3.a	High-tech EPO patents (per million population)	×	
2.3.b	High-tech USPTO patents (per million population)	Number of utility patents issued to firms or individuals per 1.000 workers	USPTO and Bureau of Economic Analysis, Regional Economic Information System
<b>3. Transmission and application of knowledge</b>			
3.1	SMEs innovating in-house (% of manufacturing SMEs)	×	
3.2	SMEs innovating through co-operation (% of manufacturing SMEs)	×	
3.3	Innovation expenditures (% of all manufacturing turnover)	×	
<b>4. Innovation finance, output, and markets</b>			
4.1	High-tech venture capital investment (% of GDP)	Value of venture capital divided by Gross Metropolitan Product	Information provided by PricewaterhouseCoopers, LLP, and Standard & Poor, U.S. Metro Economies: The Engines of America's Growth
4.2	Capital raised on parallel markets plus new firms on main markets (% of GDP)	Number of IPOs per 10 billion dollars of Gross Metropolitan Product	Securities & Exchange Commission and Standard & Poor, U.S. Metro Economies: The Engines of America's Growth
4.3	Sales of new to market products (% of all manufacturing turnover)	×	
4.4	Home internet access (% of all households)	Percentage of adults with internet access at work or at home	Scaborough Research and US Census Bureau, County Population Estimates
4.5	Share of ICT markets as a percent of GDP	×	
4.6	Share of manufacturing value-added in high tech sectors	×	

**Table 4.B. Indicators included in NEI and not included in ISB**

Section	Topic	Indicator per metropolis/state	Source
Knowledge jobs	Managers and professional workers	Managerial, professional and technology jobs divided by the workforce	Bureau of Labour Statistics, Current Population Survey and Bureau of Economic Analysis, Regional Economic Information System
	IT jobs	Employment in IT activities within non-IT industries as a share of total jobs	Bureau of Labour Statistics, Current Population Survey and Bureau of Economic Analysis, Regional Economic Information System
Globalisation	Export focus	Value of manufacturing exports in US dollars per manufacturing worker	US Department of Commerce, International Trade Administration and
	FDI	Percentage of workforce employed by foreign companies	
Economic dynamism and competition	“Gazelles” growth	Number of jobs in “Gazelles” (companies with growth rates higher than 20% or more for four strait years) as a share of total employment	Cognetics, Corporate Demographics: Corporate Almanac and Bureau of Economic Analysis, Regional Economic Information System
	Rate of economic “churn”	Number of start-ups and failures combined and as a percentage of total establishments (It is not clear whether combined means that failures are added or subtracted to start-ups)	Cognetics, Corporate Demographics: Corporate Almanac
Digital economy	Broadband telecom capacity	Number of broadband competitors per zip code area (Metropolitan index) Combined measure of high-speed lines per household and establishment and percent of household in ADSL range (no methodology is presented) (State index)	Federal Communications Commission Pinkham Group, Broadband Marketing Study
	Computer use in schools	Percentage of children using computers in the classroom (Metropolitan index) Indicator built as a weighted average of students per multimedia computer, students per internet connected computer, percentage of schools that use T1 or modem internet connection, percentage of schools were at least 50% of teachers use internet in class, percentage of schools were at least 50% of teachers have school named email addresses (no weights or methodology to derive weights is supplied) (State index)	Bureau of labour Statistics, Current Population Survey and US Census Bureau, County Population estimates Education Week, Technology Counts:2001
	Commercial internet domain names	Number of commercial internet domain names (.com) per total number of businesses	Zook, M (2000) and County Business Patters
	Internet backbone	Total capacity of all internet backbone links to other metropolitan areas as a share of employment	Malecki at University of Florida and Bureau of Economic Analysis, Regional Economic Information System

	E-government	A measure not explained is used	Lassman “The Digital Government” and Darrell “State and Federal E-Government in the US”
	Online agriculture	Percentage of farmers with internet access who use it for business	US Department of Agriculture
	Online manufacturing	Percentage of manufacturing establishments with access to internet	

### Differences in methodology for summary indices

The NEI aggregate score is calculated as follows:

1. Calculating raw score for each Metropolis/State per indicator:

Raw score Metropolis/State<sub>j</sub> on Indicator<sub>i</sub> (RS<sub>ji</sub>)= Mean<sub>i</sub> – Indicator value<sub>ji</sub> = Deviation indicator<sub>ji</sub> + 20

2. Calculating section scores for each Metropolis/State

Section<sub>h</sub> score<sub>j</sub> (SS<sub>hj</sub>)= Weighted sum of Deviations<sub>ji</sub>

3. Calculating aggregate score for each Metropolis/State

Aggregate score for each Metropolis/State (AS<sub>j</sub>)= Sum SS<sub>hj</sub> / Max Sum AS<sub>j</sub>

Thus, the aggregate score for Metropolis/State j is its sum of sections score as a percentage of the highest score achieved by any Metropolis/State

The weights used for each indicator and no methodology was presented to explain their selection:

	Metropolitan	State
<b>Knowledge jobs</b>	<b>2.00</b>	<b>3.25</b>
Professional, managerial and tech. Jobs	1.00	0.75
IT jobs in non-IT industries	-	0.75
Workforce education	1.00	1.00
Manufacturing workforce education	-	0.75
<b>Globalisation</b>	<b>1.50</b>	<b>2.00</b>
Exports focus of manufacturing	1.50	1.00
FDI jobs	-	1.00
<b>Dynamism and competition</b>	<b>3.00</b>	<b>3.00</b>
Gazelles	1.00	1.00
Job churning	1.00	1.00
IPOs	1.00	1.00
<b>Digital economy</b>	<b>4.00</b>	<b>4.50</b>
Online population	1.00	0.75
Broadband telecom capacity	0.75	1.00
Computer use in schools	0.50	0.50
Commercial internet domain	1.00	0.75
Internet backbone	0.75	-
E-government	-	0.50
Online agriculture	-	0.50
Online manufacturing	-	0.50
<b>Technological innovation capacity</b>	<b>4.00</b>	<b>4.00</b>
High-tech workers	1.00	1.00
Degrees granted in S&E	0.75	0.75
Patents	0.75	0.75
Academic R&D	0.75	-
Venture capital	0.75	0.75
Private R&D	-	0.75

## **Recommendations for innovation policy**

The NEI information is used to set up a diagnosis and also suggest some principles for public policy.

The following is a summary of the diagnosis provided in the report:

The top States and Metropolis are California and Massachusetts & San Francisco/Oakland/San Jose, Austin and Seattle. They achieve high scores in every indicator suggesting high levels and quality of resources, advanced positions in the IT revolution, solid innovation infrastructure and high adaptability.

- The bottom ranked states are Mississippi and Arkansas & Grand Rapids and Jacksonville. Historically these states lagged behind in industrialisation and have invested limited resources in education and R&D, depending more on natural resources and mass production.
- There is a strong and positive correlation between income per capita and NEI ranking for both, States and Metropolis.
- The correlation between employment growth and NEI score is weak and negative for States.
- On the other hand the correlation between income per capita growth and NEI score is weak and positive for both States and Metropolis.

Policy recommendations are probably more extensive in the NEI reports than in any other scoreboards. However, it is important to note that the link between recommendations and the NEI diagnosis summarised above is not very clear. Except for the suggestion on changing policy goal from employment growth to income per capita growth, the policy recommendations are not based on the findings of the NEI. Policy recommendations are based on case studies drawn from experiences in several States/Metropolis, independently of their score in the NEI. Additionally, some policy recommendations have little to do with the NEI, such as those related to fostering civic collaboration or promoting customer oriented government services.

The following is a summary of the main public policy recommendations:

- Change policy goal from employment growth to income per capita growth.
- Create Economic Policy Councils (leaders from business, government, labour, civic organisations, and higher education) to draw up diagnoses of actual competitive position of State/Metropolis and design strategy for the future.
- Create a skilled workforce by co-investing by means of policy measures such as the following: ensure high standards for all students, open competition between schools and reward high-performance teachers. Additionally, create consortia to provide industry specific skills training, offer tax-credits to promote non-credit earning courses enrolment and remedial basic education, offer grants to promote development of S&E curricula by local universities and funding of students
- Create a great quality of life by fighting congestion (the report suggest investing in road infrastructure, development of user charges programs, and applying IT to transportation systems), boosting amenities, and offering a secure environment.
- Co-invest in infrastructure for innovation:

- ✓ Education: increase investment in higher education research while tying a share of it to collaboration with business (industry related projects, collaborative research, technical assistance)
- ✓ Private R&D: promotion through R&D tax-credits and offer higher credits for R&D executed by universities on behalf of companies
- ✓ Expanding access to ICT infrastructure

## 5. Global Entrepreneurship Monitor

### Differences in purpose

The Global Entrepreneurship Monitor (GEM) (Reynolds, et al, 2001) aims to enhance our understanding of the role of entrepreneurship in national economic growth. While acknowledging innovation as being crucial in producing economic growth and well-being, *GEM* emphasises the role of entrepreneurship in this process. Thus it aims to measure differences in the level of entrepreneurial activity between countries, how far these are associated with economic growth and a variety of national characteristics, including innovative activities. The main questions addressed by GEM are

- Does entrepreneurial activity vary between countries?
- Are there differences in entrepreneurial activity associated with national economic growth?
- What national characteristics are related to the differences in the level of entrepreneurial activity?

In order to build the measures of entrepreneurial activity several research strategies were followed: surveys of at least 2,000 adults per country sample size, in-depth interviews with more than 950 national experts on entrepreneurship, standardised questionnaires completed by experts, and a wide selection of standardised national data.

### Difference in sources of indicators and indicators chosen and reasons

The GEM collects primary indicators of entrepreneurship through a multi-country survey and then relates these to a set of indicators collected from public sources. These latter indicators relate to background conditions (for example, level of development of the country, integration to world markets), intermediate conditions (for example, global competitiveness, government presence), venture capital and national systems of research and technological development.

The indicators selected by GEM to provide measurement of venture capital and national systems of research and technology development coincide with some of the indicators selected by the ISB, but the conceptual underpinnings are different. First, venture capital is considered separately from national system of research and technology development. Second, national systems of research and technology development is divided into inputs, processes and outputs with no clear relation between these sections (and indicators) and the ISB sections (and its indicators).

The indicators used by the GEM that are shared by the ISB are identified in table 5.A and other relevant indicators used by the GEM that are not shared by the ISB are identified in table 5.B.

**Table 5.A. Indicators shared by ISB and GEM**

No	ISB Indicator	Shared/similar Indicator	Source
<b>1. Human Resources</b>			
1.1	New S&E graduates (% of 20-29 years age class)	×	
1.2	Population with tertiary education (% of 25-64 years age class)	Gross school enrolment in tertiary education	No sources indicated
1.3	Lifelong learning (% of 25-64 years age class)	×	
1.4	Employment in medium/high-tech Manufacturing (% of total workforce)	×	
1.5	Employment in high-tech services (% of total workforce)		
<b>2. Knowledge creation</b>			
2.1	Public R&D (GERD-BERD) (% of GDP)	Total R&D expenditure as a percentage of GDP Total R&D personnel per 1,000 people	No sources indicated
2.2	Business R&D (BERD) (% of GDP)		
2.3.a	High-tech EPO patents (per million population)	Number of patents in force per 100.000 people	No sources indicated
2.3.b	High-tech USPTO patents (per million population)		
<b>3. Transmission and application of knowledge</b>			
3.1	SMEs innovating in-house (% of manufacturing SMEs)	×	
3.2	SMEs innovating through co-operation (% of manufacturing SMEs)	×	
3.3	Innovation expenditures (% of all manufacturing turnover)	×	
<b>4. Innovation finance, output, and markets</b>			
4.1	High-tech venture capital investment (% of GDP)	Number of companies and value of funding	NVCA, EVCA
4.2	Capital raised on parallel markets plus new firms on main markets (% of GDP)	×	
4.3	Sales of new to market products (% of all manufacturing turnover)	×	
4.4	Home internet access (% of all households)	×	
4.5	Share of ICT markets as a percent of GDP	ICT expenditure as a percentage of GDP	No sources indicated
4.6	Share of manufacturing value-added in high tech sectors	High-tech exports as a percentage of manufactured exports	No sources indicated

**Table 5.B. Indicators included in GEM and not included in ISB**

Section	Topic	Indicator per metropolis/state	Source
Entrepreneurship measures	Total entrepreneurship activity	Number of people per every 100 adults that are trying to start a new firm or own and manage a firm active for less than 42 months	GEM survey
	Opportunity entrepreneurship	Number of people per every 100 adults that are trying to start a new firm or own and manage a firm active for less than 42 months and pursue this activity for personal interest	GEM survey
	Necessity entrepreneurship	Number of people per every 100 adults that are trying to start a new firm or own and manage a firm active for less than 42 months because they have no better choice	GEM survey
Venture capital	Informal capital	Number of people per every 100 adults that are trying to start a new firm or own and manage a firm active for less than 42 months that received informal investment & its value	GEM Surveys
Research and technological development	National system RTD inputs	Computer power per capita (MIPS per 1,000 people)	No sources indicated
	National RTD system processes	GEM technology transfer index (no explanation was provided)	No sources indicated
		Number of science parks	No sources indicated
		Royalties and license fees as a percentage of GDP	No sources indicated
	National systems RTD outputs	Nobel prizes per capita	No sources indicated
		Percentage change in high-tech exports	No sources indicated
		Percentage change in high-tech imports	No sources indicated
		Scientific and technical journal articles per 100,000 people	No sources indicated
		Internet hosts per 10,000 people	No sources indicated
		Mobile phones per 1,000 people	No sources indicated
		Personal computers per 1,000 people	No sources indicated
Intellectual property rights	GEM property protection index (no explanation was provided)	No sources indicated	

### Differences in methodology for summary indices

No summary index is suggested.

### Recommendations for innovation policy

*GEM* contains a wide ranging set of policy implications most of which are based on a series of cross-tabulations between a number of indicators of entrepreneurship and individual characteristics such as educational attainments, age and sex. Additionally, statistically significant correlation between entrepreneurial activity and other variables is also used to draw policy recommendations. A particularly novel set of recommendations is social norms that promote entrepreneurial activity like "encourage diversity in personal income and wealth" or "accept the inevitability of business failures". However, the link between the empirical evidence provided in the report and some of these social norms is not simple and strait forward and will require a discussion that is out of the scope of this document.

Other policy recommendations are:

- Emphasise economic adaptation as a collective responsibility
- Enhance education: general and entrepreneurship-specific

- Lessen regulatory burden on new and small firms
- Strike a balance between economic security and self-sufficiency
- Facilitate greater levels of female participation in entrepreneurship
- Encourage older citizens to undertake entrepreneurial activities.

## **6. US Innovation Index**

### **Differences in purpose**

The US Innovation index (USII) (Porter and Stern, 1999) aims to create a quantitative benchmark of national innovative capacity in order to highlight the resource commitments and policy choices that most affect innovative output in the long run.

### **Difference in sources of indicators and indicators chosen and reasons**

The underlying framework of USII is that innovation capacity is related to three key elements: a common innovation infrastructure, cluster specific innovation environment and the quality of the linkages between the two. Common innovation infrastructure includes some of the same elements outlined under Human resources/knowledge creation (human capital, physical capital, knowledge resources etc.) in ISB and other scoreboards, and the concept of linkages includes some key elements of transmission and application of knowledge.

The indicators used by the USII that are shared by the ISB are identified in table 6.A and other relevant indicators used by the USII that are not shared by the ISB are identified in table 6.B.

**Table 6.A. Indicators shared by ISB and USII**

No	ISB Indicator	Shared/similar Indicator	Source
<b>1. Human Resources</b>			
1.1	New S&E graduates (% of 20-29 years age class)	×	
1.2	Population with tertiary education (% of 25-64 years age class)	Share of GDP spent in public secondary and tertiary education	World Bank
1.3	Lifelong learning (% of 25-64 years age class)	×	
1.4	Employment in medium/high-tech Manufacturing (% of total workforce)	×	
1.5	Employment in high-tech services (% of total workforce)		
<b>2. Knowledge creation</b>			
2.1	Public R&D (GERD-BERD) (% of GDP)	Aggregate expenditures on R&D in millions of PPP US dollars	OECD S&T indicators
2.2	Business R&D (BERD) (% of GDP)		
2.3.a	High-tech EPO patents (per million population)	Number of patents granted in the US to establishments from country j in year $(t+3)$ ; for the US the number of patents granted in the US and at least one other CHI reported country	CHI Research, US patent database
2.3.b	High-tech USPTO patents (per million population)		
<b>3. Transmission and application of knowledge</b>			
3.1	SMEs innovating in-house (% of manufacturing SMEs)	Percentage of R&D performed by universities	OECD S&T indicators
3.2	SMEs innovating through co-operation (% of manufacturing SMEs)		
3.3	Innovation expenditures (% of all manufacturing turnover)		
<b>4. Innovation finance, output, and markets</b>			
4.1	High-tech venture capital investment (% of GDP)	×	
4.2	Capital raised on parallel markets plus new firms on main markets (% of GDP)	×	
4.3	Sales of new to market products (% of all manufacturing turnover)	×	
4.4	Home internet access (% of all households)	×	
4.5	Share of ICT markets as a percent of GDP	×	
4.6	Share of manufacturing value-added in high tech sectors	×	

**Table 6.B. Indicators included in USII and not included in ISB**

Section	Topic	Indicator per metropolis/state	Source
Quality of common innovation infrastructure	Aggregate personnel employed in R&D	Full time equivalent S&E all sectors	OECD S&T indicators
	Openness to international trade and investment	Average survey response on a 1-10 scale regarding relative openness of economy	IMD World Competitiveness Report
	Strength of protection for intellectual property	Average survey response on a 1-10 scale regarding relative strength of intellectual property rights	IMD World Competitiveness Report
	GDP per capita	GDP per capita in thousands of PPP US dollars	World Bank

## Differences in methodology for summary indices

The methodology to build the aggregate index is as follows:

1. Estimation of weights using a time-series cross-section regression model with innovation output as the dependant variable. The number of patents is used as a very crude and incomplete proxy of innovative output, after alternative measures were tested and discarded. These included world market shares in technology markets, technology balance of payments and scientific papers. It was found that (i) world market share in technology markets or technology balance of payments were not correlated to scientific articles, but patenting was correlated with the other three measures, and (ii) patenting was the most highly correlated measure with the regressors.
2. Additionally, specification tests including a range of independent variables (alternative methods of financing innovation, access to capital, antitrust enforcement, R&D composition) and testing the appropriate lag structure for the dependant variable were performed. The final set of independent variables were chosen on the basis of the ‘best fit’.

The econometric model has the following elements:

Variable	Estimate
Dependant variable	Log Patents <sub>(t+3)</sub>
Log R&D employment	0.87
Log R&D expenditure	0.29
Openness	0.06
Intellectual property	0.22
Education share	0.15
Log GDP per capita	0.78
Private R&D funding	0.02
University R&D performance	0.01

3. Calculation of country score of the USII per year uses the following formula since the estimates come from a log-log function:

$$USII_{\text{country } j, \text{ year } t} = \exp (X_{j,t} * \beta) / \text{Population}_{j,t}$$

4. Additionally by projecting forward the underlying variables, the USII can also be projected into the future.

## Recommendations for innovation policy

The USII is used to benchmark the US against a range of other OECD countries. The main findings are:

- US and Switzerland are the most innovative countries during the last two decades. However a number of OECD countries are catching up.
- Japan, despite its economic stagnation and decreasing income per capita during 1990s, has continued to accumulate innovation capacity.

- Scandinavian countries as well as Germany also caught up with the US by the beginning of the 1990s. However France, Italy and the UK have registered little or no improvement over the 2 decades.
- New emerging innovation centres include Singapore, Taiwan, South Korea and Israel.
- Projecting the index forward, the analysis shows that there would be a dramatic fall in the US position.

It is important to highlight that the issue about future trends in the US relative to rest of OECD is based on projections. The point is that R&D and education expenditures were flat during the last part of the 1980s and 1990s and consequently the projections suggest that the US will lose the relative advantage it had by mid 1990s. However, R&D rose sharply in the US during the last part of the 1990s changing the actual future trends in its favour. Thus, it is difficult to discuss what would have happened if the past trends had been maintained or if the rise in R&D experienced by the US during last half of the 1990s was related at all with any of the policy measures suggested in the USII report. However, what is clear is that at least in 2002 the projection of relative positions of the countries does not fit with reality. Moreover the policy recommendations included in the USII report had not been put forward when R&D began to rise in the US.

US diagnosis:

Outside health care sector, the US innovation model is not working well. NASA remains an innovation driver but its size and significance have fallen. Thus, although national defence strategies will continue as an important stimulus for technological change, its effects are diminishing. Additionally, civilian needs are broader and more complex, needing substantial development of innovative capacity outside the defence arena.

US policy suggestions:

- Increasing Federal support outside health sciences and promoting private sector involvement in long term R&D projects. Tax credits is one of several policy interventions that should be promoted.
- Changes and increased investment in the education system, including the promotion of undergraduate and graduate training to overcome the stagnant supply of R&D workers. This would also require incentives for young US citizens to pursue S&E careers and also for retaining foreign graduate students, after the completion of their training in the US.
- Improvement in intellectual property rights (Bayh-Dole act, openness of Federal laboratories to partnerships with private sector, ... ) in areas such as copyrights and the development of tools that protect new forms of innovative output and its new uses.