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Benchmarking Innovation Policy and Innovation Framework Conditions

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FORA

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Foreword

In the report "The New Economy: Beyond the Hype – The OECD Growth Project (2001)", the OECD identified 4 areas that are likely to be the principal factors in driving economic growth in the future: innovation, entrepreneurship, ICT and human resources.

In the future innovation and technology diffusion will be even more critical to the economic and social progress of advanced industrialized countries. In order to pursue an effective innovation policy it is therefore necessary to build a comprehensive methodology for strengthening knowledge-transfer across the OECD.

Based on the "Roadmap for Benchmarking Business Policies" (OECD, 2002), this publication investigates innovation performance and innovation framework conditions across 27 OECD countries using a variety of quantitative and qualitative data and analysis.

The report is made in cooperation with the Norwegian Ministry for Trade and Industry and Inside Consulting.

Summary
This report benchmarks innovation and innovation policy across 27 OECD countries.

In the future innovation and innovation diffusion will be even more critical to the economic and social progress of advanced industrialized countries, highlighting the need for building comprehensive methodologies in measuring innovation and innovation performance across the OECD.

The analysis presented in this report is based on two assumptions: 1) that government initiatives have a significant impact on innovation activity and 2) that methodology can be applied to compare micro-policies in selected countries and provide policy-direction at the individual country level.

The report identifies a group of 7 countries as leaders in innovation performance: Sweden, Switzerland, Japan, Finland, the US, Germany and the Netherlands.

The analyses show that:

- There is a strong link between innovation performance and innovation framework conditions.

- A high innovation performance is directly related to an active innovation policy, i.e. policy has a key role to play in ensuring that new innovations are developed and technology properly diffused throughout the economy.

- Policy measures need to be applied in a manner that suits the national context in which countries operate if any attempt to learn from top-performing countries is to be made

Based on a mix of qualitative and quantitative information in assessing innovation performance and innovation framework conditions, the report considers the effectiveness of policies in the specific economic and institutional context in which they operate.

A number of country case studies have been prepared to compare micro-policies to provide policy-direction at the individual country level.

A country's innovation performance will depend not only on how it performs in each individual element of the *national innovation system* (NIS), but how these separate elements interact. Different configurations can result in a successful overall innovation performance.

It also follows that policy measures need to be altered to suit the national context, including institutional factors, industry specialization and size. As a result, policy instruments that may be effective in improving innovative performance in one country may be less effective or even inappropriate in another.

A simple “cut-and-paste” approach, where policy areas are randomly copied and applied by low-performing countries could easily be detrimental to innovation performance. However, we are confident that the analysis put forward will serve as an inspiration in designing policies that help improve overall innovation performance.

It is important to bear in mind that individual elements or particular combinations of the NIS may only have an effect on innovation performance with a significant lag. Thus an assessment made today of performance may imply changes both for better or for worse in the future.

Chapter I of the report defines and measures innovation performance and technology diffusion across 27 OECD. Chapter II explores and quantifies innovation framework conditions across a range of policy areas. Chapter III is devoted to exploring the link between innovation performance and innovation framework conditions.

The accompanying paper titled *“Benchmarking Innovation Policy and Innovation Framework Conditions – Country Case Studies”* examines the relationship between innovation performance and innovation framework conditions in selected countries and illustrates how these countries can learn from top performing countries in designing effective policies to boost innovation performance.

1. Defining and measuring performance in fostering innovation and technology diffusion

Countries that fail to nurture innovation activities will find themselves in direct competition with newly industrialized countries as the latter increasingly apply existing technologies and business methods. The development and exploitation of new products, processes, services and systems and the constant upgrading of those which a country already possesses is the only way in which advanced industrialized countries can maintain and increase their levels of economic and social prosperity.

Thus the impact of innovation on productivity and growth creation is not limited to the initial introduction of new products, processes, services and systems, but also to the subsequent diffusion of new technology throughout the economy.[1]

Benchmarking innovation and innovation framework conditions is by no means an easy task. For policy making purposes it is not sufficient to measure the output of a country's innovation performance, it is also necessary to ascertain how that performance was achieved.

Assessing national innovation performance is determined by 1) innovation activity, i.e. the number of products, processes, services and concepts developed and 2) technology diffusion, i.e. the diffusion of those innovations throughout the economy. For all but the largest OECD countries, the vast majority of novel innovations will come from abroad. However all OECD countries must be effective at exploiting new science and technology appropriate to their needs from wherever it is to be found in the world.

When comparing and ranking countries in the areas of innovation, competitiveness, and globalisation, composite indicators are valued for their ability to integrate large amounts of information into easily understood formats. The proliferation of composite indicators will raise questions regarding their accuracy and reliability. Due to the sensitivity of the results to different weighting and aggregation techniques as well as the problems of missing data, composite indicators can result in distorted findings on country performance. However composite indicators will continue to be developed due to their usefulness as a communication tool and for analytical purposes.[2]

[1] See also "A Strategic View of Innovation Policy: A Proposed Methodology for Assessing Innovation Policy and Performance", John Barber, OECD DSTI/STP/TIP(2003)4
[2] See also "Composite Indicators of Country Performance: A Critical Assessment", Michael Freudenberg, OECD DSTI/IND(2003)5

Measuring innovation activity
Data on innovation activity is based on surveys carried out by the EU Commission, the World Economic Forum (WEF), and the International Institute for Management Development (IMD). In addition to the survey data the number of patents in 'triadic' families has been added to the innovation index. The latter measures innovation activity in businesses and technologies that typically patent new products.

The following indicators have been applied in sizing overall innovation activity:

- *Number of companies having introduced new or significantly improved products/processes*
- *"Business' assessment of innovation activity"* is based on 3 individual indicators and measures 1) the extent to which companies develop new products and processes, 2) to which extent companies develop new designs and 3) an assessment of the extent to which innovation influences on corporate revenues.
- *The number of patents in 'triadic' patent families* measures the number of patented innovations introduced across the US, EU, and Japan.

To measure the quality of survey data a number of test have been conducted leaving us to conclude that the data used is indeed valid.[3]

The three indicators have been combined into one composite index for all 27 countries (please refer to appendix 5). Switzerland, Germany and Japan are identified as leaders in innovation activity with Sweden and the US rounding up the top-5.

Measuring technology diffusion
Measuring innovation diffusion across companies is by no means a straightforward exercise. Diffusion is facilitated by job rotation, networking, formalized collaboration, and by intra-company purchase of products and technologies.

Available data from the OECD allows for comparisons of formal diffusion, while data on informal diffusion (personal networks, job rotation) is currently unavailable.

The following indicators have been applied in sizing innovation diffusion:

[3] Please refer to Appendix 4 for an in-depth discussion on the use of survey data in benchmarking innovation

- *Import of technology, patents, franchising, and purchase of research and technical consulting.* The indicator measures to which extent companies are able to use innovations developed in other countries.
- *"Business' assessment of the application of new technology"* measures the ability of companies in introducing and using new technology.
- *Share of firms collaborating with other firms on innovation and technology* measures the ability of companies in applying knowledge, know-how and ideas developed by other companies.

The first two indicators illustrate the speed at which new technology is applied, while the third indicator measures the application of knowledge, know-how and ideas developed by other companies.

The 3 indicators have been combined into a composite index (please refer to appendix 5). The index identifies Sweden, Ireland and Finland as top performers in terms of technology diffusion. Japan and Switzerland, ranked 5 and 6, perform well and were also ranked in the top-3 on innovation activity.

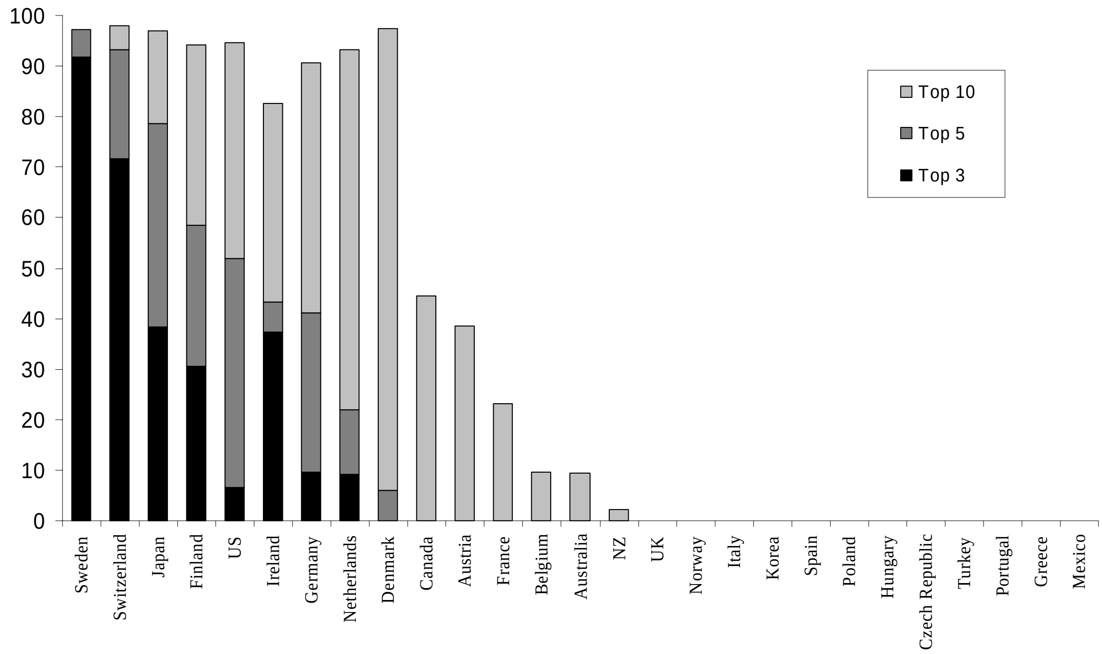
Measuring overall innovation performance

Combining innovation activity and technology diffusion into one composite indicator should take into account, the methodological weaknesses of constructing composite indicators described above.

No direct solution to the weighting[4] problem exists, but the robustness of the ranking is tested by assigning weights randomly and repeating the calculation. This provides a possible ranking for each country. Based on the distribution the probability of being among for example the top 5 performing countries can be calculated. For this purpose the calculation was repeated 3600 times for each of the 27 countries.

The distribution does not suggest a specific ranking but rather a very robust division of countries.

Figure 1.1 Possible innovation performance ranking based on 3600 randomly generated weights



[4] In addition to the weighting issue, this work points to two additional problems – missing data and standardization – with composite indicators. Appendix 2 and 3 details the methodology applied in attempting to solve these issues.

The analysis shows that Sweden, Switzerland and Japan are ranked in the top 5 in 80% of the outcomes. The 3 top performers are followed by a group of 5 countries (Finland, the US, Ireland, Germany, and the Netherlands) which all rank among the top 5 in more than 20% of the outcomes. The US, Germany and The Netherlands scores well on all indicators and are in the top 3 on 1-2 indicators.
The high Irish ranking should be treated with caution, as the country is not ranked in the top 10 in 20% of the outcomes. The selected indicators show that Ireland is ranked first on “import of foreign technology”, but only has one other top-ranking and ranks in the lower one-third on two other indicators.[5]

In conclusion, 7 countries are identified as being top performers in overall innovation performance. This group is referred to as the “top-7” throughout the report:

- Sweden
- Switzerland
- Japan
- Finland
- USA
- Germany
- The Netherlands

[5] For further analyses of the Irish ranking please refer to Chapter 3

2. Defining and measuring performance in innovation framework conditions

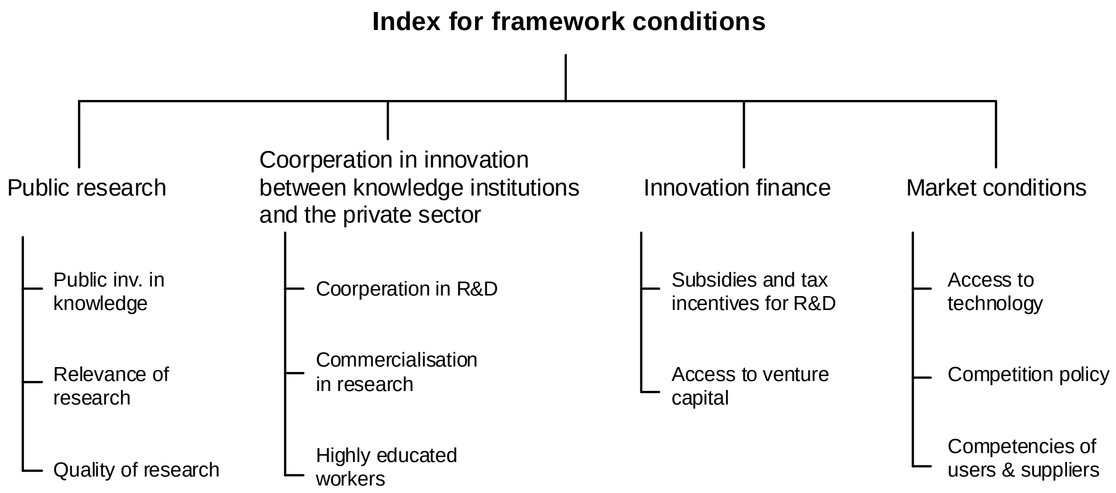
A total of 12 individual policy areas have been identified in sizing innovation framework conditions. For each of the policy areas a number of indicators have been selected to further investigate framework conditions across the selected countries (see appendix 1). Table 2.1 highlights current data coverage for each of the policy areas.

Table 2.1 Data coverage

Policy	Good coverage	Partial coverage	No coverage
Public investment in R&D	√		
Quality of research	√		
Relevance of research		√	
Cooperation in R&D	√		
Commercialization of research		√	
Highly educated workers		√	
Subsidies and tax incentives	√		
Access to venture capital	√		
Customers and suppliers		√	
Competition policy		√	
Access to technology		√	
Access to competencies			÷

The overall benchmarking of innovation framework conditions follows the structure presented in Figure 2.1 below. Benchmarking is carried out for each of the 11 policy areas with sufficient data coverage. The policy areas are then grouped in 4 sub-indices and finally one composite indicator for innovation framework conditions is presented.

Figure 2.1 Benchmarking innovation framework conditions



To further break down individual policy areas the following section highlights country performances on each of the 4 sub-indices:

Public research

Public research can be split up into three individual policy areas:

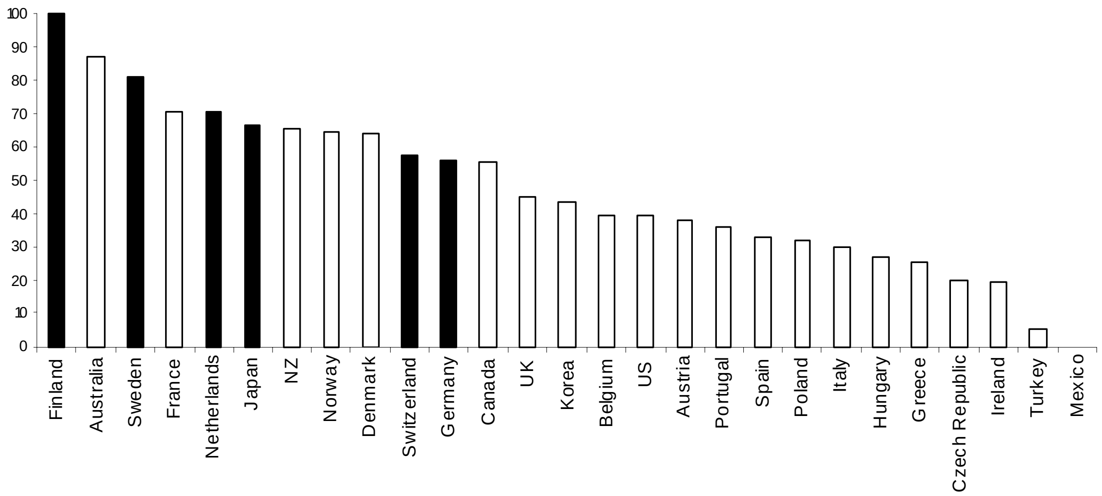
Level of public investment in research

The level of public research is typically measured by the level of government funding allocated to research as well as the number of public researchers as a share of the total work force:

- *Government appropriations or outlays for R&D in share of GDP*
- *Government researchers pr. 10 000 labour force.* Researchers are defined as professionals that are involved in the development and creation of new products, processes, methods and systems.

Figure 2.2 combines the two indicators in a composite index. Finland, Australia and Sweden make up the top-three. All top-7 countries are ranked above the OECD average.

Figure 2.2 Index for public investment in research



Relevance of research

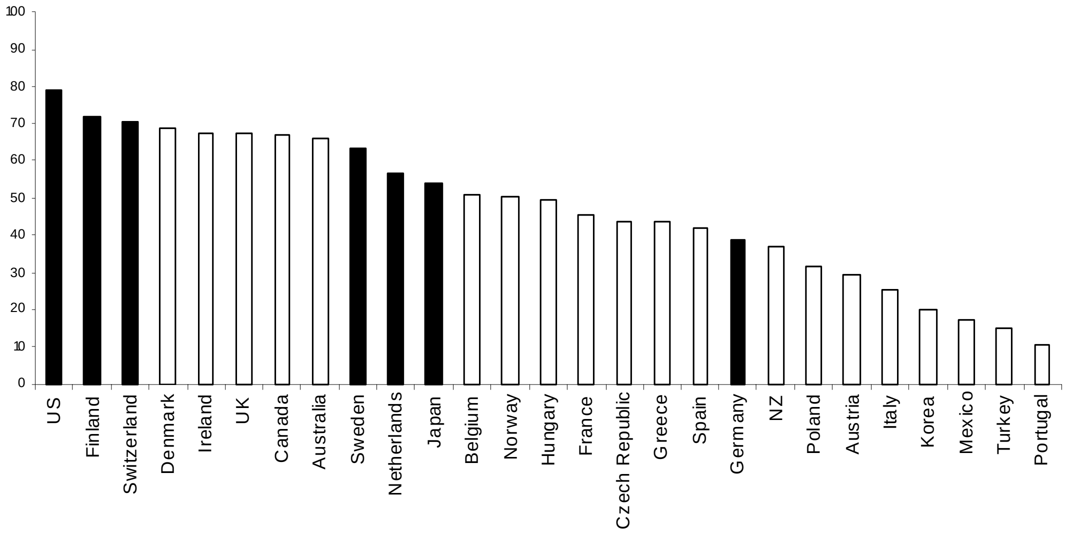
Available data fails to accurately measure the degree of relevance of public research. In response to this, the OECD and the EU has published data that helps measure relevance of public research by measuring how individual countries prioritize the allocation of government funds in technology/natural sciences, social sciences, health, humanities, etc. The more funds allocated to technology/natural sciences the higher the rating on EU/OECD indicators.

The OECD and the EU also provides data on:

- *The number of scientific papers cited in patents* which measures the number of patented innovations introduced in the US market
- *The number of scientific and technical articles published in industry-related periodicals*, which measures the degree of specialisation in areas of high industry relevance.

Figure 2.3 ranks countries based on a composite index for the above mentioned indicators. As far as the top-7 is concerned, the US, Finland and Switzerland head the ranking, whereas Sweden, The Netherlands and Japan are lacking behind. Germany is ranked in the bottom one-third.

Figure 2.3 Index for relevance of public research



Quality of research
The quality of public research is measured by the ability of scientists and researchers in fostering research that is beneficial to overall economic and social progress. Traditionally the quality of research is measured by:

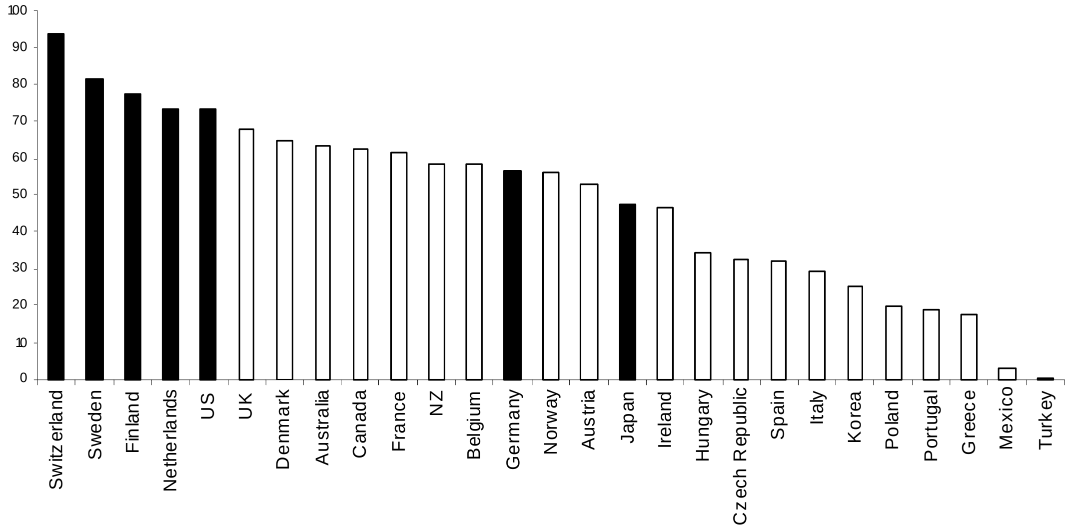
- *The number of scientific and technical articles published in internationally renowned periodicals.* This indicator measures the volume of high quality research rather than the average quality of research.

In addition data from WEF's annual survey has been added to the index:

- *"Business' assessment of the quality of public research"*

The ranking show that 5 of the top-7 head the ranking, while Germany and Japan's performance is average.

Figure 2.4 Index for quality of public research



Summary
Sweden and Finland top all three indices for public research, while Switzerland and the US are ranked high on quality and relevance in public research. Germany are lacking behind on all three indices with the Netherlands performing well on size and quality of public research. Ranked low on quality Japan show good performance in government funding.

Co-operation on knowledge-sharing between knowledge institutions and the private sector
Greater formal and informal knowledge-sharing among R&D conducting companies and between these and public research institutions are critical for boosting innovation performance. Businesses are eager to exploit research undertaken by the higher education and government sector, the higher education sector is interested in obtaining funding for current and future research activities by commercializing their research efforts and governments look to alliances that ensure the economic and social benefits from public research

There are three main drivers in measuring the level of co-operation:

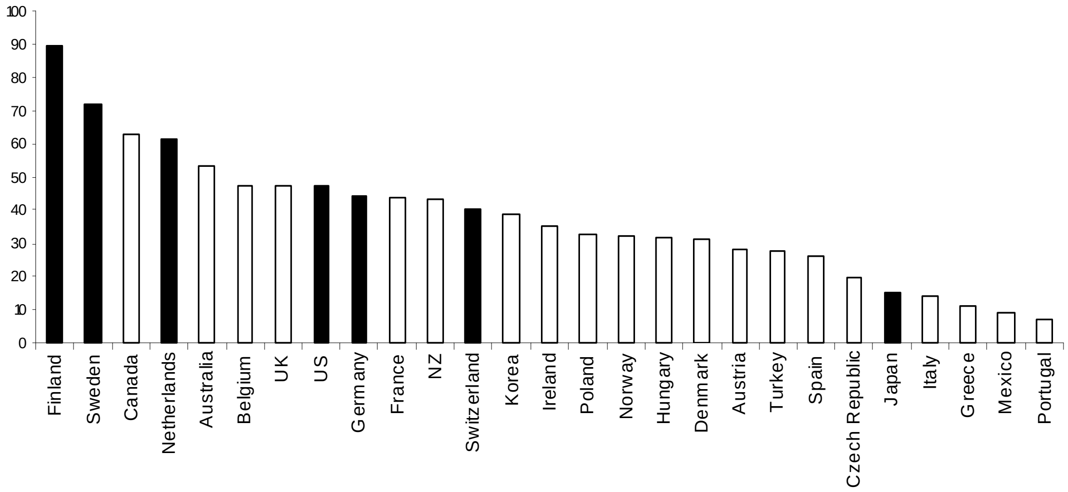
Co-operation in R&D
Collaboration in R & D is a prerequisite for transferring knowledge between public and private scientists and engineers. R&D co-operation is usually carried out in two ways: Co-funded R&D projects involving private and public researchers and commissioned research.

Current data from the OECD, the IMD and the EU cover both scenarios:

- *"Business' assessment of R&D co-operation"* measures the extent of co-operation with public research institutions.
- *Share of companies with co-operation agreements with government or higher education*
- *Business funding of public research as a share of GDP*

Finland is the top performer, with Sweden and The Netherlands ranking in the top-5. The US and Germany are in the top one-third with Japan performing well below the OECD average.

Figure 2.5 Index for co-operation in R&D



Commercialization of research
Public research can be commercialized in three ways:

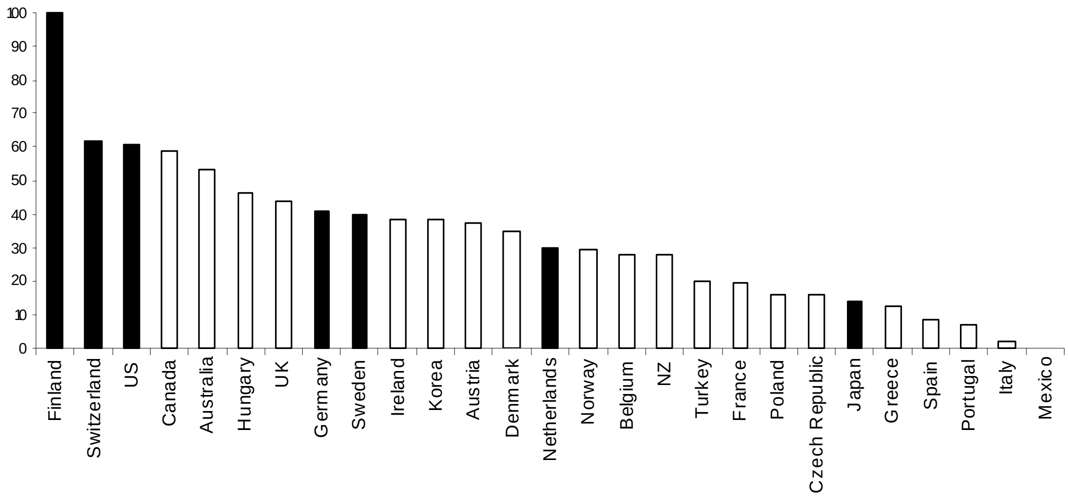
- A researcher establishes a business in order to commercialize invention
- Rights are sold to a private company, who assumes ownership of the patent
- The public institution agrees to license production to a private company agreement.

No comparable data across the OECD is available in the area of commercialisation. The only available "hard" data is the proliferation of incubators, while the IMD in their annual survey measures the level of knowledge transfer from academic institutions:

- *The number of incubators across 14 OECD countries*. Incubators are designed to stimulate the creation of new businesses.
- *"Business' assessment of technology-transfer from universities to businesses"* This indicator measures the general opinion on the level of technology-transfer between universities and private business.

The index identifies Finland as a clear leader, which is primarily a result of a large number of incubators. Switzerland and the US also perform well with Japan ranked in the lower one-third of the index.

Figure 2.6 Index for commercialisation of research



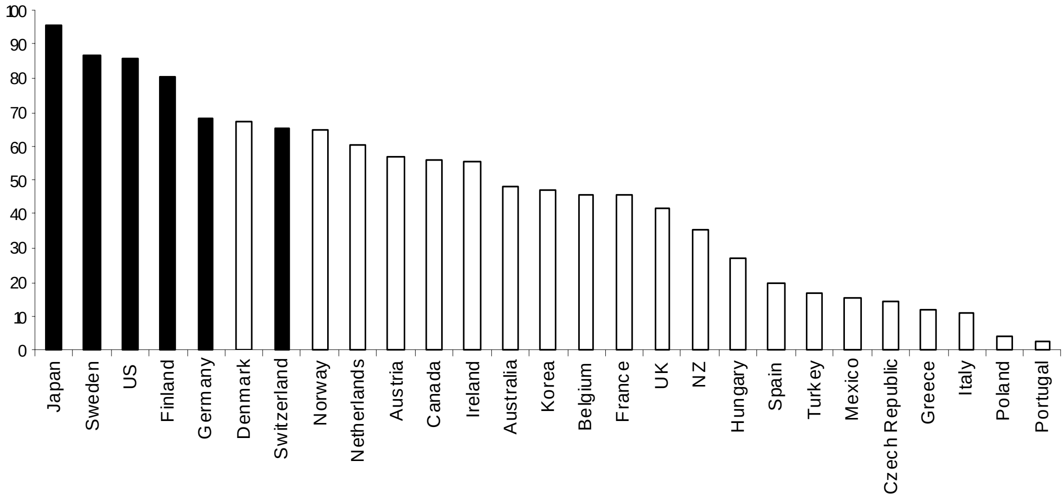
Highly educated workers

The generation of new knowledge is strongly influenced by the supply of skilled human resources. Data on the number of people with a university degree is not available. Existing data include:

- The number of scientist and engineers as share of labour force measures the number of researchers with a university degree employed in the private sector.
- Share of knowledge workers in private companies

Japan is the top performer and overall the top-7 dominates the ranking with Denmark and Norway claiming the number 6 and 8 position, respectively. In light of Japan's poor performance in indicators for "commercialization of research" and "co-operation on R&D" it is evident that the primary transfer of knowledge between higher education and the private sector in Japan is carried out through the direct recruitment of candidates from Japan's academic institutions.

Figure 2.7 Index for co-operation on knowledge-sharing between private and public sector



Summary

Finland has the best framework conditions for co-operation on knowledge-sharing between knowledge institutions and the private sector, claiming top position on all three sub-indices. Switzerland, the US and Sweden are ranked high in 2 out of 3 indicators.

Innovation financing

This report focuses on two areas of financing, subsidies and tax incentives and venture capital.

Most OECD countries have special tax treatment for R&D expenditures, such as immediate write-off of current R&D activities and various types of tax relief.

The introduction of tax incentives and government subsidies is often explained by the fact that overall social and economic benefits of nurturing R&D activities. In other words: the collective benefit for the economy in supporting R&D is far greater than the benefits incurred by the individual company. This due to the likelihood that the firm investing in R&D will not be able to fully capture all benefits, with some know-how spilling over to other firms.

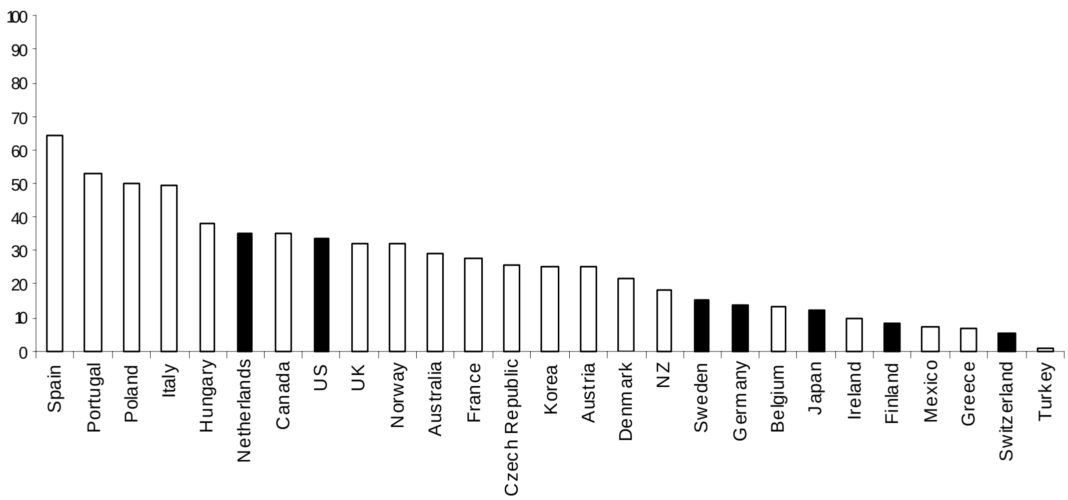
Subsidies and tax incentives for R & D

OECD data on innovation is available for two categories:

- Public financing of R & D through tax incentives
- Public financing of R & D through direct subsidies

All but two of the top-7 countries are in ranked the lower part of the index. The composite index shows Spain, Portugal, Poland and Italy claiming the largest share of government subsidies and tax incentives.

Figure 2.8 Index for government support for R&D



It is important to stress that the benchmarking analysis does not explain the causality between differences in business environment and performance. The fact that the top-7 put little emphasis on tax incentives and subsidies does not imply that subsidies and tax incentives are of little or no importance, but rather that the top-7 perform well *despite* the limited use of subsidies and tax incentives.

Access to venture capital
Venture capital is usually provided by specialized financial firms acting as intermediaries between primary source of finance (pension funds or banks) and companies (formal venture capital). Because of the asymmetries involved in assessing the high risk associated with the start-up of high-technology companies, government institutions are increasingly investing in the development of the venture capital market.

Venture capital is composed of three development phases: seed, start-up and expansion. Figure 2.9 details total venture capital investment in the OECD countries as a share of GDP. Historically the US ranks high on venture capital. Except for Japan, the performance of the other top-7 countries is average.

Figure 2.9 Venture capital investments in seed, start-up and expansion as share of GDP

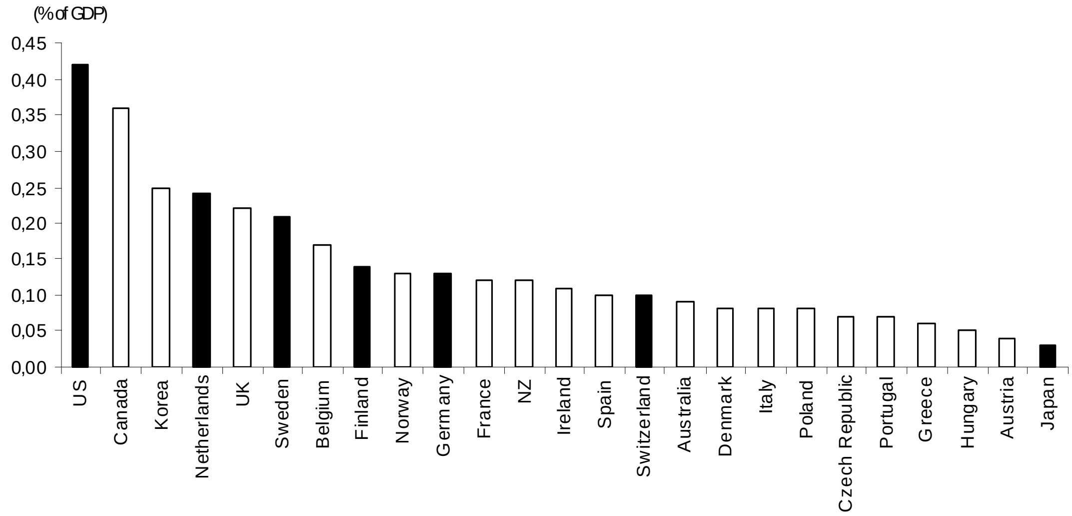


Figure 2.9 show the performance of the top-7 in the area of venture capital to be somewhat fragmented.

Relative to GDP, venture capital investment is quite small across most OECD countries, but remains a major source for funding for new technology-based firms and plays a role in promoting innovations developed by such firms, while innovation within large, well-established companies seldom is financed trough the use of venture capital.

Market conditions

Due to the scarcity of full sets of comparable quantitative data the analysis of market conditions should be treated with some caution. The analysis presented here is primarily based on high-quality surveys[6]. However they offer only partial coverage of the individual policy areas.

Competencies of users and suppliers

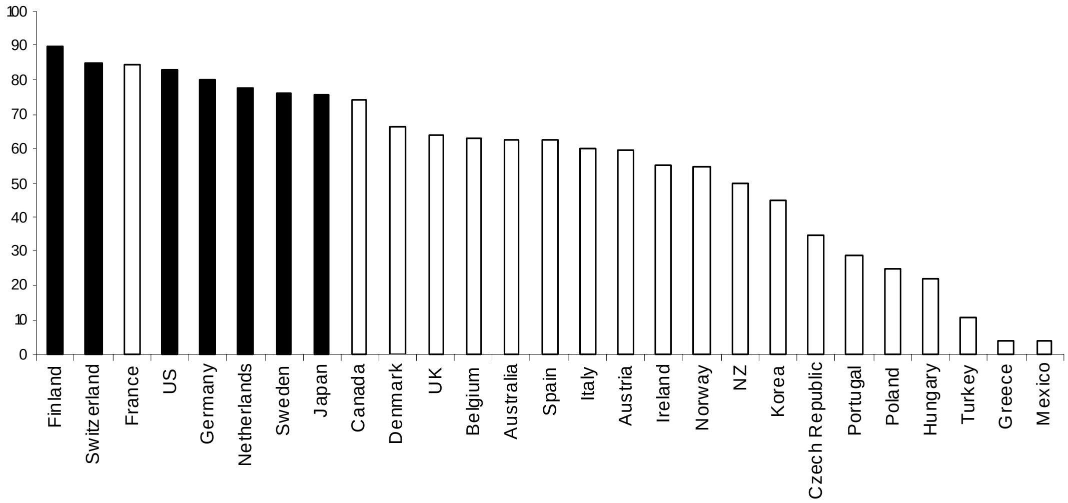
The competencies of suppliers and buyers are an important source in enhancing innovation. The indicator is highlighted in the WEF' annual questionnaire:

- "Business' assessment of whether buyers are knowledgeable and demanding/buying innovative products"
- "Business' assessment of technological capability and international competitiveness of local suppliers"
- "Business' assessment of the extent to which government procurement of advanced technology products is based on price alone or in fact encourages innovation"

[6] See Appendix 4

Indicators provide valuable information on availability of competencies and how competencies are applied in fostering innovation. Figure 2.10 shows the top-7 dominating the ranking with only France being able to match the top-7.

Figure 2.10 Index for competencies among customers and suppliers



Access to technology

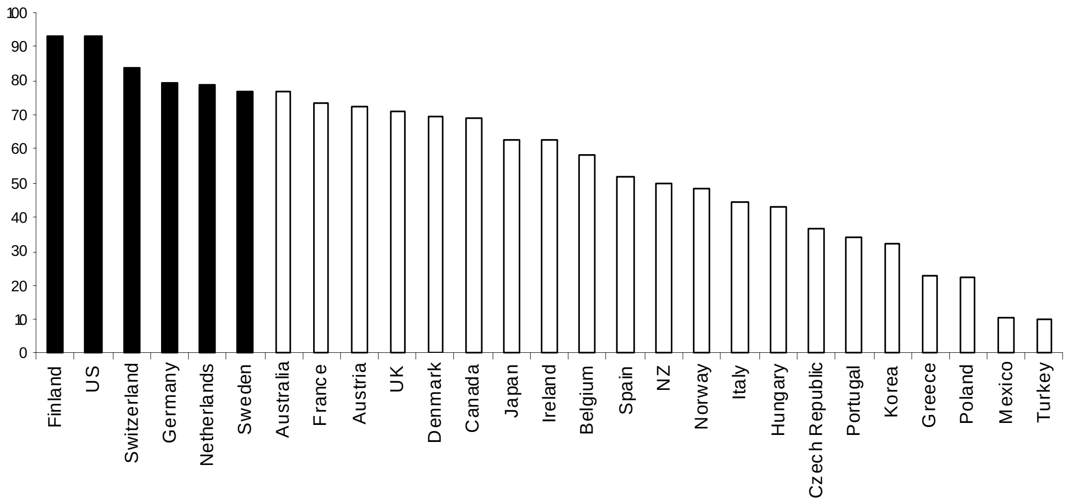
Access to technology is measured by the quality of government-supported services in terms of availability of specialized research and training locally as well as the quality of private suppliers of technology and know-how.

Surveys from the IMD and the WEF contain three questions that provide useful information on measuring access to technology:

- “Business assessment of technology diffusion”
- “Availability of specialized research and training locally”
- “Business assessment of protection of patents and IPRs”

Japan is the only top-7 country not performing well on the index with Finland and the US far ahead of their competitors.

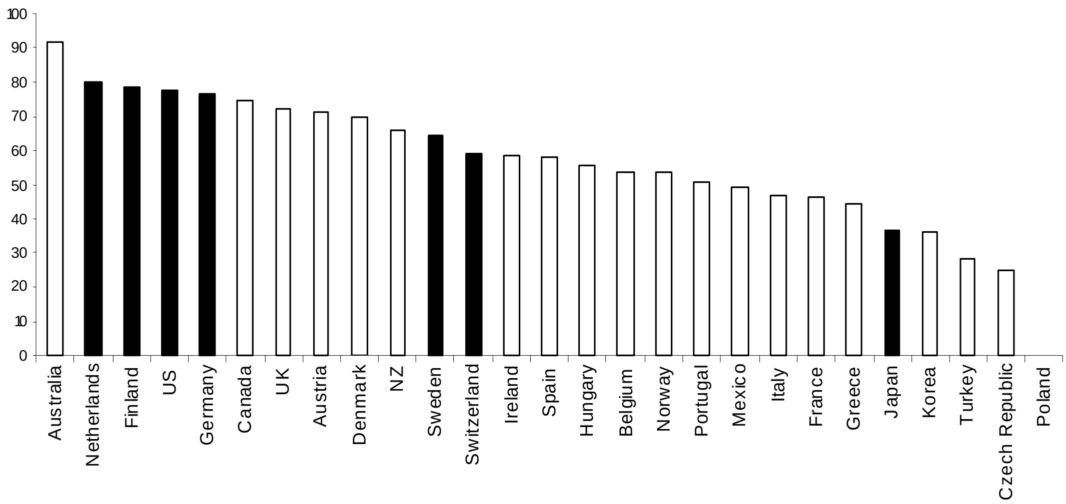
Figure 2.11 Index for companies' access to technology



Competition Policy

Based on data from the OECD, the Danish Competition Authority has developed a comprehensive index for sizing the level of government regulation of local competition. A total of 15 components are applied in composing the index, including entry barriers for start-ups and price control. [7]

Figure 2.12 Index for level of competition policy



[7] In their annual survey "Konkurrenceredegørelsen 2002" (http://www.ks.dk/publikationer/konkurrenceredegoerelsen/kr2002/), the Danish Competition Authority has measured the competitive landscape. In addition to the OECD index information on prices and profits are included. The inclusion of prices and profits raises a number of issues as far as benchmarking innovation is concerned. Innovation will often lead to higher prices and improved quality. However, it is difficult to adjust for differences in quality when comparing prices and profits on an international level. Current data does not allow for comparing actual competition across borders and current analysis is based solely on the level of government regulation.

Four of the top-7 countries are ranked in the top-5. Sweden and Switzerland are lacking somewhat behind while Japan's performance is particularly week.

Summary

Due to the nature of the survey data used in sizing "market conditions" the overall ranking should be treated with some degree of caution. The top-7 dominates the indicators for "access to technology" and "interaction with users and suppliers". However, due to the generic nature of the survey data used in sizing competition policy it is likely that the indicators measure elements from other framework conditions, notably "co-operation on R&D".

Measuring overall innovation framework conditions

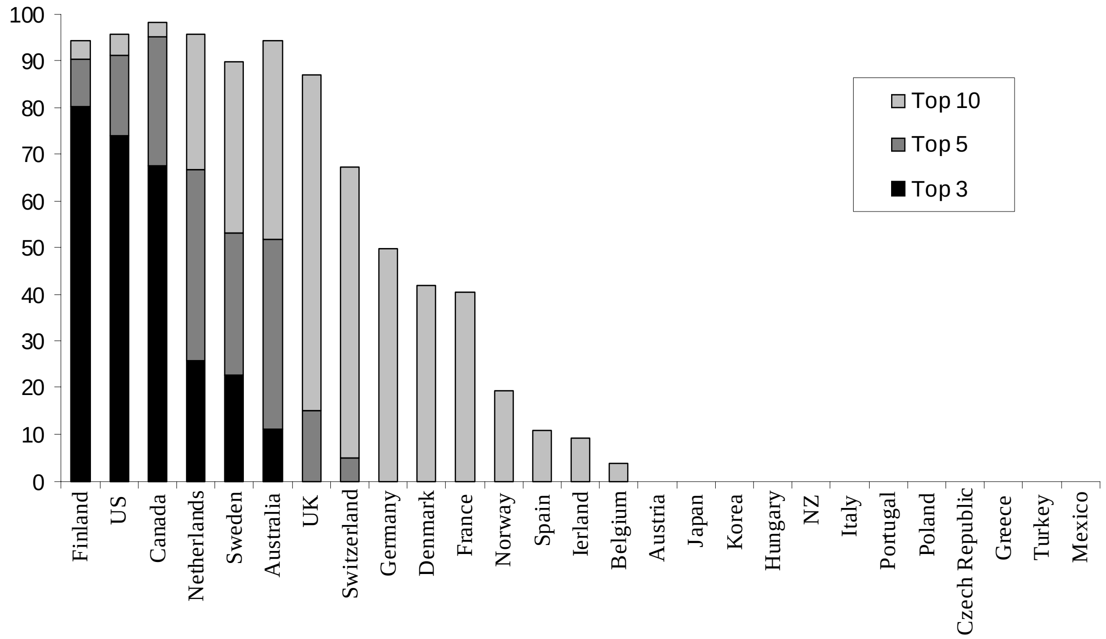
Unfortunately little knowledge exists on the relative importance of individual policy areas. To test the sensitivity of the ranking, a robustness analysis has been performed where the calculation is repeated 100.000 times using different weights and indexations methods. The robustness analysis shows the ranking to be robust. (For a detailed analysis of methodology and test results see appendix 3).

Figure 2.13 details how often individual countries are ranked in the top-3, top-5- and top-10, respectively.

Finland, the US and Canada are ranked in the top-3 in 70 to 80% of the outcomes. The data suggests that the position of Finland, the US and Canada in the composite index is independent of how individual indicators are weighed. The Netherlands, Sweden and Australia are candidates for the top-5, while Japan performs well below the OECD average.[8]

[8] Further analysis on Japan is presented in Chapter 3.

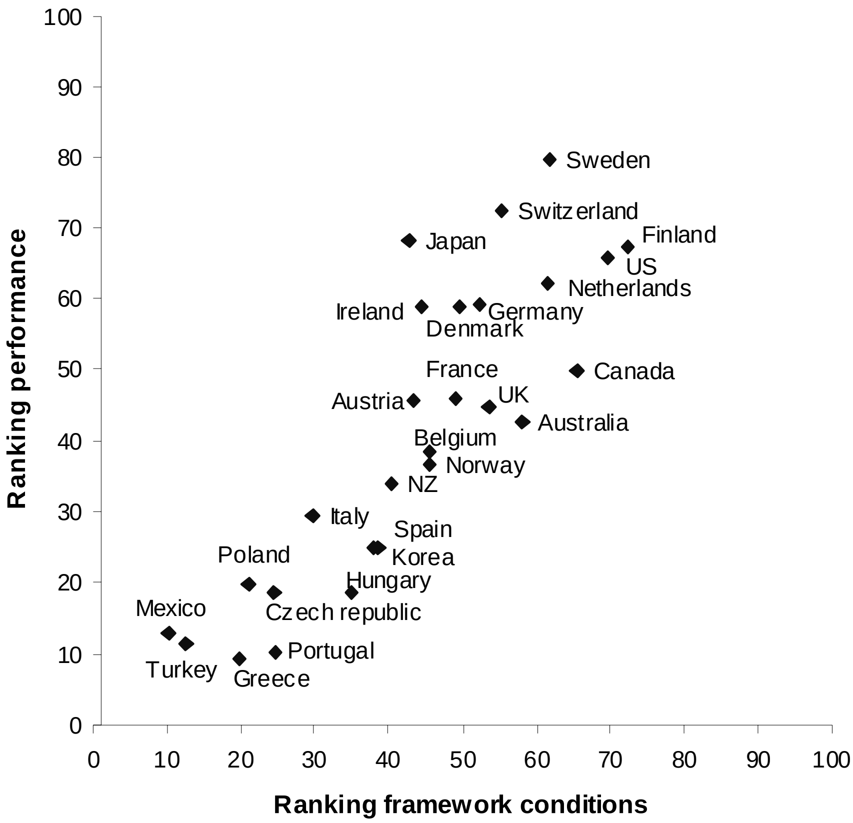
Figure 2.13 Possible innovation framework conditions ranking based on 100 000 randomly generated weights



3. Testing link between innovation performance and innovation framework

For the majority of countries analyzed in the report, there is a strong link between innovation performance and innovation framework conditions, i.e. a high ranking in performance is matched by a high ranking in innovation framework conditions.

Figure 3.1 Linking innovation performance and innovation framework conditions



While correlation is solid for most countries, Japan, Ireland, Australia and Canada are candidates for further analysis since they differ from the general conclusion that performance and framework conditions go hand-in-hand.

Japan

After Japan assumed control of the technological leadership in the 1990s, a higher priority was given to basic research. Today 40% of all basic research in R&D is carried out in private companies[9].

As a consequence, the need for technology transfer from universities to businesses is limited, while demand for highly skilled candidates is higher

[9] "Benchmarking Industry-Science Relations", the EU Commission

compared to other industrialized countries. On the other hand co-operation between companies on innovation and technology development is significant.

Overall Japan scores well on indicators related to the advancement of human resources. Data shows that Japan is ranked first in “highly educated workers” and performs well on total investments in knowledge. Correspondingly Japan is ranked below the OECD average on indicators related to more “traditional” measures such as “quality of research” and “co-operation on R&D.”

Ireland

As discussed earlier the position of Ireland on innovation performance should be treated with some caution.

An impressive “catch-up” process over the past decade has elevated Ireland’s ranking on innovation performance, while the country’s ranking on innovation framework conditions has been close to average.

Further analysis points to a number of factors that explain this apparent discrepancy. The high penetration of multinational companies has boosted Ireland’s ranking in the areas of “import of technology from abroad” and “co-operation on technology and innovation”; while Ireland is ranked much lower on all other performance innovation indicators. Given these uncertainties the country has not been included in the group of top performers (“top-7”).

Australia

Australia is ranked 5th on the index for framework conditions and 15th in innovation performance. A further analysis of Australia’s innovation policy shows that investments in framework conditions have yet to materialize in overall innovation performance.

In early 2001, the Australian government launched “Backing Australia’s Ability”, a comprehensive 4-year innovation program designed to improve framework conditions in the areas of research capacity, commercialization of research, and innovation culture. It may well be the case that Australia’s overall performance ranking will correlate with the high ranking on framework conditions once the government initiative is fully implemented.

Canada

Ranked third on innovation framework conditions, Canada showing on innovation performance is only slightly above average (10th). In 1994 the Canadian government engaged in a thorough evaluation of the Canadian innovation system. The evaluation resulted in a number of initiatives, the primary being a much stronger role for the federal government in promoting strategic partnerships between individual states, higher education and private businesses. Much of the funding for the initiatives will be allocated over an extensive period (until 2010), which would explain the apparent “lag” in innovation performance vis-à-vis improved innovation framework conditions.

Summary
In an overall evaluation of the model presented above a number of general issues may serve to explain discrepancies in innovation performance and innovation framework conditions:

1. A high innovation performance may be achieved with a more narrowly focused innovation policy thereby undermining the correlation between performance and framework conditions.

2. Framework conditions that are important to a country may be difficult to identify due to a lack of reliable data

3. Improved framework conditions may not have an *immediate* effect on a country’s innovation performance (i.e. “performance lag”)

However the solid correlation between performance and framework conditions leads to a straight-forward conclusion: Countries with lower-than-average performance can learn from specific policy areas in top-performing countries. However, a simple “cut-and-paste” approach, where policy areas are randomly copied and applied by low-performing countries could easily be detrimental to innovation performance.

In conclusion the model presented above provides a “top-down” approach in *identifying* which policy areas could be strengthened in improving overall innovation performance.

In the accompanying paper “Benchmarking Innovation Policy and Innovation Framework Conditions – Country Case Studies” the “top-down” approach is combined with a “bottom-up” analysis of specific initiatives in selected best-practice countries, providing policy direction at an individual country level.

Appendix 1 – Data description

A wide range of information sources have been drawn upon in assessing innovation performance and innovation framework conditions. As well as a wide range of numerical indictors produced and collated primarily by the OECD, the report draws on surveys from other international bodies, including the WEF, the IMD and the EU Below is a complete list of the 29 indicators used for this publication.

1) Benchmarking of Innovation

   a) Innovation

      i) **Number of patents in 'triadic' patent families in the US, Japan and Europe.** OECD, STI (2001).
      ii) **Number of companies having introduced new or significantly improved products or processes (1994-1996).** Community Innovation Survey (CIS-II), the EU. Data from CIS-II, covering the period from 1998 to 2000, were not available for inclusion in the report.
      iii) **Business' assessment of innovation activity**. Indicator is based on three individual indicators from the WEF survey (2001):
         (a) Extent to which new product designs are developed locally
         (b) The effect of innovation in generating revenue
         (c) Extent to which new products and processes are developed.

   b) Innovation Diffusion

      i) **Import of foreign technology.** OECD, STI (2001). Measures import of licenses, patents, know-how, research and technical consulting.
      ii) **Business assessment of application of new technology**. WEF (2001).
      iii) **Number of companies with co-operation arrangements on innovation activities with other enterprises or institutions (1994-1996)**. CIS-II, the EU.

2) Benchmarking of Innovation Framework Conditions

Innovation framework conditions are split into 4 main categories:

- Public knowledge creation
- Co-operation on innovation between knowledge institutions and the private sector
- Innovation financing
- Market conditions

a) Public Knowledge Creation

i) Size of Public Research

(1) **Government R&D expenditures as a percentage of GDP**. OECD, STI (2001).

(2) **Government researchers per 10 000 labour force**. OECD, STI Scoreboard (2001). Researchers are defined as professionals engaged in the conception and creation of new knowledge, products, processes, methods and systems.

ii) Quality of public research

(1) **Scientific and technical articles per million population**. OECD, STI (2001).

(2) **Business' assessment of the quality of research**. WEF (2001).

iii) Relevance of public research

(1) **Number of scientific and technical articles cited in patents issued in the United States.** Based on data from the US.

(2) **Number of scientific and technical articles in 19 industry-relevant disciplines per million populations.** OECD, STI (2001).

(3) **Scientists and engineers employment as a share of the labour force.** OECD, STI (2001).

(4) **Business' assessment of the relevance of research**. WEF (2001). Indicator measures assessment of availability of scientist and engineers in natural sciences.

b) Co-operation on innovation between knowledge institutions and the private sector

i) Co-operation on R & D

(1) **Share of firms with co-operation agreements with government or higher education (1994-1996).** CIS-II survey, the EU.

(2) **Business' assessment of collaboration with universities in R&D activities.** WEF (2001). Measures extent of co-operation with public research institutions on R&D.

(3) **Business funding of public research as a share of GDP.** OECD, STI (2001).

ii) Commercialization of research

(1) **Incubators per million populations.** Cordis database for incubators (2002)

(2) **Business assessment of knowledge transfer between universities and companies**. IMD (2001).

iii) Highly Educated Workers

(1) **Business researchers per 10 000 labour force**. OECD, STI (2001).

(2) **Share of "knowledge-intensive workers".** OECD, DSTI (2002) "Measures of Skills from Labour Force Survey – An Assessment".

c) Innovation Financing

i) Subsidies and tax incentives

(1) **Public financing of private R&D**. OECD, STI (2001).

(2) **Business assessment of public support to private R&D**. WEF (2001).

(3) **Rate of tax subsidies for 1 US dollar of R&D, SMEs**. OECD, STI (2001). The amount of tax subsidies to R&D is calculated as 1 minus the B-index, where A = the net present discounted value of depreciation allowances, tax credits and special allowances on R&D assets, and τ = the statutory corporate income tax (CITR). In a country with full write-off of current R&D expenditure and no R&D tax incentive scheme, $A = \tau$, and consequently $B = 1$. The more favourable a country's tax treatment of R&D, the lower its B-index.

(4) **Rate of tax subsidies for 1 US dollar of R&D, large companies.** OECD, STI (2001).

(5) **Business' assessment of government tax credits for firms conducting R&D.** WEF (2001).

ii) Venture capital

(1) **Venture capital investment in start-up as share of GDP.** Data National Venture Association (the US), Canadian VCA, European VCA and the Asian VC Journal. Annual average investment 1998-2001.

(2) **Venture capital investment in expansion as share of GDP.** As above.

d) Market conditions

(1) **Business assessment of development and application of technology being supported by the legal environment.** IMD (2001).

(2) **Business assessment of intellectual property protection.** WEF (2001).

(3) **Business assessment of availability of specialized research and training services.** WEF (2001).

ii) Competitive environment

(1) **Index for government regulation.** Danish Competition Authority.

(2) **Business' assessment of competition legislation in preventing unfair competition**. IMD (2001).

iii) Quality of customer and suppliers

(1) **Business' assessment of whether buyers are knowledgeable and demanding/buying innovative products**. WEF (2001).

(2) **Business' assessment of technological capability and international competitiveness of local suppliers**. WEF (2001).

(3) **Business assessment of the extent to which government procurement of advanced technology products is based on price alone or encourages innovation**. WEF (2001).

Appendix 2 – Missing values
Like most statistical series, composite indicators are plagued by the problems of missing values. In many cases, data are only available for a limited number of countries[10] or only for certain data components.

The following methods have been applied throughout the report in dealing with the problem of missing values:

1) Calculating missing values using auxiliary variable (Z)

2) Missing values is determined by the average of other values used in calculating a sub index

To illustrate the methodology, missing values for 12 countries on the indicator "Share of companies introducing new or technologically improved products" are calculated.

Assume that a country is missing a value of variable X. To determine the value the auxiliary variable (z) is used. The size of the missing value of variable X is determined by 3 intervals on the variable z. The following intervals are used:

$$I_1 = \left\{ z < {}^1\!/_{n_z} \sum_{i=1}^{n} z_i - {}^1\!/_2\ \sigma_z \right\} \qquad (1)$$

$$I_2 = \left\{ z < {}^1\!/_{n_z} \sum_{i=1}^{n} z_i - {}^1\!/_2\ \sigma_z \leq z \leq {}^1\!/_{n_z} \sum_{i=1}^{n} z_i + {}^1\!/_2\ \sigma_z \right\} \qquad (2)$$

$$I_3 = \left\{ z < {}^1\!/_{n_z} \sum_{i=1}^{n} z_i - {}^1\!/_2\ \sigma_z \right\} \qquad (3)$$

j is the country with missing values for indicator X. n is the total number of countries and σ the standard deviation of the auxiliary variable z. I_1, I_2 and I_3 are the 3 intervals. To calculate the missing value for country j it must be determined in which of the 3 intervals that country j corresponds to Z. If country j is high on Z we assume the same to be true for variable x. It follows that if country j is low on variable Z, then the country will also be low on variable X.

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[10] As an example information from Eurostat only cover member countries of the European Union

The calculation of missing values for variable X is determined by (4) – (6), where k is the country for which variable X is missing.

$$x_j = \begin{cases} \frac{1}{n_x} \sum_{i=1}^{n_x} x_i - \sigma_x \text{, } hvis\ z_i \in I_1 & (4) \\ \frac{1}{n_x} \sum_{i=1}^{n_x} x_i - \sigma_x \text{, } hvis\ z_i \in I_1 & (5) \\ \frac{1}{n_x} \sum_{i=1}^{n_x} x_i - \sigma_x \text{, } hvis\ z_i \in I_1 & (6) \end{cases}$$

Method 2 is used when an auxiliary variable is not identified. The method implies that a country's performance on indicators with missing values will be equally as good as on indicators with full data coverage. Table 1 illustrates the elements used in method 2. The table shows standardised values for variables α, β and γ that make up a sub-index. The assigned value for country A for indicator β is the average of the other standardised indicators that are covered by data (α and γ) divided by the number of indicators containing data for country A. In this example country A is assigned the value 0,3 on the standardised indicator β.

Table 1 Method 2 used in calculating missing values.

		Standardised variables		Average Assigned values
Country	α	β	γ	
A	0,2	-	0,4	0,3
B	0,4	0,3	0,8	0,5
C	-	-	0,4	0,4

Appendix 3 - Use of composite Indices and robustness analysis

The appendix describes how composite indices for innovation performance and innovation framework conditions are calculated and explains how the robustness analysis is designed and performed.

Composite Indices

Composite indices are increasingly used in comparing and ranking countries in different areas such as industrial competitiveness, globalization and innovation. The proliferation of composite indices raises questions regarding their accuracy and reliability.

Hence when constructing composite indices a number of issues have to be dealt with:

- Standardizing variables to allow comparisons
- Weighting variables and groups of variables and
- Conducting robustness analysis of aggregated variables

Standardizing variables

Variables are often expressed in various units and have to be normalized to render them comparable. Several techniques can be used to standardize individual indicators. Commonly used methods include the following:

- *Standard deviation from the mean*, which imposes a standard normal distribution (i.e. a mean of 0 and a standard deviation of 1).
- *Distance from the mean*, where the mean value is given 100 and countries receive scores depending on their distance from the mean.
- *Distance from the group leader*, which assigns 100 to the leading country and other countries are ranked as percentage points away from the leader
- *Distance from best and worst performer*, where positioning is in relation to the global maximum and minimum and the index takes values between 0 (laggard) and 100 (leader)

In the simple ranking of innovation performance and innovation framework conditions the “minimum-maximum method” has been selected.

Weighting variables
In ranking countries all variables are given common weights.

When constructing a composite index (CI) for country *i*, using indicators X1…. Xn, X is the given indicator and n the number of indicators used for calculating the composite index. To add up indicators in the CI, data must be standardized by applying one of the four methods presented above.

The standardised variables are now shown as $x_1 \ldots x_n$. The composite index for country *i*, variable *j* is calculated as the sum of the standardised values x_{ji}, weighted with the coefficient w_j (A1).

$$CI_i = w_1 x_{1i} + w_2 x_{2i} + \ldots\ldots + w_n x_{ni}$$

$$CI_j = \sum_{j=1}^{n} w_j x_{ji}$$

For wj weights in CI equals 1

$$\sum_{j=1}^{n} w_j = 1$$

Testing for robustness
A variety of difficulties can arise with regards to selecting, weighting, standardizing and aggregating variables into a composite indicator. Outcomes and country rankings may depend largely on the approach selected. For this reason, sensitivity test should be conducted to analyze the impact of including and excluding various variables, changing weights, using different standardization techniques on the results of the composite indicator.

To test the sensitivity of composite indices a robustness analysis of weights and standardizations methods has been performed.

First a number of combinations of weights and standardisation methods are constructed. The result of the simulation is expressed in actual index values (CI1, CI2… CIn)

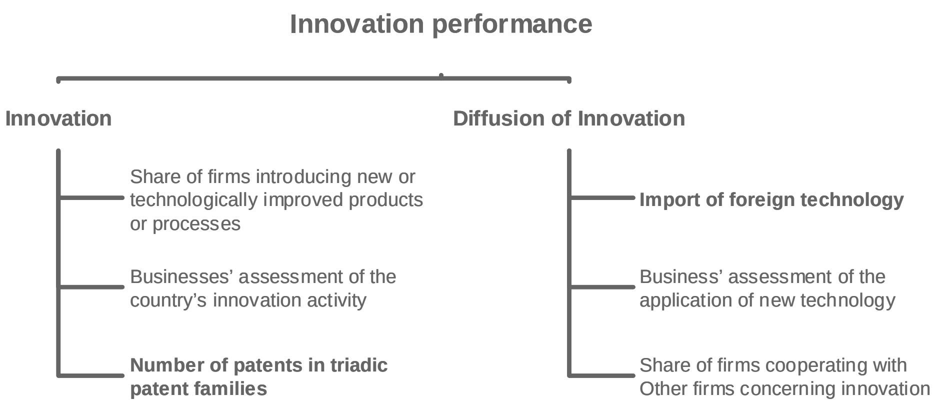
CIi = f (Xin) → Simulation → [CI1, CI2, CI3 ……CIn] → Ranking

The results of the analysis are shown in Figure 2 among others, which shows the possible spread for each individual country, and in Figure 4, which shows the frequency (in %) that a given country is among the top-3, -5 and -10, respectively.

Possible distribution of countries on innovation performance
The composite index for innovation performance is composed of two sub-indices each with 3 underlying indicators

Initially a simple weighting is performed, where individual indicators are assigned identical weights. The two sub-indices (*Innovation activity* and *technology diffusion)* have each been assigned the weight ½.

Figure 1 Innovation Performance



Robustness is tested by applying 900 different weights for each of the 4 standardizations methods resulting in 3600 different ranks

Figure 2 Possible spread of the index for innovation performance.

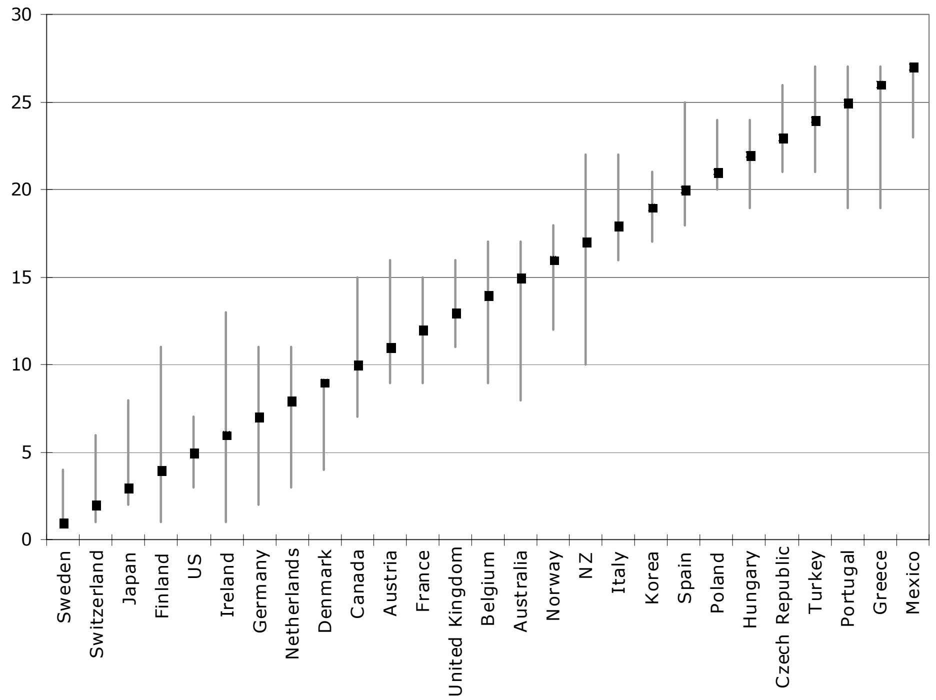


Figure 2 shows the distribution to be relatively robust, with only Ireland and New Zealand showing significant fluctuations. In selecting the top innovation performers figure Sweden, Switzerland and Japan are among the top-5 in at least 80% of the outcomes. Finland, the US, Ireland and Germany are ranked in the top-5 in 40 to 60% of the outcomes.

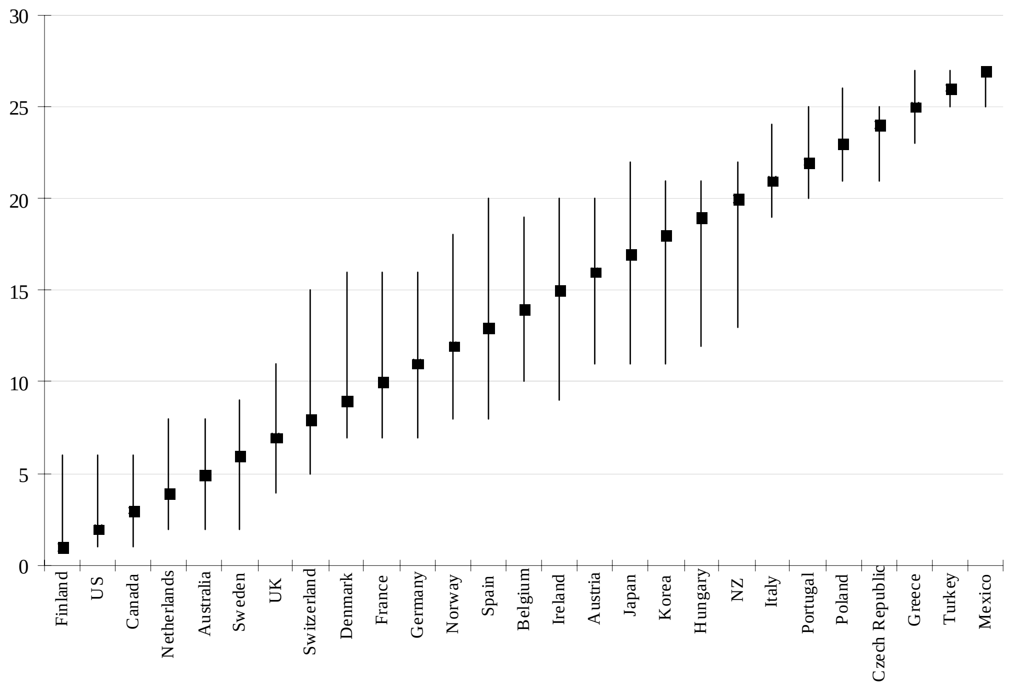
Possible distribution of countries on innovation framework conditions

The overall index for framework conditions is composed of 4 sub-indices: Public Research, Co-Operation on R&D, Innovation Financing and Market Conditions. For each of the 4 sub-indices, 11 policy areas have been defined.

The four sub-indices have each been assigned the weight ¼. Each of the 11 policy areas and underlying indicators has been assigned identical weights.

Robustness is tested by applying 25 000 different weights for each of the 4 standardizations methods resulting in 100 000 different ranks.

Figure 3 Possible spread of the index for innovation framework conditions



Results indicate a higher level of sensitivity compared to the robustness analysis carried out on innovation performance, which in effect can be attributed to the diversity of policy areas analyzed.

Figure 4 Possible ranking based on 100 000 randomly generated weights.

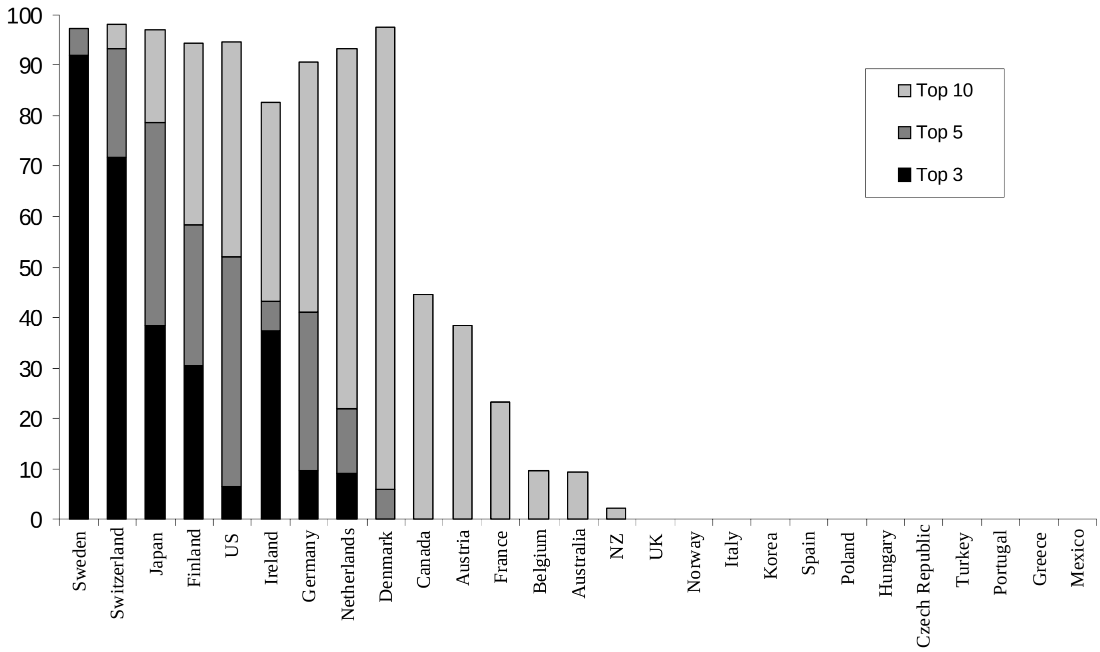


Figure 4 shows the frequency (in %) that a given country is among the top-3, -5 and -10, respectively. Finland, the US and Canada are in the top-5 in more than 90% of the outcomes, with Sweden, the Netherlands and Australia ranked in the top-5 in more than 50% of the outcomes.

Appendix 4 – Use of survey data in benchmarking innovation

Because there is no single definite set of indicators for any given purpose, the selection of data to incorporate in a composite can be quite subjective. Due to a scarcity of full sets of comparable quantitative data, qualitative data from surveys are often used in composite indicators.

Survey data can serve as an indicator of the validity of "hard" data and may also be used for deriving missing values in quantitative data (see Appendix 2).

The EU Commission

Every 4 years the EU commission publishes the Community Innovation Survey (CIS) based on interviews with companies across all member countries. The purpose of the CIS is to provide analysis of the level of innovation activity within the EU.

The latest survey, CIS3, covers the period from 1998 to 2000 but results were not available for this report. Instead three questions from CIS2 (1997-1999) were used.

World Economic Forum - WEF

WEF's *Global Competitiveness Report* sizes growth potential based on two indices:

- A growth index
- A micro-economic competitor index

A total of 174 indicators are applied in constructing the two indices, of which 80% are indicators from WEF's annual survey. The survey covers 80 countries and respondents are chosen by WEF's national partners, i.e. academic institutions.

14 questions from the WEF survey are used in the benchmarking report

International Institute of Management Development - IMD

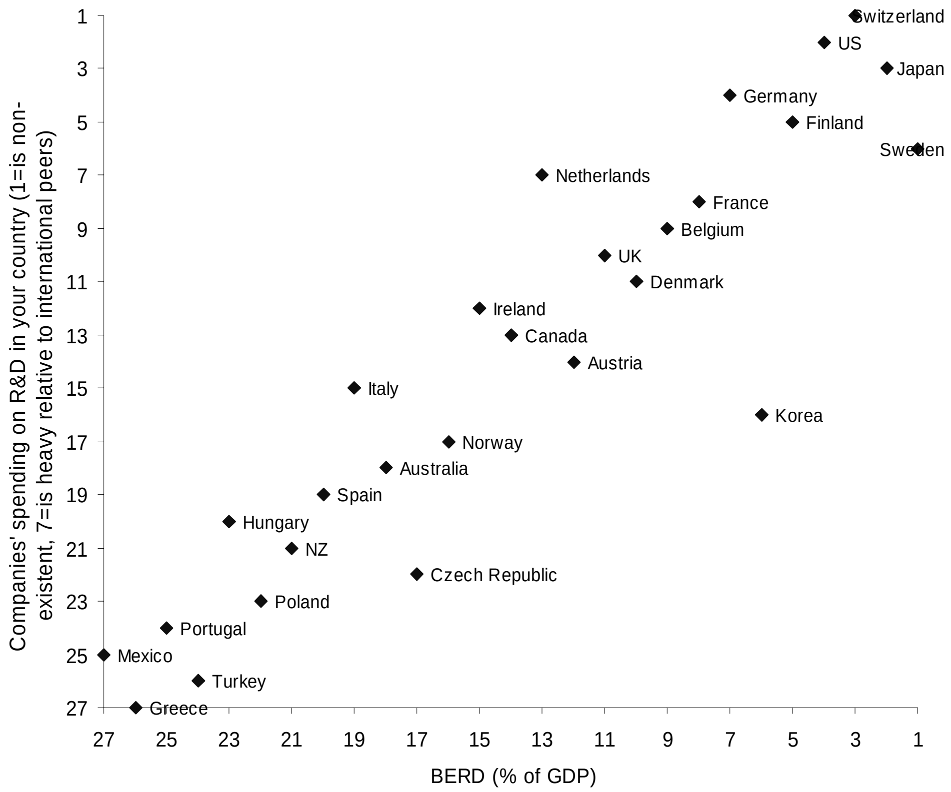
Every year the IMD publishes the World Competitiveness yearbook that highlights the competitive situation across 49 countries. A total of 314 indicators are used, of which 40% originate from IMD's annual survey, which measures management's assessment of various growth factors.

Respondents are CEO's with MBA from IMD. 3 questions from IMD survey are used throughout the report

Testing quality of survey data

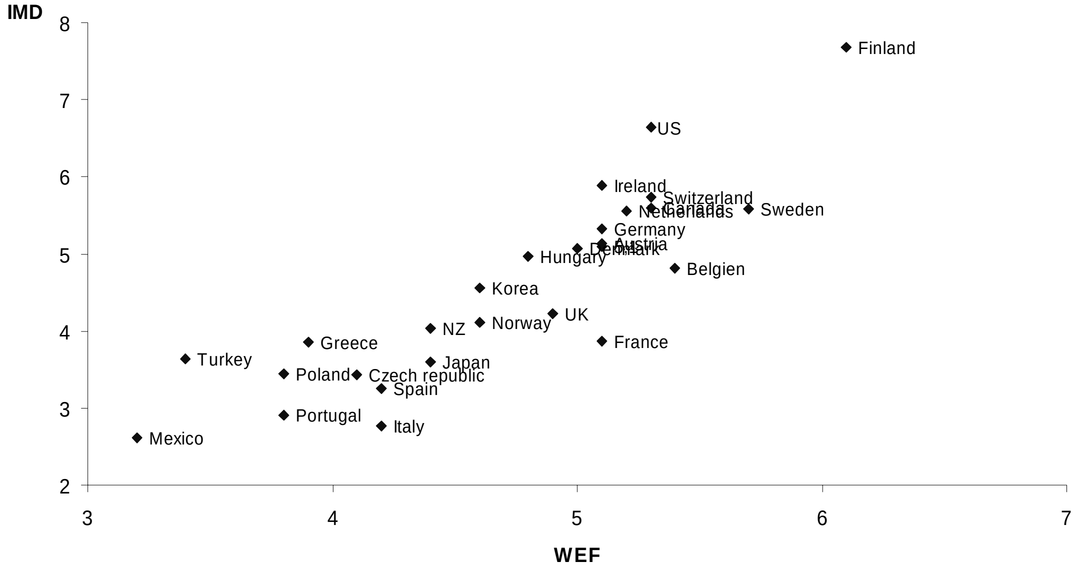
An assessment of the quality of survey data should be treated with some caution. In the benchmarking study 2 methods are applied in testing the quality of survey data used.

In the first method “hard” data and survey data are compared. If survey data is to be considered of high quality there should be a distinctive correlation between the two types of data. Figure 1 ranks countries on “business expen-



Another method in testing validity is by comparing survey data from different sources. Surveys from the WEF and the IMD contain identical questions on management’s assessment of co-operation on knowledge transfer between private and public sectors. Figure 2 shows a high correlation between the two sets of data.

Figure 2 Comparing data from the WEF and the IMD



In conclusion the survey data included is of high quality. However, caution must be observed in using survey data, and cultural differences as well as respondents' ability to answer question appropriately should be considered.

Appendix 5 - Tables

Table 1.1 Ranking innovation activity

Country	Rank	Country	Rank	Country	Rank
Switzerland	1	France	10	Spain	19
Germany	2	UK	11	Korea	20
Japan	3	Canada	12	Czech Rep.	21
Sweden	4	Ireland	13	Poland	22
US	5	Norway	14	Mexico	23
NL	6	Belgium	15	Hungary	24
Finland	7	Australia	16	Greece	25
Denmark	8	Italy	17	Portugal	26
Austria	9	NZ	18	Turkey	27

Table 1.2 Ranking technology diffusion

Country	Rank	Country	Rank	Country	Rank
Sweden	1	Australia	10	Spain	19
Ireland	2	NZ	11	Italy	20
Finland	3	Germany	12	Hungary	21
US	4	Belgium	13	Turkey	22
Japan	5	France	14	Poland	23
Switzerland	6	UK	15	Czech Rep.	24
Canada	7	Austria	16	Portugal	25
NL	8	Norway	17	Mexico	26
Denmark	9	Korea	18	Greece	27