European Trend Chart on Innovation

2003 European Innovation Scoreboard: Technical Paper No 4 Sectoral Innovation Scoreboards

November 2003

European Commission
Enterprise Directorate-General

A publication from the Innovation/SMEs Programme

The European Trend Chart on Innovation

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

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

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

The Trend Chart products

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

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

The present report was prepared by **Lionel Nesta and Pari Patel** of **SPRU** and **Anthony Arundel** of **MERIT**. The information contained in this report has not been validated in detail by either the Member States or the European Commission.

Contact: Peter Löwe: peter.loewe@cec.eu.int

European Innovation Scoreboard

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

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

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

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

The EIS is complemented by six technical papers:

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

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

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

Table of Contents

Summary

The TrendChart European Innovation Scoreboard (EIS) has been criticized on the grounds that many of the EIS indicators focus on a country's performance in high-technology industries. While such industries are important, they are only a small component of the industrial make-up of most economies. Thus the overall innovation performance of a country should also take into account the performance of the country in a range of industries in which it is active. This report explores the feasibility of constructing sectoral innovation scoreboards (SIS), to complement the EIS, by analysing the innovation performance of EU countries within broad industry groupings. We use the characterisation of sectors according to R&D intensity first proposed by the OECD, which aggregates all manufacturing industries into four different categories based on the average R&D intensity across a range of OECD countries: High-, Medium-High, Medium-Low, and Low technology. The main question addressed is the extent to which the same countries are leaders or laggards in innovation performance in each of these categories.

The analysis is based on a maximum of 10 indicators available at the sector level and for 14 EU countries for which sectoral data were available. Eight of the 10 SIS indicators are similar to indicators in the EIS. At a general level, the results show that a country with a high ranking in high technology industries is also likely to have a high ranking in medium-high, medium-low, and low technology industries. Thus Finland is ranked 2nd amongst the EU countries in high technology and 1st in medium-low technology industries. The countries that have above average performance in all four sectors are the Netherlands, Finland, Sweden, Germany, and Belgium. The countries that lag behind most EU countries in all four sectors are Greece, Spain and Portugal. The latter is slightly more innovative in the two low-technology categories than in the two high-technology categories. The remaining five EU countries show heterogeneous performances across the different industries.

The main conclusion from this exploratory analysis is that there is a great deal to be gained by analysing innovation performance across sectors. The single most important constraint is the lack of data at the sector level for some key variables.

1. Introduction

One of the criticisms of the TrendChart European Innovation Scoreboard (EIS) is that it overemphasises the contribution made by high-technology sectors to overall innovation performance of countries. Underlying any aggregate innovation indicators, such as the ones used in EIS, is the structural make up of the economy, which differs greatly between EU countries. Such structural differences can have an important role in explaining some of the differences in innovation performance. The main reason is that there is a great deal of diversity amongst industrial sectors in terms of innovation process, innovation inputs and outputs[4]. Amongst the major differences are the size of the innovating unit, which is typically *large* in certain industries such as Chemicals, Motor vehicles, and Aircraft, and *small* in Machinery, Instruments and Software. Moreover the objectives of innovation are different amongst sectors. In Pharmaceuticals and Machinery sectors the main aim is to introduce *product* innovations, in the Iron and Steel industry the major objective of innovative activity is to come up with *process* innovations, and in the Motor vehicles industry both are important. There is a great deal of diversity amongst the sources of innovation. In Agriculture and Traditional Manufacturing industries (such as Textiles, Wood and Paper) *suppliers* are important source of innovative ideas, in Instruments, Machinery and Software, *users* play this role. *In-house R&D laboratories* are important in the Chemicals industry and many parts of the Electronics industry. In Pharmaceuticals a major source of innovative ideas is *basic research*. This implies that there will be major differences across sectors in many of the indicators used in the EIS, for example those based on R&D, patenting, SMEs and innovation expenditures.

The overemphasis on the activities of the 'high-tech' sectors is also misplaced for two other reasons. Firstly their importance is greatly exaggerated in economic activity. Thus although high technology products such as pharmaceuticals, mobile telephones, computers and airplanes are glamorous and can be very profitable, the demand for these products is limited. Keith Smith (2002)[5] recently evaluated the direct economic impacts of high technology manufacturing[6] on GDP within the OECD and concluded that their contribution is 'surprisingly small' – accounting for less than 3% of GDP in the United States, which is the OECD country with the largest share of high technology manufacturing. These results show that there is a limit to the economic contribution of high technology manufacturing. Secondly although the low and medium-low technology sectors do not generate a high proportion of innovations within a country, they are big users of such innovations. Overall productivity gains within an economy are strongly dependent on the extent to which the innovations generated by high-technology sectors are incorporated in the new products and processes within the rest of the economy.

---

[4] See Tidd, J., Bessant,J and Pavitt, K. (2001) "*Managing innovation: integrating technological, market and organizational change*", John Wiley, Chichester.
[5] See Smith, K. "What is the 'Knowledge Economy'? Knowledge Intensity and Distributed Knowledge Bases", UNU-INTECH Discussion Paper: DP 2002-6 (http://www.intech.unu.edu/publications/discussion-papers/2002-6.pdf)
[6] This includes ICT, aerospace, pharmaceuticals, and precision instruments.

2. How to deal with Sectoral Diversity?

In light of the above discussion, there are two main alternative strategies for enhancing the analysis in the EIS. The first is to produce industry-standardised indicators and the second is to produce sector specific scoreboards. Very briefly, the former involves adjusting each EIS indicator by the industrial structure of the country. This method is useful for comparing national innovative capabilities across all sectors, but it does not illuminate where the weaknesses and strengths occur. In the current report we have adopted the latter strategy.

There are a number of different ways in which a sectoral scoreboard may be constructed. This may be done simply on the basis of a number of 2 or 3 –digit NACE industries, resulting in many different scoreboards. The alternative is to aggregate the sectors according to their innovation characteristics. Again there are many different possibilities. For example, this could be done on the basis of the Pavitt taxonomy, which aggregates sectors according to a range of different measures of the innovation process. In the analysis below we use the characterisation of sectors according to R&D intensity first proposed by the OECD. Essentially this aggregates manufacturing industries into 4 different categories based on the average R&D intensity across a range of OECD countries: high-, medium-high, medium-low, and low technology. Table 1 defines each of these four sector groups using the NACE classification system.

For simplicity, we refer to each of these sector groups as a 'sector', even though they contain several sectors at the two-digit NACE level.

The aim of this report is to analyse the innovation performance of EU countries within each of these sectoral aggregations. To achieve this we produce four Sectoral Innovation Scoreboards (SIS) and examine the similarities and differences across countries in each of them. The SIS can be used to 1) evaluate differences in innovation performance across countries within the same sector and 2) identify areas of innovation specialisation within each country.

The plan of the report is as follows. Section 3 outlines the indicators that comprise the scoreboards, Section 4 reports the results and Section 5 gives the main conclusions.

Table 1. Definition of high, medium-high, medium-low and low-technology manufacturing industries

High-technology manufacturing industries	NACE rev. 1
Manufacture of pharmaceuticals, medicinal chemicals and botanical products	244
Manufacture of office machinery and computers	30
Manufacture of radio, television and communication equipment and apparatus	32
Manufacture of medical, precision and optical instruments, watches and clocks	33
Manufacture of aircraft and spacecraft	353
Medium-high-technology manufacturing industries	NACE rev. 1
Manufacture of chemicals and chemical products (excl. Manufacture of pharmaceuticals, medicinal chemicals and botanical products)	24 excl. 244
Manufacture of machinery and equipment n.e.c.	29
Manufacture of electrical machinery and apparatus n.e.c.	31
Manufacture of motor vehicles, trailers and semi-trailers	34
Manufacture of railway and tramway locomotives and rolling stock	352
Manufacture of motorcycles and bicycles	354
Manufacture of other transport equipment n.e.c.	355
Medium-low-technology manufacturing industries	NACE rev. 1
Manufacture of coke, refined petroleum products and nuclear fuel	23
Manufacture of rubber and plastic products	25
Manufacture of other non-metallic mineral products	26
Manufacture of basic metals	27
Manufacture of fabricated metal products, except machinery and equipment	28
Building and repairing of ships and boats	351
Low-technology manufacturing industries	NACE rev. 1
Manufacture of food products and beverages	15
Manufacture of tobacco products	16
Manufacture of textiles	17
Manufacture of wearing apparel; dressing and dyeing of fur	18
Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	19
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	20
Manufacture of pulp, paper and paper products	21
Publishing, printing and reproduction of recorded media	22
Manufacture of furniture; manufacturing n.e.c.	36
Recycling	37

3. Indicators and Data Availability

The complete results for the SIS are given in Annex A. Table A1 gives the reference year for each indicator and Tables A2-A5 provide the results for each of the four sectors.

The underlying idea of the SIS is to adhere as closely as possible to the indicators used in the EIS. However a major difficulty is the availability of EIS indicators at the sector level. Table 2 lists the original EIS indicators and their sector availability. Some indicators are obviously not relevant such as 1.4, “Employment in medium-high and high-tech manufacturing”, indicator 1.5, “Employment in high-tech services (% of total workforce)”, and 4.1, “Share of high-tech venture capital investment (‰ of GDP)”, although venture capital investment by sector would be useful. The major problem is that none of the relevant indicators on Human Resources are available at the sector level at the time of writing this report.

Table 2. EIS Indicators and their inclusion in the SIS

1.	**Human resources**	**Sector availability**
1.1	New S&E graduates (% of 20-29 years age class)	No
1.2	Population with tertiary education (% of 25-64 years age classes)	No
1.3	Participation in life-long learning	No
1.4	Employment in medium-high and high-tech manuf. (% of total workforce)	Not relevant
1.5	Employment in high-tech services (% of total workforce)	Not relevant
2.	**Knowledge creation**	
2.1	Public R&D expenditures (GERD - BERD) (% GDP)	No
2.2	Business expenditure on R&D (BERD) (% GDP)	*Variant available*
2.4.1	EPO patent (per million population – date of grant)	*Variant available*
2.4.2	USPTO patent applications (per million population – date of grant)	*Variant available*
3.	**Transmission and application of knowledge**	
3.1	SMEs innovating in-house (% of manufacturing SMEs)	**Yes**
3.2	Manufacturing SMEs involved in innovation cooperation)	**Yes**
3.3	Innovation expenditures (% of all turnover in manufacturing)	**Yes**
4	**Innovation finance, output and markets**	
4.1	Share of high tech venture capital investment (% all venture capital)	No
4.2	Early stage venture capital investment (‰ of GDP)	No
4.3.1	New to market' products (% of sales by manufacturing firms)	**Yes**
4.3.2	New to firm products (% of sales by manufacturing firms)	**Yes**
4.4	Internet use by firms	No
4.5	ICT expenditures (% of GDP)	No
4.6	Percent of total manufacturing value-added	*Variant available*
4.7	Volatility rate of SMEs	No

Table 3 lists the available indicators for the SIS and gives the data source and indicator definition. In addition to the EIS indicators discussed above, two new indicators have been included in the SIS. Within the category *Transmission and Application of Knowledge*, we have added *Investment per Employee*, and within *Innovation finance, output and markets,* we have included *value-added per employee* (a variant of EIS indicator 4.6). As a note of caution, there are differences between countries in the two-digit level sectors included in the definition of indicator 2.4 (see Annex table A1 for details).

Table 3. Data definition and Sources

	Indicator	Data Source	Definition (limited to each sector)
1.1	Business R&D over Value Added (%)	OECD-STAN	Business R&D expenditures as a proportion of the sector value added.
1.2a	EPO Patent per Employee	MERIT	The number of granted EPO patents per thousand employees.
1.2b	USPTO Patent per Employee	MERIT	The number of granted USPTO patents per thousand employees.
2.1	SMEs innovating in-house (%)	EUROSTAT CIS3	Percentage of all SMEs that innovated in-house (at any time between 1998-2000).
2.2	SMEs innovation co-operation (%)	EUROSTAT CIS3	Percentage of all SMEs involved in innovation cooperation (at any time between 1998-2000).
2.3	Innovation expenditures (%)	EUROSTAT CIS3	All innovation expenditures as percentage of total sector turnover.
2.4	Investment Per Employee (KEuro)	OECD-STAN	Gross Fixed Capital Formation per employee (thousand Euros)
3.1	Value Added per Employee (KEuro)	EUROSTAT SBS	Value-added per employee (thousand Euros)
3.2	Sales new to firm and to market (% of total turnover)	EUROSTAT CIS3	Turnover of new or significantly improved products that are new to the market, as a percentage of total sector turnover.
3.3	Sales new to firm, not to market (% of total turnover)	EUROSTAT CIS3	Turnover of new or significantly improved products that are new to the enterprise but not to the market, as a percentage of total sector turnover.

Table 4 shows the number of the 10 SIS indicators that are available per country. On the basis of this information, we have formed 3 groups of countries. Group 1 includes 11 EU-countries for which we have more than 6 indicators for each sector: Austria, Belgium, Germany, Denmark, Spain, Finland, France, Greece, Italy, the Netherlands and Sweden. Group 2 includes countries for which fewer indicators are available: Luxembourg, Portugal, Iceland and the UK. Ireland, Norway, the USA and Japan are excluded from the analysis due to the lack of data.

Table 4. Number of indicators per country

	HT (High technology)	MHT (Medium-high technology)	MLT (Medium-low technology)	LT (Low technology)	Group
Austria	9	9	8	8	1
Belgium	10	10	8	8	1
Germany	10	10	10	10	1
Denmark	9	10	7	7	1
Spain	10	10	6	6	1
Finland	10	10	9	9	1
France	10	6	10	6	1
Greece	8	9	6	6	1
Ireland	0	0	0	0	*Excluded*
Italy	10	10	10	10	1
Luxembourg	1	6	6	4	2
The Netherlands	6	9	9	6	1
Portugal	4	5	9	8	2
Sweden	10	10	7	7	1
United Kingdom	5	5	5	5	2
Iceland	3	5	5	3	2
Norway	1	5	1	5	*Excluded*
USA	2	2	2	2	*Excluded*
Japan	1	1	1	1	*Excluded*

4. Main Findings

4.1. Results for European Countries

Before presenting the results of the SIS, it is important to bear in mind the structural make up of the countries under consideration. Table 5 shows the proportion of manufacturing value-added in each of the 4 industry groups by country in 2000. For all manufacturing value-added, the share of the high-technology industries varies from around 3% in Luxembourg, 6% in Spain and Portugal to more than 23% in Finland. On average the EU countries have around 14% of their output in these industries. Some country differences to note are that Germany is highly specialized in the medium-high technology industries, and Portugal and Spain in low-technology industries.

Table 5. Structure of the manufacturing economy in 2000 (EU countries only).

	Percent of total manufacturing value-added in each sector				
	HT	**MHT**	**MLT**	**LT**	
Austria	11.3	27.4	27.8	33.5	100%
Belgium	12.4	31.2	27.3	29.1	100%
Germany	11.4	42.5	23.5	22.5	100%
Denmark	14.3	24.0	21.3	40.5	100%
Spain	6.2	14.4	33.1	46.3	100%
Finland	23.7	18.7	19.9	37.7	100%
France	17.8	27.5	24.9	29.7	100%
Greece	6.2	14.4	33.1	46.3	100%
Ireland	*30.2*	*34.5*	*6.0*	*29.4*	100%
Italy	9.8	27.1	28.8	34.3	100%
Luxembourg	3.1	14.7	54.1	28.1	100%
Netherlands	11.9	26.3	24.7	37.1	100%
Portugal	6.3	18.6	25.7	49.4	100%
Sweden	16.0	33.0	19.6	31.4	100%
United-Kingdom	17.9	24.0	21.9	36.2	100%
EU15 MEAN	**13.7**	**30.9**	**24.4**	**31.0**	**100%**
EU15 CV × 100	**54.2**	**32.3**	**38.7**	**21.6**	

Data source: Eurostat - Structural Business Statistics

The two main points to note are: 1) that there is considerable variety in the structural make-up of the different countries, as indicated by the coefficient of variation (given in the last row of Table 5); and 2) cross-country heterogeneity is greater for the high technology sectors than for the low technology sectors. For example, the coefficient of variation is much larger, at 54.2, for the high technology sector compared to 21.6 for the low technology sector. These structural differences set the context for the analysis below.

Table 6 summarizes the main findings of the SIS. For each indicator and for each industry group, Table 6 provides the EU mean, the leading country in Europe, and the coefficient of variation.

Table 6. Main Findings in the Sectoral Innovation Scoreboards (EU countries only)

		Hi-Tech			Med-Hi-Tech			Med-Low-Tech			Low-Tech		
No	Indicator	Av	EU 1st	CV	Av	EU 1st	CV	Av	EU 1st	CV	Av	EU 1st	CV
1.1	Business R&D	23.3	43.1 S	38.1	8.1	14.1 S	42.6	1.7	4.1 FIN	48.3	0.7	1.8 FIN	53.5
1.2a	EPO Patent	5.9	10.3 NL	63.2	1.0	1.9 NL	73.6	0.5	1.1 S	72.7	0.2	0.4 B	65.8
1.2b	USPTO Patent	2.2	3.9 B	64.5	0.9	1.4 FIN	61.4	0.3	0.5 S	67.8	0.0	0.1 DK	78.4
2.1	SMEs inn. in-house	61.2	78.3 B	38.5	57.1	67.0 D	22.4	41.0	51.3 D	29.0	36.4	47.0 D	28.7
2.2	SMEs inn. Coop.	25.3	60.3 AT	60.7	15.0	28.1 FIN	55.5	8.9	19.6 FIN	54.8	4.1	18.3 FIN	160.2
2.3	Innovation exp.	10.7	25.3 NL	66.4	4.0	6.4 B	36.7	1.6	4.7 GR	65.3	1.4	3.2 P	54.4
2.4	Investment	7.9	14.3 S	37.9	8.7	13.4 NL	47.1	8.0	12.0 B	27.6	6.7	13.3 S	42.3
3.1	Value Added [a]	73.1	126.4 FIN	34.1	58.3	78.0 B	23.6	50.4	70.4 LU	21.7	42.0	67.6 LU	31.2
3.2	Sales new to market	14.3	26.2 IT	46.6	10.4	19.2 IT	55.4	7.2	11.9 IT	52.2	10.3	16.1 IT	46.3
3.3	Sales new to firm	33.4	48.6 FIN	31.8	24.3	34.4 DK	25.1	16.3	22.7 NL	43.5	19.9	25.1 IT	36.1

[a] Calculations for EU mean and CV exclude Ireland. Calculations for EU mean with Eurostat CIS3 data (indicators 2.1, 2.2, 2.3, 3.2 and 3.3) are weighted by country value added, as provided by Eurostat SBS.

The EU countries that lead most frequently in the high technology sector are Belgium, Finland, the Netherlands and Sweden, each with a lead in 2 indicators. Italy and Austria appear next with a lead in 1 indicator. This is somewhat surprising, for Austria and Italy perform relatively poorly in the main EIS. Respectively, they are the leading European countries for indicator 2.3, "SMEs Innovation Expenditures" and indicator 3.2, "Sales new to market". A consistent picture to emerge from this analysis is that the Nordic countries (Finland, Sweden and to a lesser extent Denmark) are leaders in many of the indicators across the different categories of industries (of a total of 40 rankings, Nordic countries are in the top position 16 times). For example, Finland is the top EU country in 2 out of the 10 indicators in all four categories. The Benelux countries (Belgium, Luxembourg and the Netherlands) also have an excellent overall performance, with 13 lead positions. Of notable importance is the leading performance of Greece and Portugal in innovation expenditures (indicator 2.3) in medium-low and low technology sectors.

Table 6 also displays the coefficient of variation (CV, multiplied by a hundred), which is a measure of the degree of dispersion around the EU mean. The two patent indicators 1.3a and 1.3b shows a very high variance in all types of industries, revealing heterogeneity in patent grant rates across Europe for each sector.

4.2. The SIS Composite Performance Index

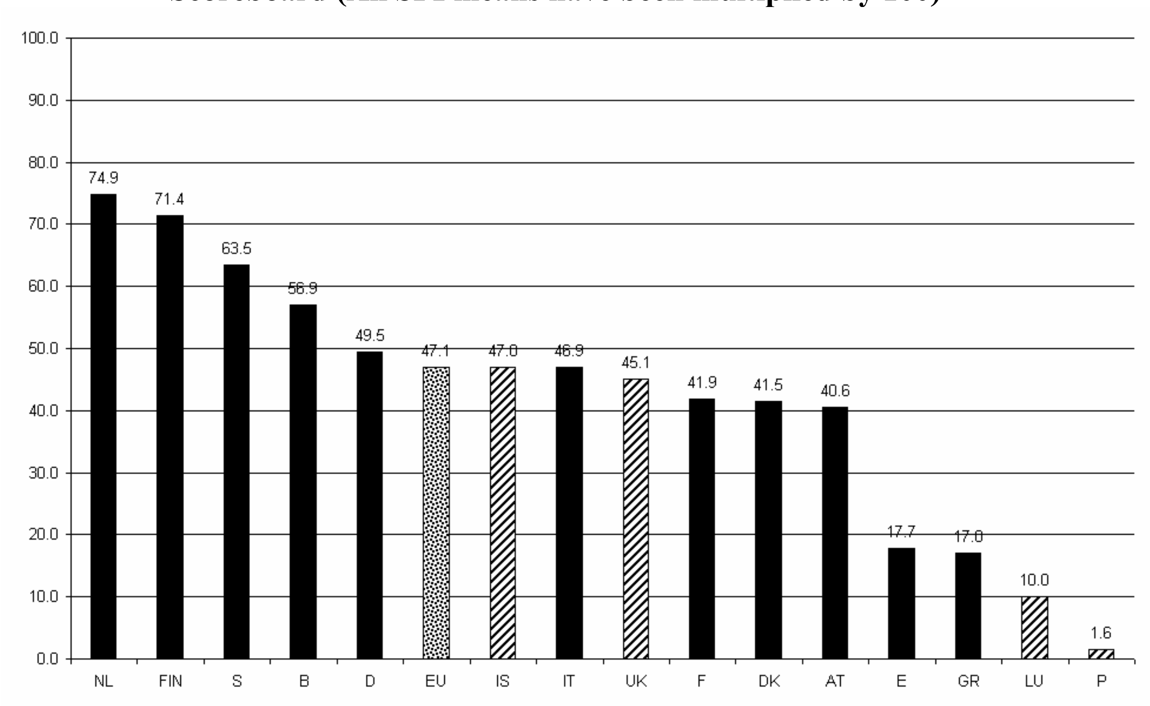
A composite Sector Performance Index (SPI) was constructed along the lines suggested in the EIS Methodology Report (2002) for TrendChart. Briefly for a given indicator, each country's score is first converted into a standardized value (z score). Each score is then re-scaled to vary within an identical range (0 to 1). The SPI is then the average of the re-scaled z-values and reveals the average relative performance for all indicators for which data are available. Although the SPI is less sensitive to the uneven distribution of indicators across countries than other indicators (see EIS

Methodology Report, 2002), the results must be interpreted with care. As shown in Table 4, the number of indicators per country ranges from 4 to 10. For countries with a large number of indicators such as Belgium, Finland, France, Italy, Spain and Sweden the SPI is a better reflection of performance in a wide range of industry types than for countries with fewer indicators such as Luxembourg (one indicator only in high-technology sectors), Portugal and the UK.

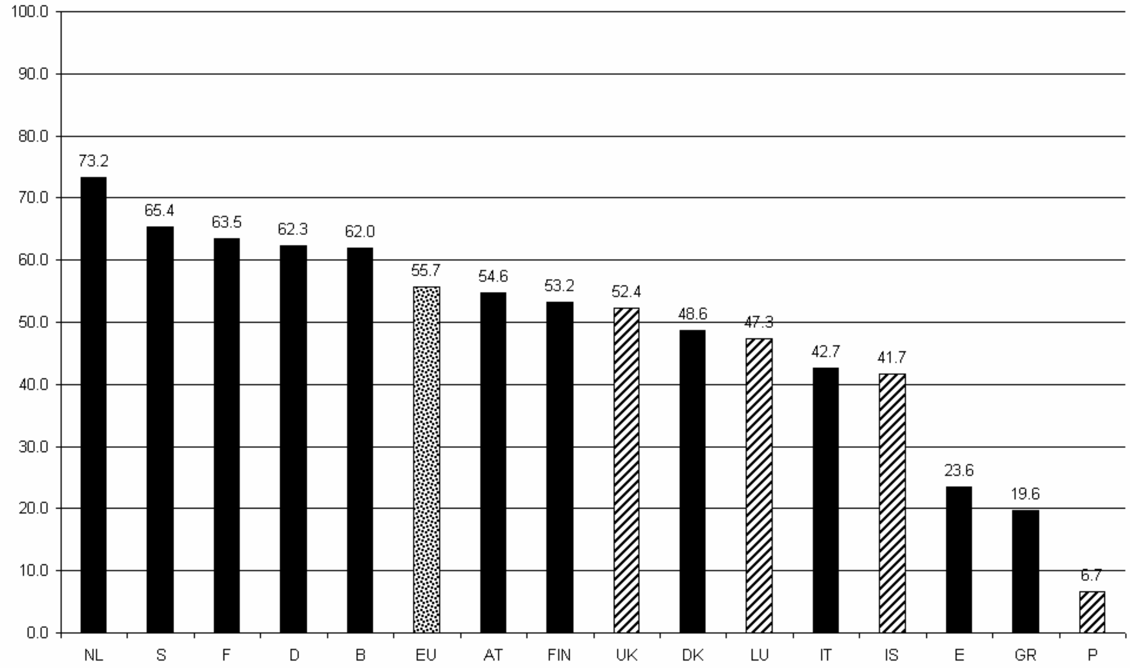
Graphs 1 to 4 display the SPI for all four sectors. The two groups of countries are distinguished with a solid column for group 1 countries (countries with a sufficient number of indicators available), and with a striped column for group 2 countries (countries with a low number of indicators available). The EU mean is also displayed.

Graph 1 shows that the Netherlands is the leader in the high-technology sector, followed by Finland, Sweden, and Belgium. Germany also performs above the EU average. Iceland, Italy and the UK are around the EU average, and Austria, France and Denmark just below. Finally Spain, Greece, Luxembourg and Portugal are some way behind all the other EU countries. Graph 2 shows the SPI for the medium high-technology industry group. Once again, the Netherlands is the best performing country, followed by Finland, Sweden, Belgium, and Germany. Again Spain, Greece and especially Portugal are some way behind the leading countries.

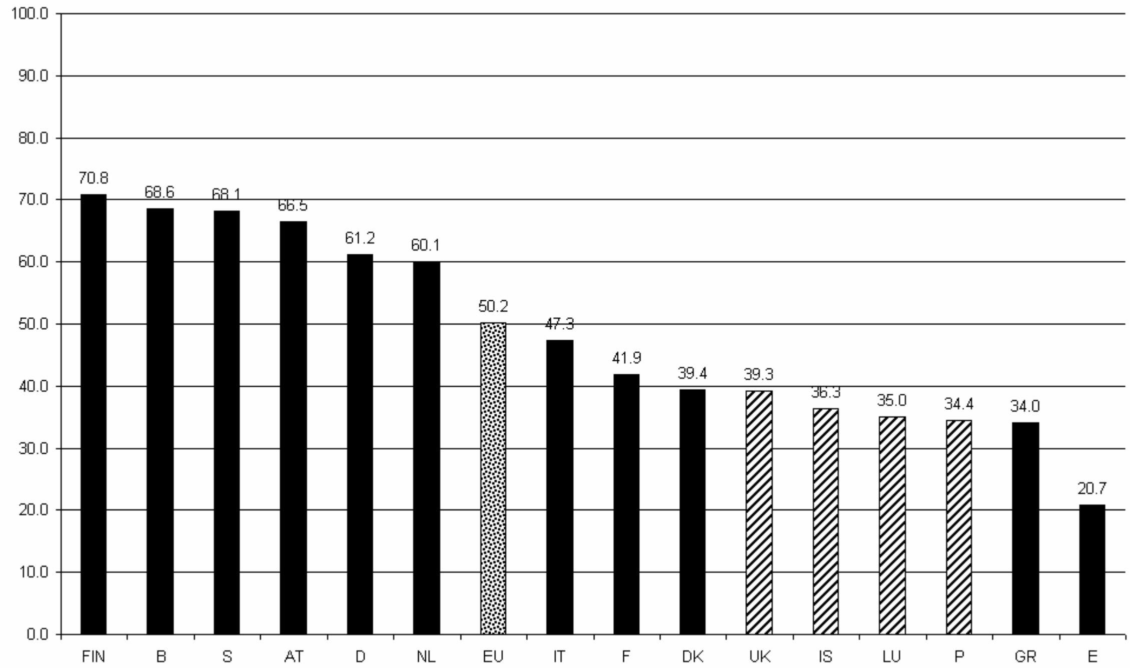
Graph 1. Sector Performance Index for the High-Technology Innovation Scoreboard (All SPI means have been multiplied by 100)



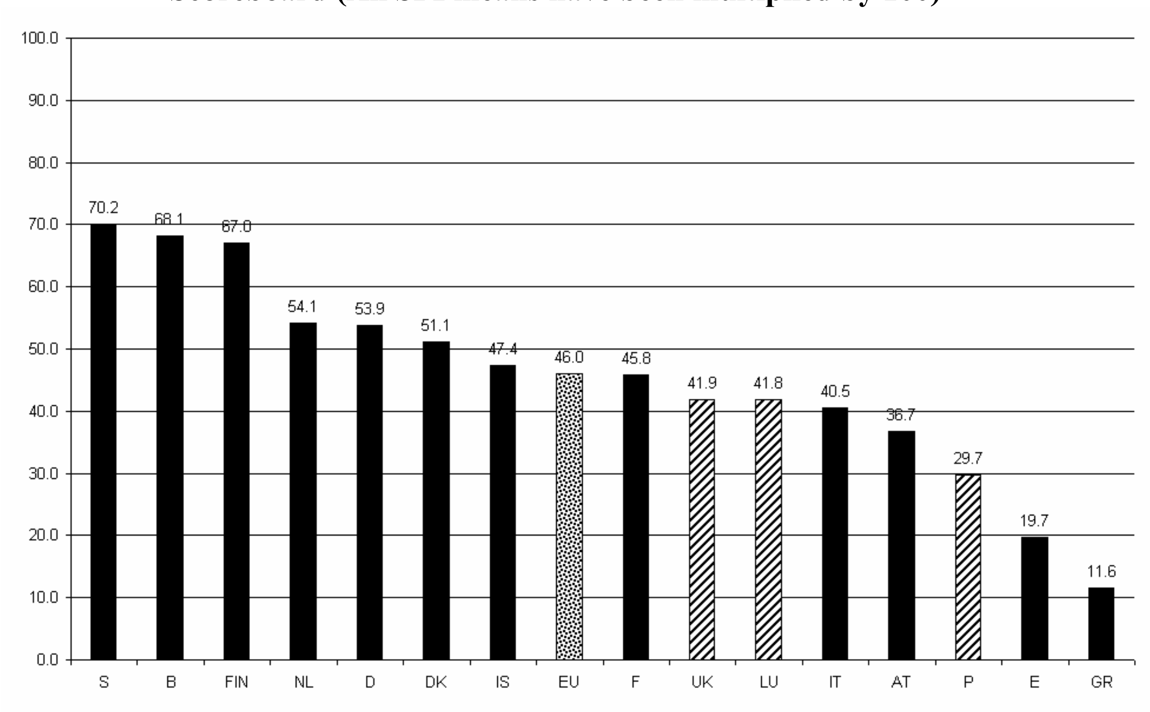
Graph 2. Sector Performance Index in the Medium High-Technology Innovation Scoreboard (All SPI means have been multiplied by 100)



Graph 3. Sector Performance Index in the Medium Low-Technology Innovation Scoreboard (All SPI means have been multiplied by 100)



Graph 4. Sector Performance Index in the low-technology Innovation Scoreboard (All SPI means have been multiplied by 100)



Graph 3 and 4 display the results for lower technology sectors. In the medium-low technology sector (Graph 3), Finland, Belgium, Sweden and Austria are the EU leaders with very similar levels of performance. Spain continues to lag behind the other EU countries. In the low-technology sector (Graph 4), the most notable result is that five out of the seven EU countries with a high level of performance are also those that are best performers in the high-technology group, namely Finland, Belgium, the Netherlands, Sweden and Germany. Taking the two lower technology industrial groupings together, France performs below the EU average, and Spain is some way behind most EU countries.

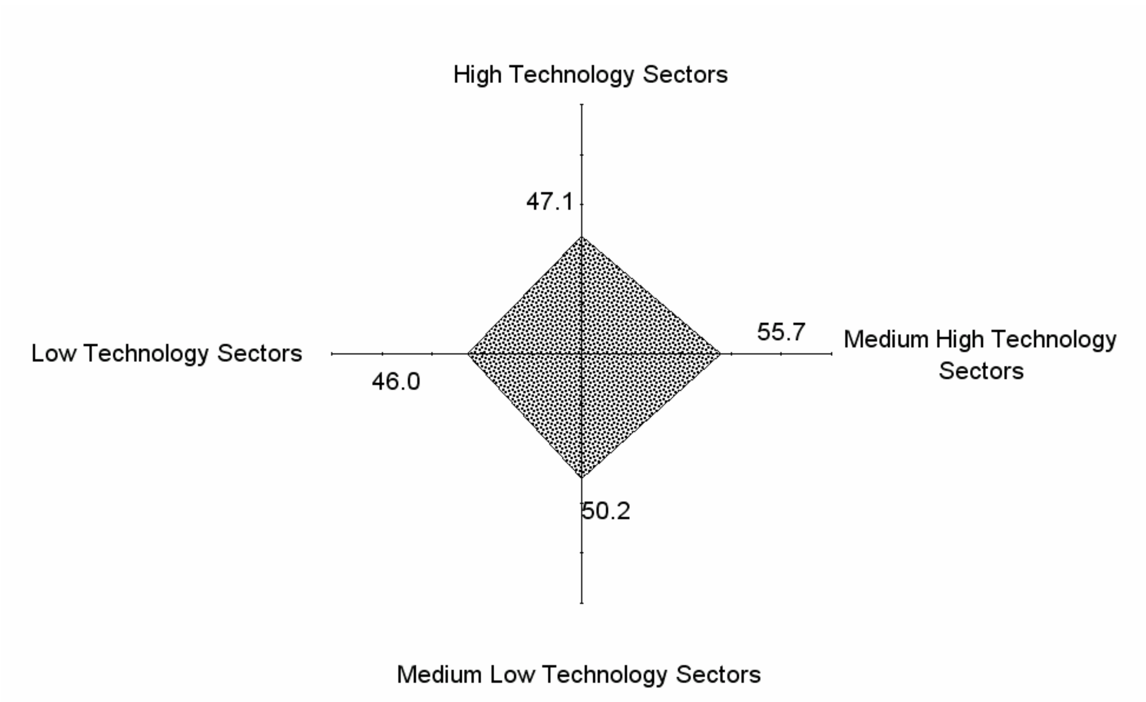
Overall we note both persistency and divergence across Graphs 1-4. Persistency results from the fact that the better performing countries in one sector tend to also perform well in other sectors. This applies to countries such as Belgium, Finland, Sweden, Germany and the Netherlands. Divergence results from the fact that some countries specialise in one sector, for example Denmark in low-technology. This suggests that we need to investigate further the profile of each country according to its SPIs in each industry group.

4.3. National Profiles in Sectoral Innovation Scoreboards

In order to demonstrate country profiles we use radar-graphs. Such graphs display as many axes as there are dimensions under consideration. In our case, each country is described by its SPI for each of the four sectors. The advantage of such graphs is that the larger the area a country occupies the better the performance of the country in all SPIs. Thus keeping the scale constant from one graph to another enables us to make comparisons between countries very easily. When a country performs equally in all four type of industry, the result is a squared surface. Different values of the SPI for different sectors result in the surface leaning more towards one axis (referring to a particular sector type), revealing the sectoral specialisation of a country.

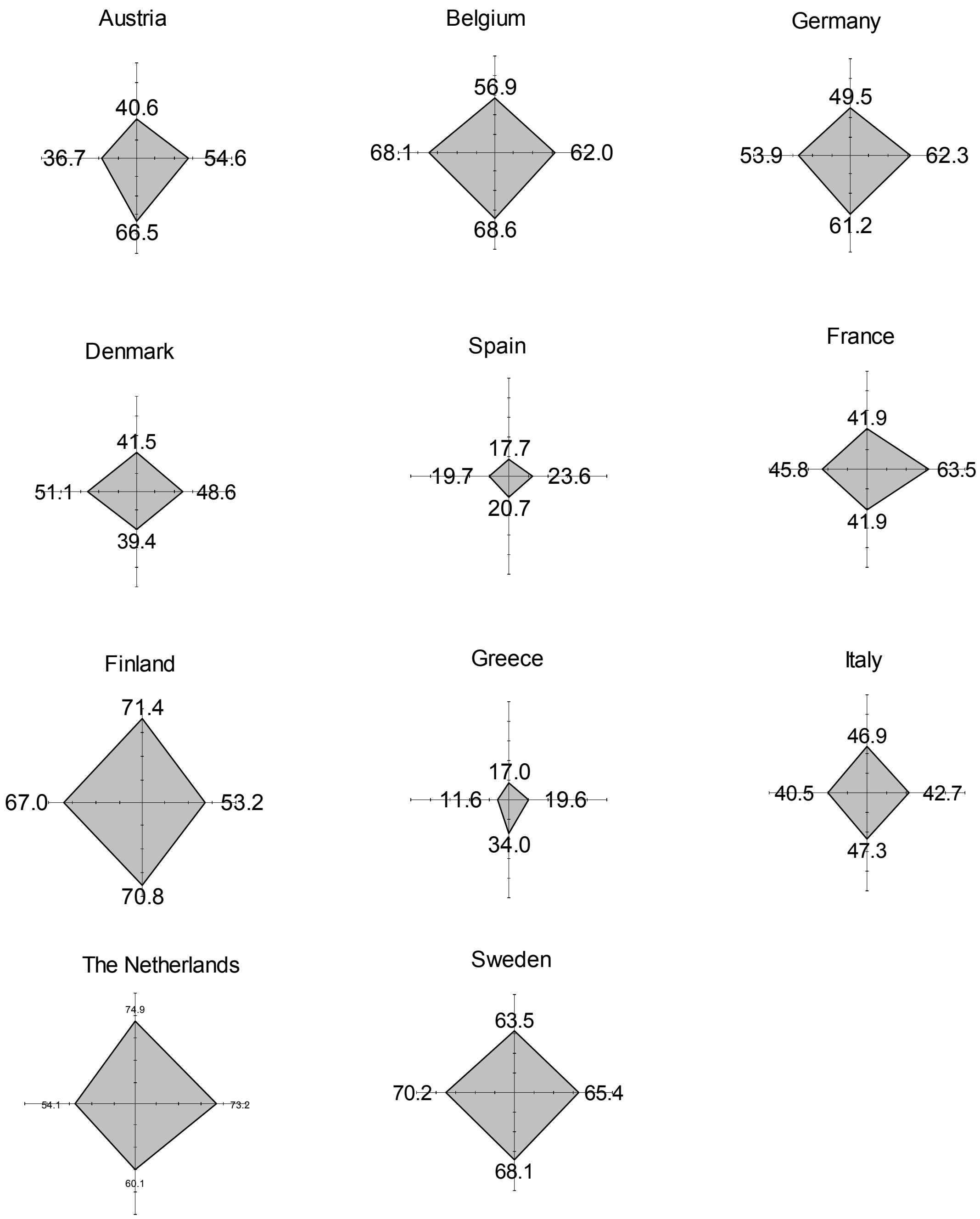
Graph 5 displays the radar graph for the European Union as a whole. The North axis relates to the SPI in high technology industry group (HT), the East axis relates to the SPI in medium high-technology industry group (MHT), the South axis relates to the SPI in medium low-technology industry group (MLT), and the West axis relates to the SPI in low-technology industry group (LT). Graph 5 shows that there are no clear specialisation patterns for the EU. This is not surprising since the EU score reflects the mean value of heterogeneously specialized EU countries.

Graph 5. Sectoral Profiles for the EU as a whole



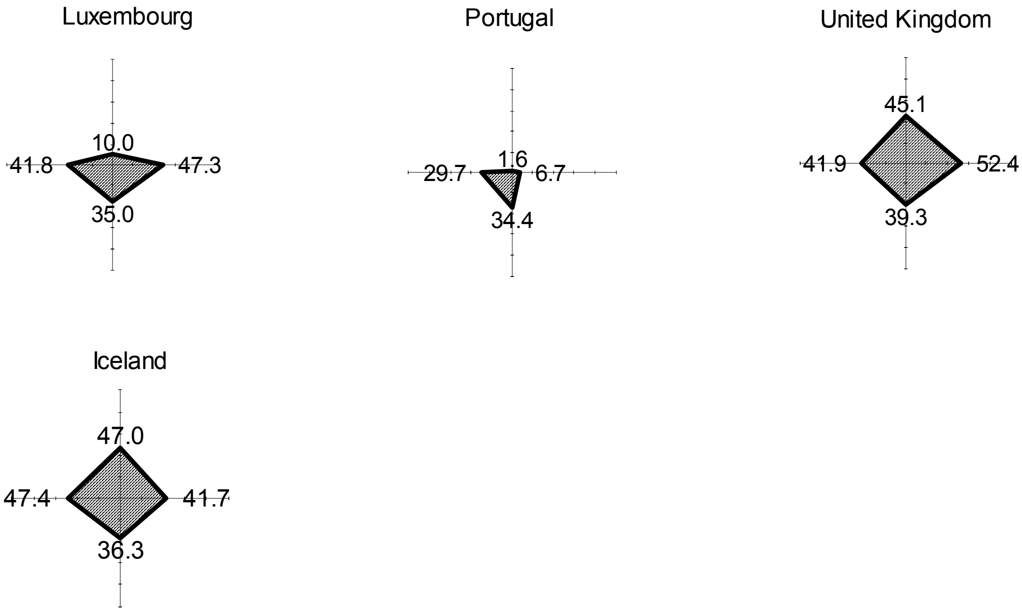
Graphs 6 displays the radar diagrams for group 1 countries (those with a relatively high number of indicators). As expected, Belgium, the Netherlands, Finland, and Sweden are European leaders in all four sectoral innovation scoreboards. However their specialization profiles are different. We observe a strong domination of the Netherlands, which specialises in high technology and medium high-technology industries, where it has a leading position. Belgium has a specialization in medium-low and low technology industries, and Finland in high, medium-low and low technology industries. Graph 6 also shows that Denmark is specialized in low technology categories. Italy shows specialisation in medium low-technology industries. Finally, Greece shows a similar specialisation patterns towards lower technology industry groups, but its overall performance remains weak, as that of Spain, which displays no clear specialisation pattern.

Graph 6. Sectoral Profiles for Group-1 countries



Graph 7 displays radar graphs for group 2 countries. For this exercise we have only a few indicators that are common across countries, thus the results need to be treated with caution. The United Kingdom shows a relatively balanced specialization pattern, similar to that of France. Iceland's specialisation profiles leans towards high and low technology sectors. Portugal shows a specialisation pattern in lower technology industries, but as for Greece, its overall performance remains weak.

Graph 7. Sectoral Profiles for Group-2 and Group-3 countries



Altogether these results show a strong lead by the Netherlands, Belgium and the Nordic countries. Germany scores relatively well as compared to France, Italy and the UK, which exhibit similar patterns of specialisation, with an average SPI significantly lower than that for the leading countries. Finally Greece, Spain and Portugal show a lower level of performance in general.

4.4. Correlation Analysis of Country Rankings

One of the salient questions in the sectoral innovation scoreboard relates to the possibility that a country that performs poorly in high technology sectors could perform better in low-technology sectors. Do we observe a "shuffling" of the country ranks from one industry group to the other? Or, do we observe persistence of the rankings? To answer these questions, we computed both Pearson correlation coefficients based on the interval level SPI data and Spearman's *rho* using the rank order for each country on each of the four industry groups. Both sets of correlations are similar, but we only give the Spearman correlation coefficients in Table 7 because they are more robust[7]. The results are based on the 14 EU countries for which we have some data.

[7] The Spearman rank correlation is a non-parametric measure of correlation between two ordinal variables. The values of each of the variables are ranked from smallest to largest, i.e. all countries are ranked, and a Pearson correlation coefficient is computed on the ranks. The advantage in using the Spearman calculation is that it does not assume normality in the distribution of the variables, an assumption that is likely to be violated here when considering the number of observations at hand. A Wilcoxin test of the rankings for each of the six combinations failed to reject the null hypothesis that each rank order pair was equivalent.

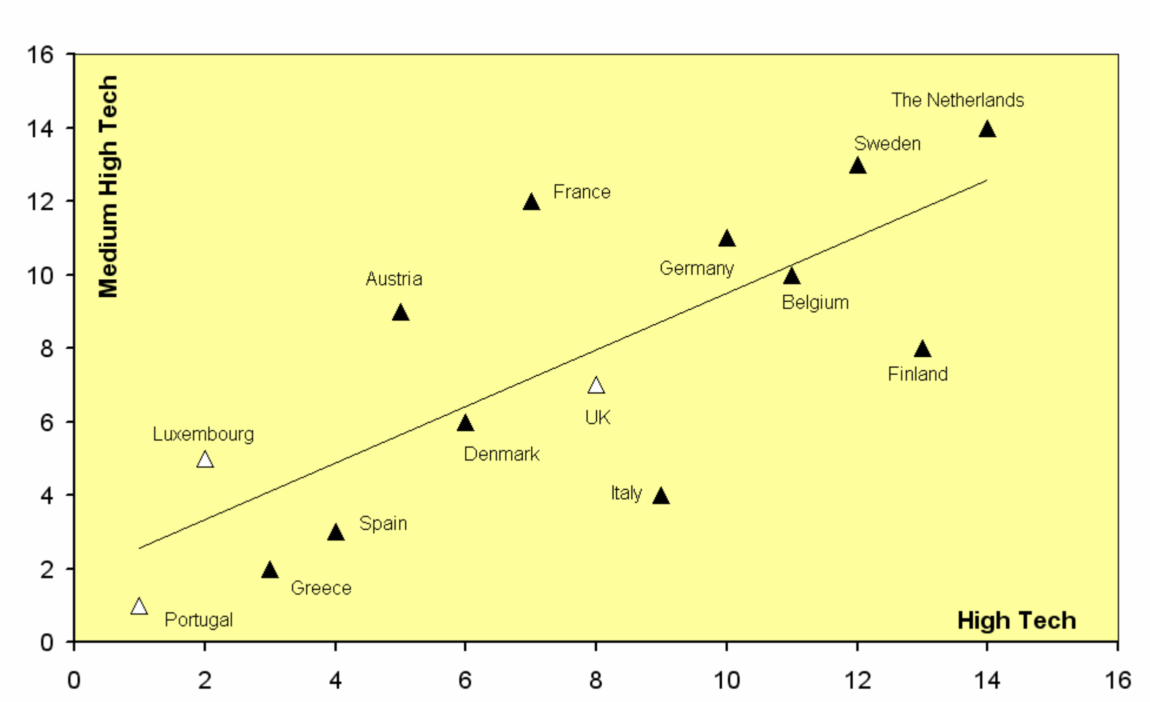
Table 7. Spearman correlation coefficients for the rank order of the SPI for each industry group

	High	Medium-high	Medium-low	Low
High	1.000 (-)			
Medium-high	.767 (.001)	1.000 (-)		
Medium-low	.793 (.001)	.714 (.004)	1.000 (-)	
Low	.837 (.000)	.793 (.001)	.802 (.001)	1.000 (-)

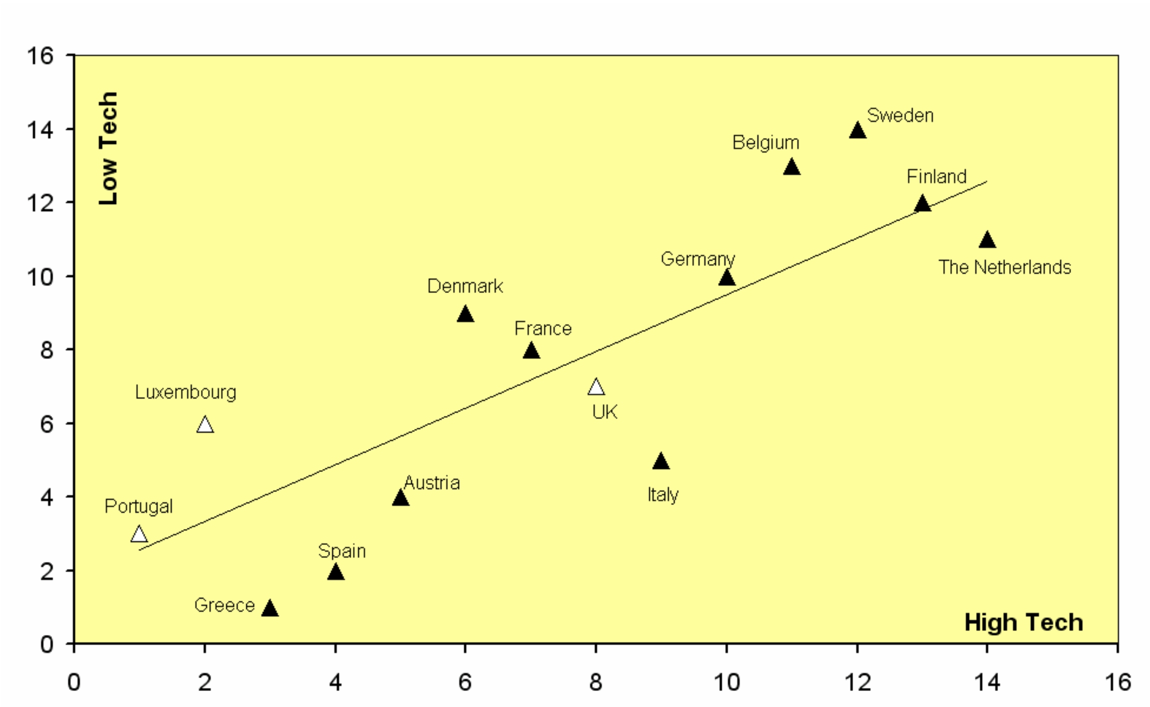
Notes: p values (two-tailed) are in parentheses. All correlation coefficients are significant at 1% level.

For all six correlations, the two rankings are statistically significant. This shows that the country rankings are similar across most industry classes. For example, a country with a high ranked SPI in the high technology sector is also likely to have a high ranking in the medium-high, medium-low, and low technology sectors. As an illustration, Graph 8 provides the results for the high and medium-high technology industries while Graph 9 provides the results for high and low technology industries (colour triangles indicate group-one countries and white triangles indicate group-two countries). The essential finding here is that countries that do well in high technology industries also tend to do well in low technology industries.

Graph 8. High technology by Medium High Technology Country rankings



Graph 9. High Technology by Low Technology Country rankings



Similar to Graphs 8 and 9, Table 8 shows the relative strengths and weaknesses of each country, but provides a direct comparison with other countries. We can see that Portugal is slightly more innovative in medium-low and low technology industries than in high and medium-high technology industries, but it still lags behind most EU countries in all industries. Greece's performance is weak in all types of sectors, but is relatively weaker in low-technology industries. Conversely, Denmark is markedly stronger in low-technology industries.

Table 8. Country rank orders by technology group (13 = highest rank)

Rank	High	Medium-high	Medium-low	Low
14	NL	NL	FIN	S
13	FIN	S	B	B
12	S	F	S	FIN
11	B	D	AT	NL
10	D	B	D	D
9	IT	AT	NL	DK
8	UK	FIN	IT	F
7	F	UK	F	UK
6	DK	DK	DK	LU
5	AT	LU	UK	IT
4	E	IT	LU	AT
3	GR	E	P	P
2	LU	GR	GR	E
1	P	P	E	GR

5. Conclusions

The TrendChart European Innovation Scoreboard (EIS) has been criticised on the grounds that many of the EIS indicators focus on a country's performance in 'high-technology' industries. While such industries are important, they are only a small component of the industrial make-up of most economies. Thus overall innovation performance of a country should also take into account the performance of the country in a range of industries in which it is active. This report explores the feasibility of constructing sectoral innovation scoreboards (SIS) to complement the EIS by analysing the innovation performance of EU countries within broad industry groupings. We use the characterisation of sectors according to R&D intensity first proposed by the OECD, which aggregates all manufacturing industries into 4 different categories based on the average R&D intensity across a range of OECD countries: High-, Medium-High, Medium-Low, and Low technology. The main question addressed is the extent to which the same countries are leaders or laggards in innovation performance in each of these major sector groups.

The analysis is based on 10 indicators for 14 EU countries, for which sectoral data were available to date. Eight out of the 10 indicators are similar to EIS indicators. For one of the EIS categories, *Human Resources*, none of the indicators are available by industry. An additional difficulty encountered was that for many of the countries a number of indicators were not available. Consequently, Ireland, Japan and the US have been excluded from the analysis as they have too few indicators.

The method permits two types of comparisons: across countries for the same sector, and across sectors within the same country. The latter can identify areas of sectoral specialisation in innovation.

At a general level, the results show that a country with a high ranking in high technology industries is also likely to have a high ranking in medium-high, medium-low, and low technology industries. Thus Finland is ranked 2nd amongst the EU countries in high technology and 1st in medium-low technology industries. A similar pattern occurs for the Netherlands. Both these countries have a significant lead in Europe in all industry groupings. Other countries that have above average performance in all four sectors are Sweden, Germany, and Belgium. The countries that lag behind most EU countries in all four industry groupings are Greece, Spain and Portugal. The remaining five EU countries show heterogeneous performances across the different industries.

The main conclusion from this exploratory analysis is that there is a great deal to be gained by analysing innovation performance across sectors. At odds with what could be expected, there is no reshuffling of country rankings when one looks at the innovation performance in industries other than high-tech. In addition, the single most important constraint is the lack of suitable data for some key variables, which would enable the analysis to include countries outside the EU-15. In the future, it would be of interest to have sector level data for the 10 acceding countries and for the United States.

ANNEX A. Sectoral Innovation Scoreboard. Data definition, Sources and Results

Table A1. Year of reference and details of computations.

	EU	AT	B	D	DK	E	FIN	F	GR	IT	LU	NL	P	S	UK	IS
1.1	1999	--	1999	1999	1999	1999	**1998**	1999	1999	1999	1999	1999[4,7,9]	1999	1999[1]	1999[1]	--
1.2a	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	--	1997[4,7,9]	1997	1997	1997	--
1.2b	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	--	1997[4,7,9]	1997	1997	1997	--
2.1	2000	2000	2000	--	2000	2000	2000	2000	2000	2000	2000	--	2000	2000	--	**2000**
2.2	2000	2000	2000	--	2000	2000	2000	2000	2000	2000	2000	--	2000	2000	--	**2000**
2.3	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	--	**2000**
2.4	1999	1999	1999[3,5,9]	1999	1999[2,9]	1999	**1998**	1999[3,6,9,10]	1999	1999	--	1999[4,7,9]	**1997**[2,8,9]	1999	1999	--
3.1	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	--
3.2	2000	2000	2000	--	2000	2000	2000	2000	2000	2000	2000	--	2000	2000	--	**2000**
3.3	2000	2000	2000	--	2000	2000	2000	2000	2000	2000	2000	--	2000	2000	--	**2000**

Years highlighted in **bold** indicate that the country is not included in the computation of the EU mean.

[1] Data for Low technology sectors is the sum of sectors 15 to 37 minus sectors 23 to 35 included.

[2] Data for High technology not available.

[3] High technology includes "Manufacture of pharmaceuticals, medicinal chemicals and botanical products" only.

[4] "Manufacture of aircraft and spacecraft" not included in High technology.

[5] "Manufacture of electrical machinery and apparatus n.e.c." and "Manufacture of motor vehicles, trailers and semi-trailers" not included in Medium-High technology.

[6] "Manufacture of electrical machinery and apparatus n.e.c." and "Manufacture of railway and tramway locomotives and rolling stock" not included in Medium-High technology.

[7] "Manufacture of railway and tramway locomotives and rolling stock" not included in Medium-High technology.

[8] Medium-High technology includes "Manufacture of electrical machinery and apparatus n.e.c." only.

[9] "Building and repairing of ships and boats" not included in Medium-Low technology.

[10] "Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials" not included in Low technology.

Table A2. Sectoral Innovation Scoreboard. High Technology Sectors

		EU	AT	B	D	DK	E	FIN	F	GR	IT	LU	NL	P	S	UK	IS
1.1	Business R&D over Value Added (%)	23.3	--	24.4	24.5	23.2	12.3	**38.6**	27.1	--	13.0	--	30.2	--	**43.1**	21.0	--
1.2a	EPO Patent (per thousand employees – date of grant)	5.9	5.2	8.5	8.7	5.1	*1.2*	8.4	6.1	*0.5*	3.5	--	**10.3**	*0.1*	6.7	3.8	--
1.2b	USPTO Patent (per thousand employees – date of grant)	2.2	1.5	**3.9**	2.4	2.5	*0.3*	3.1	2.8	*0.1*	*1.0*	--	**3.4**	*0.1*	**3.3**	2.2	--
2.1	SMEs innovating in-house (%)	61.2	*12.1*	78.3	70.4	*7.8*	46.1	57.2	56.4	40.4	66.6	--	--	--	59.5	--	39.4
2.2	SMEs innovation co-operation (%)	25.3	**60.3**	34.5	26.1	15.8	*11.1*	**43.1**	26.5	34.7	*11.0*	--	--	--	36.9	--	**39.4**
2.3	Innovation expenditures (%)	10.7	8.9	15.5	5.8	*1.7*	*3.7*	9.7	10.1	6.0	**17.7**	--	**25.3**	*2.9*	**15.8**	--	10.8
2.4	Investment Per Employee (KEuro)	7.9	9.2	6.9	8.6	--	4.7	10.3	*2.6*	--	8.9	--	10.3	--	14.3	9.0	--
3.1	Value Added per Employee (KEuro)	73.1	71.0	103.0	65.2	79.1	56.5	**126.4**	71.7	44.3	58.2	44.0	69.5	*34.8*	76.4	82.5	--
3.2	Sales new to firm and to market (% of total turnover)	14.3	13.4	*6.7*	11.4	**24.9**	10.6	13.4	13.1	8.6	**26.2**	--	--	--	8.8	--	--
3.3	Sales new to firm, not to market (% of total turnover)	33.4	18.2	24.8	36.4	39.3	27.3	48.6	26.1	*14.7*	41.3	--	--	--	30.1	--	--

Indicators are highlighted in **bold** when 50% or more above the EU mean and in *italics* when more than 50% below the EU mean.

Table A3. Sectoral Innovation Scoreboard. Medium High Technology Sectors

		EU	AT	B	D	DK	E	FIN	F	GR	IT	LU	NL	P	S	UK	IS
1.1	Business R&D over Value Added (%)	8.1	--	7.8	10.4	7.0	2.8	8.5	8.2	--	*3.0*	--	7.7	--	**14.1**	7.5	--
1.2a	EPO Patent (per thousand employees – date of grant)	1.0	0.9	1.3	1.3	*0.4*	0.2	0.6	1.5	*0.1*	0.5	--	1.9	*0.0*	1.0	0.6	--
1.2b	USPTO Patent (per thousand employees – date of grant)	0.9	0.8	1.1	1.2	1.1	0.1	**1.4**	1.2	*0.0*	0.5	--	**1.4**	*0.0*	**1.4**	0.9	--
2.1	SMEs innovating in-house (%)	57.1	45.3	56.1	67.0	*20.6*	40.0	46.2	--	29.3	39.6	49.1	55.2	--	42.9	--	51.9
2.2	SMEs innovation co-operation (%)	15.0	*7.4*	18.5	17.4	**25.5**	6.5	**28.1**	--	8.6	*4.1*	**24.3**	15.2	--	20.8	--	20.0
2.3	Innovation expenditures (%)	4.0	3.3	**6.4**	4.2	*0.9*	2.4	3.1	3.8	3.4	3.0	3.6	3.4	2.7	6.1	--	4.0
2.4	Investment Per Employee (KEuro)	8.7	8.1	9.0	9.0	*4.2*	6.9	*3.6*	8.4	*2.2*	9.0	--	**13.4**	*1.6*	10.4	8.6	--
3.1	Value Added per Employee (KEuro)	58.3	63.1	78.0	59.6	50.5	47.4	58.8	58.5	40.3	48.3	68.7	71.5	*26.3*	65.2	59.8	--
3.2	Sales new to firm and to market (% of total turnover)	10.4	13.3	7.8	7.8	**17.8**	6.6	13.6	--	9.6	19.2	*1.2*	--	--	*4.5*	--	*3.9*
3.3	Sales new to firm, not to market (% of total turnover)	24.3	32.0	17.6	21.8	34.4	22.0	19.1	--	19.4	31.4	18.8	28.6	--	22.5	--	18.3

Indicators are highlighted in **bold** when 50% above the EU mean and in *italics* when 50% below the EU mean.

Table A4. Sectoral Innovation Scoreboard. Medium Low Technology Sectors

		EU	AT	B	D	DK	E	FIN	F	GR	IT	LU	NL	P	S	UK	IS
1.1	Business R&D over Value Added (%)	1.7	--	**3.3**	1.9	2.5	1.1	**4.1**	2.6	--	*0.4*	--	1.9	--	**2.6**	1.6	--
1.2a	EPO Patent (per thousand employees – date of grant)	0.5	**0.8**	0.4	**1.0**	0.4	*0.1*	0.4	0.6	*0.0*	0.3	--	0.8	*0.0*	**1.1**	0.3	--
1.2b	USPTO Patent (per thousand employees – date of grant)	0.3	0.4	0.4	**0.4**	0.3	*0.0*	**0.5**	0.3	*0.0*	*0.1*	--	0.4	*0.0*	**0.5**	0.2	--
2.1	SMEs innovating in-house (%)	41.0	41.0	47.0	51.3	*9.7*	--	39.5	31.0	21.1	38.9	21.8	38.5	39.7	30.6	--	36.9
2.2	SMEs innovation co-operation (%)	8.9	8.5	--	10.4	--	--	**19.6**	11.6	--	*3.3*	12.9	9.7	5.9	--	--	10.7
2.3	Innovation expenditures (%)	1.6	--	--	1.5	1.9	1.4	--	1.1	**4.7**	1.8	1.5	1.5	2.1	2.1	--	*0.6*
2.4	Investment Per Employee (KEuro)	8.0	9.7	**12.0**	7.9	7.9	7.0	8.0	4.6	5.4	11.4	--	8.2	5.9	9.5	6.4	--
3.1	Value Added per Employee (KEuro)	50.4	59.7	66.7	52.7	48.5	42.5	58.8	51.8	53.5	44.3	70.4	62.0	*23.7*	53.4	55.1	--
3.2	Sales new to firm and to market (% of total turnover)	7.2	6.6	3.6	6.4	--	--	5.3	4.2	--	**11.9**	*0.1*	--	10.4	--	--	*1.3*
3.3	Sales new to firm, not to market (% of total turnover)	16.3	18.1	11.0	17.1	--	--	16.8	8.4	--	21.6	*0.4*	22.7	18.0	--	--	13.9

Indicators are highlighted in **bold** when 50% above the EU mean and in *italics* when 50% below the EU mean.

Table A5. Sectoral Innovation Scoreboard. Low Technology Sectors

		EU	AT	B	D	DK	E	FIN	F	GR	IT	LU	NL	P	S	UK	IS
1.1	Business R&D over Value Added (%)	0.7	--	**1.4**	0.7	1.0	0.5	**1.8**	0.9	--	*0.1*	--	**1.3**	--	**1.7**	0.6	--
1.2a	EPO Patent (per thousand employees – date of grant)	0.2	0.2	**0.4**	**0.3**	**0.3**	*0.0*	0.2	0.3	0.0	0.1	--	**0.3**	*0.0*	**0.3**	0.1	--
1.2b	USPTO Patent (per thousand employees – date of grant)	0.02	0.01	**0.05**	**0.03**	**0.06**	*0.00*	0.03	**0.03**	*0.00*	*0.00*	--	0.03	*0.00*	**0.04**	0.03	--
2.1	SMEs innovating in-house (%)	36.4	30.9	40.9	47.0	20.2	--	37.5	--	*12.3*	27.9	--	--	32.1	31.2	--	46.1
2.2	SMEs innovation co-operation (%)	4.1	3.8	--	4.4	--	--	**18.3**	--	--	*1.3*	**12.8**	--	4.5	--	--	**8.9**
2.3	Innovation expenditures (%)	1.4	--	--	1.4	*0.4*	1.5	--	1.1	1.1	1.7	--	1.2	**3.2**	1.0	--	*0.4*
2.4	Investment Per Employee (KEuro)	6.7	6.7	11.3	7.2	8.7	4.5	8.6	6.3	*3.1*	7.4	--	6.2	*2.7*	**13.3**	5.7	--
3.1	Value Added per Employee (KEuro)	42.0	47.2	49.1	42.7	45.5	30.6	**65.7**	41.6	33.2	35.0	**67.6**	55.2	*15.4*	58.8	54.2	--
3.2	Sales new to firm and to market (% of total turnover)	10.3	*3.4*	5.8	8.2	--	--	6.5	--	--	**16.1**	*0.9*	--	7.4	--	--	--
3.3	Sales new to firm, not to market (% of total turnover)	19.9	12.8	10.6	19.9	--	--	11.2	--	--	25.1	*2.6*	--	13.5	--	--	--

Indicators are highlighted in **bold** when 50% above the EU mean and in *italics* when 50% below the EU mean.