

R&D IN EUROPE

**EXPENDITURES ACROSS SECTORS,
REGIONS AND FIRM SIZES**

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Cover photo depicts a simulation of the decay of a Higgs particle following a collision of two protons at the Large Hadron Collider (LHC) of the European particle physics institute (CERN), based outside Geneva.

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FOREWORD

Insufficient investment in R&D is often adduced as the key reason why Europe has lagged over the years behind the US in terms of economic growth. The biggest financial crisis in living memory has now abruptly thrown the economies on both sides of the Atlantic into a deep recession, shifting the attention of policy-makers and market operators from longer-term growth factors towards the issue of how to sustain demand in the short run. It would be a grave mistake, however, to neglect fundamental issues such as R&D because of the urgency of the crisis.

This study provides an in-depth comparative analysis of the structure of R&D in Europe. Its findings contradict the often held idea that the gap between Europe and the US is due mainly to a greater specialization of the US in high-tech industries. Differences in firm size also seem to play only a minor role. R&D is usually associated with industry, and particularly manufacturing given that its main purpose is to find new products or better ways to produce existing ones. This study shows that R&D could also be a key factor in services. As services account for over two-thirds of GDP and employment, it is appropriate to understand the importance of R&D for this sector as well.

An abrupt fall in investment played an important role in precipitating the recession and it will now be important to understand whether this represents a structural shift because financial markets are no longer willing to finance R&D investment. It remains to be seen whether the bank-based system adopted in Europe (especially on the continent) will provide a more resilient source of funding for R&D than the market based systems of the US and other countries with Anglo-Saxon-type financial systems.

It is thus a pleasure for us at CEPS to present this study undertaken by Kristian Uppenberg, Senior Economist at the European Investment Bank, to the wider public. The EIB represents the institution which allows

member states to pool their financial resources to foster investment and thus growth. Its mission has become even more important in these difficult times, and understanding the contribution of R&D to economic growth remains crucial.

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EXECUTIVE SUMMARY

The 2010 initial deadline for achieving the Lisbon goals is fast approaching. It has been known for some time, however, that this ambitious agenda will not be achieved on time. Thus, this target year has long been abandoned from official policy documents. But while the Lisbon agenda's initial timetable may have turned out to be unreasonable, its underlying economic logic is not.

This study focuses on one of the targets set out at Lisbon: raising the level of research and development (R&D) in the business sector. The Lisbon agenda set the goal of raising the EU's R&D spending to 3% of GDP, of which two-thirds should be by businesses rather than by the government or education sectors. This goal reflects widespread concern emerging in the late 1990s that Europe's lingering gap in productivity growth vis-à-vis the US stemmed in no small part from a shortage of innovation in the business sector. This appeared to be a structural phenomenon, as the EU's R&D gap with respect to the US and Japan had been in place and relatively constant over several decades.

If this gap is to be narrowed, a better understanding of its causes is required. With the aim of aiding this understanding, this study decomposes aggregate business expenditures on R&D along several dimensions. Following the introduction, chapters 2 and 3 look at the sectoral distribution of business R&D spending across EU countries. Chapters 4 and 5 decompose R&D spending by firm size and by region, respectively.

The sectoral decomposition shows that the business R&D gap between the EU and the US is not the result of different sectoral allocations. On the contrary, Europe is actually more specialised in relatively R&D-intensive manufacturing sectors. Therefore, if over time Europe were to emulate a US-style sectoral composition and expand services at the expense

of manufacturing, the R&D gap would actually widen, other things being equal. Europe's lower overall level of R&D intensity is thus the result of lower levels of R&D intensity in individual sectors. This is especially the case in the manufacturing of information and communications technology and other non-transportation equipment as well as in the services sector. Although the R&D intensity in services is low when compared with manufacturing, its large size in the economy nevertheless translates into a large absolute number. Indeed, the services sector alone accounts for three-quarters of the overall EU-US R&D gap.

The second decomposition of R&D spending is by firm size. Survey data produced by Eurostat offer a wealth of information on R&D and innovation across countries and firm size classes. R&D by small and medium-sized enterprises (SMEs, with up to 250 employees) accounts for a substantial proportion of total business R&D spending in some countries, although less so in large or highly innovative ones. Notably, in the US, Japan, Germany, the UK, France, Italy, Sweden, Finland and a few others, SMEs account for 20% or less of total business sector R&D. Pertinently, since the SMEs' share of total R&D is smaller in countries with high overall R&D spending, including the US and Japan, it seems implausible that Europe's lower overall level of R&D can be addressed through increased R&D by SMEs.

Furthermore, reflecting their typically large share in total business R&D, large firms also receive the bulk of government support for R&D. Still, in most countries, SMEs are treated relatively favourably, receiving a greater share of public R&D support than their shares in total business R&D spending. One can therefore not argue that SMEs are being short-changed by public R&D policies.

Chapter 5 takes a regional look at R&D in Europe. Business R&D is concentrated in certain economic clusters as a direct consequence of the geographical concentration of economic activity in general. Yet the agglomeration of R&D goes even beyond this explanation, since R&D intensity (i.e. the ratio of R&D spending to regional value added) also tends to be higher in certain economic centres. The extent to which R&D is clustered in certain regions differs across countries. Typically, regional concentration is higher in countries with high aggregate levels of R&D spending. This is for instance the case in Germany and Sweden. Also, in the new member states in Central and Eastern Europe, R&D is usually more concentrated, reflecting the tendency of a large share of R&D activity to be located around the capital city and possibly one more economic centre.

That a high degree of regional clustering of R&D is otherwise more predominant in countries with high levels of R&D suggests that a successful elevation of other countries' R&D intensities would also be accompanied by an increased regional density of R&D.

Regional concentration of R&D is not a problem per se. There is strong evidence of non-negligible localised spillovers in R&D. This means that the R&D spending of one firm is more productive in terms of patent applications if it is located close to the R&D activities of other firms. Indeed, empirical studies show that the positive spillover effects of this kind of regional concentration are quite substantial. It follows from this that if R&D activities were evenly spread across Europe, for instance as a result of regionally targeted public support, such localised spillovers would be squandered. This would then lower the overall productivity of R&D and probably also of the economy as a whole.

The different disaggregations of R&D data presented in this study help us to better understand the characteristics of the EU-US R&D gap. While the EU lags behind the US in aggregate R&D (and especially business R&D) spending, that is not true for all EU countries, regions or sectors. Although this study does not discuss specific policies to help boost business R&D spending in the EU or its effectiveness, any such policies will have to take into account this diversity.

1. INTRODUCTION

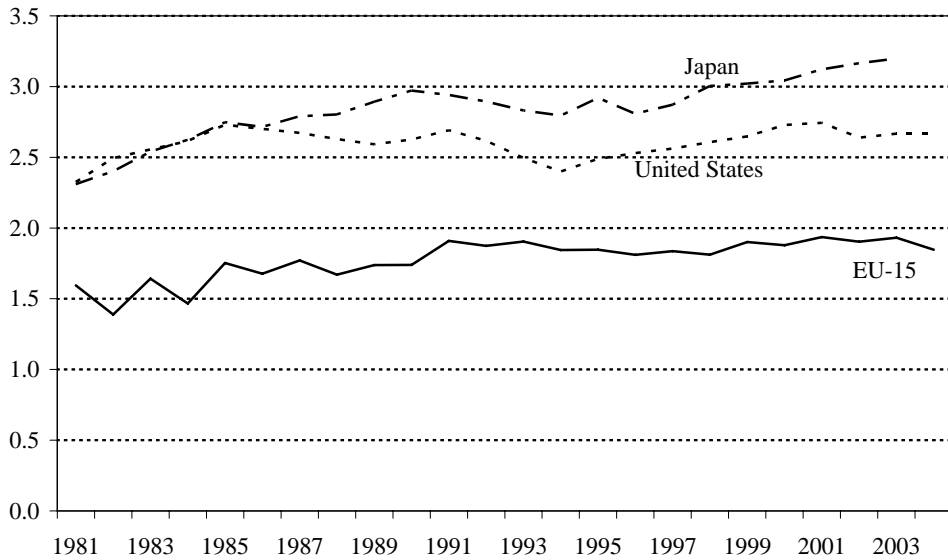
The empirical literature on economic growth of the past several decades has broadly converged on the view that long-term economic success depends crucially on what is known as total factor productivity (TFP). TFP is that part of economic growth that does not stem from increasing the amount of fixed capital or labour, but from their more effective use in terms of output. One key ingredient in achieving such productivity gains is product and process innovation. Innovation is the output of a complex process that includes organisational designs, incentives and competition, none of which is easily measured. A more readily measurable input into the innovative process is the resources allocated directly to the invention of new products and processes in the form of research and development (R&D). Although only one of several inputs into the innovative process, R&D expenditures have been found to have a strong causal influence on innovation outputs such as patents and productivity gains.

The 2000 Lisbon strategy grew out of the recognition that Europe was persistently lagging behind the US, Japan and other leading industrial nations in terms of innovation and productivity growth. Its goal was to close this growth gap by directly targeting several of those key inputs that have been found to affect economic growth, including employment rates, higher education and R&D.

The focus of this study is to shed some light on Europe's relatively low level of R&D spending when compared with the US and Japan. One key characteristic of this gap is its persistence and constancy over the past several decades, as suggested by Figure 1. US R&D spending averaged 2.6% of GDP in the period 1981-90, exactly the same as the 1991-2004 average. In Japan the ratio rose, from 2.7 to 3.0%, while in the EU it rose from 1.6 to 1.9% of GDP. These figures strongly suggest that the R&D gap

between the EU-15 and its main competitors is a long-term phenomenon that has structural rather than cyclical causes, and that these structural causes are still in place. The stability of these variables imply that including one or two more years of data (which is currently not possible owing to the long lags in the publication of these statistics) would not substantially change the picture.

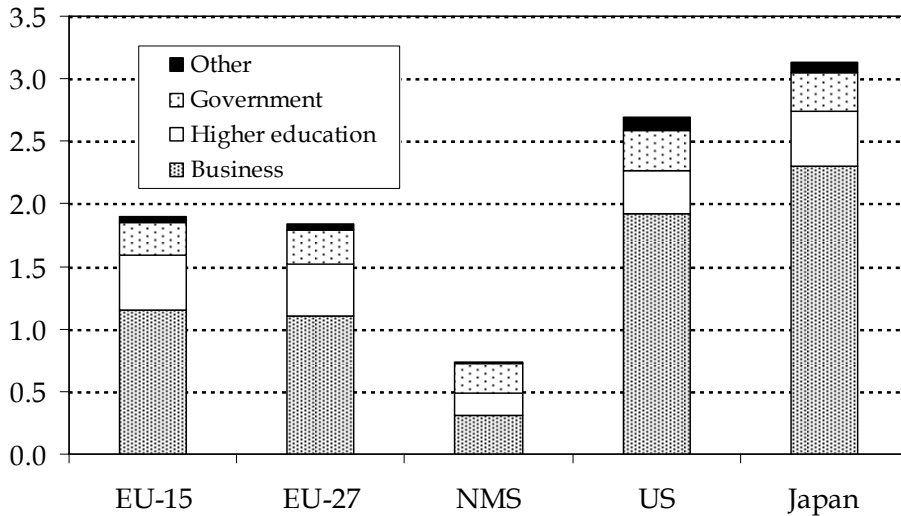
Figure 1. Gross domestic expenditure on R&D (as a percentage of GDP)



Source: Eurostat.

A second key characteristic of the EU-US R&D gap is that it is entirely attributable to the business sector, as shown in Figure 2. In the government and higher education sectors, there is little difference in R&D spending across the major economies. As recognised in the Lisbon strategy, if Europe is to boost its overall level of R&D spending towards those levels seen in the US and Japan, it will mostly have to occur in the business sector. For this reason, the rest of this report concentrates on the business sector.

Figure 2. Breakdown of R&D spending (as a percentage of GDP, 2000–04)



Sources: Eurostat and own calculations.

While the basic facts of R&D spending discussed above are relatively well known, there is a wealth of information hidden within these aggregates that is less frequently discussed. The purpose of this study is to illuminate the causes of Europe's relatively low R&D spending through a more in-depth exploration of the R&D statistics. For this purpose, the following four chapters of this book decompose business R&D spending along several dimensions. Chapters 2 and 3 look at the distribution of business R&D spending across sectors and across EU countries. A key question posed here is to what extent cross-country differences in business R&D spending can be accounted for by their sectoral specialisation. Chapter 4 decomposes R&D by firm size, focusing in particular on the role of small and medium-sized enterprises (SMEs) in R&D spending. Chapter 5 looks at the regional distribution of business R&D spending in the EU. In this context, we also address the influence of the positive externalities of R&D on its geographical concentration.

For the most part, data limitations mean that the EU is represented in this study by the EU-15 or some sub-sample of the 'old' EU member states. In this context, terms such as 'EU-10' always refer to sub-samples of old EU member states. As suggested by Figure 2, R&D spending in the new member states (NMS) of the EU remains substantially below the EU average. Because of both data limitations and the particular circumstances of these countries, R&D in the NMS is not covered in any great detail in this study.

2. R&D: A SECTORAL DECOMPOSITION

Not all sectors of any economy are equally intensive in the use of R&D. Some sectors, such as the manufacturing of information and communications technology (ICT) or transport equipment, depend on extensive product and process innovation to thrive in their highly contested global marketplace. Other sectors, notably services, devote a much smaller share of their resources to R&D. A natural starting point when trying to understand the aggregate R&D gap between the EU and the US is therefore to disaggregate R&D expenditures by sector. This will help us address two important questions:

- i) Does the R&D gap stem from different sectoral specialisations or from lower R&D intensities in individual sectors?
- ii) Does the R&D gap exist in just a few sectors or is it an economy-wide phenomenon?

The answers to these questions have great bearing on how to design policies aimed at raising aggregate R&D intensity in the EU. In addressing them, we draw on sectoral R&D and value added data published by the OECD for the business sector.¹

2.1 Is sectoral composition at the root of the EU's low overall R&D intensity compared with the US?

To obtain a sectoral measure for R&D intensity that is comparable to the country aggregates above, we divide the non-agricultural business sector

¹ The data used in this chapter are from the OECD's Analytical Business Enterprise Research and Development database (ANBERD), also available in paper format as OECD (2006).

R&D (BERD) by the total value added in each sector, i.e. the sectoral equivalent of GDP. The major sectors² we look at are the following:

- Manufacturing of transport equipment
- Manufacturing of ICT and other non-transport machinery and equipment
- Manufacturing of chemicals, pharmaceuticals and non-metal minerals
- Manufacturing of food, textiles, leather, wood and paper products
- Manufacturing of basic metals and metal products
- Other manufacturing
- Electricity, gas and water supply
- Construction
- Commercial services

The EU is represented here by 10 EU countries (henceforth the EU-10) for which industry-level data are available. These are Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Spain, Sweden and the UK.³ The data have been averaged over the 2000–03 period to eliminate any short-term cyclical effects.

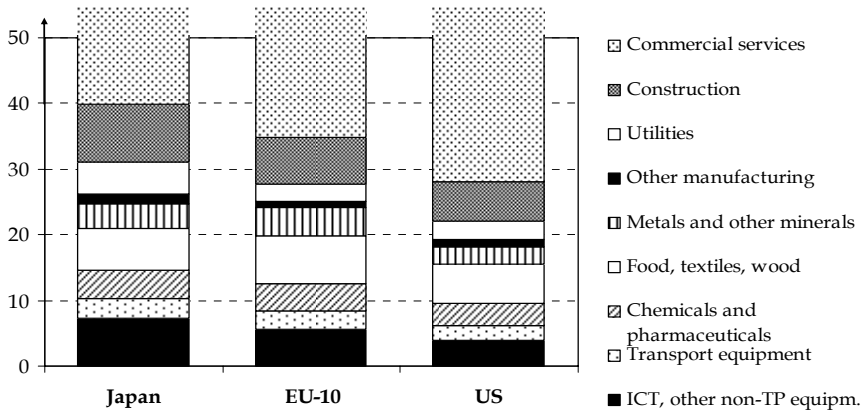
To begin with, Figure 3 shows the sectoral composition of the three economies studied, by value added. Commercial services are by far the single largest industry, accounting for well over half the value added of the non-agricultural business sector. If it were the case that the EU specialised in less R&D-intensive sectors, then this would also imply that its lower aggregate R&D intensity was at least partly a sectoral problem, as opposed to a problem of insufficient R&D spending in individual sectors. But that is not the case, at least not at this level of sectoral disaggregation. The three sectors with the highest levels of R&D intensity are shown at the bottom of the figure, more specifically:

- 1) the manufacturing of transportation equipment,
- 2) the manufacturing of ICT and other non-transport equipment, and
- 3) the manufacturing of chemicals, pharmaceuticals and non-metal minerals.

² Some smaller sectors have been bundled together.

³ These 10 countries account for 96% of the GDP of the EU-15.

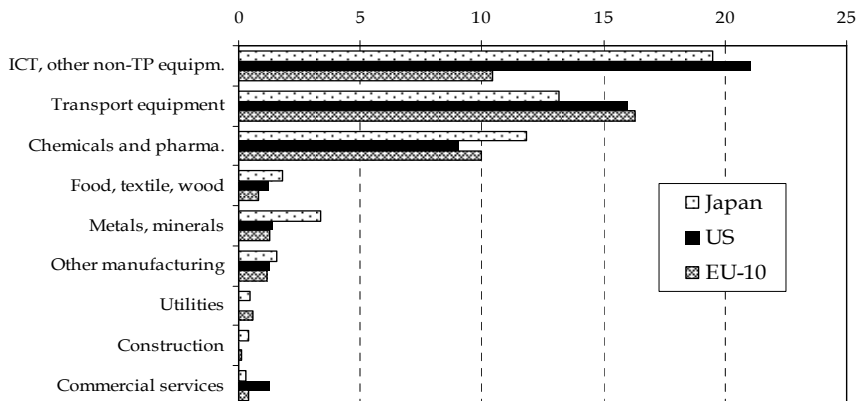
Figure 3. Sectoral composition of value added (as a percentage of country/region total, average 2000–03)



Source: OECD.

We can see in Figure 3 that these three relatively R&D-intensive sectors account for a larger share of the total business sector value added in the EU than in the US (although their share is even higher in Japan). As Figure 4 shows, R&D spending as a share of value added averages between 10 and 20% in these three sectors, compared with less than 5% of value added in all other business sectors. These three groups account for 60-80% of total business R&D spending in the EU, the US and Japan, while constituting only 10-15% of total business value added.

Figure 4. R&D intensity in selected industries (R&D spending as a percentage of value added, average 2000–03)



Source: OECD.

To illustrate the relative importance of sectoral specialisation vs. sectoral R&D intensity in accounting for the overall R&D gap between the EU and the US, we conduct two simple counterfactual simulations, shown in Table 1.

Table 1. Business sector R&D intensity (as a percentage of value added)

US business sector R&D intensity, actual	2.7
EU-10 business sector R&D intensity, actual	1.9
1) EU R&D intensity with US sectoral composition	1.5
2) EU sectoral composition with US R&D intensity	3.0

Source: Own calculations based on OECD data.

First, let us assume that the EU had the same sectoral composition as the US, but kept its actual R&D intensity sector-by-sector (1). Since this sectoral reallocation would actually reduce the shares of the three most R&D-intensive sectors in the EU economy, the result would be to *lower* the EU's overall R&D intensity, from 1.9 to 1.5% of value added.

Second, let us assume instead that the EU's R&D intensity was identical to that of the US, sector-by-sector, while maintaining its own sectoral composition (2). This would raise the R&D intensity of the EU to 3.0% of value added, above that of the US.

On balance, this simple exercise shows that at this level of sectoral disaggregation, the EU's relatively low overall R&D intensity is not caused by a sectoral specialisation skewed towards less R&D-intensive sectors, but by low R&D intensity within sectors.

2.2 The R&D gap between the EU and the US is concentrated on just a few sectors

The EU may be suffering from an overall R&D deficit relative to the US and Japan, but that is not the case in all sectors. On the contrary, as illustrated by Table 2, virtually the entire R&D gap between the EU and the US stems from just two broad sectors:

- First is the manufacturing of ICT and other non-transportation machinery and equipment. In this sector, US R&D intensity is twice as high as that of the EU.
- Second is the commercial services sector. Here US R&D intensity is three times that of the EU.

Table 2. Sources of the EU-US gap in business sector R&D intensity

	<u>% of sector value added</u>			US-EU gap as a % of EU level
	EU-10	US	US-EU gap	
Transport equipment	16.3	16.0	-0.3	-2
ICT and other non-transport equipment	10.5	21.0	10.6	101
Chemicals and pharmaceuticals	10.0	9.0	-1.0	-10
Metals and minerals	1.3	1.4	0.1	9
Food, textiles, wood and paper	0.8	1.2	0.4	57
Utilities	0.6	0.1	-0.5	-88
Commercial services	0.4	1.3	0.9	215
Construction	0.1	0.1	0.0	-45
All industries	1.9	2.6	0.7	37

Source: OECD.

The large lead that the US has in these three sectors contrasts sharply with some other sectors, where Europe is on par with or even above the US levels of R&D intensity. These include, notably, the manufacturing of transport equipment and the chemicals and pharmaceuticals sector.

So let us take a closer look at the two major sectors in which the US has a clear lead in terms of R&D intensity, beginning with the manufacturing of ICT and other non-transport machinery and equipment. To illustrate the importance of this sector, if we assume counterfactually that the EU were to raise the R&D intensity in the ICT and other non-transport equipment sector to that of its US equivalent, while leaving R&D spending in all other sectors unchanged, this alone would bridge over four-fifths of the EU's business sector R&D gap vis-à-vis the US.

Services are the second sector in which there is a large gap in R&D intensity between the EU and the US. In the EU-10, R&D spending amounts to 0.4% of the sector's value added, against 1.3% in the US. In addition, the US commercial services sector is larger, accounting for 72% of business sector value added, against 65% in the EU. Similar to the previous case, bridging the EU-US R&D gap in commercial services alone (i.e. leaving R&D intensity in all other sectors unchanged) would eliminate some four-fifths of the EU-US R&D gap for the business sector as a whole. Even though R&D intensity in services is low relative to that in manufacturing,

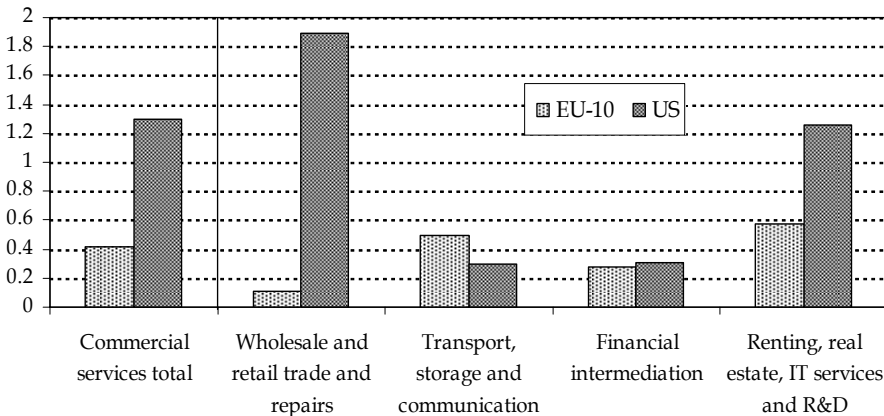
the very large size of this sector nevertheless makes it a significant element in the total.

To better understand where the EU-US R&D gap in commercial services lies, it helps to decompose commercial services into its main industries:

- wholesale and retail trade and repairs;
- transport, storage and communication;
- financial intermediation; and
- renting, real estate, IT services and R&D.⁴

As shown in Figure 5, it turns out that there are distinct differences across these sub-sectors when it comes to the R&D gap. In effect, a significant gap exists in only two of the four sectors listed above: in *wholesale and retail trade and repairs*, and in *renting, real estate, IT services and R&D*. Together these two sectors account for more than two-thirds of the commercial services sector’s value added and R&D spending in both the EU and the US.

Figure 5. R&D intensity within commercial services (R&D spending as a percentage of value added, average 2000–03)



Source: OECD.

⁴ In the OECD ANBERD tables, this category is referred to as “Real estate, renting and business activities”. This category contains a heterogeneous set of activities, including IT services, software and R&D.

The EU-US gap in R&D intensity in *retail and wholesale trade and repairs* is particularly noteworthy. This sector accounts for around one-quarter of the value added of the services sector and the transatlantic divide in terms of R&D spending is enormous. In the US, firms in this sector spend 1.9% of value added on R&D, against 0.1% in the EU.⁵

The second R&D gap in services is in the sector that we call *renting, real estate, IT services and R&D*. US R&D intensity in this sector is double that of the EU. This is by far the largest services-sector segment, accounting for just under half the value added of the commercial services sector in both the US and the EU.

2.3 Sectors with a large transatlantic gap in R&D also tend to have a large gap in productivity growth

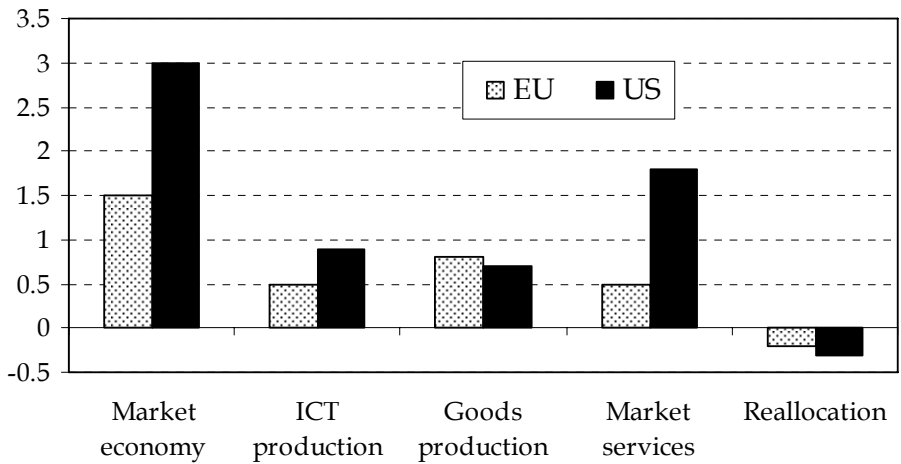
The sectoral distribution of the EU-US R&D gap becomes especially interesting when compared with productivity developments. Without inferring a direct causality from R&D to productivity, it is nevertheless striking that the sectoral productivity gap between the EU and the US largely mirrors the R&D gap described above. A string of recent studies have analysed the widening EU-US productivity gap using a sectoral approach. Several papers by Bart Van Ark and his co-authors observe, for example, that virtually the entire gap in productivity growth between the EU and the US is attributable to only a few sectors, particularly ICT production and market services (Figure 6).⁶

The productivity gap in market services is furthermore driven almost exclusively by *distribution services* (i.e. wholesale and retail trade) and *finance and business services*. In other words, the EU-US productivity gap stems from exactly those sectors in which the R&D gap is also the greatest (Figure 7).

⁵ R&D data for France are not available for this sector, so the EU average is based on the other nine countries in the sample.

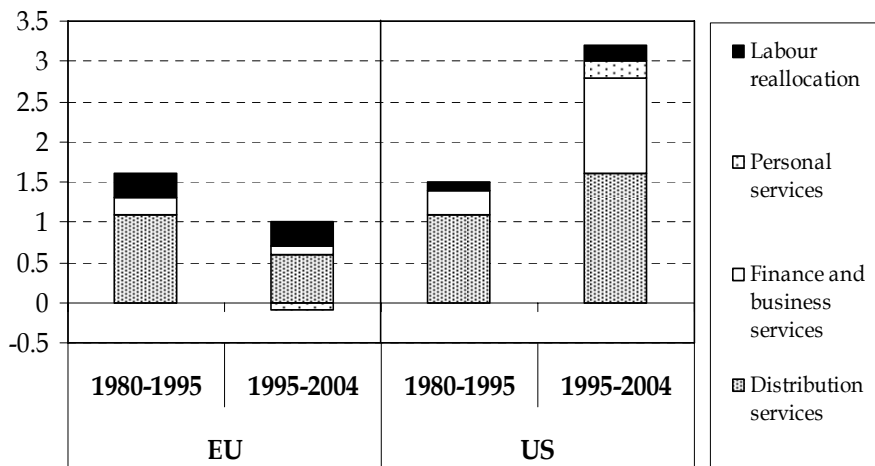
⁶ See B. Van Ark, J. Melka, N. Mulder & M. Timmer (2002), B. Van Ark, R. Inklaar & R.H. McGuckin (2002 and 2003) and B. Van Ark, M. O'Mahoney & M.P. Timmer (2008).

Figure 6. Productivity growth gap between the US and the EU at a sectoral level (percent)



Source: Van Ark et al. (2008).

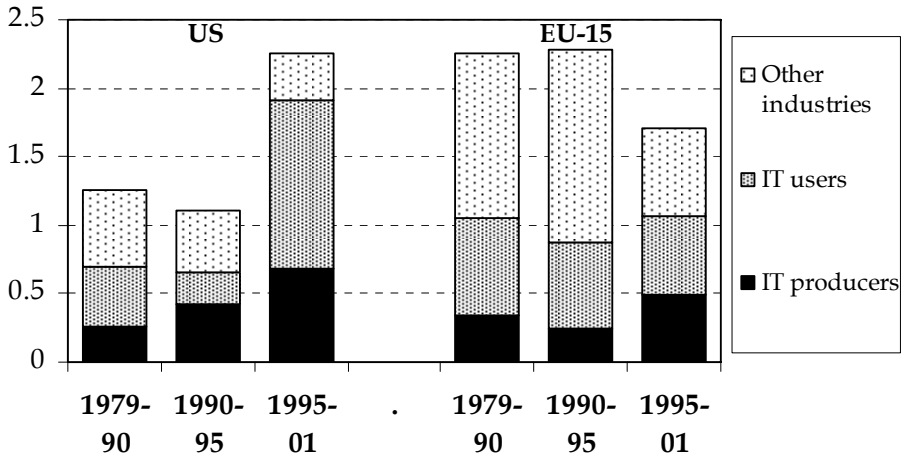
Figure 7. Sectoral contribution to aggregate labour productivity growth (percent)



Source: Van Ark et al. (2008).

Another recent study, by Daveri (2004), complements these results by focusing on the distinction between IT-producing and IT-using sectors. It finds that as much as two-thirds of the EU-US productivity growth gap can be accounted for by IT-using sectors (Figure 8).

Figure 8. Labour productivity growth in the US and the EU-15 (percent)



Source: Daveri (2004).

Heavy spending on R&D in conjunction with a high level of investment in ICT therefore appears to have helped boost innovation and productivity gains in the US. In Europe, by contrast, these industries are characterised by a lower R&D intensity and less investment in ICT. This literature has stressed that the higher levels of R&D spending and productivity growth in these sectors in the US may in turn derive from a more competitive environment. This has paved the way for new approaches to organising these industries on a large scale that draws heavily on ICT investment.

2.4 Concluding remarks

This chapter has made a few key observations based on sectoral data from the OECD. First, the EU-US R&D gap cannot be explained simply as a by-product of different sectoral specialisations, as it reflects a genuinely lower R&D intensity at a sectoral level as well. Second, a relatively small number of sectors account for this R&D gap, while in many others the EU is on par with the US. Third, there is a striking sectoral overlap between the R&D deficit and the productivity deficit when comparing the EU with the US, suggesting that R&D is indeed a crucial ingredient in the US productivity lead.

That the services sector is both larger and more R&D-intensive in the US than in the EU suggests that services cannot be ignored when trying to close the R&D gap. On the contrary, the EU is likely to see its services sector grow over time, thus following the US example. One reason is that higher incomes tend to shift aggregate demand towards services. Another is that the EU faces more competition from world trade in manufacturing than in services. In this context, Europe's relatively favourable R&D position in manufacturing offers little consolation. If Europe cannot close its R&D gap with the US in services, the overall R&D gap is likely to widen rather than narrow as the share of services in total value added grows. But in order for business R&D to pick up in the services sector, lingering structural impediments to innovation in this sector must be addressed. The US example strongly suggests that higher R&D spending, innovation and productivity gains in the services sector are all inexorably linked to competition. Short of implementing these broader structural changes, it is difficult to see how Europe can expect substantial convergence in total business R&D spending towards the level seen in the US.

One caveat may be necessary, however. One needs to be aware that the results of this kind of sectoral study are not independent of the chosen level of sectoral disaggregation. The more aggregated the sectors used, the greater is the risk that each sector consists of sub-sectors that are not homogeneous. As a consequence, what may appear to be a gap in sectoral R&D intensity at an aggregated level can sometimes be explained by a different sectoral specialisation at higher levels of disaggregation, rather than different R&D intensities in the disaggregated sectors. This is for instance the case in the sector that we refer to as 'ICT and other non-transport equipment'. This sector contains both very R&D-intensive IT manufacturing and less R&D-intensive manufacturing of other types of equipment. The US is more specialised towards IT manufacturing within this sector than the EU. When IT is bundled together with other types of equipment manufacturing, it appears as if R&D intensity is much higher in the US than in the EU, even though the two economies have a similar R&D intensity in the narrowly defined IT sector.⁷ What seems like a higher sectoral R&D intensity in the US may in reality be a greater specialisation in high-tech/highly intensive R&D segments within each sector. Still, although there is a need to be aware of these issues, they are unlikely to materially alter our main conclusion, which is that the EU-US R&D gap stems from just a few sectors and not from the economy as a whole.

⁷ For further discussion, see Sheehan & Wyckoff (2003).

3. R&D VARIES ACROSS EU COUNTRIES, BUT IN THE SERVICES SECTOR THEY ALL LAG BEHIND THE US

The previous chapter concluded that the EU's R&D intensity lags behind that of the US because of just a few sectors, notably services. This chapter uses the same OECD data set to explore differences in sectoral R&D spending across EU countries. One question that is posed here is whether countries in the EU with high levels of R&D could serve as role models for the rest of the EU.

R&D spending varies markedly across EU countries and – as shown in Table 3 and Figure 9 – there has been little tendency for these differences to diminish over time.

In terms of overall R&D intensity (which includes government, education and business sectors), EU countries can be divided into three broad groups:

- The first group consists of countries that have maintained below-average R&D spending. This group includes Greece, Portugal, Spain, Italy and Ireland. Also, what little improvement there has been in overall R&D spending is not accounted for by the business sector.
- A second group consists of EU countries (including many of the large ones) that have maintained R&D spending levels close to or marginally above the EU average, but have failed to close the gap vis-à-vis Japan and the US. This group includes Germany, France, the UK, Belgium and the Netherlands.

- A third group consists of several smaller EU countries – Sweden, Finland, Denmark and Austria – that have made clear progress in raising their R&D spending levels since the 1980s. Sweden and Finland have even attained R&D intensities above that of the US.

Table 3. R&D spending by sector (percent of GDP)

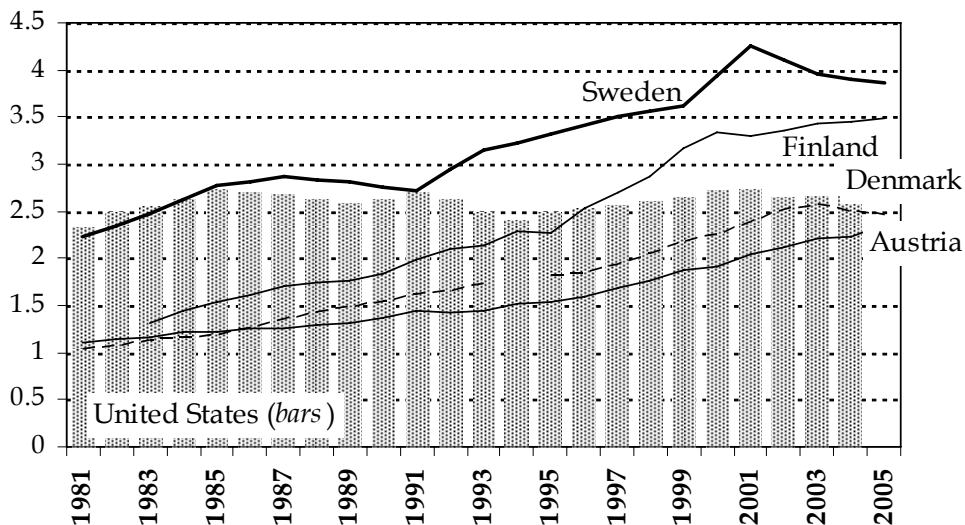
	Total R&D		Business R&D		Government and education R&D	
	1990-99	2000-05	1990-99	2000-05	1990-99	2000-05
Japan	2.9	3.2	2.0	2.3	0.9	0.8
US	2.6	2.7	1.8	1.9	0.7	0.8
EU-15	1.8	1.9	1.1	1.2	0.7	0.7
Sweden	3.2	4.0	2.3	3.0	0.9	1.0
Finland	2.4	3.4	1.5	2.4	0.9	1.0
Germany	2.3	2.5	1.6	1.7	0.7	0.8
Denmark	1.8	2.4	1.1	1.7	0.7	0.8
France	2.3	2.2	1.4	1.4	0.9	0.8
Austria	1.6	2.1	na	1.4	na	0.7
Belgium	1.7	1.9	1.2	1.4	0.5	0.6
Netherlands	2.0	1.8	1.0	1.0	0.9	0.8
UK	1.9	1.8	1.3	1.1	0.7	0.6
Ireland	1.1	1.2	0.8	0.8	0.4	0.4
Italy	1.1	1.1	0.6	0.5	0.5	0.6
Spain	0.8	1.0	0.4	0.5	0.4	0.5
Portugal	0.6	0.8	0.1	0.3	0.5	0.5
Greece	0.5	0.6	0.1	0.2	0.4	0.4

Source: OECD.

The success of the third group in boosting R&D spending raises the question of whether it might serve as a role model for other EU countries. To answer this question, it helps to distinguish between cross-country differences in sectoral R&D intensity and differences in sectoral composition (similar to the exercise that we conducted earlier for the EU

and the US). Again, to compare R&D intensities at the sectoral level, these have been calculated as the ratio of sectoral R&D spending to each sector's value added, i.e. the sectoral equivalent of GDP.

Figure 9. R&D intensities in selected EU countries (percent of GDP)

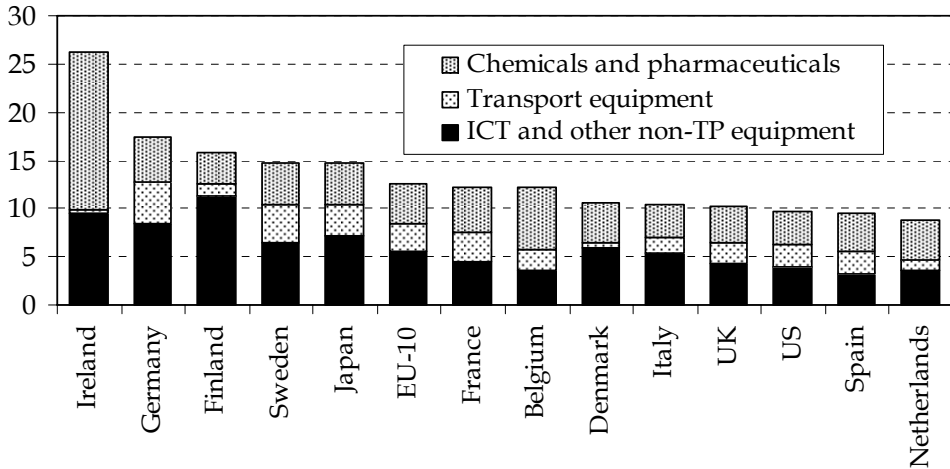


Source: Eurostat; 1994 data missing for Denmark.

3.1 Most EU countries have lower R&D intensities than the US does, but not because of a specialisation towards less R&D-intensive sectors

As we discussed for the EU as a whole in the previous chapter, a low aggregate level of R&D intensity can be the result of either a sectoral orientation away from R&D-intensive sectors or a low R&D intensity in individual sectors. As shown in Figure 10, the second explanation is closer to the mark in the EU. In virtually all EU countries, the three most R&D-intensive manufacturing sectors account for a share of total value added that is equal to or larger than that in the US. This is true even for those EU countries that have particularly low levels of national R&D intensities, such as Italy and Spain. This makes it unlikely that EU countries could boost aggregate R&D intensity simply through a shift towards more R&D-intensive sectors. We illustrate that point more clearly in Box 1.

Figure 10. Percentage share of the top three 'R&D-intensive' sectors in the total non-farm business value added, average 2000–03



Source: OECD.

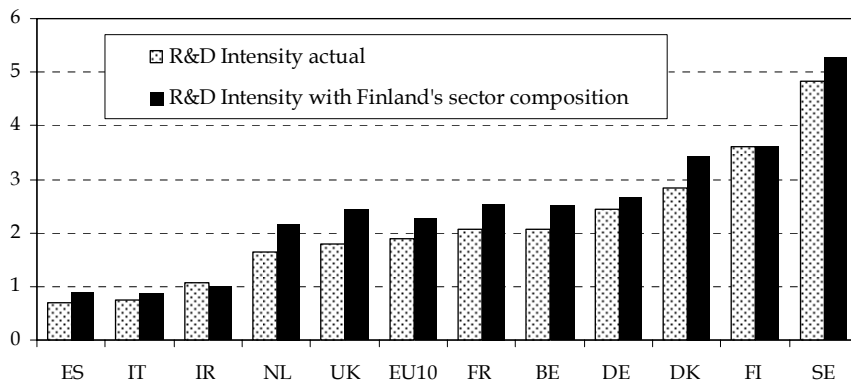
Since sectoral composition cannot account for low aggregate R&D intensities in EU countries, the answer lies in low R&D intensities in individual sectors. In countries with low aggregate R&D intensities, such as Italy and Spain, below-average R&D intensity is found in virtually all sectors of the economy, including the top three most R&D-intensive ones mentioned earlier.

Box 1. What if all EU countries were like Finland?

Let us assume – counterfactually – that Spain and Italy had the same sectoral specialisation as Finland, while maintaining their actual R&D intensities sector-by-sector. As shown in Figure B1.1, this would only raise the overall R&D intensity in Italy and Spain from around 0.7% of value added to 0.9%. The order of magnitude of the impact is similar in most EU countries. For the EU-10 as a whole, a sectoral specialisation like that of Finland’s would raise its R&D intensity from 1.9 to 2.3% of value added.

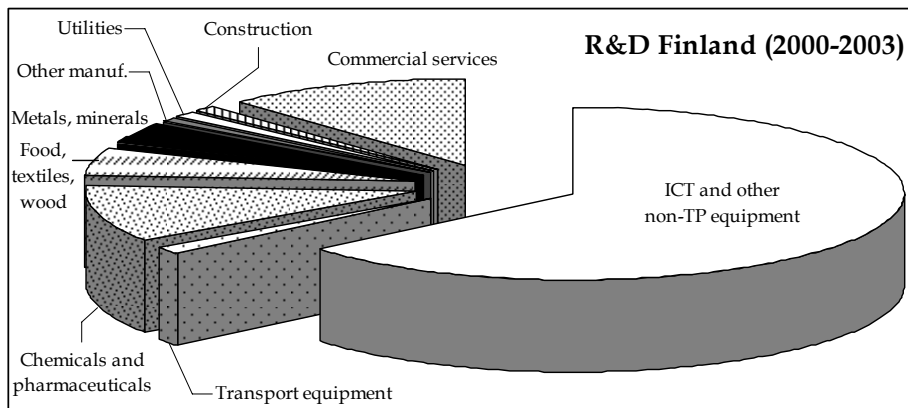
Box 1. cont'd

Figure B1.1 Actual and simulated business sector R&D intensity in a selection of European countries (percentage of value added)



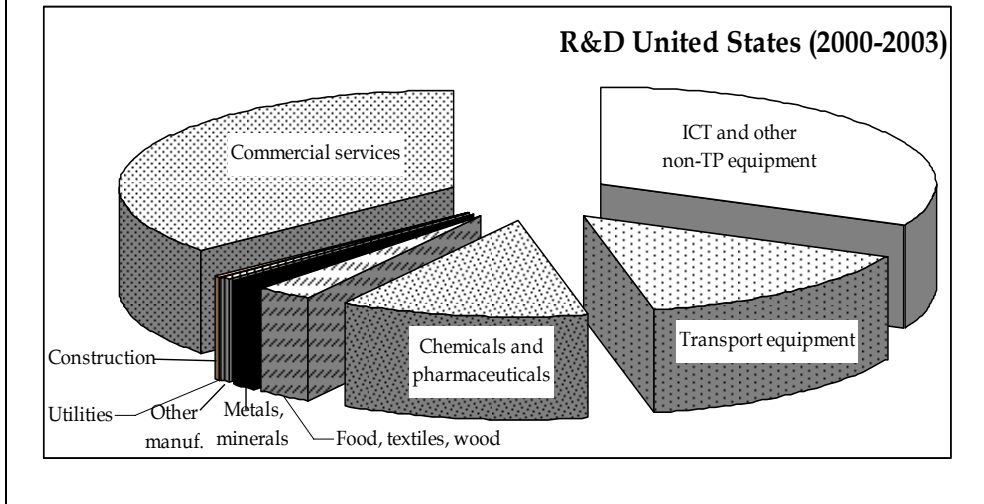
But a sectoral reallocation is not the answer, nor is it likely that the rest of the EU could replicate Finland's R&D intensity in manufacturing. Finland (along with Sweden) has achieved its very high levels of R&D intensity primarily in manufacturing (with 85% of total R&D spending compared with 63% in the US) and especially in ICT manufacturing. This makes the Nordic countries questionable role models for the rest of the EU. As the pie charts in Figures B1.2 and B1.3 illustrate, a large share of US R&D spending is concentrated in the services sector. As Europe is over time likely to emulate this sectoral shift towards services, it does not seem reasonable to expect to close the gap with the US predominantly through higher levels of R&D in manufacturing.

Figure B1.2 Sectoral distribution of R&D expenditures in Finland



Box 1. cont'd

Figure B1.3 Sectoral distribution of R&D expenditures in the US

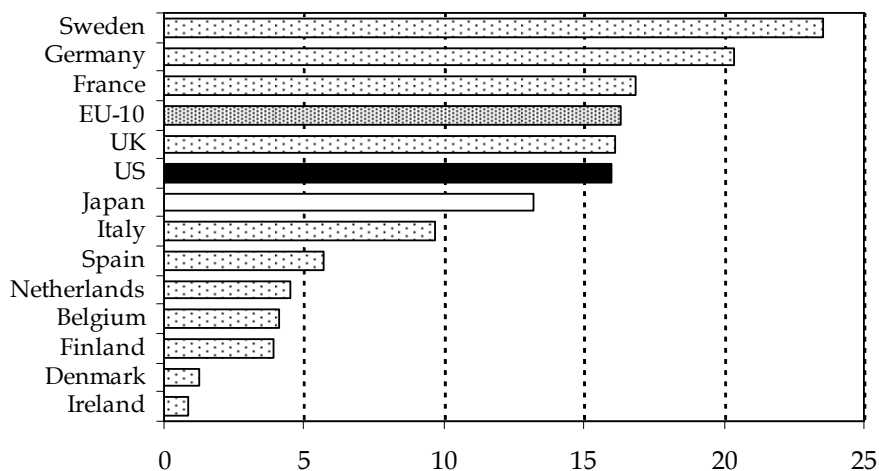


3.2 High levels of R&D intensity in certain sectors for the EU as a whole does not mean high levels in all countries

One consequence of economic integration is increased cross-border ownership and a concentration of R&D activities in key agglomerations. Positive, localised spillover effects imply that there are significant benefits from a geographical concentration of R&D.

The manufacturing of transport equipment is a good example of this. As shown in Figure 11, there is substantial variation in the R&D intensity in this sector across EU countries. Those countries that have the highest R&D intensities in this sector – Sweden, Germany and France – are also typically major producers in this sector. Other EU countries have evolved – partly as a result of mergers and acquisitions – into primarily production sites with relatively little research and development in this sector. Examples of this are Finland, Spain and Belgium, all of which have large foreign-owned manufacturing plants of transport equipment such as automobiles.

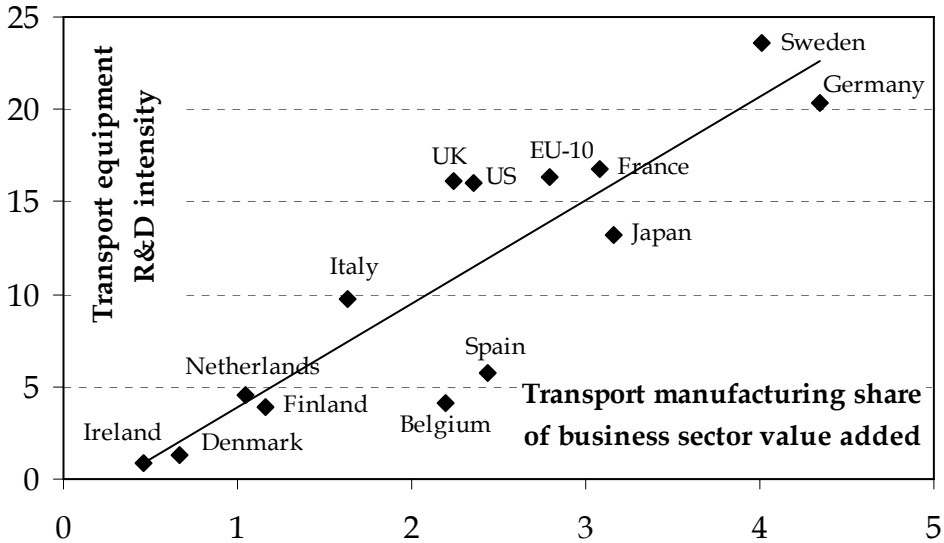
Figure 11. R&D intensity in the manufacturing of transport equipment (percentage of sector value added)



Source: OECD.

To illustrate more clearly the detachment of production and R&D in this sector, Figure 12 plots the size of the transport equipment sector on the horizontal axis against the sector's R&D intensity on the vertical axis. To take an example, Sweden is in the top right corner of the diagram, with a high share of transport equipment in total business value added (4%) and a high level of R&D intensity in this sector (24% of transport sector value added). At the opposite end of the spectrum, Denmark engages in very little manufacturing of transport equipment and very little R&D in this sector, thus finding itself in the lower left corner of the diagram. Most countries fit into a broadly positive, linear relationship represented by the line in the diagram. This positive relationship essentially says that countries where the manufacturing of transport equipment accounts for a larger share of the economy are also more likely to have technologically leading companies with high levels of R&D intensity. The exceptions to this pattern are found below the line. Both Spain and Belgium have a substantial stake in the production of transport equipment, close to the EU average of between 2 and 3% of business value added. But their levels of R&D intensity in this sector are only one-third of the EU average. This reflects the fact that they are primarily production sites in this sector.

Figure 12. Transport equipment manufacturing: Value added share and R&D intensity, average 2000–03 (percentage)



Source: Own calculations based on OECD data.

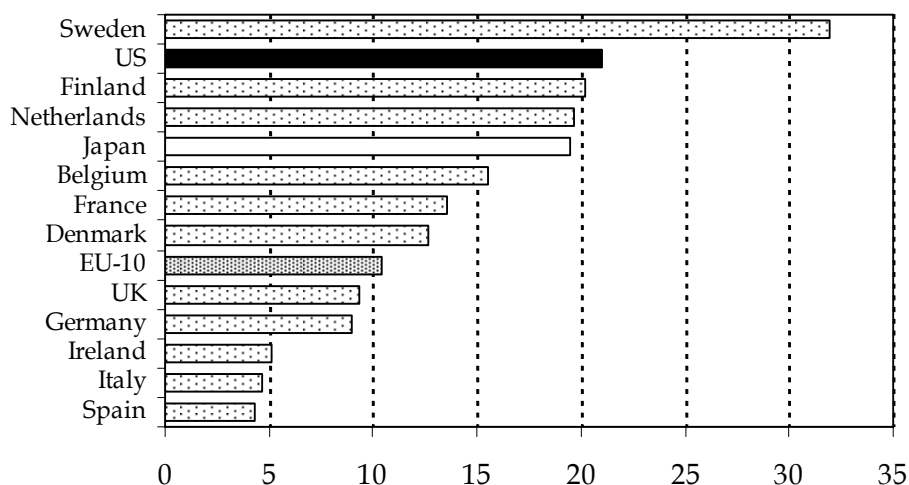
The concentration of transport equipment R&D to just a few agglomerations is not in itself a problem. On the contrary, there is little economic justification for spreading R&D across all EU countries. If R&D in the transport equipment sector were to be evenly spread out across all EU countries, some of the localised knowledge spillovers in R&D would go to waste and the overall R&D conducted in Europe in this sector would likely be lower. It is noteworthy in this context that even though R&D intensity in some countries is low, the EU as a whole is on par with the US in this sector.

3.3 In ICT and other non-transport equipment, a few EU leaders cannot make up for the many laggards

In the manufacturing of transport equipment, the level of R&D is sufficiently high in the leading countries to compensate for low levels of R&D intensity in others. Hence, the aggregate R&D intensity for the EU as a whole compares favourably with that of the US. The same is true for the chemicals and pharmaceuticals industry, where the EU also compares favourably with the US. One major manufacturing sector where this is not the case is the manufacturing of ICT and other non-transport equipment.

As shown in Figure 13, high levels of R&D intensity in this sector are limited to a few countries. These cannot compensate for the fact that several major EU economies – including large countries such as Italy, Spain, Germany and the UK – lag far behind the US in this area. In short, in this sector the R&D leaders in the EU are too few and too small to compensate for the laggards. As a result, this sector is a major contributor to the overall business R&D gap vis-à-vis the US.

Figure 13. R&D intensity in the manufacturing of ICT and other non-transport equipment (percentage of sector value added)



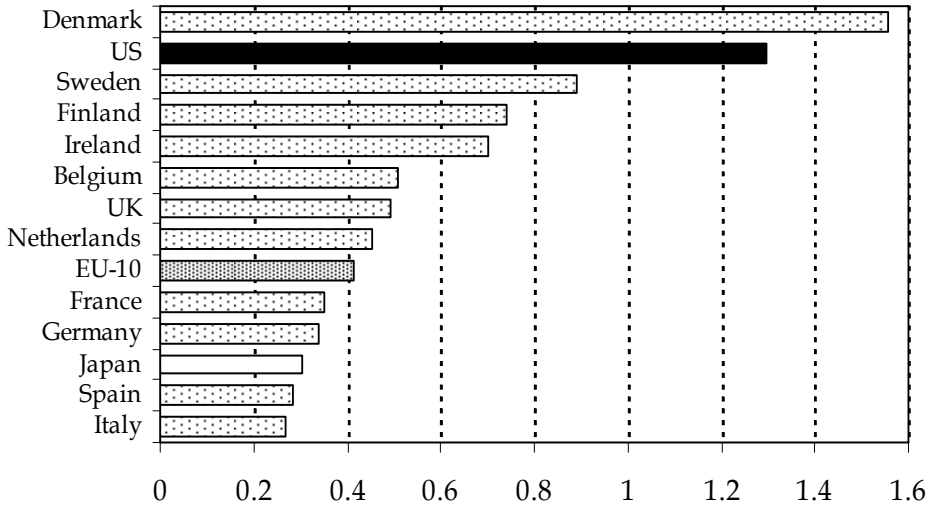
Source: Own calculations based on OECD data.

3.4 In the services sector, the EU's R&D intensity lags far behind that of the US almost without exception

In commercial services, the picture is different from manufacturing in the sense that Europe's low level of R&D intensity relative to the US characterises virtually all countries, with the notable exception of Denmark (Figure 14).⁸

⁸ The OECD has observed that there are still shortcomings in measuring R&D in services. As a result, some of the EU-US gap – although hardly all of it – may diminish over time as data quality improves.

Figure 14. R&D intensity in commercial services (percentage of sector value added)



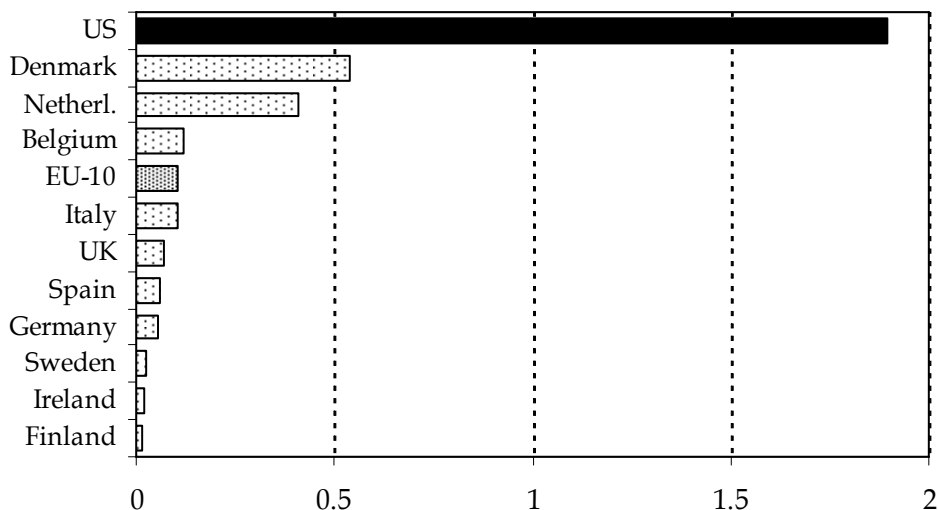
Source: Own calculations based on OECD data.

There is particular diversity within the commercial services sector, however. The large R&D gap is especially visible in *wholesale and retail trade and repairs* (Figure 15), a sector that has been instrumental in driving US productivity gains in recent years (as discussed in the previous chapter). The fact that virtually all EU countries trail so far behind the US in this respect points to deep-seated systemic causes. Factors that have fostered innovation and R&D in this sector in the US are deregulation and competition. In addition, this sector has invested heavily in ICT in the past decade, using new technologies and organisational flexibility to create highly efficient ‘big box’ retail solutions that have so far seen limited application in Europe.

These organisational innovations and the economies of scale that accompany them make R&D in this sector profitable for investing firms in the US. But to spend the same amount of money on R&D in Europe without the accompanying deregulatory changes would be unlikely to bring sufficient gains for the investor to make such spending worthwhile.⁹

⁹ The notion that competition and deregulation are key to fostering R&D finds strong support in a recent cross-country study by the OECD (2005). The OECD finds that a reduction in anti-competitive product market regulations stimulates

Figure 15. *R&D intensity in wholesale and retail trade and repairs (percentage of sector value added)*



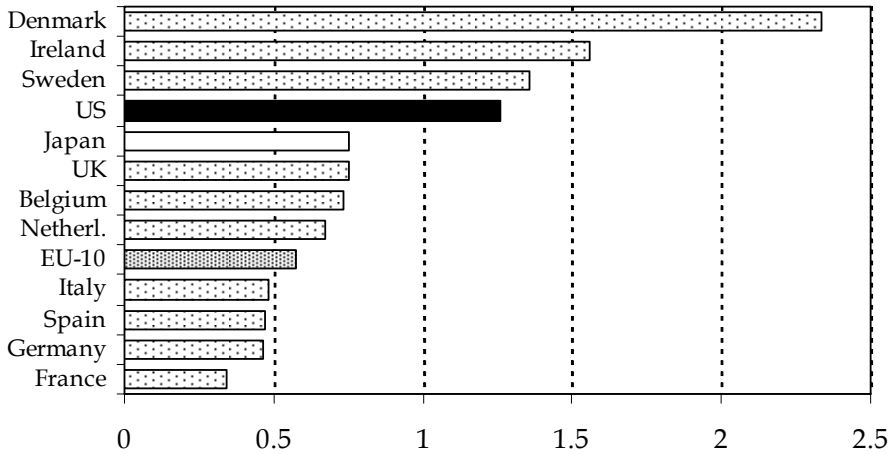
Source: Own calculations based on OECD data.

A second area of services in which the EU as a whole lags far behind the US is the sector that we call *renting, real estate and computer services*. Although a mix of very different activities, this group contains R&D-intensive sub-sectors such as the provision of IT services. As Figure 16 illustrates, the three largest Continental EU countries – France, Germany and Italy – are far behind the US in this sector. Again, there is marked diversity within the EU. Three smaller countries – Denmark, Ireland and Sweden – are even ahead of the US in this sector.

This sector has been found to account for a substantial (and growing) proportion of the US productivity lead over the EU in recent years. Uncovering the underlying causes of this gap not only in R&D but also more broadly in innovation and productivity is therefore crucial if Europe is to bridge its growth gap vis-à-vis the US.

business R&D spending substantially, while restrictions to foreign direct investment and employment protection legislation are found to have a much smaller impact on R&D spending.

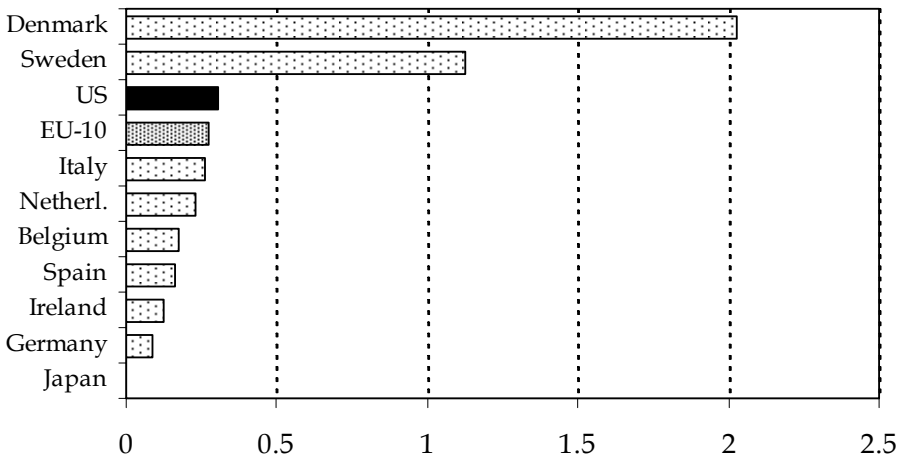
Figure 16. R&D intensity in renting, real estate, IT services and R&D (percentage of sector value added)



Source: Own calculations based on OECD data.

One sector in which Europe compares relatively favourably – somewhat surprisingly – is *financial intermediation*, although the usefulness of the EU average is limited by the unavailability of data for France and the UK. As Figure 17 shows, in Germany R&D intensity in this sector is only one-third of that in the US.

Figure 17. R&D intensity in financial intermediation (percentage of sector value added)



Source: Own calculations based on OECD data.

3.5 Concluding remarks

The comparison of R&D across EU countries in manufacturing and services provides an illuminating qualification to Europe's overall R&D gap relative to the US. Essentially, in manufacturing there is a clear dispersion among EU countries. Some EU member states are on par with or even above the US in terms of R&D spending in key manufacturing sectors, while others serve primarily as production sites with little own R&D. As a result, while there is an aggregate R&D gap in manufacturing, it is neither substantial nor consistent across countries and sectors.

An uneven distribution of manufacturing R&D across EU countries should not be regarded as a problem in itself. On the contrary, several recent studies have pointed to positive, localised spillover effects in R&D that are substantial, which implies that the concentration of R&D in a few agglomerations boosts its overall productivity. Public policies aimed at dispersing R&D efforts geographically could easily be counterproductive, as such an outcome would lower the overall productivity of R&D spending and hence erode the incentives for individual firms to increase their R&D efforts.

In contrast with manufacturing, the R&D deficit in services relative to the US is more evenly spread across EU member states. In services, the EU has few R&D leaders to match the US, Denmark being the apparent exception. As we also argued in the previous chapter, this suggests that the reasons for the R&D gap in services are more likely to be systemic. Given that R&D in services accounts for such a large proportion of the overall EU-US R&D gap (as discussed in the previous chapter), addressing these systemic impediments to R&D are essential to closing the EU's overall R&D gap vis-à-vis the US.

4. R&D ACROSS DIFFERENT FIRM SIZES

The Lisbon strategy emphasised that the corporate sector would have to take the lead in boosting R&D spending in Europe. To see how this can be achieved, it helps to have a better understanding of where in the corporate sector R&D spending takes place with respect to firm size. As we have seen in previous chapters, there are distinct differences across both sectors and geographical entities. This chapter focuses on another, yet no less important element: the variation in R&D spending across different firm sizes. The discussion draws primarily on Eurostat data, as reported in *OECD Science, Technology and Industry: Scoreboard 2007* (OECD, 2007).

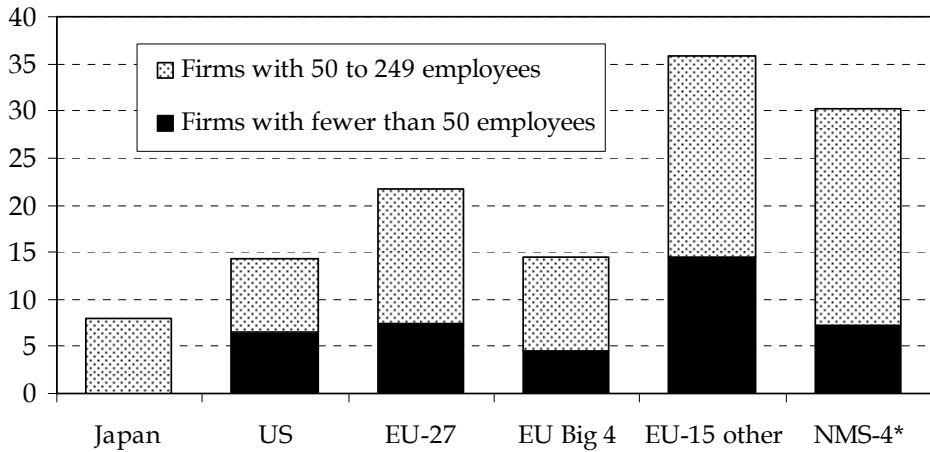
We need to stress up front that the focus on a single dimension of business sector R&D – in this case firm size – calls for some caution in the interpretation. Specifically, observed relationships between for instance R&D intensity across firm sizes and country size may be spurious, i.e. driven by other, unobserved variables such as sector characteristics. That being said, even this simple decomposition of business sector R&D by firm size is quite illuminating.

4.1 SMEs account for a larger share of total business sector R&D in smaller countries

R&D is by no means conducted solely by large industrial firms. As Figure 18 shows, firms with fewer than 250 employees (which is the upper boundary of SMEs) account for some 22% of total business sector R&D in the EU, 14% in the US and 8% in Japan.

The SMEs' share of R&D spending differs markedly, however, between what we call the 'EU Big 4' – Germany, France, Italy and the UK – and the rest of the EU (old and new). The SMEs' share of R&D in the EU Big 4 is almost identical to that of the US, whereas in the rest of the EU it is noticeably higher than in the US.

Figure 18. Business R&D by firm size (percentage of business sector R&D, 2005 or latest)

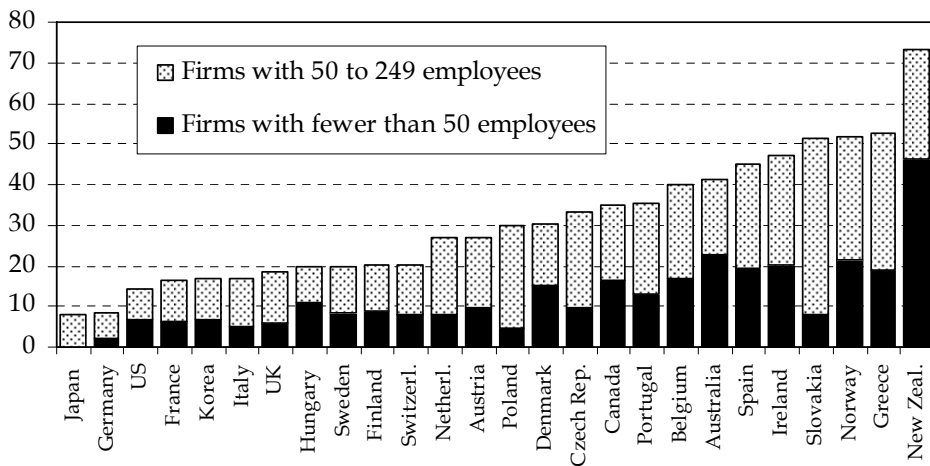


* Czech Republic, Slovakia, Poland and Hungary

Source: OECD.

If we look at individual countries (Figure 19), we see that this diversity in the SMEs' share of R&D is also visible outside the EU.

Figure 19. Business R&D by firm size in individual countries (percentage of business sector R&D, 2005 or latest)

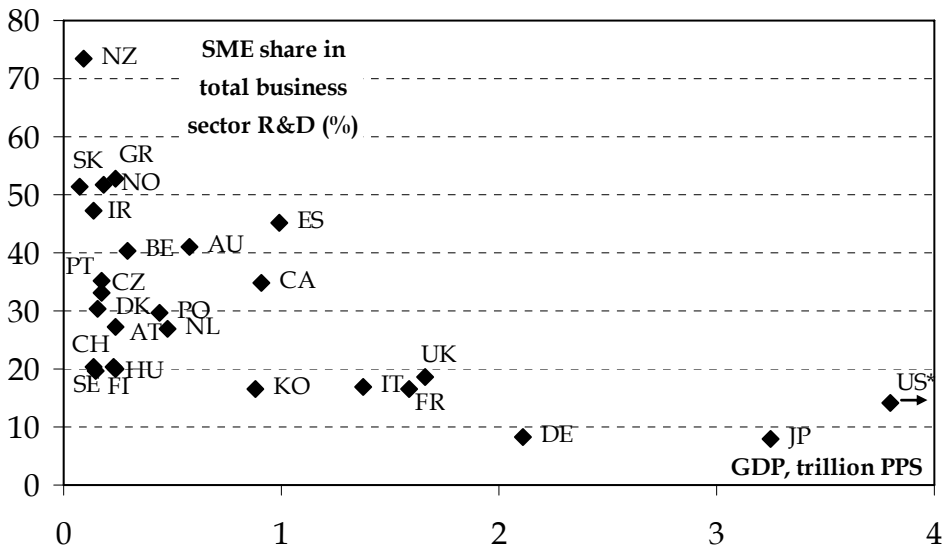


Source: OECD.

An economy’s sectoral composition obviously has a large influence on the role of SMEs. Countries with large-scale manufacturing sectors such as Germany, Sweden and Finland not surprisingly have smaller SME shares in total business R&D spending than countries such as Norway, New Zealand and Greece.

Country size also appears to have a distinct influence on the role of SMEs in total business R&D spending (Figure 20). With a few noteworthy exceptions (such as Sweden and Finland), SMEs tend to account for a larger share of total business R&D spending in small countries. In large ones such as the US, Japan, Germany, France and the UK, SMEs account for no more than 20% of total business R&D spending. One explanation for this strong relationship between country size and large-firm R&D dominance could be that substantial home markets allow more large-scale industrial firms to develop and grow. Another factor could be that companies in large countries are more likely than are those in small countries to keep their R&D centres close to their corporate headquarters, i.e. within their own national borders.

Figure 20. Business R&D in SMEs vs. country size

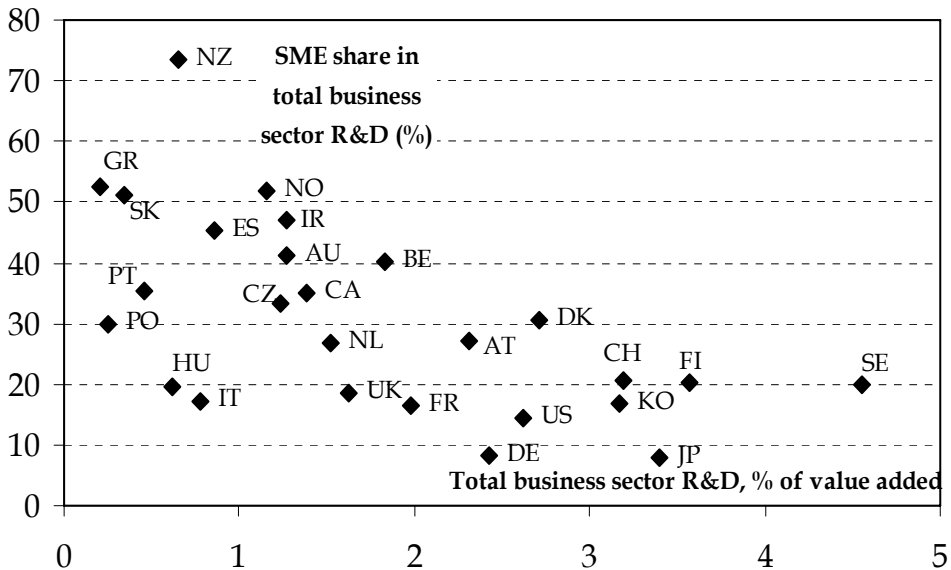


* US GDP was \$10.2 trillion in purchasing power standards (PPS) in 2005.

Sources: OECD and European Commission.

A second pertinent observation from this data is that large firms play a more dominant role in relatively more R&D-intensive countries. Other things being equal, a country dominated by SMEs is unlikely to have a high level of business R&D spending (Figure 21).

Figure 21. R&D intensity in SMEs vs. the aggregate business sector

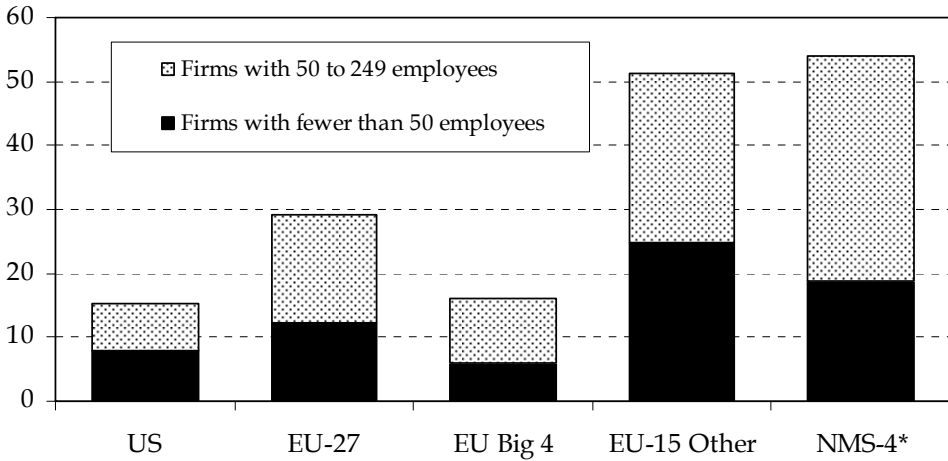


Source: OECD.

4.2 Is public support for R&D biased towards large firms or SMEs?

The predominantly large countries that have high ratios of business R&D spending to value added also direct a larger share of their public R&D support to large firms. As shown in Figures 22 and 23, a smaller share of public R&D support in the US and the EU Big 4 goes to SMEs (less than 30%) than is the case in smaller EU economies. That is not surprising, as we have already seen that large firms also tend to account for a greater share of business R&D spending in larger countries.

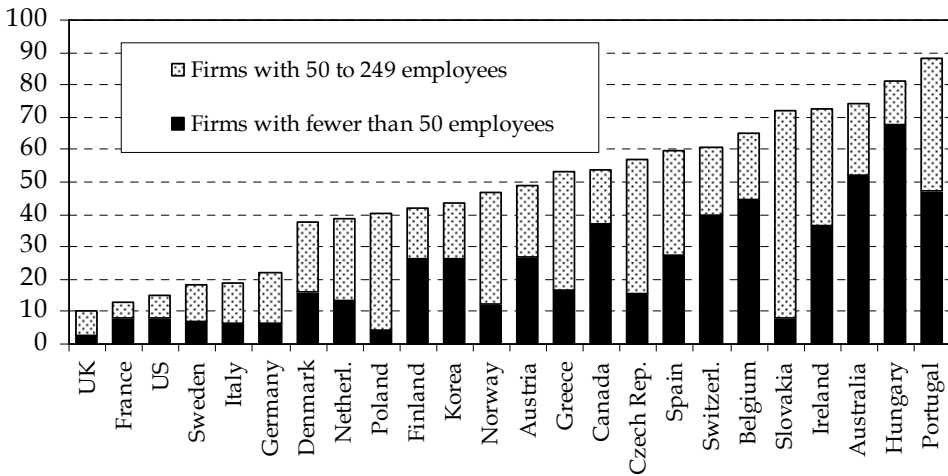
Figure 22. Government-financed business R&D by SMEs (as a percentage of total government-financed business R&D, 2005 or latest)



*Czech Republic, Slovakia, Poland and Hungary

Source: OECD.

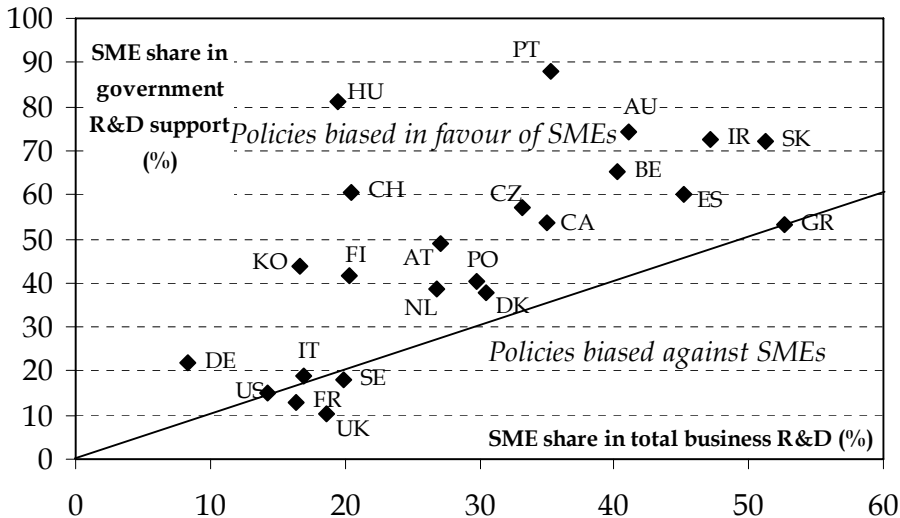
Figure 23. Government-financed business R&D by SMEs: Individual countries (as a percentage of total government-financed business R&D, 2005 or latest)



Source: OECD.

One way to illustrate the relationship between the SMEs' share of business R&D and the SMEs' share of public support is to plot these two in a scatter diagram, as shown in Figure 24. Here we clearly see the positive relationship between the two ratios.

Figure 24. SMEs' share of business R&D and government support (percentage)



Source: OECD.

If public policy were completely neutral with respect to firm size, all countries would be on the straight line drawn in the diagram. On this line, the SMEs' shares of total business R&D and public SME support are identical. As the diagram shows, however, in most countries there is a clear bias towards SMEs. In all countries above the line, SMEs receive a larger share of public support than their R&D share. This bias is particularly strong in Germany, Korea, Portugal, Hungary and Switzerland, in all of which SMEs receive a share of public R&D support that is more than double their share in business R&D spending.

By comparison, in the US, Italy, France, Sweden and the UK, SMEs are treated neutrally or they even receive less than a proportionate share of public support. These countries also have notable domestic military hardware sectors, which tend to enjoy substantial public R&D support. This sector is usually dominated by large firms, which consequently attract a larger share of public R&D support.

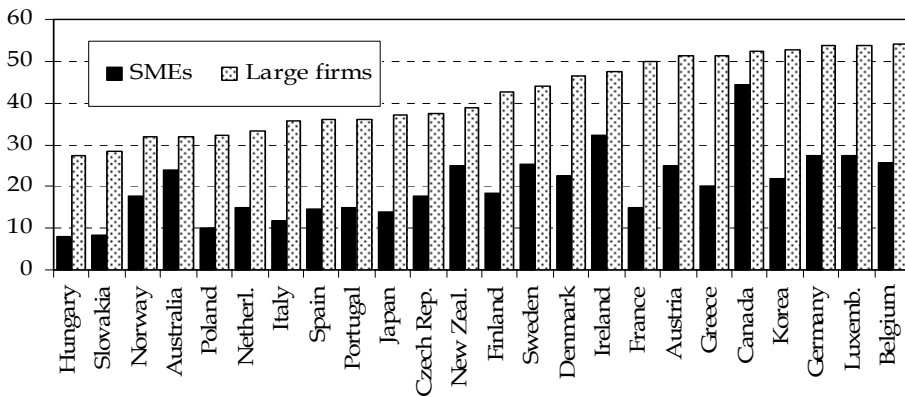
4.3 The latest Community Innovation Survey suggests that SMEs rely less on in-house innovation than large firms do

Surveys such as the recent Community Innovation Surveys¹⁰ (the CIS 4, conducted in 2004 with results reported in 2007 is the most recent) provide information about investments in R&D and innovation in small and large firms in different sectors across Europe. In these innovation surveys, inputs to the innovation process are primarily measured by spending on R&D. Innovation outputs are measured by the number of new products launched in markets or the turnover achieved with products no older than three years. The next three sections present some key results of the latest survey.

1) In-house innovation, by firm size

Productivity-enhancing innovation can either be developed in-house or be acquired from the outside. As might have been expected, the CIS survey shows that SMEs tend to be ‘adopters’ more frequently than large firms. In almost half of the countries surveyed, more than 40% of all large firms had developed a product innovation in-house. Among SMEs, the share developing product innovations in-house exceeded 20% in only around one-third of the countries (Figure 25).

Figure 25. In-house product innovators by size (as a percentage of all firms)

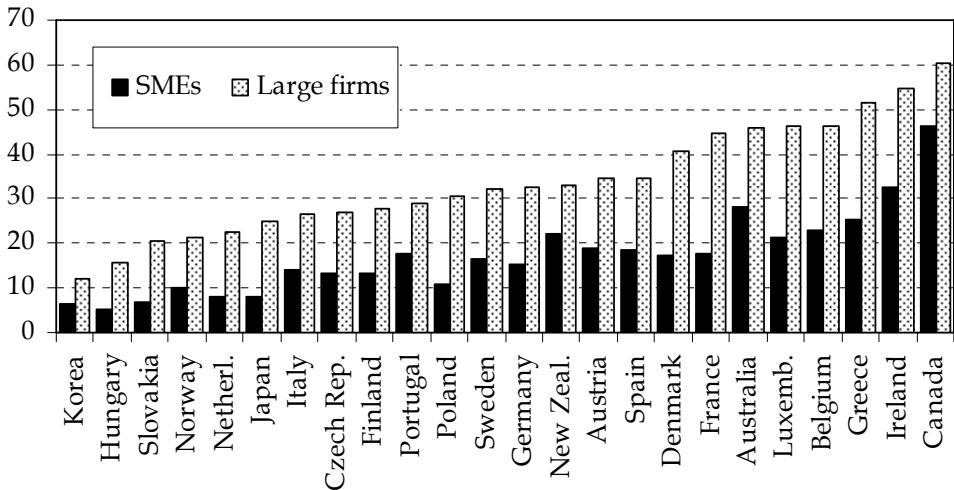


Source: OECD.

¹⁰ The Community Innovation Surveys are carried out by national statistical offices throughout the EU. Data from these surveys is used for the annual European Innovation Scoreboard, published by the European Commission’s Directorate General for Enterprise and Industry.

The pattern is similar for in-house process innovations (Figure 26). The highest rates were found among large firms (over 45%), in Canada, Ireland, Greece, Belgium, Luxembourg and Australia. The same countries plus New Zealand had rates above 20% for SMEs.

Figure 26. In-house process innovators by size (as a percentage of all firms)



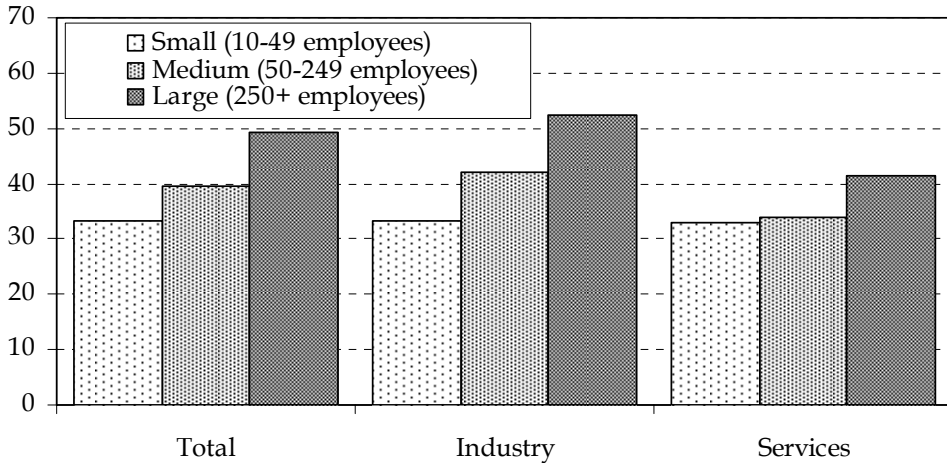
Source: OECD.

2) Innovation and economic performance

Innovation is not conducted for its own sake, but aims at generating a competitive edge in the market. It is thus important to take stock of the output of the innovative process.

In the survey, the innovation output is measured in the form of new or significantly improved products (Figure 27). In the EU-27, there are marked differences across firm size classes. Large enterprises accounted for the highest share of enterprises introducing new or improved products to the market. Although this was the case in both industry and services, the gap was clearly smaller in the latter.

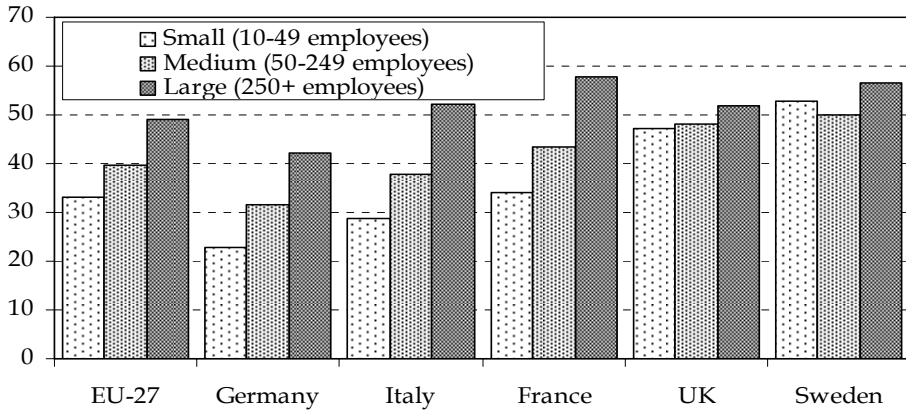
Figure 27. Firms that introduced new or improved products to the market (as a percentage of all firms engaged in innovation activity, by sector and size class, EU-27, 2004)



Source: Eurostat.

The importance of firm size in the introduction of new products differs across countries in ways that are quite illuminating. As shown in Figure 28, the cross-country variation is small for large firms. Presumably, large firms all operate in a similarly competitive, international business environment. That is not the case for SMEs, however. Since SMEs tend to be much more domestically oriented, their business environment is to a greater extent determined by domestic institutional and competitive conditions. In this sense, it is noteworthy that SMEs in Germany, Italy and France introduce new or improved products to a lesser degree than do their peers in the UK and Sweden. In the latter two countries, SMEs are not much different from large firms in this respect. One interpretation of this finding is that the UK and Sweden have gone further in competition-enhancing product market liberalisation, hence forcing SMEs to become more innovative to stay in business. In contrast, SMEs in the large Continental European countries seem to operate in a more protected environment, which in turn requires less innovation.

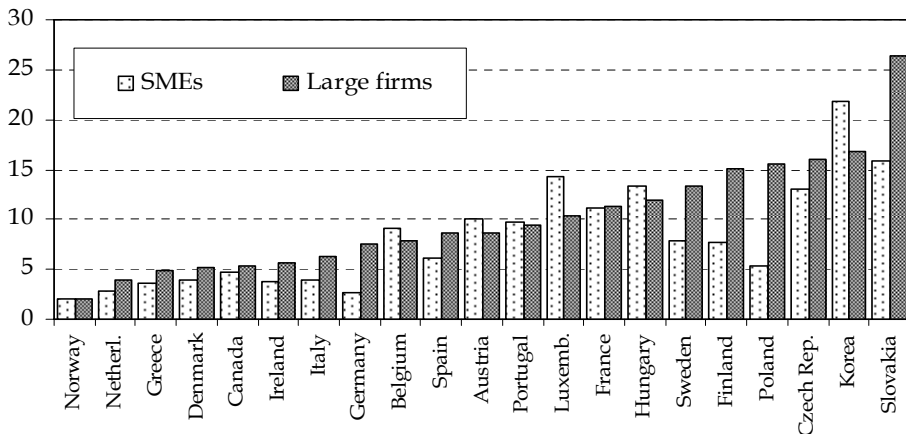
Figure 28. Firms that introduced new or improved products to the market (as a percentage of all firms engaged in innovation activity, by sector and size class, 2004)



Source: Eurostat.

One measure of the importance of innovation for individual firms is the share of their turnover that stems from new-to-market product innovations. As seen in Figure 29, in most countries the difference between SMEs and large firms in this respect is not very significant. Exceptions are Germany and Poland, where the share of turnover from such innovations was three times higher for large firms than it was for SMEs.

Figure 29. Share of turnover owing to new-to-market product innovations by size (as a percentage of turnover for all firms, 2002-04)



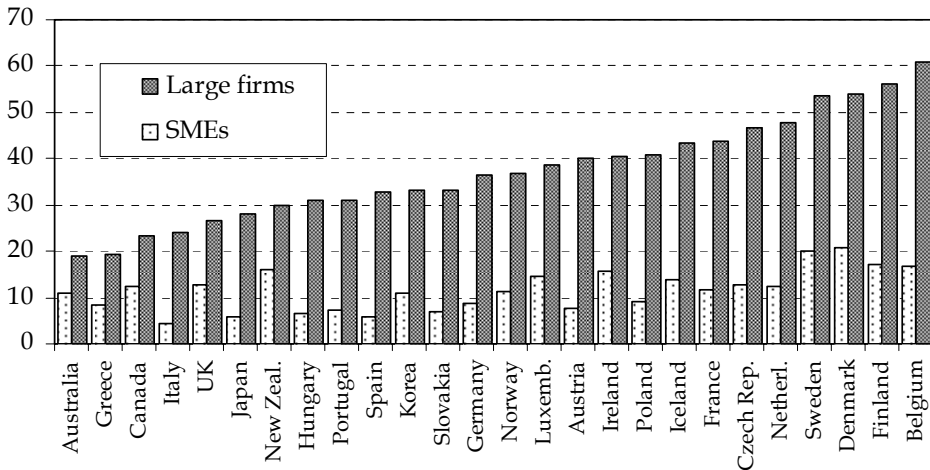
Source: OECD.

3) *Collaboration with public research organisations by innovating firms*

Collaboration is an important part of the innovation activities of many firms. As defined by Eurostat, this involves “active participation in joint innovation projects with other organisations”, but excludes the pure subcontracting of work. Collaboration can involve the joint development of new products, processes or other innovations with customers and suppliers, as well as horizontal work with other enterprises or public research bodies.

Around one in ten of all firms (or one in four innovating firms) in Europe collaborated with a partner for their innovation activities during 2002–04 (Figure 30). Large firms were four times more likely to collaborate than SMEs were. Among SMEs, the rate of collaboration is fairly similar across countries, ranging between 10 and 20% of all firms in more than half of the countries surveyed, but it varies widely for large firms.

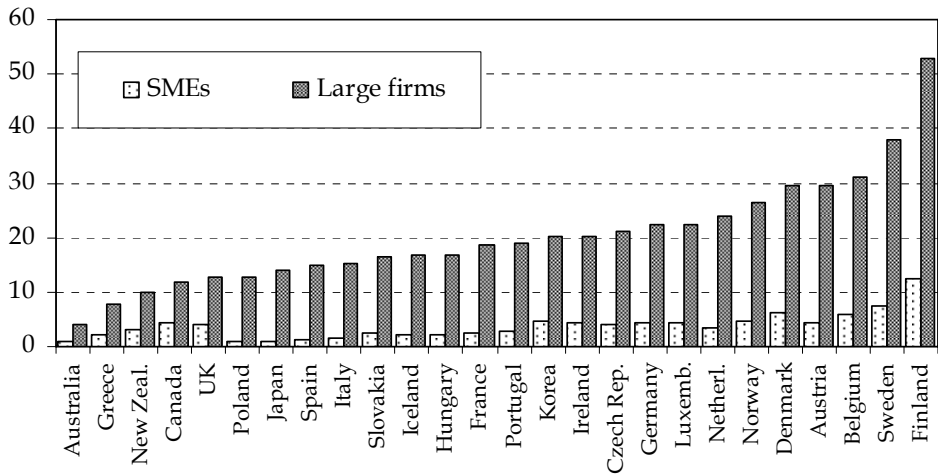
Figure 30. *Firms collaborating in innovation activities, by size class (as a percentage of all firms, 2002–04)*



Source: OECD.

Collaboration with public research organisations (higher education or government research institutes) can be an important source of knowledge transfer for the innovation activities of firms. Here again, large firms are much more active than SMEs are and show much more cross-country variation (Figure 31). Collaboration between large firms and public research organisations is particularly common in the smaller northern European countries.

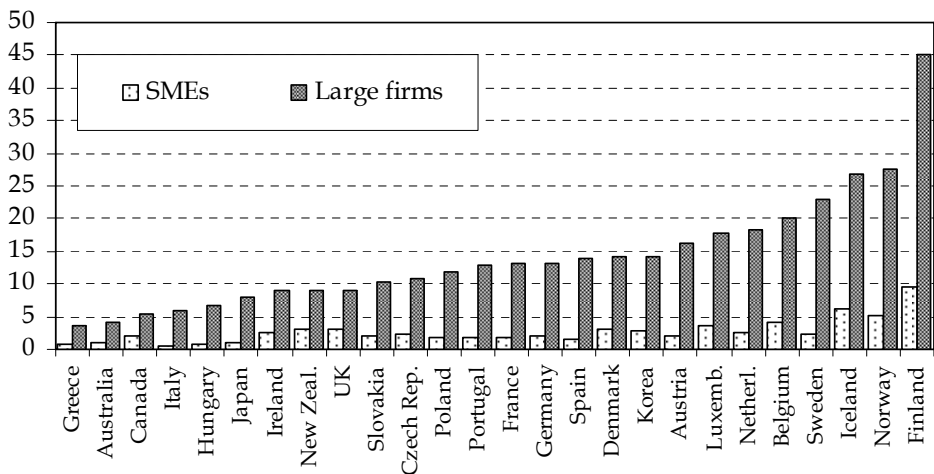
Figure 31. Firms collaborating in innovation activities with higher education institutions, by size (as a percentage of all firms, 2002–04)



Source: OECD.

Firms collaborate on average less with government research centres than with higher education institutions, although the overall distribution across countries is similar in the two cases (Figure 32).

Figure 32. Firms collaborating in innovation with government institutions, by size (as a percentage of all firms, 2002–04)



Source: OECD.

4.4 Concluding remarks

The statistics and survey results presented in this chapter provide a snapshot of R&D across different firm sizes in Europe. On balance, the evidence shows that whereas SMEs are not negligible sources of business R&D spending, R&D activities are still dominated by large firms. This large-firm dominance of R&D spending is particularly true for the US and Japan, which is noteworthy as both serve as role models for Europe's ambition to boost overall business R&D spending. These observations raise serious questions regarding the ability of SMEs to play more than a supporting role in elevating Europe's business R&D spending.

5. THE REGIONAL DISTRIBUTION OF R&D SPENDING

We have seen in earlier chapters how R&D intensities in European countries vary across sectors, countries and firm sizes. Understanding this variability affords us a greater understanding of where the EU-US R&D gap originates. Just as US R&D spending is not evenly distributed across these dimensions, it is unlikely that any future increase in EU R&D spending would be achieved uniformly across all sectors, countries or firm sizes. Nor would R&D spending likely be applied optimally if that were the case.

Similarly, R&D spending is subject to a substantial gravitational pull from innovative clusters. Using Eurostat data, this chapter first takes a descriptive look at the regional concentration of R&D intensities (i.e. R&D clustering beyond what can be accounted for by the concentration of economic activity). Second, it investigates whether such clustering makes R&D more or less productive in terms of patent applications.

5.1 R&D spending by NUTS 2 regions

Eurostat collects and disseminates increasingly detailed regional statistics on R&D spending, human capital for research and patents. On the basis of these data, it is clear that R&D activity is heavily concentrated in a relatively small number of regional clusters. Table 4 offers an overview of the distribution of R&D intensities across European countries.

Table 4. R&D intensity: Top and bottom NUTS 2* regions in each country (as a percentage of GDP, 2003)

National average			Top regional R&D intensity			Bottom regional R&D intensity		
Country	All sectors	Business sector	Top Region	All sectors	Business sector	Bottom region	All sectors	Business sector
EU-25	1.90	1.22						
EU-15	1.95	1.26						
NMS-10	0.77	0.34						
SE	3.95	2.93	Västsvrige	6.03	5.26	Mellersta Norrland	0.52	0.26
FI	3.43	2.42	Pohjois-Suomi	4.60	3.55	Åland	0.16	0.08
DK	2.56	1.77	Denmark	2.56	1.77	Denmark	2.56	1.77
DE	2.52	1.76	Braunschweig	8.70	6.75	Weser-Ems	0.57	0.34
FR	2.17	1.36	Midi-Pyrénées	3.72	2.40	Corse	0.24	0.16
BE	1.89	1.31	Vlaams Gewest	2.08	1.51	Bruxelles-Capitale	1.18	0.57
UK*	1.79	1.14	Eastern (NUTS1)	4.34	3.53	N. Ireland (NUTS1)	1.00	0.46
NL	1.76	1.01	Noord-Brabant	2.68	2.37	Zeeland	0.76	0.70
LU	1.66	1.48	Luxembourg	1.66	1.48	Luxembourg	1.66	1.48
SI	1.32	0.84	Slovenia	1.32	0.84	Slovenia	1.32	0.84
CZ	1.25	0.76	Střední Čechy	2.59	2.29	Severozápad	0.30	0.27
IE	1.16	0.77	South-East (NUTS1)	1.21	0.80	Mid-West (NUTS1)	0.92	0.65
IT	1.11	0.52	Lazio	1.89	0.48	Valle d'Aosta	0.37	0.25
ES*	1.05	0.57	Comunidad de Madrid	1.69	0.96	Canarias	0.52	0.09
HU	0.93	0.34	Közép-Magyarország	1.38	0.58	Észak-Magyarország	0.27	0.08
EE	0.79	0.27	Estonia	0.79	0.27	Estonia	0.79	0.27
PT	0.74	0.25	Lisboa	1.03	0.36	Região Autón.Madeira	0.19	0.01
LT	0.67	0.14	Lithuania	0.67	0.14	Lithuania	0.67	0.14
EL*	0.63	0.20	Attiki	0.93	0.37	Kentriki Ellada	0.30	0.03
SK	0.58	0.32	Bratislavský kraj	1.12	0.39	Východné Slovensko	0.28	0.14
PO	0.54	0.15	Mazowieckie	1.14	0.27	Swietokrzyskie	0.06	0.02
BU	0.50	0.10	Yugozapaden	1.03	0.16	Severozapaden	0.02	0.00
RO	0.39	0.22	Bucuresti	1.13	0.46	Sud-Est	0.12	0.08
LV	0.38	0.13	Latvia	0.38	0.13	Latvia	0.38	0.13
CY	0.35	0.07	Cyprus	0.35	0.07	Cyprus	0.35	0.07
MT	0.26	0.08	Malta	0.26	0.08	Malta	0.26	0.08
US	2.67	1.86	New Mexico	7.12	...	Wyoming	0.40	...
JP	3.20	2.40

* NUTS 1 data for the UK, Spain and Greece

Sources: Eurostat and the US National Science Foundation (for American states, 2001).

The regional heterogeneity in R&D intensity is striking. While some EU NUTS 2 regions have R&D spending near or even above the Lisbon target of 3% of GDP, the least active employ only 0.1% of GDP in R&D.

Although regional R&D data are not yet available for all EU countries, Eurostat has identified 21 EU regions that have already achieved the 3% Lisbon target. Nine of these are in Germany, among them Braunschweig, the region with the highest R&D intensity of all, at 8.7% (Table 4).

The other regions that have exceeded the 3% target are in Sweden (four regions out of Sweden's eight), Finland (three regions out of its five), France and Austria (two regions each) and the UK (one region).

In addition to the above-mentioned 21 regions, R&D expenditure exceeded 2% of GDP in another 17. Most of these regions were in Germany (five), France (four), the Czech Republic and the Netherlands (two each), and one each in Belgium, Denmark, Sweden and the UK.

The regions with the lowest R&D intensity are mainly in eastern and southern Europe. Of the 104 EU regions with R&D intensities below 1% of GDP, 41 were in the new member states.¹¹

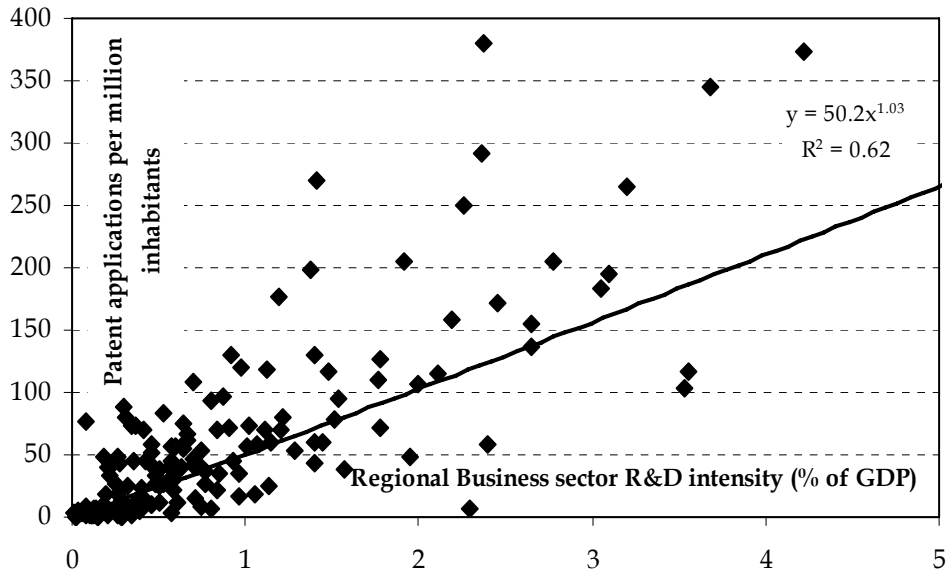
5.2 Patent applications by NUTS 2 regions

R&D expenditure is the most commonly used proxy for the resources allocated to the innovative process. With respect to economic impact, however, only the outputs count. One proxy for innovative output is patent applications.

Also, patents are subject to dense clustering at the regional level. The region with the highest number of patents per capita is Noord-Brabant in the Netherlands. This is followed by seven German regions with more than 300 patent applications per million inhabitants. The other most patent-intensive regions are found in Sweden (three) and in Finland and the UK (two each). Most of these correspond fairly closely to high levels of business R&D expenditures. As shown in Figure 33, there is a strong (slightly non-linear) correlation between regional business R&D intensity and patent applications per million inhabitants (the correlation has an R^2 of 0.62 in the case of business R&D, against 0.59 for all-sector R&D). The non-linearity suggests increasing returns to R&D. This means that a doubling of inputs (R&D) more than doubles the output (patent applications). This observation is also consistent with the existence of positive localised spillovers, an issue that is discussed in greater detail later on.

¹¹ A map visually representing these regional differences can be found in Eurostat (2007b).

Figure 33. A non-linear correlation between R&D intensity and patent applications across NUTS 2 regions



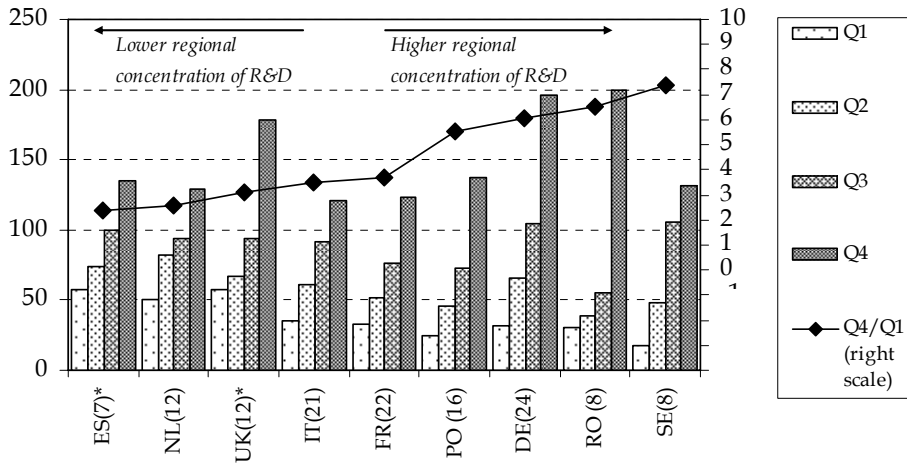
Source: Eurostat.

If the clustering of R&D has real economic consequences, then there is value in studying whether this clustering differs across countries.

Below we measure and compare regional R&D dispersion across countries. To make countries comparable to one another we normalise regional R&D intensities so that each country's national average is 100. We then rank the regions of each country by R&D intensity and calculate quartile averages. The 1st quartile hence includes the quarter of regions in a country with the lowest R&D intensities, while the 4th quartile is the quarter of regions in a country with the highest R&D intensities.

The four quartiles are shown for a selection of - mostly larger - countries as bars in Figure 34. For example, in Spain the average R&D intensity of the 4th quartile was 135% of the Spanish national average. By contrast, average R&D intensity in the 1st quartile was only 57% of the national average (the number of regions in each country is shown in parentheses).

Figure 34. R&D intensity by NUTS 2 region quartile (percentage of national average)



* NUTS 1 for the UK and Spain

Source: Own calculations based on Eurostat data.

To compare the regional dispersion of R&D intensities across countries more easily, we also calculate the ratio of the highest (4th) to the lowest (1st) quartile. The more dispersed the R&D intensities in a country, the higher is this ratio. If all regions had exactly the same R&D intensity, this ratio would be 1. In the diagram, this is shown as the black diamonds, measured against the right-hand scale.

As Figure 34 shows, there are notable differences across countries in terms of regional dispersion of R&D intensity, thus measured.¹² In the case of Spain and the Netherlands, R&D intensity in the top quartile is only around 2.5 times that of the bottom quartile, while in Germany and Sweden it is 6-7 times greater. A general pattern is that the regional dispersion is higher in countries with high overall levels of R&D intensity (Germany, Sweden and Finland), as well as in the new member states, where the bulk of R&D is heavily concentrated in one or two regions against a mostly rural backdrop. The pattern of higher regional R&D disparities in countries such

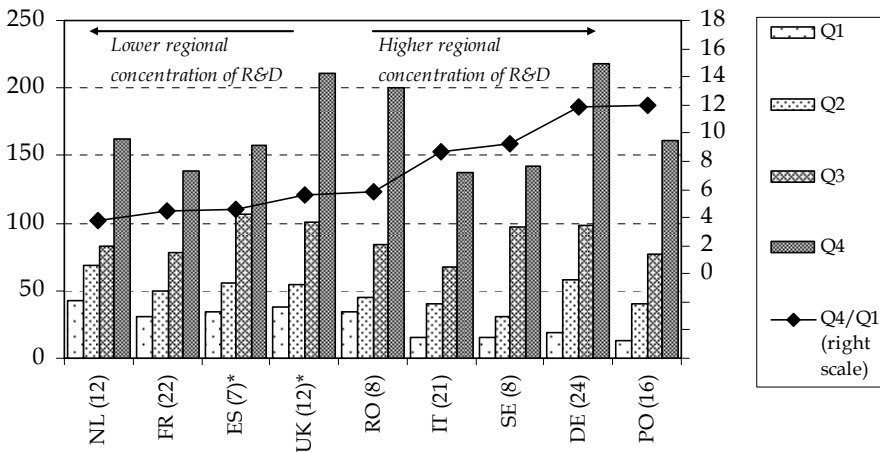
¹² An alternative measure of regional disparities is to calculate the standard deviation across all regions and scale this to the average, also known as the coefficient of variation (CoV). This statistically more precise (if less intuitive) measure does not leave us with a dramatically different impression. Disparities in Sweden and Germany are still higher than elsewhere.

as Germany and the Nordic countries would be repeated in other countries if they were to increase spending on R&D in key innovative centres. Taking again the example of Spain, if we assume that R&D spending was to double in all regions except for those in the bottom quartile, then the 4th/1st ratio would also double, from 2.4 to 4.7.

5.3 Regional dispersion is higher in business sector R&D

Across the board, the regional dispersion increases when we zoom in on business sector R&D (Figure 35). In Italy, Sweden, Romania, Germany and Poland, the 4th to 1st quartile ratio is now above 8. This result is not unexpected, since business R&D is more likely to feel the pull of agglomeration forces than either the government or education sectors, which in turn serve as a form of regional equaliser in the aggregate R&D figures (although, it should be stressed, not necessarily with positive overall economic results).

Figure 35. Business R&D intensity by NUTS 2 region quartile (percentage of the national average)



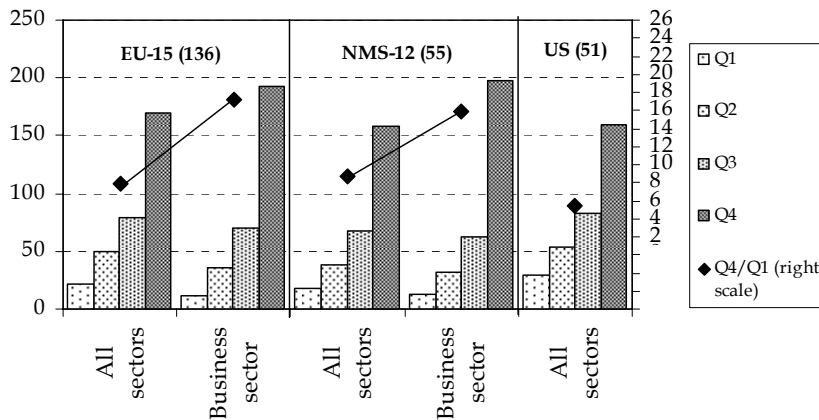
*NUTS 1

Source: Own calculations based on Eurostat data.

We have limited the presentation in the two figures above to larger countries. Discussing regional disparities in countries with only a few regions is less meaningful. We have also included the smaller EU countries in the aggregates shown in Figure 36, however. The much larger number of regions in these aggregates provides a fairly reliable picture of the regional disparities for the EU as a whole.

Interestingly, there is little difference between the EU-15 and the NMS-12. In both cases, business sector R&D is more regionally concentrated than aggregate R&D. In the EU-15 and the NMS-12 alike, the top quartile has an R&D intensity that is around 8-9 times higher and a business R&D intensity that is 16-17 times higher than the bottom quartiles. For comparison, we have also included data on the US - based on all-sector state-level data.¹³ Although this regional level is not fully comparable with European NUTS 2 regions, the data indicate that US R&D is somewhat less regionally concentrated than it is in the EU-15.¹⁴ Still, the difference between the US and the EU-15 is not substantial, which suggests that the regional concentration of innovative activity observed in the EU is close to what one should expect in open, competitive economies.

Figure 36. Business R&D intensity by NUTS 2 region quartile (percentage of national/group average)



Note: The number of regions is shown in parentheses.

Sources: Own calculations based on data from Eurostat and the US National Science Foundation.

¹³ Plus Washington, D.C.

¹⁴ This is also the conclusion of some empirical studies, for instance one by Crescenzi, Rodríguez-Pose & Storper (2007).

5.4 Is the clustering of R&D a good thing?

Is the clustering of R&D a good thing or is it a regional equity problem? If there are agglomeration effects or positive localised spillovers, then the clustering of R&D activity makes it more productive, boosting aggregate productivity and output. Positive 'localised' spillovers here means that the R&D activities of one firm have a positive influence on the productivity of R&D by other firms, but only so long as they are not too far away. To understand why this may be the case, it is useful to distinguish between codified and uncoded knowledge. Spending on R&D by one firm gives rise to new knowledge that can be shared by other firms, thus making their own R&D efforts more productive. Some of this new knowledge is typically documented in the form of a patent, which should be as easily understandable for distant users as for those nearby, assuming that they know how to read patents. This 'codified' part of the innovative output is hence a pure public good and independent of distance. But there is also a wealth of imperfectly codified knowledge attached to the researchers involved in the research project generating the patent. Certain aspects of this knowledge are only transferable through face-to-face interactions. One can think of this as a 'local public good', benefiting scientists within the region or in neighbouring regions but fading away with distance as contacts and interactions decrease.

That there are positive but geographically concentrated spillovers from R&D is elegantly demonstrated by Bottazzi & Peri (2003). They estimate the relationship between R&D spending (a measure of the inputs to the innovative process) and patent data (a measure of innovation output) across 86 European regions (both variables are normalised to intensities per square km in order to eliminate the influence of varying region size). Since this relationship has been found in the literature to be of a long-term nature, the authors use a cross-section of long-run averages across regions for the 1977 to 1995 period, disregarding changes over time.

R&D spending is assumed to consist of both a private component that cannot be shared with other producers and an 'idea' component that can. They then test whether R&D spending in one region is affected by R&D spending in neighbouring regions.

The authors make some very illuminating observations on R&D spillovers. They find that there are indeed statistically significant positive spillovers from R&D, but only up to a range of 300 km.

The way Bottazzi & Peri demonstrate that spillovers are localised is to split the region sample into sub-samples according to distances between regions (five different distance classes). They also include country dummies to account for border effects. The results are striking. Doubling R&D spending in a region is found to increase innovation output (patent applications) by 80-90% in that region. This is known as the internal effect. In addition, there are statistically significant spillover (external) effects on bordering regions, boosting patent applications there by 2-3%, but only in regions within 300 km. Beyond that there are no statistically significant spillovers. A 2-3% spillover does not seem like a very large impact compared with the internal effect. Yet, as the average European region has about 15 other regions within a 300 km distance from itself, the overall effect if each of them were to double their R&D intensity would be a quite sizeable 40% more patenting owing to external effects, on top of the 80-90% increase owing to internal effects. Taken together, a doubling of inputs leads to more than a doubling of output when clustered regions act together.

That R&D generates tacit knowledge not easily transferred over large distances is a common result in much of the empirical literature on knowledge spillovers. Jaffe, Trajtenberg & Henderson (1993) show that inventors are more likely to cite patents whose origins are geographically nearer than those from further afar. Griffith, Harrison & Van Reenen (2006) similarly show that British firms that locate R&D labs in the US were more able to tap into American knowledge than those that did not. Much of this literature uses older data, however, and says little about changes over time. One recent study, by Griffith, Lee & Van Reenen (2007) bridges an important gap in this respect by comparing "home bias" in patent citations of an early period (1975-89) with those of a later period (1999-99). Similar to earlier studies, evidence of a substantial home bias emerges. German firms are notably quicker to refer to other German citations, the British to other British citations, and so on. But comparing the results from the two periods also shows that this home bias has declined over time. This trend is

interesting in that it is consistent with an increasingly interconnected European economy, driven by falling transport and communication costs, which might be making R&D spillovers less localised than they used to be.¹⁵

5.5 Concluding remarks

Given the magnitude of the localised spillovers suggested by the aforementioned research, the return to R&D investment is bound to remain substantially higher in regional clusters with already high levels of R&D spending. These agglomeration effects generate a formidable first-mover advantage for R&D clusters that will likely prove difficult to dislodge. Public policies that aim at 'creating' new innovative centres where none has existed before may therefore prove highly wasteful. To the extent that the goal is to maximise the impact of R&D on economic growth in Europe, a more fruitful approach by public policy is probably to create an environment conducive to more innovation by firms in existing R&D agglomerations.

¹⁵ The authors allow for fixed effects to account for possible unobserved factors that are correlated with geography, for instance persistent quality differences in patents across countries. This reduces the size and occurrence of the home bias relative to earlier studies but does not eliminate it altogether.

6. CONCLUSIONS AND RECOMMENDATIONS

This report has aimed at shedding some light on the EU's R&D gap vis-à-vis the US and Japan by disaggregating R&D expenditure data in several ways. We have seen that there is indeed notable diversity in R&D spending across sectors, firm sizes and geographical entities in Europe. But such diversity also exists in the US, which suggests that a closing of the R&D gap, if and when it occurs, is unlikely to take place homogeneously across all these dimensions. There are sound economic reasons for R&D spending to be concentrated in certain industries, countries and regions. As discussed in this study, innovation is characterised by positive externalities, which means that the productivity of a euro spent on R&D is affected by the environment and circumstances in which it is spent. One example we have seen concerns locational spillovers, where the productivity of R&D spending in terms of patent applications is higher if it takes place near the R&D activities of other related firms. Another example is that the rate of return on investing in R&D is influenced by the competitiveness in each sector. Policies that seek to boost spending on R&D in the European business sector will have to target the factors that give incentives for firms to innovate, taking these issues into consideration. Doing so would not only likely be more successful in boosting R&D spending, it would also make these R&D activities more effective.

But perhaps the most important lesson from the data presented in this study is that there are many areas in which the EU does not differ from or lag behind the US. In large segments of the manufacturing industry, for example, European firms spend as much on R&D as US firms do. The biggest gaps in R&D spending between the US and the EU are in market

services and high-technology manufacturing, which not coincidentally is also where a large share of the US-EU productivity gap can be found. As economies develop, market services tend to grow in size relative to the manufacturing industry. Europe is gradually following the US example in this direction. As in the US, Europe's future comparative advantage is unlikely to be in medium-technology manufacturing. Therefore, if the innovative and productivity shortfalls in market services and high-technology sectors were to remain, then Europe would over time widen rather than narrow its distance behind the US.

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