Moncada-Paternò-Castello, Pietro; Ciupagea, Constantin; Smith, Keith; Tübke, Alexander; Tubbs, Mike

Working Paper

Does Europe perform too little corporate R&D? A comparison of EU and non-EU corporate R&D performance

IPTS Working Papers on Corporate R&D and Innovation, No. 11/2009

Provided in Cooperation with:
Joint Research Centre (JRC), European Commission

Suggested Citation: Moncada-Paternò-Castello, Pietro; Ciupagea, Constantin; Smith, Keith; Tübke, Alexander; Tubbs, Mike (2009) : Does Europe perform too little corporate R&D? A comparison of EU and non-EU corporate R&D performance, IPTS Working Papers on Corporate R&D and Innovation, No. 11/2009, European Commission, Joint Research Centre (JRC), Seville

This Version is available at:
https://hdl.handle.net/10419/202112

JRC Technical Notes

IPTS WORKING PAPER on
CORPORATE R&D AND INNOVATION - No. 11/2009

Does Europe perform too little corporate R&D?
A comparison of EU and non-EU corporate R&D performance

Pietro Moncada-Paternò-Castello, Constantin Ciupagea, Keith Smith, Alexander Tübke and Mike Tubbs

JRC EUROPEAN COMMISSION

ipts Institute for Prospective Technological Studies

EUROPEAN COMMISSION
Directorate-General for Research

The ***IPTS Working Papers on Corporate R&D and Innovation*** shed light on economic and policy questions related to industrial research and innovation and their contribution to the European competitiveness. Mainly addressed to policy analysts and the academic community, these are scientific papers (policy relevant, highlighting possible policy implications) and proper scientific publications which will be typically issued at the moment they are submitted to peer-reviewed scientific journals. The working papers are useful to communicate to a broad audience the preliminary research findings of the work we develop, to generate discussion and to attract critical comments for further improvements. The working papers are considered works in progress and are subject to revision.

These *IPTS Working Papers on Corporate R&D and Innovation* can take the form of more *policy oriented notes*, mainly addressed to EU policy-makers. These kinds of papers take a position on a sharply focused policy issue based on the most compelling empirical evidence available. They present policy implications derived from our own research and the views of the most prominent authors in the field, making the appropriate references.

The present Working Paper (No. 11/2009) is issued in the context of ***the Industrial Research Monitoring and Analysis (IRMA)***[1] activities that are jointly carried out by the European Commission's Joint Research Centre (JRC) – Institute for Prospective Technological Studies (IPTS) and the Directorate General Research - Directorate C, European Research Area: Knowledge-based economy.

IRMA activities aim to improve the understanding of industrial R&D and Innovation in the EU and to identify medium and long-term policy implications. More information, including activities and publications, is available at: http://iri.jrc.es/ and http://ec.europa.eu/invest-in-research/

The main authors of this paper are Pietro Moncada-Paternò-Castello (JRC-IPTS), Constantin Ciupagea (Institute of World Economy and Romanian Centre for Economic Modelling, Romania), Keith Smith (Australian Innovation Research Centre, University of Tasmania, Australia), Alexander Tübke (JRC-IPTS) and Mike Tubbs (Innovomantex Ltd and Ashcroft International Business School, United Kingdom). The work has benefitted from the review of and input from Marco Vivarelli (Catholic University of Milan) and Nick con Tunzelmann (SPRU, United Kingdom).

The *IPTS Working Papers on Corporate R&D and Innovation* are published under the editorial responsibility of Dr Andries Brandsma, Mr Pietro Moncada-Paternò-Castello and Dr Michele Cincera at the Knowledge for Growth Unit – Industrial Research and Innovation Action of IPTS / Joint Research Centre of the European Commission.

Contact information - including for the submission of short abstracts (maximum 1 page) for the *IPTS Working Papers on Corporate R&D and Innovation*: P. Moncada Moncada-Paternò-Castello
European Commission, Joint Research Centre - Institute for Prospective Technological Studies
Edificio Expo
C/ Inca Garcilaso, 3
E-41092 Seville (Spain)
Fax: +34 95 448 83 00; E-mail: jrc-ipts-secretariat@ec.europa.eu
IPTS website: http://ipts.jrc.ec.europa.eu/; JRC website: http://www.jrc.ec.europa.eu
DG RTD-C website: http://ec.europa.eu/invest-in-research/index_en.htm

IPTS WORKING PAPER on CORPORATE R&D AND INNOVATION - No. 11/2009
Full electronic version of the paper can be downloadable at http://iri.jrc.es/

JRC51955 Luxembourg: Office for Official Publications of the European Communities

[1] IRMA activities correspond to the implementation of the approach set out in "Investing in research: an action plan for Europe" (COM, 2003) and in further Communications of the Commission: "More Research and Innovation – Investing for Growth and Employment – A common approach", COM (2005) 488 final, "Implementing the Community Lisbon Programme: A policy framework to strengthen EU manufacturing – Towards a more integrated approach for industrial policy", COM (2005) 474 final.

Abstract

This paper examines whether there are differences in private R&D investment performance between the EU and the US and, if so, why. The study is based on data from the 2008 EU Industrial R&D Investment Scoreboard. The investigation assesses the effects of several very distinct factors that can determine the relative size of the overall R&D intensities of the two economies: these are the influence of sector composition (structural effect) vis-à-vis the intensity of R&D in each sector (intrinsic effect) and the company demographics. The paper finds that the lower overall corporate R&D intensity for the EU is the result of sector specialisation (structural effect) - the US has a stronger sectoral specialisation in the high R&D intensity (especially ICT-related) sectors than does the EU, and also has a much larger population of R&D investing firms within these sectors. Since aggregate R&D indicators are so closely dependent on industrial structures, many of the debates and claims about differences in comparative R&D performance are in effect about industrial structure rather than sector R&D performance. These have complex policy implications that are discussed in the closing section.

JEL Classification: O33

Keywords: Research and Development intensity, EU-US R&D gap, size of firms

1 Introduction

1.1. Comparative R&D expenditure performance: a policy issue?

Research and Development (R&D) expenditures have long been an important concern of innovation analysts, who have used them as a proxy for innovation inputs and as a determinant of productivity growth. Perhaps, as a consequence, governments have increasingly seen R&D policy as an instrument for achieving their wider objectives related to growth, productivity and competitiveness. One effect of this is that many governments, as well as the EU as a whole, have established R&D intensity targets (for a comprehensive overview, see: Sheehan and Wyckoff (2003)). Some governments have brought in R&D tax credit schemes to encourage additional R&D investment and some of these schemes give tax relief based on an R&D intensity measure.

In the Lisbon strategy – seeking to make the EU 'the most competitive knowledge-based economy' - the EU formulated a commitment to higher levels of R&D intensity as well as to changes in R&D organisation and framework conditions. Such objectives rest partly on proposals to increase publicly-funded R&D, but also emphasize the need for significant increases in business-funded R&D. The EU's aim in doing this is to approach and possibly surpass the effort made by competing economies (namely the US). In fact, as Soete (2006) put it in an interesting paper, while Europe has kept up with the US in investing public resources in knowledge, both in higher education and research, the EU has dramatically failed to convince the private sector and its citizens to invest in knowledge, the key to its own long term future.

Building on the Lisbon objective, the 2002 Barcelona European Council set a target for EU R&D of 3% of EU GDP, of which 2/3 should be financed by the private sector (European Commission (2003)).

These targets are appealing and enticingly easy to grasp. However, they are even more easily misunderstood because aggregate R&D numbers for countries or regions are not simply an effect of R&D 'effort': they are a combined outcome of firm strategies, company demographics, industrial structures, and macroeconomic dynamics (Soete (2005)).

A complete model of these determinants of R&D expenditure would probably be very complex indeed (see for example Jaumotte and Pain (2005) and Falk (2004) for relevant modelling efforts). It is important to keep these underlying issues in mind when thinking about the appropriateness of particular policy strategies, and about whether and how specific targets for R&D might be reached. A common approach is to distinguish between 'intrinsic' and 'structural' factors in shaping R&D intensity: intrinsic factors reflect within-sector effort, while structural factors reflect the relative size of R&D-intensive sectors to other sectors within an economy. Low aggregate R&D intensity can simply reflect the absence or small size of R&D-intensive sectors (or the very large size of sectors with high sales but relatively low R&D), rather than any general failure of R&D performance (Griffith and Harrison (2003), for example, have shown that the UK's low aggregate R&D intensity largely reflects structural factors).

1.2. Aim and research questions

This article aims to investigate the differences in private-sector R&D investment between EU companies and their competitors in other major economies. It utilises recent company data to identify structural and specialisation characteristics that explain the sizeable differences in aggregate R&D intensity observed between two populations of companies (EU and non-EU ones) . The specific research question guiding our investigation is whether the explanation for

the lower overall corporate R&D intensity of the EU vis-à-vis the US and Japan is mainly because of lower EU R&D intensities across a wide range of sectors or because the structure of the EU economy has a relative larger share of low R&D intensity sectors and hence a smaller share of high intensity sectors. In other words, does the explanation lie mainly in an "intrinsic" vs. "structural" effect? This study also investigates the distributions of R&D and R&D intensity for the three main world regions as well as the demographics of R&D intensive firms to investigate whether these effects play a role in determining the differences in overall R&D intensity between these different world regions. Finally, the study analyses the possible consequences of the findings for policy-making.

1.3. Structure of the paper

The paper is organised as follows:

After the above introduction, section 2 reviews briefly the main findings and relevance of benchmarking private R&D investment performance within the literature on "Economics of Research and Innovation".
Section 3 provides an overview of the tools used to benchmark R&D investment as well as presenting the data used in this study, namely the R&D investment of a large set of firms derived from the information listed in their annual accounts.
Section 4 investigates the distribution of R&D by comparing R&D across different sector groups using R&D intensity levels (following a widely-used approach to characterise industrial sectors according to their technological activity as measured by their level of R&D intensity).
This is followed by section 5 which introduces the methodology to decompose R&D intensity into 'structural' and 'intrinsic' effects, within the major economies under study. This method of decomposition is then applied to an extensive set of company R&D data; key features are discussed and the results for the main economies compared.
Following this, section 6 analyses the distribution of R&D across top R&D investing firms to examine R&D intensity by company size to see if differences in this contribute to differences between world regions.
Finally, section 7 sums up the main findings and offers some concluding remarks relevant for policy-making.

2 Industrial R&D Investment Performance in the EU

This section sets out the conceptual framework reliably anchored to the published economic literature and highlights why the nature and causes of the EU private R&D investment performance profile matters and why they are important for policy-making. It also briefly reviews the relevance of benchmarking private R&D investment performance within the literature on the "Economics of Research and Innovation".

2.1 Why private R&D investment performance matters

Economic theory (Solow (1957)) points to technical change as the major source of productivity growth in the long run. R&D is a major source of technical change (Romer (1990), Guellec and van Pottelsberghe de la Potterie (2001)) which is recognised as a key element for increasing the knowledge base and, with it, the growth, productivity and competitiveness of an economy (Coccia (2008), Mowery and Rosenberg (1989)).
As a matter of fact, most of the arguments that provide justification for policies targeted at raising the level and efficiency of R&D rely on the assumption of close links between R&D spending and micro- & macro-economic performance (Kafouros (2008), Bilbao-Osorio and Rodríguez-Pose (2004), Griffith, Redding and Van Reenen (2004), Mitchell (1999)).
It follows that, given the role played by competitive innovation-led enterprises in the economy (i.e. the return in terms of economic and social benefits), policy initiatives do not aim at raising the level of private R&D per se, but aim at making R&D investment more effective and at overcoming possible barriers to innovation and hence to economic & social prosperity (Pessoa (2007), Soete (2007), Jones and Williams (1998)).
It is not our intention to debate here whether, in order to address the EU R&D investment deficit to achieve a knowledge-intensive economy and society, the EU needs a long-term, structured industrial policy or simply short-term policy actions that address one-by-one the different market failures which impede the magnitude, effectiveness & impact of R&D investment.
We are however convinced that, within this context, it is important to characterise the nature and characteristics of the EU's deficit in R&D intensity and performance since this would affect the shape and the effectiveness of whatever R&D-related policies and means might be employed.

2.2 The EU R&D intensity deficit: nature and reasons

There is an extensive literature dealing with the deficit in the EU's overall company R&D intensity compared to that of competing economies and the various factors that determine it. For instance, there are many scientific papers that consider firms' demography, their size and dynamics (capacity to grow fast) as factors that may influence the deficit.
Bartelsman et al. (2003) have conducted an analysis, based on a dataset of sectoral indicators of firm dynamics at country level together with information from business registers. They conclude that post entry performance differs markedly between Europe and the US (in favour to the US), while O´Sullivan et al. (2007) associate the EU weakness in the growth of new, technology-based firms´ as one of the causes of the EU R&D intensity deficit. This finding is confirmed by the recent work of Ortega-Argilés and Brandsma (2008). They conducted an econometric analysis – including a sequence of regressions to test the regularities and differences shown in the descriptive analysis - of the EU-US differences in the size of R&D intensive firms using a panel of data with 338 EU and 557 US firms and

concluded that firm size plays a role in the overall R&D intensity gap, independent of the sectoral composition of R&D.

Besides the dynamics of firms and their size, there are also studies (e.g. Aghion (2006) and Cohen & Lorenzi (2000)) pointing out various framework conditions as additional causes contributing to the EU R&D intensity deficit. These include a less entrepreneurial culture, a more costly IPR regime, high taxation, more difficult access to finance and to adequate skills, costly social security regimes, overregulation of labour and capital markets, etc.

However, a large part of the scientific effort devoted to studying this phenomenon seems to address one main issue - i.e. the "intrinsic" vs. "structural" effect - and reaches two divergent conclusions. There is one group of researchers who are more inclined to consider that the EU R&D deficit as being mainly due to companies' underinvestment in R&D (intrinsic effect). Conversely, other researchers tend to conclude that the gap is manly due to the structure of the economy (structural effect).

Erken and van Es (2007) disentangle the differences in business R&D between 14 EU countries and the US in 36 sectors over a 17-year period using OECD-STAN and ANBERD data. They conclude that the contribution of the sector composition to the R&D funding gap between the EU and the US was very low, whereas the intrinsic effect was by far responsible of the private R&D gap. They also argue that, if only manufacturing sectors are taken into account, corporate R&D intensity does not differ much between the US and the EU. Rather, the size of high R&D intensity sectors (especially the larger size of the US' ICT-related sectors) explains the difference in R&D expenditure between the manufacturing sectors of the US and the EU. However, the main conclusion of their work is that the European R&D shortfall is mainly caused by the negative intrinsic effect of the service sector, especially citing comparability problems with R&D data for the services sector as between the US and the EU.

Therefore, it is hardly surprising that another study, Mathieu and Van Pottelsberghe de la Potterie (2008), limits their analysis of R&D intensity to 20 manufacturing sectors, concluding that BERD intensity is mainly driven by the degree of specialization in R&D intensive industries. It therefore supports the arguments for a sectoral composition effect as the cause of the low EU R&D intensity. This study was focused on 10 European member states using a panel of data between the years 1991 and 2002; all the service sectors are treated as a single aggregate sector.

Van Ark, Inklaar and McGuckin (2003) observed that U.S. expenditures on R&D outside the manufacturing sector have been increasing since the mid-1990s and now account for about a third of total R&D expenditures, up from less than one fifth in 1995. So, while the manufacturing sector accounts for the majority of R&D expenditures, its share is declining. They note that European growth in services R&D has been slower than in the US and has still not reached 20% of total R&D. At least part of this gap is probably real since ICT diffusion has been slower in Europe than the US.

Several studies implemented in the last few decades investigate the reasons for the commonly observed pattern of a "falling behind" in the area of knowledge investments for Europe as a whole relative to the US. For example, Pavitt and Soete (1982) found that one of the main factors that underlie this phenomenon was related to the strongly increased international specialisation of individual EU member countries.

The conclusions of these earlier studies are confirmed by other more recent studies such as those implemented by O' Sullivan (2007) and Ciupagea and Moncada-Paternò-Castello (2006), which suggest that the European private R&D investment deficit is mainly due to a sectoral composition effect.

In line with this finding, a paper from Lindmark, Turlea and Ulbrich (2008), in which European Commission' (2007a) micro-data as well Eurostat, OECD, EU, KLEMS' national statistics were used and EU and US R&D intensities decomposed, concludes that the R&D intensities of companies are very similar, but the sector composition is very different. The study found the R&D intensity difference was caused by the smaller size of the ICT sector in the EU compared to the US. In fact the ICT sector in the EU also contributes much less to overall business expenditure on R&D in relative terms than does its counterpart in the US. This conclusion

confirms the findings of O'Sullivan (2007), GFII (2007) and the European Commission (2007a and 2007b).
In this context, it should be emphasised that the high-tech sectors are important not only because companies in them invest at a higher R&D intensity but also because in such sectors the link between R&D and productivity turns out to be larger and more significant (Ortega, Piva, Potters and Vivarelli (2009)).
In summary, the divergent findings in the literature concerning the causes of the R&D intensity gap between EU and US companies suggest caution in drawing general conclusions based on individual studies. Some methodological problems make it difficult to converge on generally-accepted measures of structural and intrinsic effects. The results of decomposing the R&D deficit into these two components have been shown to be highly sensitive to the level of detail at which industries are compared (Jaumotte and Pain (2005)). Furthermore, the divergence of results also seems to be dependent on whether or not service sectors are taken into consideration together with manufacturing. More importantly, in the case of studies considering both manufacturing and service sectors, the result lacks robustness because of the widely recognized comparability problems for services sector R&D data between the US and the EU which are subject to very different statistical norms (Erken and van Es (2007); Duchêne et al. (2008)). Moreover, the conclusions of these studies cannot necessarily be applicable to all countries and all economies because of their possible heterogeneity in R&D intensities and industrial structures: 'intrinsic' may dominate in some countries while 'structural' dominates in others.
The present paper seeks to improve understanding of the causes of the under-performance of European firms in R&D investment. It mainly focuses on the effects of sectoral structures and business demographics in shaping comparative performance differences between the EU and US with the aid of very recent company R&D data.

3 Introduction to Benchmarking Tools and the Data Used

This main section starts with a short review of the data used for benchmarking R&D, then centres on the R&D data used in this study (the R&D investment of firms as listed in their annual accounts), introduces their characteristics, and outlines the main differences of the data approach used compared to the OECD's Frascati system.

3.1 Introduction to benchmarking data tools

Most R&D analyses rest on official statistics collected according to the procedures of the OECD Frascati Manual, which is in effect a global standard for R&D official data collection (OECD (2002)). The Frascati approach classifies R&D data on a territorial basis in terms of sources of funding and sectors of expenditure, as well as in terms of socio-economic objectives, research fields and types of research.
However this is not the only way of looking at R&D, particularly in the corporate sector, where multiple ways of looking at R&D performance can give differing perspectives on international comparative issues.
Scoreboard rankings are popular tools for benchmarking performance across firms, sectors and countries. In the business world, scoreboards have been used over a long period to compare companies on the basis of market capitalisation or the value of brands. Within innovation studies, two types of scoreboards have emerged: those which construct composite indicators, and those which produce rankings of one selected indicator. Composite scoreboards by definition include multiple indicators and some method of combining them to reduce them to a single ranking. Since the 1990s, more and better data on R&D and innovation have become available, for example, through the Community Innovation Survey

(CIS, Eurostat (2007)). Such developments have led to the establishment of scoreboards as an increasingly popular measure to compare the performance of countries as a policy-making tool. Examples of these ranking devises are the OECD Technology and Industry Scoreboard, the UK R&D Scoreboard, the US Industrial R&D Leaderboard, and the Australian R&D and Intellectual Property Scoreboards. It is worth mentioning as well the European Commission's Innovation Scoreboard based on a multi-indicator methodology that provides an annual assessment of innovation performance in the Member States.
However, the geographic coverage, indicators, data sources and methods for data generation for these scoreboards vary, and it is impossible to derive satisfactory comparable information on the distributions and concentrations of corporate R&D investment worldwide from the existing national or partially global Scoreboards. It is this consideration which led to the creation of the EU Industrial R&D Investment Scoreboard.

Box 1. Comparing the EU R&D Scoreboard with Business Expenditure on R&D (BERD)

The data used for the Industrial R&D Investment Scoreboard are different from those provided by statistical offices, e.g. BERD data collected by national statistical agencies. The Scoreboard refers to all R&D financed by a particular company from its own funds, regardless of where that R&D activity is performed. The Scoreboard therefore presents an indicator of a particular corporation's global financial commitment to R&D. BERD, on the other hand, refers to all R&D activities performed by businesses within a particular territory (which therefore include small parts of many global businesses), regardless of the location of the business's headquarters, and regardless of the sources of finance. In brief, the distinction between Scoreboard and BERD data can be seen overall as 'global corporate funding' vs. 'activity within a geographical area'.
Further, the Scoreboard collects data from audited financial accounts and reports. BERD typically takes a stratified sample, covering all large companies and a representative sample of smaller ones. Additional differences concern the definition of R&D intensity (BERD uses the percentage of value added, while the Scoreboard measures it as the R&D/Sales ratio) and the sectoral classification they use (BERD follows NACE, the European statistical classification of economic sectors, while the Scoreboard classifies companies' economic activities according to the Industrial Classification Benchmark (ICB)).
It is difficult to compare the Scoreboard figures and BERD data directly (European Commission (2007a)). Even if both were fully comprehensive and accurately measured, the global measurements would still differ as BERD includes non-company sources of R&D finance, and because the measurements refer to different samples of firms. Non-company sources for R&D finance can be significant: for example, government-financed BERD is approximately twice as high in the US – both in absolute terms and as a proportion of GDP – than the EU 25. This is an important and neglected fact in differences in BERD intensities between the US and the EU (Dosi et al. (2005)).
We suggest that both types of measure are useful to policy-makers seeking a complete picture of private R&D investment trends and patterns. The Scoreboard gives policymakers and others some insight into companies' global R&D commitments and their relationship to firm-level economic outcomes. This focus indicates how much firms, rather than the parts of firms within particular national territories, are investing in R&D and in which industries the most R&D-active companies operate.

3.2. Data and samples selected for the analysis

Data used in this study are collected from the 2008 edition of the EU Industrial R&D Investment Scoreboard (Scoreboard). This dataset enables the comparison between large-scale corporate R&D performers in the EU and non-EU worlds. It contains data of the 1000 largest R&D-performing firms in the EU, and the 1000 largest ones in the non-EU world. The data have been collected from publicly available audited annual reports and accounts of listed, private and state-owned companies in the last reporting year (i.e. 2007/8) and made available as of 29 July 2008.

As far as individual disclosures allowed, R&D investment was corrected in order to reflect the share funded by the company itself and its subsidiaries. The Scoreboard therefore excludes R&D financed by third parties such as governments or other companies. It also excludes a given company's share of any associated company or joint venture R&D investment, which is listed separately. Where part or all of the R&D costs have been capitalised, the additions to the appropriate intangible assets are included to calculate the cash revenue investment and any amortisation eliminated.

The definitions of R&D used by companies in their audited reports follow accepted international accounting standards, specifically IAS 38, which accords with definitions used for official statistics (as set out, for example, in the Frascati Manual, OECD(2002)). All monetary amounts were converted to euros.

In the consolidation process, companies that were subsidiaries of another company were excluded to avoid double counting. Majority-owned subsidiaries were consolidated in the accounts of the parent, whereas joint ventures that were 50 % owned by each of two partners were included as stand alone companies.

The classification of the location of a given company depends where (in which country) the ultimate parent has its registered office. The registered office is the company address notified to the official company registry. It is normally the place where a company's books are kept.

Sector classification is based on the Industrial Classification Benchmark (ICB) system. The Scoreboard encompasses 36 out of the 45 ICB sectors, disaggregated at the three-digit level. Classification is based on the companies stating where their main activities lie (see the characterisation of the data sample in Annex 1, Table A1). Taken together, all 2000 Scoreboard companies invested a total of €379.3 billion in R&D in 2007/08.

When using the Scoreboard data for comparative analyses there are a number of factors that should be taken into account because they potentially affect the interpretation of the figures. In particular, the following points should be noted:

a) Scoreboard figures are nominal and expressed in euros with all foreign currencies converted at the exchange rate prevailing on 31 December 2007. Financial indicators consolidated from companies' activities in different currency areas are influenced by fluctuations in exchange rates. This has an impact on firms' relative positions in the world rankings based on these indicators. Moreover, the ratios between indicators or the growth rate of an indicator may be affected. For example, the euro appreciated significantly against the US dollar and the pound sterling between 2006 and 2007, rising from $1.32 to $1.46 and from £0.67 to £0.73. This means that the Scoreboard underestimates the R&D growth rate of EU companies based in the euro area and operating in the US. Conversely the growth rate of US companies with substantial operations in the euro area is overestimated in this case.

b) Growth in R&D can be organic, due to acquisitions, or a combination of the two. Consequently, mergers and acquisitions may explain sudden changes in R&D growth rates and rankings of specific companies.

c) Other important factors to take into account are the difference in the various countries' (or sectors') business cycles that may have a significant impact on companies' investment decisions as well as the adoption of the International Financial Reporting Standards (IFRS). It should be also noted that although the accounting standards lead to a certain standardisation in the data reported, some degree of choice remains for companies as to what may be declared as R&D or not. This can have important impacts.

Finally, it should be pointed out that, for the sake of this study, both the full sets of EU 1000 and non-EU 1000 companies as well as comparable sub-samples of these companies are examined. In fact, the EU 1000 and non-EU 1000 groups include companies with different volumes of R&D investment. For the 2008 edition of the Scoreboard, the R&D investment threshold for the EU group is €4.27 million and that for the non-EU group €24.21 million. In order construct sub-samples of comparable EU and non-EU companies, it is preferable to consider only companies with R&D above the non-EU threshold. These groups comprise a set of 402 EU companies, 544 US and 244 Japanese companies, all with R&D of at least €24.2m.

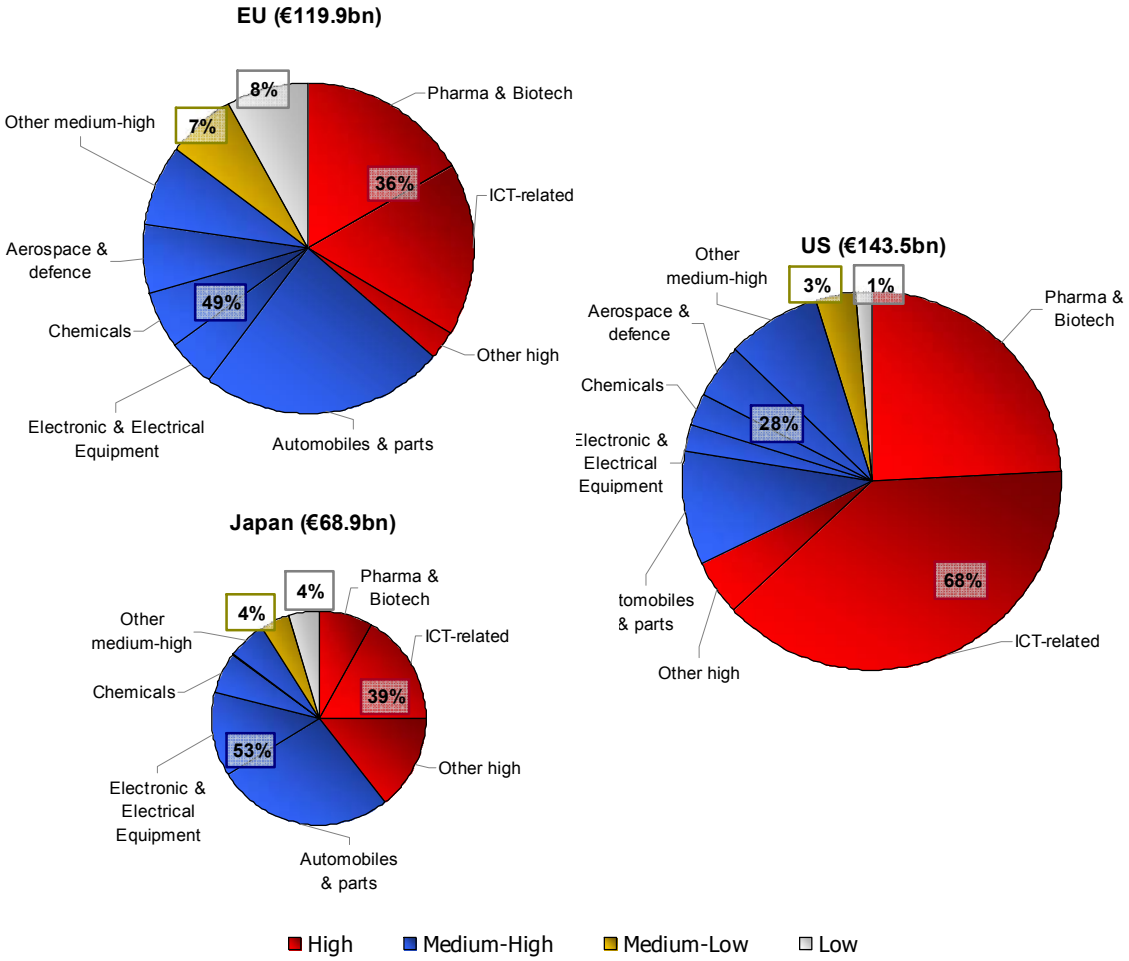
4 The Distribution of R&D across Sectors

The comparison of R&D intensity data for different groups of sectors selected by the level of their R&D intensity follows a widely-used approach to characterise industrial sectors according to their technological activity measured by the level of R&D intensity, i.e. from high to low technological content. The data used here are available in the ICB sector classification. Using R&D over net sales as R&D intensity, the sector classification is matched to the OECD high technology sector and product classification (OECD (1997)).
The sectors are divided into the following four groups by their average R&D intensity:

Group 1: High R&D intensity sectors (higher than 5%), comprising pharmaceuticals & biotechnology, health-care equipment & services, technology hardware & equipment, software & computer services and leisure goods.
Group 2: Medium-high R&D intensity (between 2% and 5%), comprising automobiles & parts, aerospace & defence, electronics & electrical equipment, industrial engineering & machinery, chemicals, personal goods, household goods, general industrials, support services and travel & leisure.
Group 3: Medium-low R&D intensity (between 1% and 2%), such as food producers, media, oil equipment, general retailers, tobacco, mobile and fixed line telecommunications.
Group 4: Low R&D intensity (below 1%),such as oil & gas, industrial metals, banks, construction & materials, food & drug retailers, beverages, industrial transportation, mining, electricity and multi-utilities.

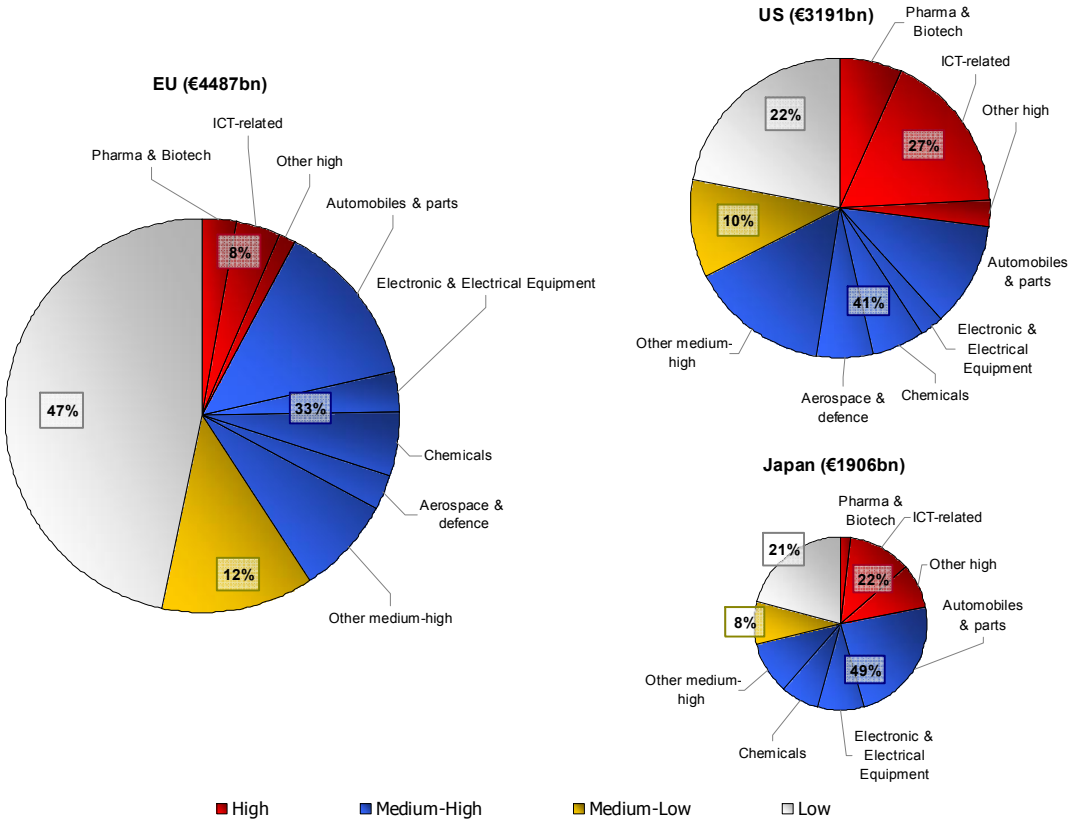
As a first step, the sectoral composition of the EU, the US and Japan by sector group is illustrated below. Figure 1 comprises the sectoral composition in terms of R&D investment, and figure 2 in terms of net sales, so both determinants of Scoreboard R&D intensity are covered.

Figure 1: Shares of R&D investment and the R&D intensity of companies by world region and sectors



Note: The size of the circles is approximately proportionate to the total amount of R&D investment.
Source: Computed from the EU Industrial R&D Investment Scoreboard data (European Commission, 2008)

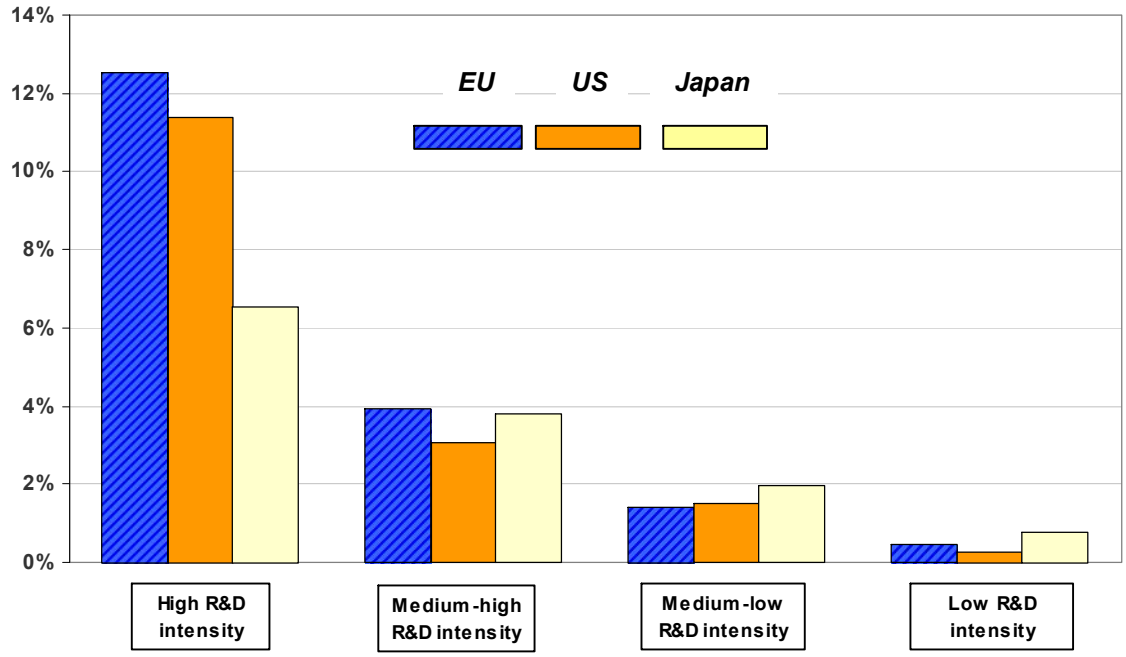
Figure 2: Shares of net sales and the R&D intensity of companies by world region and sectors



Note: The size of the circles is approximately proportionate to the total amount of net sales.
Source: Computed from the EU Industrial R&D Investment Scoreboard data (European Commission, 2008)

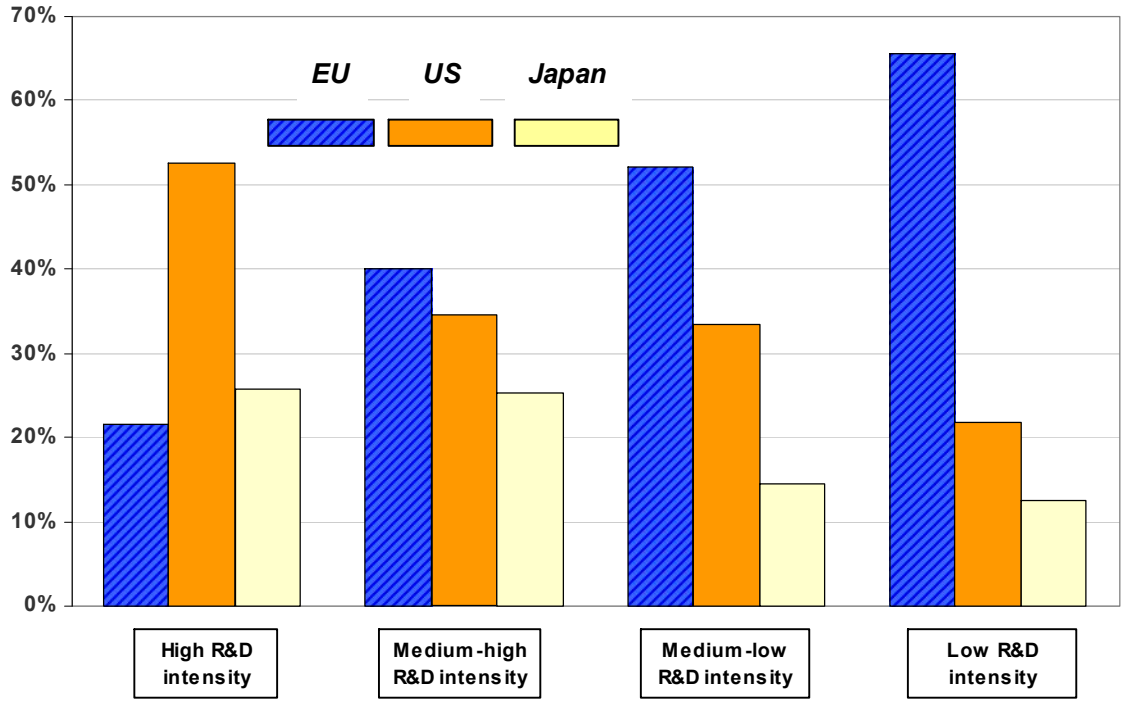
The figures show considerable differences in the sector mix of the three world regions, both in terms of R&D investment and net sales.
Two other figures below takes the same concept of sector groups and apply it to compare the R&D intensities of these three world regions.

Figure 3: R&D intensity of Scoreboard companies by sector group and world region



Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2008)

Figure 4: Shares of net sales of Scoreboard companies by sector group and world region



Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2008)

Figures 3 and 4 show that, also with respect to R&D intensities and net sales within these world regions, considerable differences can be observed.

The following conclusions can be drawn from figures 1-4 above:

- ⇨ The EU companies have the highest R&D intensity in the Group 1 and R&D intensities comparable to the ones of the other regions in Groups 2, 3 and 4. However, they have the lowest proportion of R&D investment in Group 1 and the second highest proportion in Group 2. A consequence of this is the low contribution of high R&D intensity sectors to the overall R&D intensity of the EU. This explains, to a large extent, the fact that the US and Japan both have a much higher R&D intensity than the EU. The latter is also explained by the large size of many of the EU's companies operating in low R&D intensity sectors which account for significantly higher shares of net sales than of R&D investment.
- ⇨ The US firms invest over two thirds of their total R&D in the high R&D-intensity Group 1 and only 4% in the Medium-low and Low R&D-intensive Groups 3 and 4 and only 28% in group 2. The US thus has much lower proportion of R&D investment in Groups 2, 3 and 4 than the EU and Japan. This is the main reason for the US companies showing, on aggregate, a much higher R&D intensity than the EU and Japan.
- ⇨ Japanese companies concentrate their overall R&D investment in both Group 1 and Group 2. They have a significantly higher R&D intensity than the US companies in Group 2, but this is more than offset by a much lower proportion of total R&D than the US companies in Group 1. This reflects the main weakness of the Japanese companies listed in the dataset which has a low proportion of companies operating in pharmaceuticals & biotechnology and software & computer services.

5 Decomposition of R&D Intensity

In order to better understand the reason behind the EU's deficit in business R&D intensity, we consider quantitatively the relative contributions of the sectoral structure of the economy (structural effect) vis-à-vis the R&D intensity efforts of firms in each sector (intrinsic effect). This comparison has been conducted by considering a) the non-EU block as the benchmark vis-à-vis the EU and also b) the US economy as the benchmark vis-à-vis the EU and Japan.
In order to implement the decomposition and calculate the percentage contributions of the two possible reasons to the total change in R&D intensity in the different economies, we have followed the approach of Haveman and Donselaar (2008), Erken and van Es (2007), Hollanders and Verspagen (1998), and van Velsen (1988)). The approach is also similar to that used by van Reenen (1997a, b) who, as compared to van Velsen, uses value added instead of share of industry as a measure of output in a given economy.
The following formula was used for the R&D intensity decomposition (1):

$$RDI_X - RDI_Z = \sum_i RDI_{X,i}\,(S_{X,i} - S_{Z,i}) + \sum_i S_{X,i}\,(RDI_{X,i} - RDI_{Z,i}) \quad (1)$$

where:

- X refers to one of the two samples to be compared (in our case the EU or the Japanese sample)
- Z is the other sample in the comparison (in our case the non-EU or the US sample)
- RDI stands for R&D intensity (R&D/Y); the value of "Y" is the overall amount of net sales of companies operating in a given sector.
- S is the share of the sector i in terms of net sales within a given economy (yi/Y).

Therefore, the aggregate change in R&D intensity for a given economy is equal to the sum of the changes in R&D intensity for all sectors over the period, weighted by their average share of net sales over the same period (intrinsic effect) plus the sum of the changes in output shares of net sales, weighted by their average intensities (structural effect). Thus, if the share of the R&D-

intensive industries within the overall economy of country A is larger than in country B, the sector composition effect is positive for country A and negative for country B.
We implemented the R&D intensity decomposition calculations also with a comparable subset of these 2000 companies from the EU, US and Japan with a minimum R&D investment threshold of €24.21 million. This comprises a group of 402 EU companies, representing approximately 95% of total R&D investment by the EU group, and 544 companies and 244 Japanese companies representing 100% of total R&D investment by the these non-EU groups.
Table 1 below shows the total R&D investment and intensity (R&D as a proportion of net sales) by the Scoreboard companies by world region.

Table 1: Total R&D investment and intensity (R&D/Sales) by world region

	EU-402	US-544	Japan-244	RoW
R&D investment (€ billion)	119.9	143.5	66.9	40.5
R&D intensity (%)	2.7	4.5	3.6	2.6

Note: For possible comparison, the total R&D investment and R&D intensity by the un-truncated sample of company grouping is € 126.4 and € 253.0 billion for EU-1000 and Non-EU 1000 respectively; while the R&D intensity is 2.3% for the EU-1000 and 3.8% for Non-EU 1000.
Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2008)

The shares of net sales and R&D intensity by sector of 402 EU, 544 US and 244 Japanese companies from the Scoreboard dataset are provided in Table 2.

Table 2: Shares of net sales and R&D intensity by sector of 402 EU, 544 US and 244 Japanese companies from the *Scoreboard*.

		EU-402		US-544		Japan-244	
4-digit ICB code	**4-digit ICB Sector in the *Scoreboard***	**Share of Sales**	**R&D inten-sity**	**Share of Sales**	**R&D inten-sity**	**Share of Sales**	**R&D inten-sity**
353	Beverages					0,92%	1,30%
357	Food producers	2,16%	1,73%	2,91%	0,87%	1,08%	2,30%
378	Tobacco	0,30%	1,19%	1,15%	1,28%	1,53%	0,86%
173	Forestry & paper	1,01%	0,55%	0,36%	0,42%	0,78%	0,75%
555	Media	1,00%	2,60%	1,28%	0,56%	1,00%	1,83%
177	Mining	1,58%	0,32%			0,46%	0,69%
53	Oil & gas producers	16,31%	0,30%	15,89%	0,21%	3,35%	0,22%
57	Oil equipment, services & distribution	0,39%	0,83%	1,82%	2,24%		
135	Chemicals	5,29%	2,86%	5,38%	2,40%	7,05%	3,17%
376	Personal goods	1,10%	1,68%	1,15%	1,72%	0,77%	2,88%
4573	Biotechnology	0,10%	21,42%	0,83%	26,76%	0,11%	9,41%
4577	Pharmaceuticals	2,75%	15,51%	5,70%	15,25%	1,75%	16,27%
235	Construction & materials	3,02%	0,69%	0,83%	1,00%	4,19%	1,13%
175	Industrial metals	3,76%	0,47%	0,70%	1,15%	4,79%	1,05%
272	General industrials	1,23%	2,84%	6,10%	2,37%	2,38%	2,76%
372	Household goods	1,12%	2,28%	2,82%	2,46%	1,55%	1,17%
2757	Industrial machinery	2,29%	2,80%	1,00%	1,74%	1,70%	2,59%
9572	Computer hardware	0,03%	5,60%	5,44%	4,70%	7,49%	5,18%
9574	Electronic office equipment	0,09%	6,65%	0,49%	4,22%	1,15%	5,70%
9576	Semiconductors	0,57%	16,85%	3,15%	16,41%	1,03%	6,64%
2733	Electrical components & equipment	3,06%	3,43%	1,27%	1,83%	3,52%	3,66%
2737	Electronic equipment	0,35%	5,68%	1,13%	5,99%	5,37%	6,30%
374	Leisure goods	0,69%	5,90%	0,82%	7,78%	8,15%	6,23%
9578	Telecommunications equipment	2,04%	13,04%	2,49%	12,76%	0,23%	2,96%
453	Health care equipment & services	0,71%	4,36%	1,89%	7,81%	0,23%	5,63%
335	Automobiles & parts	13,63%	4,68%	11,34%	3,90%	23,58%	4,07%
2753	Commercial vehicles & trucks	1,54%	3,54%	2,93%	2,66%	1,21%	2,90%
271	Aerospace & defence	2,71%	6,57%	6,18%	3,33%	0,04%	6,09%
753	Electricity	3,60%	0,74%			4,97%	0,68%
757	Gas, water & multiutilities	5,38%	0,21%	0,08%	1,68%	0,82%	0,79%
533	Food & drug retailers	1,97%	0,33%	4,07%	0,28%	0,47%	0,38%
537	General retailers	2,62%	0,36%	0,48%	7,45%		
575	Travel & leisure	0,22%	0,89%	0,39%	3,34%	1,47%	1,90%
653	Fixed line telecommunications	5,76%	1,64%	2,55%	0,83%	3,46%	2,53%
277	Industrial transportation	1,82%	0,31%				
657	Mobile telecommunications	1,08%	0,66%			1,07%	0,46%
835	Banks	6,19%	0,95%	0,85%	0,92%		
857	Life insurance	0,83%	0,40%				
853	Nonlife insurance	0,20%	0,79%				
877	Other financials	0,25%	2,37%	0,05%	10,06%		
279	Support services	0,38%	2,40%	0,50%	3,39%	0,61%	1,28%
9533	Computer services	0,41%	3,08%	2,60%	5,39%	1,74%	4,79%
9535	Internet			0,55%	13,91%		
9537	Software	0,47%	15,52%	2,82%	14,78%		
	Grand Total	**100%**	**2,67%**	**100%**	**4,50%**	**100%**	**3,62%**

Source: Computed from the EU Industrial R&D Investment Scoreboard data (European Commission, 2008)

The calculations for the decomposition of R&D intensity have been operated on the EU-402, the US-544 and Japan-244 samples, taking the US-544 as the benchmark. The results are shown in Table 3.

Table 3: Decomposition of R&D intensity for the sample of 402 EU, 544 US and 244 Japanese companies from the *Scoreboard*.

	Difference in R&D intensity from US-544	of which Structural effect:	of which Intrinsic effect:
EU-402	**-1,80**	-1,84	0,05
Japan-244	**-0,35**	-0,37	0,02

Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2008)

The calculations for the EU 402 vs. the US 544 sample show that the intrinsic effect is only slightly positive. Further, the overall EU R&D intensity gap is entirely due to the structural effect. A similar observation, but with less significance, can be found for the 244 Japanese companies compared to the 544 US ones.

We have also implemented the same decomposition calculation using the full set of companies, i.e. 1000 EU vs. 1000 non-EU samples . It results in a difference in R&D intensity of -1,53, of which -1,19 is due to structural and -0,34 is due to intrinsic effects. This decomposition for the EU-1000 vs. the non-EU1000 sample reveals that only around one fifth (22.2 %) of the R&D intensity gap is due to the intrinsic effect.

Thus, the decomposition operated for the un-truncated samples shows a less pronounced dominance for the structural effect than the one seen for the EU 402 vs. the US 544. However, in the EU-1000 vs. non-EU-1000 comparison, a size bias intervenes resulting in the minor relevance of the structural effect, as the non-EU sample in this case is bigger in size and therefore more R&D intensive than the EU one.

By and large, our analyses do not point to a systematic underinvestment in R&D by the companies in the EU samples (EU-402 and EU-1000) compared to those in the US-544, in the Japanese-244 or in the overall non-EU-1000 sample. Rather, they confirm the big difference in sector mix that exists between these three economies.

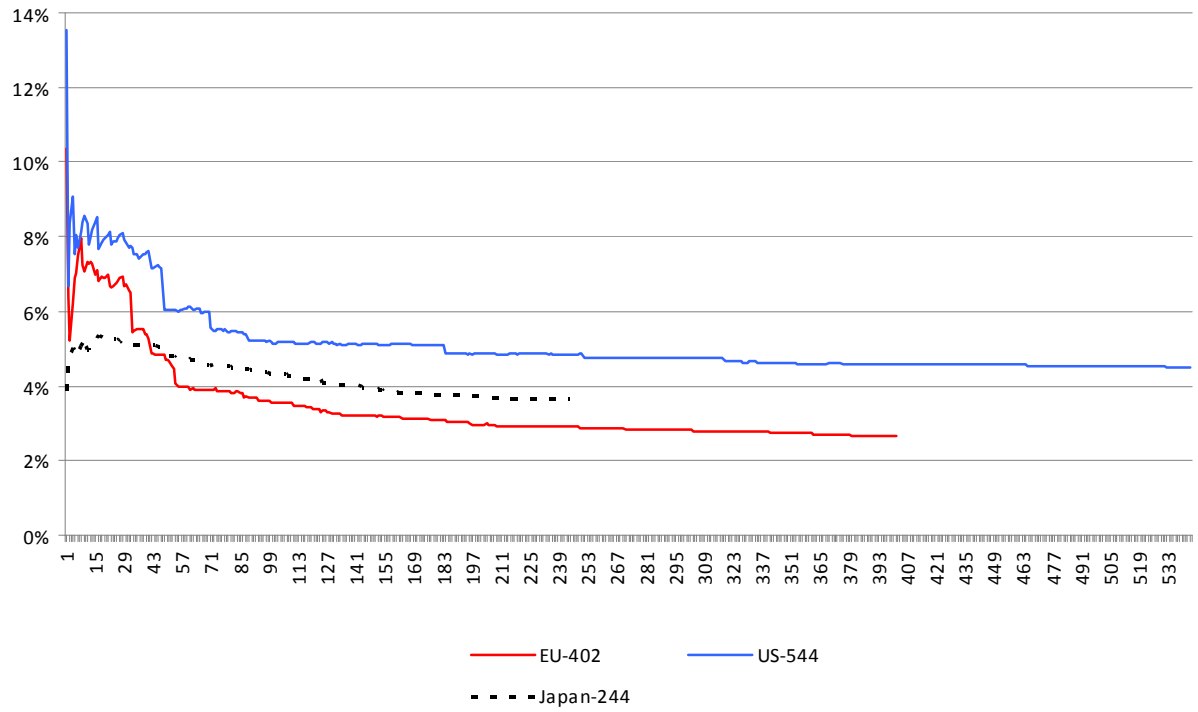
These results differ from those of other R&D decomposition analyses (Erken and van Es (2007), ETEPS (2007), Pianta (2005), Dosi (1997), or van Reenen (1997a, b)) based on BERD/OECD-STAN data. In our opinion, the main reason for dissimilar results concerns the methodological heterogeneity (as pointed out in section 3.1) between the datasets and statistical sources. In addition, comparing the decompositions of R&D intensity using Scoreboard data and BERD can be further troubled because of other weaknesses of both datasets. For example, there could be a systematic overestimation of the role of the intrinsic effect in the EU/US comparison in the BERD/OECD-STAN data due to the significantly overestimated service R&D expenditure in the US compared to the EU (Duchêne et al., 2009, NSF, 2005). On the other hand, Scoreboard companies classified in one sector in many cases have significant operations in others (e.g. IBM, Philips, Siemens). In addition, the Scoreboard companies -and their R&D investment- are allocated to the country of registered office, while the execution of their R&D investment may be spread over several other countries. Most large multinationals now find it necessary to place some of their R&D in each of the three main world regions – the EU, North America and Asia Pacific. Nevertheless, a company with its registered office and headquarters in one region is likely to take decisions in that region on the shape of its global business and its R&D strategy and intensity. Finally, one might argue that the Scoreboard dataset has a sample bias affecting

the results, because it only represents the top R&D investors (picking winners). However, this argument doesn't appear to be convincing since the 1000 EU and the1000 non-EU companies altogether represent approximately 80% of business expenditure on R&D worldwide. While non-R&D investors were excluded in the screening process, where the accounts of 5,913 companies were examined for R&D activity, the objective of the present study is not to examine the structure of the whole economy, but to focus on the structure of R&D investment for the private sector. For investigating the structure of R&D investment in the main private R&D investing world regions (i.e. EU, US and Japan), the potential activity of smaller R&D investors is much less significant.

6 Distribution of R&D across Top R&D Investing Firms

The previous section has provided further evidence that the sources of differences in EU R&D investment performance lie primarily in the structural effect and that the intrinsic effect has only a minor influence. In order to analyse this further, we examine cumulative average R&D intensity by company size and world region (see Figure 5 below).

Figure 5: Cumulated average R&D intensity of the examined samples of 402 EU, 544 US and 244 Japanese companies, in 2007 (%)



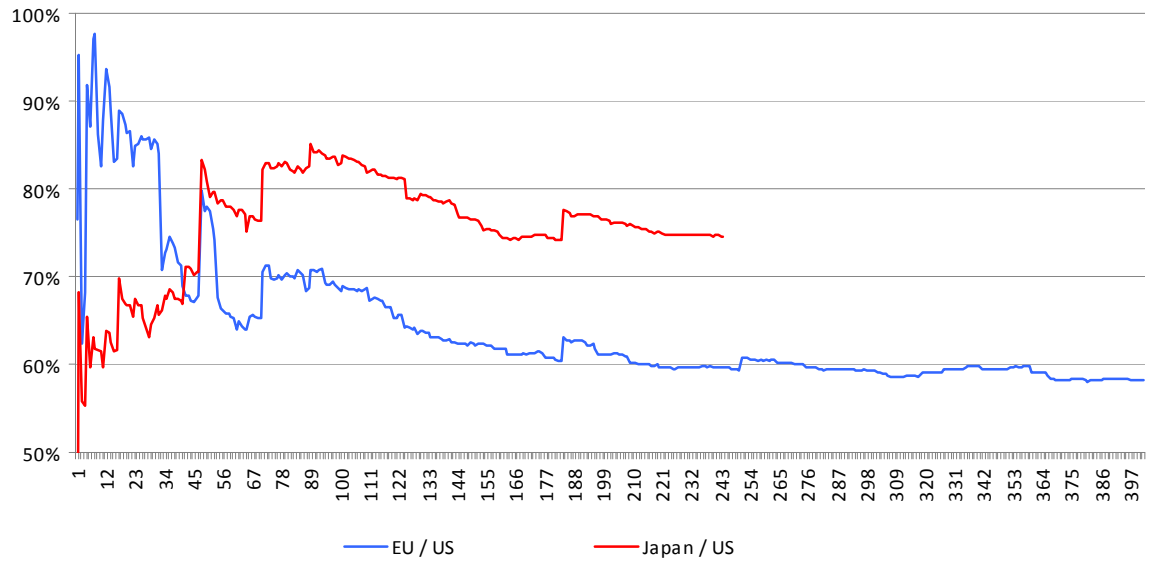
Note: Cumulative average R&D intensity is calculated by summing the R&D investment from the biggest to the smallest R&D investor in the group, dividing by cumulative sales. The figure plots the average R&D intensities for each group of n top companies from largest to smallest R&D investor against the number of companies. As there are only 244 Japanese companies in the sample we analyse, the graph for Japanese companies stops at 244 on the horizontal axis, while it goes up to 402 for the set of EU companies and 544 for the US companies.

Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2008)

This figure shows that corporate R&D is asymmetrically distributed with a large difference in the degree of concentration between EU and non-EU sets of companies. This suggests that differences in overall R&D intensities also reflect business demographics. Moving down the rankings, there is a large population of smaller US companies that invests more strongly in R&D, and in a more consistent way than the EU companies, thus raising the overall R&D performance of the United States. US firms are performing considerably more R&D at smaller

firm-size levels. One reason that could explain this observation is that these companies are concentrated in sectors that are intrinsically more R&D intensive.
It is also clear that the very big R&D investors are more R&D intensive. For both the US and EU, the cumulative average R&D intensities fall sharply before the 47th and the 30th company respectively and then flatten off. Moreover, the cumulative R&D intensity is sharply reduced at particular points by the sudden inclusion in the list of several large companies with very low R&D intensity.
The gap in R&D intensity between the EU and US companies is much smaller amongst the first 30 companies than later-on, and the EU companies have an even higher cumulative average R&D intensity than the Japanese ones for the first 40 companies. However, after these points, there is a much smaller proportion of high R&D intensity companies in the EU sample and this increases the gap in cumulative average R&D investment. This means that R&D activity is more concentrated amongst the bigger companies in the EU sample than in the others, but also that in the EU sample there are more large R&D-investing companies with very low R&D intensity. Examples of EU companies with very large sales compared to their R&D investment are Total, BP, Shell, Electricité de France and ENI.
Figure 6 illustrates the relative concentration of R&D investment for the EU and Japanese samples compared to the US sample in terms of cumulative average of R&D investment. The ratio used is the cumulative R&D investment of the top company, then top2 companies, continuing up to the maximum number of companies in the EU and Japanese samples, each divided by the corresponding sum for the same number of US companies. Therefore, Figure 6 has a horizontal axis showing number of companies (maximum 402 for the EU and 234 for the Japanese sample, with R&D investment of US companies taken as denominator) and a vertical axis showing the ratio between the cumulated R&D investments of similar number of companies in any pair of two of the three major regions.

Figure 6: Ratio of cumulative R&D investment for of the examined samples of 402 EU and 244 Japanese companies as compared to the 544 US companies, in 2007 (%)



Note: The ratio for top n EU companies as compared to top n US companies is computed by dividing the cumulated R&D investment of n EU companies by the cumulated R&D investment of the same number of top US companies. The same applies to Japanese companies as compared to US companies. As there are only 244 Japanese companies in the sample we analyse, the graph for Japanese companies stops at 244 on the horizontal axis, while it goes up to 402 for the set of EU companies.
Source: Computed from the "EU Industrial R&D Investment Scoreboard" (European Commission, 2008)

The top 32 companies in the EU sample have more than 80% of the R&D investment of their US counterparts, with the EU/US ratio oscillating between 62 % and 98%. The overall trend of the curve for the EU vs. the US companies is downwards. It is again companies with very big sales compared to their R&D investment, like those mentioned above, that bring the cumulated ratio down. .

A different pattern is observed for the Japanese vs. US companies. The curve is climbing at the very beginning, reaching 84% after 91 companies. A number of Japanese companies in high R&D intensity sectors, e.g. Advantest, Taisho Pharmaceuticals or Tanabe Seiyaku (now Mitsubishi Tanabe Pharma), is responsible for this. After that, the trend in the curve for Japanese vs. US companies is downward, running in parallel to that for the EU vs. US curve, but at a higher level. This underlines the role of business demographics when measuring overall average R&D intensities: moving down the rankings, there is a population of US companies that invests more strongly in R&D, and in a more consistent way than the EU companies, thus raising the overall R&D performance of United States. US firms are performing considerably more R&D at lower firm-size levels, not least due to a concentration of these companies in sectors that are intrinsically R&D intensive.

In turn, the role of R&D in small and medium enterprises (SMEs) is crucial in transforming an SME into a fast growing company. While some SMEs are potentially innovative and ready to grow, others are revolving-door firms which stay for a while on the fringe of an industry with no chance of entering its core and being doomed to exit the market. However, according to Ortega, Vivarelli and Voigt (2009), this positive process is frequent only in technologically-advanced countries. Therefore, SME growth could depend very much on the specific country, sector and technology under consideration.

7 Conclusions and Policy Issues

Targets for R&D intensity or expenditure are appealing and apparently easy to grasp, but they are even more easily misunderstood because the R&D 'effort' is the result of a combination of firm strategies, company demographics, industrial structures, and macroeconomic dynamics. Given their widespread use and ever-increasing importance for both policy-making and the measurement of competitiveness, it is necessary to increase our knowledge about these composite indicators by understanding their structure using a methodologically sound approach and a reliable dataset.

Aggregate R&D performance is affected by a wide range of factors, including industrial structures, company demographics, relative fiscal and monetary stances, business cycles, and corporate strategies.

This paper has examined the cause of the possible EU/US R&D investment intensity gap by investigating two possible determining factors: the effect of the sector composition (structural effect) vis-à-vis the intensity of R&D in each sector (intrinsic effect) together with the role of company demographics in R&D investment.

The data used in this study show that there are two basic reasons why EU-1000 firms have a lower aggregate R&D intensity than non-EU 1000 firms.

The first is the difference in the sectoral distribution among these firms, with the EU having a stronger specialisation in automobiles and parts, and a much weaker specialisation in IT hardware, electronics and software.

Our decomposition of the R&D intensity gap between the EU and the non-EU, the EU vs. the US and Japan vs. the US into a structural and an intrinsic effect has shown that structural differences between economies explain almost all of this gap.

The second reason – related to the first, but not determined by it – is a difference in company populations: this analysis points out that there is not a big underinvestment gap by individual EU companies with respect to the US and Japanese ones for companies at the very top of the R&D ranks. However, there is a substantial proportion of business R&D carried out by a relatively small number of EU firms which perform large volumes of R&D - as compared to the US ones, where there is a more broadly spread distribution of the level of R&D investment intensity across companies. Thus, this sub-population of firms may be a target for public policies aimed at increasing the levels and intensities of R&D in the EU.

There is disagreement about the policy significance of structural effects in R&D intensity. Jaumotte and Pain (2005) argued that structural effects are of little relevance because "the policy implications would be unclear, especially for governments seeking to raise the aggregate rate of R&D intensity".

Our view is that difficulty in identifying implications does not mean that they are unimportant. On the contrary, we suggest that structural effects raise important issues about the appropriate focus of policy analyses. Given the pervasive effects of these structural differences, one way of approaching the R&D policy debate in Europe would be to say that its implicit sub-text is a concern with Europe's industrial structure. This is almost never discussed openly in Europe (or anywhere else, for that matter), although Dosi et al. (2005) suggest in passing that it ought to be focussed on explicitly.

Does this mean that policy should consist of an attempt to emulate the industrial structures of Japan and the US? Actually that is in fact what policy has consisted of in many EU countries, and throughout the OECD. Despite the ostensible rejection of industrial policy measures based on support for specific industries, many OECD countries have adopted R&D policies that closely support sectors such as ICT, pharmaceuticals and aerospace: it is almost impossible to find an

OECD country with public R&D policies that are not focused on some combination of these R&D fields (usually combined with nanotechnology, which is not yet the basis of a sizeable industry). These R&D policies are quasi-industrial policies, in the sense that they seek to use R&D policy to support the growth of certain industries, thus shifting industrial structures towards so-called high-technology areas.

Yet it is far from clear whether industrial structures can in fact be an object of policy in this way. There are two broad issues here. One is that the non-EU advantage in R&D intensity depends not on R&D in itself but on a much stronger record of company creation, especially of mid-size companies, in ICT and related sectors. The US in particular has demonstrated an ability to create, sustain and grow a much wider array of companies, across a broader range of activities within ICT, than has the EU. Therefore, the most important issue should be the factors that facilitate this, and these are likely to extend well beyond R&D performance. They include the creation of a variety of technological opportunities, the ability to initiate new ventures, and the ability to finance the long term growth of firms. Any policy attempting to emulate US capabilities in firm creation would have to address the underlying issues of opportunity recognition, finance, risk management, and the like, which lead not only to business creation but also to business growth. A second, much more difficult question is whether such an effort would be justified at all. A curious feature of those who regard Europe as a failure in terms of R&D performance (and other areas of S&T performance) is that they simply assume that growth is shaped by R&D inputs in ICT, biotech etc, and rarely discuss the wider dimensions of EU versus non-EU economic performance. The real issue is not an idealised industrial structure, but how actual industrial structures (which as we have seen differ markedly) perform in terms of macroeconomic stability, sustainability of growth, innovation, employment quality, productivity, income and wealth distribution, access to services, government budgetary performance or external balances. Relating such performance outcomes to industrial structures would require widening the focus of innovation analysis away from R&D inputs, and exploring how different forms of innovation may occur across industries; this would require a focus on the innovation performance of industries that use non-R&D inputs to innovation, and more generally on the innovation and growth characteristics of low-R&D intensity industries (Hirsch-Kreinsen et al., (2005)). Our analysis suggests that it is time to shift the debate towards issues such as the industrial and business creation and sustained growth, and to explore the often unexpected economic outcomes of different industrial and business structures. This is a complex challenge, but an increasingly urgent policy issue.

As long as R&D is understood as one of the relevant inputs to economic growth, along with increasing skilled employment and competitiveness, R&D intensity targets will remain common in the policy sphere. However, policy-makers should become more aware of the appropriate focus of policy analysis and its implications: our decomposition shows that these may imply possible shifts towards more knowledge intense sectors of the economy. At the same time, it is auspicious to favour organic, R&D-led growth of smaller companies in new, growing sectors as preparation to enhance the future competitiveness of the EU in the global economy.

ANNEX: TABLES CHARACTERISING THE SCOREBOARD DATASET

Table A1. Characterisation of the data sample

4-digit ICB code	Sector name 4-digit ICB	EU number of companies	EU R&D (million €)	non-EU number of companies	non-EU R&D (million €)
271	Aerospace & defence	24	8 093.89	26	7 134.15
58	Alternative energy	1	17.20		
335	Automobiles & parts	45	28 781.21	55	34 644.82
835	Banks	23	2 734.85	1	38.92
353	Beverages	4	63.79	3	476.85
4573	Biotechnology	67	1 506.93	62	7 912.61
135	Chemicals	45	7 066.54	74	9 634.10
2753	Commercial vehicles & trucks	17	2 533.26	18	3 669.79
9572	Computer hardware	9	163.88	49	16 673.40
9533	Computer services	22	688.05	13	6 294.53
235	Construction & materials	29	1 129.63	20	1 362.31
2733	Electrical components & equipment	35	4 917.05	29	4 816.44
753	Electricity	21	1 387.35	11	1 197.82
2737	Electronic equipment	37	1 206.46	64	15 627.91
9574	Electronic office equipment	2	266.35	5	1 913.46
653	Fixed line telecommunications	15	4 309.70	7	3 626.12
533	Food & drug retailers	5	331.47	3	391.01
357	Food producers	35	1 888.68	17	2 467.28
173	Forestry & paper	7	275.36	3	160.01
757	Gas, water & multiutilities	10	560.98	3	168.57
272	General industrials	23	1 698.81	28	6 557.40
537	General retailers	17	525.22	3	1 180.23
453	Health care equipment & services	32	1 541.67	46	5 166.60
372	Household goods	24	1 274.29	18	2 577.85
2757	Industrial machinery	75	3 402.13	35	2 051.84
175	Industrial metals	12	842.63	17	1 680.41
277	Industrial transportation	14	367.79		
9535	Internet	3	41.20	9	2 552.12
374	Leisure goods	8	1 843.49	24	11 929.94
857	Life insurance	3	171.69		
555	Media	15	1 296.82	8	577.23
177	Mining	6	251.86	3	561.20
657	Mobile telecommunications	2	324.27	4	403.62
853	Nonlife insurance	8	139.72		
53	Oil & gas producers	11	2 220.07	15	3 543.41
57	Oil equipment, services & distribution	9	207.67	9	1 303.11
877	Other financials	19	415.68	3	170.45
376	Personal goods	21	981.15	13	1 511.16
4577	Pharmaceuticals	61	19 413.83	65	43 466.12
9576	Semiconductors	22	4 447.92	102	20 626.23
9537	Software	85	3 893.23	68	13 916.61
279	Support services	33	654.83	10	900.80
9578	Telecommunications equipment	27	12 107.15	42	12 367.17
378	Tobacco	2	170.70	3	723.05
575	Travel & leisure	15	201.93	12	1 007.12
	Grand Total	**1 000**	**126 358.38**	**1 000**	**252 983.77**

Source: Computed from the "EU Industrial R&D Investment Scoreboard" (European Commission, 2008)

Table A2: Shares of net sales and R&D intensity by sector for in the 1000 EU and 1000 non-EU *Scoreboard* sample

4-digit ICB code	Sector name 4-digit ICB	EU		non-EU	
		Share of Sales	R&D intensity	Share of Sales	R&D intensity
271	Aerospace & defence	2,29%	6,40%	3,31%	3,25%
58	Alternative energy	0,02%	2,00%		
335	Automobiles & parts	11,25%	4,64%	13,51%	3,86%
835	Banks	5,84%	0,85%	0,06%	0,98%
353	Beverages	0,82%	0,14%	0,67%	1,07%
4573	Biotechnology	0,10%	26,02%	0,48%	25,03%
135	Chemicals	4,64%	2,76%	5,25%	2,76%
2753	Commercial vehicles & trucks	1,33%	3,46%	2,20%	2,51%
9572	Computer hardware	0,04%	7,59%	5,85%	4,29%
9533	Computer services	0,39%	3,17%	1,80%	5,25%
235	Construction & materials	3,80%	0,54%	1,72%	1,19%
2733	Electrical components & equipment	2,61%	3,42%	2,34%	3,11%
753	Electricity	3,97%	0,63%	2,00%	0,90%
2737	Electronic equipment	0,44%	4,97%	4,95%	4,76%
9574	Electronic office equipment	0,07%	6,65%	0,57%	5,08%
653	Fixed line telecommunications	5,04%	1,55%	3,05%	1,79%
533	Food & drug retailers	2,43%	0,25%	2,09%	0,28%
357	Food producers	2,55%	1,34%	2,80%	1,33%
173	Forestry & paper	0,98%	0,51%	0,40%	0,60%
757	Gas, water & multiutilities	4,75%	0,21%	0,28%	0,92%
272	General industrials	1,47%	2,09%	5,11%	1,93%
537	General retailers	3,77%	0,25%	0,31%	5,70%
453	Health care equipment & services	0,60%	4,62%	1,03%	7,54%
372	Household goods	1,11%	2,08%	1,80%	2,15%
2757	Industrial machinery	2,39%	2,58%	1,53%	2,02%
175	Industrial metals	3,41%	0,45%	2,66%	0,95%
277	Industrial transportation	2,07%	0,32%		
9535	Internet	0,00%	39,43%	0,28%	13,75%
374	Leisure goods	0,57%	5,86%	2,86%	6,28%
857	Life insurance	0,93%	0,34%		
555	Media	1,14%	2,07%	0,90%	0,96%
177	Mining	1,32%	0,35%	0,46%	1,82%
657	Mobile telecommunications	0,88%	0,67%	0,62%	0,98%
853	Nonlife insurance	1,62%	0,16%		
53	Oil & gas producers	14,34%	0,28%	15,46%	0,35%
57	Oil equipment, services & distribution	0,44%	0,85%	0,88%	2,24%
877	Other financials	0,82%	0,92%	0,03%	7,48%
376	Personal goods	1,04%	1,71%	0,92%	2,46%
4577	Pharmaceuticals	2,84%	12,40%	4,27%	15,34%
9576	Semiconductors	0,48%	16,73%	2,27%	13,70%
9537	Software	0,47%	14,95%	1,45%	14,46%
279	Support services	0,89%	1,34%	0,64%	2,13%
9578	Telecommunications equipment	1,69%	12,96%	1,56%	11,93%
378	Tobacco	0,27%	1,14%	0,99%	1,10%
575	Travel & leisure	2,06%	0,18%	0,62%	2,46%
	Grand Total	**100,00%**	**2,29%**	**100,00%**	**3,81%**

Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2008)

Table A.3: R&D intensity of Scoreboard companies by group of sectors and world region

R&D intensity	EU	USA	Japan	RoW
High	12.6%	11.4%	6.5%	8.5%
Medium high	3.9%	3.1%	3.8%	2.6%
Medium low	1.4%	1.5%	1.9%	1.9%
Low	0.5%	0.3%	0.8%	0.7%

Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2008)

References

Aghion P., (2006) "A Primer on Innovation and Growth" – Bruegel Issue 2006-06 October 2006

Azagra-Caro, J.M. and Grablowitz, A.(2008): "Data on Business R&D: Comparing BERD and the Scoreboard", European Commission, Joint Research Centre, Institute for Prospective Technological Studies, Technical Report EUR 23364 EN

Bartelsman E., Scarpetta S., Schivardi F., (2003) "Comparative Analysis of Firm Demographics and Survival: Micro-Level Evidence for the OECD Countries", OECD Working Paper - No. 348, 16/01/2003

Bilbao-Osorio B., Rodríguez-Pose A., (2004) "From R&D to Innovation and Economic Growth in the EU", *International Journal of Growth and Change*, Vol. 35 Issue 4, pp. 434-435

Ciupagea C., Moncada-Paternò-Castello P. (2006), "Industrial R&D Investment: A comparative analysis of the top EU and non-EU companies Based on the EU 2004 R&D Scoreboard", *Revista de Economía Mundial*, n. 15, 2006, pp. 89-120 – ISSN: 1576-0162

Coccia M., (2008) "What is the optimal rate of R&D investment to maximize productivity growth?", *Technological Forecasting & Social Change*, in press.

Cohen E., Lorenzi J-H., (2000) "Politiques Industrielles pour l'Europe" – Rapport du CAE, No. 26, Paris, La documentation française ISBN 2-11-0044598

DIUS, (2008) "The 2008 R&D Scoreboard", UK Department for Innovation, Universities and Skills, London

DTI, (2006) "The 2006 R&D Scoreboard" by Tubbs M., UK Department of Trade and Industry, London

Dosi G., Llerrena P., Sylos Labini, M,(2005) "The relationship between science, technologies and their industrial exploitation", paper presented to Conference on science, technology and innovation policy, in memory of Keith Pavitt, UNU-Merit, Maastricht.

Dosi G., (1997), "Opportunities, incentives and the collective patterns of technological change", *Economic Journal*, 107: 1530-1547.

Duchêne V., Lykogianni E., Verbeek A., (2009) "EU R&D in Services Industries and the EU-US R&D Investment Gap", European Commission, Joint Research Centre, Institute for Prospective Technological Studies and Directorate General Research "IRMA Working Papers Series" No. 03/2009 - JRC50911

Erken H. and van Es F. (2007): "Disentangling the R&D shortfall of the EU vis-à-vis the US", Jena Economic Research Papers, 2007-107,

ETEPS (2007), "Impact of industrial R&D on business performance: Evidences from quantitative analyses based on company data and official statistics" Contract 150083-2005-02-BE for the European Commission, JRC-IPTS.

European Commission (2008): "The 2008 EU Industrial R&D Investment Scoreboard", Joint Research Centre, Institute for Prospective Technological Studies and Directorate General Research - Scientific and Technical Research series – EUR 23530 EN; ISSN 1018-5593

European Commission (2007a), "Data on Business R&D: Comparing BERD and the Scoreboard" - Joint Research Centre – Institute for Prospective Technological Studies and Directorate General Research - Scientific and Technical Research series – EUR 23364 EN; ISSN 1018-5593

European Commission (2007b), "Key figures 2007 on Science, Technology and Innovation Towards a European Knowledge Area", ISBN 92-79-03450-2

European Commission, (2003), "Investing in research: an action plan for Europe", Communication from the Commission COM (2003) 226 final/2, Brussels, 4 June 2003

Eurostat, (2007) "Community Innovation Statistics - More than half of the innovative enterprises in the EU do in-house R&D", European Commission, Statistics in Focus on CIS 4 data, issue No. 72/2007 Falk, M., (2004) "What Drives Business R&D Intensity Across OECD Countries?", WIFO Working Paper No. 236/2004

GFII, (2007) "Research and Development in Information and Communication Technologies in the Major Industrial Countries Statistical Analysis of Investment" - Study prepared for the French Ministry for Education, Higher Education and Research by the French Association of Electronic Information Industry (Groupement Français de l'Industrie de l'Information: GFII) in partnership with M.V. Études et Conseil, February 2007

Godin B., (2002) "Technological Gaps: an important episode in the construction of S&T statistics", *Technology in Society*, 24, pp.387-413

Griffith R, Redding S, Van Reenen J., (2004) "Mapping the two faces of R&D: productivity growth in a panel of OECD industries". Rev Econ Stat 2004;86 (4):883–95.

Griffith R., Harrison R., (2003) "Understanding the U.K.'s Poor Technological Performance", *IFS Briefing Note* No.37.

Guellec D., van Pottelsberghe de la Potterie B., (2001) "R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries", *OECD Economic Studies*, 33, 3, 2001, pp.103-126Haveman E., Donselaar P., (2008) "Analysis of the Netherlands' private R&D position", Innovatieplatform Position Paper, September 2008.

Hirsch-Kreinsen H., Jacobson D., Laestadius S., (eds.) (2005) "Low-tech Innovation in the Knowledge Economy", (Book) - 334 pp., Peter Lang Editor ISBN 3-631-53682-8 – US-ISBN 0-8204-7700-1

Intellectual Property Research Institute of Australia, (2006) "R & D and Intellectual Property Scoreboard 2006: Benchmarking Innovation in Australian Enterprises", University of Melbourne, Van Dyke N. (editor), pp. 54, A4, ISSN 1444-2639Jaumotte, F. and Pain, N. (2005), "Innovation in the Business Sector", OECD Economics Department Working Paper 459, ECO/WKP (2005) 46.

Jones C. I., Williams J. C., (1998) "Measuring The Social Return To R&D", *The Quarterly Journal of Economics*, 113, 1119-1135.

Kafouros M.I., (2008), "Economic Returns to industrial research" *Journal of Business Research*, Volume 61, Issue 8, August 2008, Pages 868-876

Lindmark S., Turlea G., Ulbrich M., (2008) "Business R&D in the ICT Sector – Paper presented at the Conference "Knowledge for Growth – European Strategies in the Global Economy" – Toulouse, 7-9 July 2008 and submitted to Science and Public Policy in 2008.

Mathieu A., Van Pottelsberghe de la Potterie B., (2008) "A Note on The Drivers of R&D Intensity", Centre for Economic and Policy Research, Working Paper No. DP6684, February 2008. Available at www.cepr.org/pubs/dps/DP6684.asp.asp

Mitchell G.R.,(1999) "Global Technology Policies for Economic Growth", *Technological Forecasting and Social Change*, Volume 60, Issue 3, March 1999, Pages 205-214

Mowery D.C., Rosenberg N., (1989) "Technology and the Pursuit of Economic Growth" (book), Cambridge University Press – ISBN 0521-38033-2

NSF (2005) National Science Foundation, Division of Science Resources Statistics "National Patterns of Research and Development Resources", NSF 05-308, Brandon Shackelford, Arlington, http://www.nsf.gov/statistics/nsf05308/pdf/front.pdf

OECD, (2008) "OECD Science, Technology and Industry Scoreboard 2007", Organisation for Economic Co-operation and Development, Paris p.p. 228, ISBN: 978-92-64-03788-5

OECD, (2002) "Frascati Manual 2002: Proposed Standard Practice for Surveys on Research and Experimental Development", Organisation for Economic Co-operation and Development, Paris. OECD, (1997) "Revision of the High-Technology Sector and Product Classification", by Hatzichronoglou, T., - OECD Science, Technology and Industry Working Papers, 1997/2, OECD Publishing doi:10.1787/134337307632

Ortega-Argilés R. and Brandsma A., (2008) "EU-US differences in the size of R&D intensive firms: Do they explain the overall R&D intensity gap?" European Commission, JRC-IPTS and DGRTD, "IRMA Working Papers Series" No. 02/2009 - JRC50908Ortega-Argilés R., Piva M, Potters L., and Vivarelli M. (2009), "Is Corporate R&D Investment in High-Tech Sectors More Effective?", European Commission, JRC-IPTS and DGRTD, "IRMA Working Papers Series" No. 03/2009 - JRC50909

Ortega-Argilés R., Vivarelli M. and Voight P., (2009) (guest's editors) "Drivers and impacts of corporate R&D in Small and Medium-sized Enterprises" – *Small Business Economics Journal*– Special Issue - To appear in the course of 2009.

O'Sullivan M., (rapporteur), (2007) "The EU's R&D Deficit and Innovation Policy", report based on contributions of the members of the EU Commissioner J. Potočnik's Expert Group on "Knowledge for Growth"

Pavitt K., Soete L., (1982) "International differences in economic growth and the international location of innovation", in H. Giersch (ed.). *Emerging Technologies*, pp. 105-33, Tubingen: Mohr

Pessoa, A., (2007) "Innovation and Economic Growth: What is the actual importance of R&D?," FEP Working Papers 254, Universidade do Porto, Faculdade de Economia do Porto.

Pianta, M., (2005) 'Innovation and employment', in J. Fagerberg, D. Mowery and R. Nelson (eds.), *The Oxford Handbook of Innovation*, Oxford University Press, Oxford: 568-598.

Romer P.M., (1990) "Endogenous technical change", *Journal of Political Economy*, No. 98 (1990) (5), pp. 71–102.

Sheehan J., Wyckoff A., (2003) "Targeting R&D: Economic and Policy Implications of Increasing R&D Spending," OECD Science, Technology and Industry Working Papers 2003/8, OECD Directorate for Science, Technology and Industry

Soete L., (2007) "From Industrial to Innovation Policy", *Journal of Industry, Competition and Trade* – Springer - Volume 7, Numbers 3-4 / December, 2007.

Soete L., (2006) "A Knowledge Economy Paradigm and its Consequences" – UNU-MERIT Working Paper No.2006-001, January 2006.

Soete L., (2005) "On the dynamics of innovation policy: A Dutch perspective," in De Gijsel, P. and Schenk, H. (eds.), Multidisciplinary Economics. Dordrecht, (Springer).

Solow R.M., (1957) "Technical change and the aggregate production function", *Review of Economics and Statistics* 39, pp. 312-320.

Van Ark B., Inklaar R., McGuckin RH., (2003) "ICT and Productivity in Europe and the United States Where Do the Differences Come From?", CESifo GroupCESifo Economic Studies 2003 49(3):295-318; doi:10.1093/cesifo/49.3.295

Van Reenen J., (1997a) "Why has Britain had slower R&D growth?", *Research Policy*, 26 1997, pp.493-507

Van Reenen J., (1997b) "Employment and technological innovation: evidence from U.K. manufacturing firms', *Journal of Labour Economics,* 15: 255–284

Velsen, J.F.C. van (1988), "R&D en economische structuur", *Economisch Statistische Berichten*, 73(3684), blz. 1133-1137

Verspagen, B., Hollanders H., (1998) "De Nederlandse innovatie-achterstand", *Economisch Statistische Berichten*, 83, 290-291.

The mission of the JRC-IPTS is to provide customer-driven support to the EU policy-making process by developing science-based responses to policy challenges that have both a socio-economic as well as a scientific/technological dimension.

European Commission

JRC51955 – Joint Research Centre – Institute for Prospective Technological Studies

IPTS WORKING PAPER on CORPORATE R&D AND INNOVATION - No. 11/2009

Title: Does Europe perform too little corporate R&D?
A comparison of EU and non-EU corporate R&D performance

Author(s): Pietro Moncada-Paternò-Castello (JRC-IPTS), Constantin Ciupagea (Institute of World Economy and Romanian Centre for Economic Modelling, Romania), Keith Smith (Australian Innovation Research Centre, University of Tasmania, Australia), Alexander Tübke (JRC-IPTS) and Mike Tubbs (Innovomantex Ltd and Ashcroft International Business School, United Kingdom)

Luxembourg: Office for Official Publications of the European Communities
2009

Technical Note

Abstract
This paper examines whether there are differences in private R&D investment performance between the EU and the US and, if so, why. The study is based on data from the 2008 EU Industrial R&D Investment Scoreboard. The investigation assesses the effects of several very distinct factors that can determine the relative size of the overall R&D intensities of the two economies: these are the influence of sector composition (structural effect) vis-à-vis the intensity of R&D in each sector (intrinsic effect) and the company demographics. The paper finds that the lower overall corporate R&D intensity for the EU is the result of sector specialisation (structural effect) - the US has a stronger sectoral specialisation in the high R&D intensity (especially ICT-related) sectors than does the EU, and also has a much larger population of R&D investing firms within these sectors. Since aggregate R&D indicators are so closely dependent on industrial structures, many of the debates and claims about differences in comparative R&D performance are in effect about industrial structure rather than sector R&D performance. These have complex policy implications that are discussed in the closing section.

The mission of the Joint Research Centre is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of European Union policies. As a service of the European Commission, the Joint Research Centre functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

JRC
EUROPEAN COMMISSION

Publications Office
Publications.eu.int