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Monitoring industrial research:

Industrial R&D economic and policy analysis report 2006

Directorate General Joint Research Centre
Directorate General Research

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Preface

The Economic and Policy Analysis Report sheds light on policy questions related to industrial research and innovation. It elaborates on the findings of the Industrial Research Investment Monitoring (IRIM) activities that are jointly carried out by the European Commission's Directorate General Joint Research Centre and the Directorate General Research. The report uses, in particular, the results of the *EU Industrial R&D Investment Scoreboard* and the *EU Survey on Business Trends in R&D Investments*. The wider economic context and recent trends are derived from the literature reviewed in the *Annual Digest of Industrial Research*, including the main documents from other Commission services.

Policymakers in the EU and at national level attach great importance to private sector R&D and innovation as a means to leverage EU economic growth and increase competitiveness. The Commission's 3% Action Plan was designed to increase R&D spending in the EU to 3% of GDP – two-thirds of which should come from the private sector. In that Action Plan, the Commission requested the creation of an 'industrial research monitoring activity, including a scoreboard, to analyse trends and facilitate benchmarking of research investment and research management practices'. More recently, the Commission has specifically called for an expanded monitoring and analysis of prospective trends in private R&D investment and innovation. The Commission's Communication "More Research and Innovation: A Common Approach", COM (2005) 488 final, outlines a European Industrial Research and Innovation Monitoring System which will supplement the annual European industrial R&D investment scoreboard with annual surveys of prospective trends by sector of economic activity.

This first edition addresses policy questions of a more general nature, largely on the basis of the existing literature and estimates of the impact of private R&D. It has benefited considerably from the comments of experts in the field. Future editions will also make use of publicly available information. This will be complemented to a greater extent by original statistical and econometric work, using the results of the IRIM activities and drawing from the analysis of industrial research investment at firm, sector, country and EU levels, including economic model simulations of the impact of R&D.

Monitoring Industrial Research:
The Economic and Policy Analysis Report

Summary

The proportion of GDP spent on R&D in the EU is lower than that in the US and Japan and the EU is unlikely to catch up within the next decade. Does EU growth suffer from underinvestment in R&D, or is the lack of R&D a reflection of more general imperfections of the single market? Industrial research investment monitoring can only provide part of the answer. The analysis in this paper elaborates on the finding that EU companies in sectors with traditionally high levels of R&D spend as much on R&D as their competitors. This is combined with evidence from surveys showing that lack of funding for R&D is not the most binding constraint for investing companies. The internationalisation and outsourcing of R&D appears to carry on regardless of differences in government financial support. Market-oriented reforms and complementary policies to improve the structure of the European economy may therefore be more effective in raising R&D expenditures – and in generating growth through innovation – than direct incentives.

Introduction

In 2002, at the Council in Barcelona, the EU adopted a target of raising R&D expenditures to 3% of GDP. The Council specified that two thirds of this should be financed by the private sector, but how and by what instruments this objective could be achieved was largely left to the Member States. This paper analyses some of the implications of the results of the industrial research investment monitoring activities for EU policymaking on R&D.

The Barcelona objective is part of the Lisbon strategy, which has been refocused to aim for higher growth and more jobs. R&D in enterprises contributes to economic growth because it leads to increases in productivity and to new and better products. It is important for policymakers to recognise that innovation is an essential step in the commercial exploitation of research, in other words in establishing the link between R&D and growth, and that the innovation process can be hampered by constraints on the accumulation of human and physical capital.

In some branches of industry R&D is crucial for companies to maintain their competitive position. In other sectors, in particular in services, economic success depends more on the speed by which new ideas are picked up and exploited and on the introduction of new business models. Applying information and communication technologies, and adapting patterns of work to use them effectively, is generally recognised as the most significant source of economic growth in recent decades, in sectors which have little R&D as well as more R&D-intensive ones. This shows the need for policymakers to be aware of and anticipate technological developments and trends that could shake up the industrial structure in the future.

The impact of a rise in R&D on growth is estimated to be high. In a simulation study undertaken for DG Research by the ERASME team, using an adapted version of the NEMESIS model, attaining the 3% of GDP objective was estimated to have a significant impact on long-term growth and employment. On average, it would raise GDP by 0.5% and allow for the creation of 400,000 jobs per year after 2010. (Results presented in Investing in research: an action plan for Europe, COM (2003) 226 final). Gelauff and Lejour (Netherlands Bureau for Economic Policy Analysis, 2006), in a study for DG Enterprise, used the WORLDSCAN general equilibrium model to simulate the impact of different parts of the Lisbon strategy. In 2025 the increase in GDP resulting from raising R&D expenditures in Europe to 3% of GDP by 2010 and maintaining this level thereafter would be in the range of 3.5 to 11.6% in 2025. The accumulated impact in the ERASME study (7.8%) falls neatly within this range. The width of the range reflects the different assumptions on the social returns to R&D investment, which in any case are estimated to be much higher than the private returns.

How to persuade enterprises to spend more on R&D, while the benefits are reaped partly by other firms and partly by society at large, remains a great challenge to policymaking. Back-of-the-envelope calculations show that, on current trends, it would take until the end of the century to reach the level of business expenditure on R&D implied by the Barcelona objective. Even though the *2006 EU Industrial R&D Investment Scoreboard* (European Commission, 2006d) shows R&D investment to have grown faster than nominal GDP in the EU in 2005, much of the increase disappears when the upward trend in R&D spending abroad by EU firms is taken into account. There is also a slight downward trend in the R&D expenditure in the EU of non-EU companies.

In this light the main questions addressed in the paper are:

- To what extent can policies aimed at increasing R&D in enterprises be expected to contribute to higher growth and employment?
- Is the potential impact of R&D policies constrained by the sector structure of an economy?
- What are the main determinants of the location of R&D activities and how could they be affected by policy?
- Should the policy focus be on influencing the research investment behaviour of enterprises, possibly differentiated by sector, or on improving the business environment in which companies operate?

The Economic and Policy Analysis Report is part of the of the Industrial Research Investment Monitoring (IRIM) activities[1] carried out by the European Commission's Directorate General Joint Research Centre in close co-operation with Directorate General Research. This first edition of the report is structured as follows. Section 1 briefly reviews the literature on economic growth and investigates the link between R&D and growth on a macroeconomic level. Section 2 analyses the differences in R&D performance by sector and asks to what extent they explain the differences in the overall R&D intensity of national economies. Section 3 looks at the trends in the concentration and internationalisation of R&D. Section 4 then discusses whether R&D in enterprises can best be stimulated by measures to attract R&D

[1] Such as the *EU Industrial R&D Investment Scoreboard*, the *EU Survey on Business Trends in R&D Investment*, and the *Annual Digest of Industrial Research* – see http://iri.jrc.es/ and http://ec.europa.eu/invest-in-research/

to particular locations or by measures to remove the obstacles to market-led innovation. This section includes some further suggestions on directions to take.

1. R&D and growth

Any policy aiming at generating more growth through R&D assumes that research and development have a positive effect on productivity and that policy instruments are available to influence the level of R&D in a country. Both assumptions need to be underpinned by empirical evidence. There are many quantitative studies that confirm the favourable impact of R&D on economic growth. The effects are assumed to be brought about by innovation and productivity growth at the level of the firm, although the impact studies have mostly been on the macroeconomic level. This section deals primarily with the relation between R&D and growth. Whereas the policy question – R&D as an intermediate target for policymaking – is addressed later on, the analysis in this section already suggests that raising R&D without proper regard for conditioning factors is unlikely to lead to higher economic growth and more jobs.

There is an extensive literature estimating the size of the impact of R&D on productivity (thorough reviews by Griliches, 1994; Nadiri, 1993; Fagerberg, 1994; Bassanini and Scarpetta, 2001; de la Fuente and Ciccone, 2002). Where most of these analyses have examined the rate of return on R&D investment, the following findings are relevant:

- There is a positive correlation between R&D intensity and productivity growth.
- Productivity growth is caused by R&D investment, with a certain delay in transmission, and the effect varies with sector and with country. The output elasticity to R&D investment – i.e. the percentage increase in productivity as a result of a 1% increase in the R&D stock – for which estimates range from 0.04 to 0.54 (Nadiri, 1993). There are some indications that the estimated elasticity varies between periods of recession and economic recovery.
- The results of elasticity estimations vary with the level at which surveys are performed: industry or company (Nadiri, 1993).
- The effect on productivity growth within a given sector is often smaller than the overall impact on the economy's other macro-variables. This is because of the impact of the uptake of new knowledge in other sectors. The overall effect is due to this spillover effect as well as the direct effect on the individual firm or sector.
- R&D has a positive impact on total factor productivity (extensive literature can be found here, led by the school of thought inspired by Griliches). The Granger causality test indicates that R&D leads to higher total factor productivity (and hence GDP growth) rather than the other way round (see Rouvinen, 2002).

Apart from the direct impact of R&D on productivity in companies and sectors, there are economic and social considerations at a macroeconomic level which support arguments for stimulating R&D:

- Social rates of return to R&D investment 'remain significantly above private rates' of return (Griliches, 1992; Griffith, 2000). The inter-sectoral spillover effects of R&D are, in most sectors, more important than the direct effects of this type of investment.

- While the direct short-term impact of investment in R&D on employment rates remains uncertain, the long-term effect seems to be positive, at a national macro level. This relationship differs by sector and is dependent on input-output linkages with the rest of the economy.
- There is a positive correlation between investment in R&D and the quality of the human capital, which ultimately adds to the significance of the technical progress term in the production function.
- FDI is an important source of R&D spillovers beyond the national borders. There is a positive correlation between R&D intensity and the inflow of foreign direct investment (FDI) at the sectoral level. The correlation coefficient is sensitive to the geographical origin of the FDI flows and the degree of concentration within the sector (Barrell and Pain, 1997; Jungnickel and Keller, 2003).

In addition, there is evidence to suggest that certain specific socioeconomic conditions must be met for R&D investment to actually lead to innovation. There is some evidence from empirical regional studies: 'innovation averse' and 'innovation prone' regions have different capacities to ensure high R&D productivity (Bilbao-Osorio and Rodríguez-Pose, 2004; Rodríguez-Pose, 1999). There is also some evidence that social capital – defined by Putnam (1993) as features of social organisation, such as civic participation, norms of reciprocity and trust in others – facilitates cooperation for mutual benefit and that firms and regions with higher levels of social capital are characterised by higher levels of innovation (Ruuskanen, 2004).

While R&D intensity influences a country's competitiveness, competitiveness does not rely solely on the R&D performed in the country. Thus, the fact that a country is a strong player in R&D is no guarantee of its competitiveness. Many countries with relatively low R&D intensities continue to do well in terms of overall economic performance. Typically these are countries that do not operate at the technology frontier and are catching up on the basis of imported technology and a sufficiently high level of human capital. Conversely, there are also examples of countries with a relatively high R&D intensity that do not seem to benefit from higher rates of economic growth than their competitors.

Measuring R&D productivity

Although spending on R&D is treated as expenditure by business and government in the System of National Accounts (SNA), it is recognised to have the character of an investment since the benefits are spread over a longer – and often considerably longer – period of time than the year in which the expenditure was made. Several countries have made calculations of the effect of treating spending on R&D as an investment. The results of such calculations are based on many assumptions and are difficult to interpret reliably.

The US Bureau of Economic Analysis (BEA), with support from the National Science Foundation, has recently published preliminary calculations showing that the treatment of R&D as investment would have raised the level of GDP by 2.6% and real GDP growth by an average 0.1 percentage points per year in the period since 1959. In their calculations this jumps to an average 0.8 percentage points per year in 1995-2002, adding up to a contribution of about 6.5% to real GDP growth in this period (Okubo et al, 2006). This illustrates that there are measurement problems with GDP, how to treat R&D being one of the difficulties.

There is no direct measure of the contribution of R&D to sales, nor can all R&D be priced as an asset for which there is a market. The US BEA report notes that, in practice, the reporting by the business sector is mostly related to R&D in natural sciences and engineering, adhering to a more limited concept than in the Frascati Manual. The results for the US also seem to be affected by double counting of spending on software, which is already treated as an investment in the US national income and product accounts. This could explain part of the estimated jump in the contributions of R&D to GDP since 1995. Even without that, the estimated increase in the level of GDP of 2.3-2.6% is higher than for the other countries in which a similar exercise has been undertaken. Estimates in a study for the Netherlands, using data for the period 1970-1999, show an upward adjustment in GDP of slightly more than 1% if spending on R&D were to be capitalised (De Haan and Van Rooijen-Horsten, 2004).

Overall economic performance may be too aggregate a measure of the success of R&D. The quality improvements of goods and services resulting from R&D tend to be underestimated when using GDP. It also fails to capture the effects of research on the welfare of a country. More direct measures of R&D productivity are available. The most common indicator used to measure R&D productivity is the patents to R&D ratio, even if it needs to be recognised that this captures only part of the successful applications of R&D and that patenting behaviour differs between sectors. The higher this ratio, the more patent applications have been made per given amount invested in R&D.[2]

Where there are significant difficulties in comparing patent data, the triadic patent family indicator has been constructed by the OECD in order to reduce the comparability problems concerning the data derived from patents filed at a single patent office. A patent is considered triadic if it is filed at the European Patent Office (EPO), the Japanese Patent Office (JPO) and the United States Patent and Trademark Office (USPTO). The holders of triadic patents are mainly large firms. In general, only inventions with a very high potential for world-wide exploitation are patented as triadic patents (UK National Statistics, 2005).

There is a strong positive correlation between the number of triadic patent families (i.e. those registered in Europe, the US and Japan) and industrial R&D expenditure. Countries having a high level of industrial R&D expenditure (such as the US, Japan and Germany) also have large numbers of triadic patent families. Conversely, Eastern and Southern European countries have a low level of industrial R&D expenditure and of triadic patent families (OECD, 2004a).

The leading countries in terms of ‘patent per BERD’ ratios are Sweden, followed by Germany, Japan, the Netherlands, the US, France and the UK (European Commission, 2002).

Much of the power of R&D intensity in explaining the differences between countries derives from its close correlation with other indicators of research and innovation (Jaumotte and Pain, 2005). Not surprisingly, R&D intensity is (a) highly correlated with the shares of scientists and other R&D employees in the workforce. It is also positively correlated with (b) triadic patents, which is an indicator of R&D success rather than necessarily of economic gains on the basis of successful R&D. Moreover, the correlation between business R&D intensity and (c) publicly funded R&D intensity in OECD countries is sufficiently high to assert that there may be particular institutional or structural features in many economies which tend to either stimulate or hold back both types of investment in R&D. This would suggest that R&D

[2] There are problems associated with using patents as measurement for R&D. It is well known that some large companies (particularly in the ICT sector, e.g IBM or Microsoft) have a strategic approach to patenting, which does not accurately reflect their level of innovation.

intensity may be useful as an indicator of national R&D and innovation efforts, but less so as an isolated target for national policymaking.

R&D as a source of innovation

Conceptually, R&D can only affect the growth and performance of an economy through innovation. The commercial exploitation of research involves making improvements to existing products, introducing new products and services where they meet demand and redesigning production methods. Although such innovations are implemented at the level of the firm they have spillovers to other parts of the economy and lead to constant changes in the composition of gross domestic product (GDP). The overall economic impact of investment in R&D leading to innovation cannot be established by simply adding up individual company results. Any evaluation needs to take into account the changes in the structure of the economy.

In general, the empirical evidence on the returns to investment in R&D is stronger at higher levels of aggregation. Countries with a higher R&D intensity tend to do better in terms of overall economic performance. The evidence at company level is much weaker. This can be taken as evidence that the social returns are much higher than the private returns, or at least that the impact of raising R&D intensity on economic results at the national level is more significant than at the company level. It also raises questions about what motivates companies to invest in R&D, questions that are all the more relevant given the emphasis of the Lisbon strategy on R&D efforts in the private sector.

Studies by the OECD (Jaumotte & Pain, 2005) show a positive correlation between R&D intensity and inventiveness, measured by the number of patents, and between R&D and innovativeness, measured by the proportion of companies that are innovative. At the same time, high R&D intensities are not necessarily associated with economic success. The correlation with the proportion of firms based in the country applying for a patent is weak, as is the correlation with the number of new products launched. One explanation lies in the fact that R&D as well as patenting in a country is concentrated in a small number of companies, which introduce only a small number of new products onto the market.

Human capital is vital

The quality of the human capital is vital for R&D and for its impact on factors of competitiveness (Bradley, Morgenroth and Untiedt, 2000). The number of years of education, especially at tertiary education level, the number of highly-skilled researchers, and the mobility of these researchers can be shown to have an effect on R&D and innovation-driven growth in the economies of some OECD countries (UK, Australia, France, US). For there to be R&D, there needs to be investment in human capital. This apparently intuitive statement cannot be stressed enough, especially against the backdrop of the Barcelona target, which emphasises the *demand* for researchers (by encouraging greater investment in R&D) but does not explicitly specify a corresponding target for the *supply* of researchers. A clear view is needed of where the development of business activities might be held back by a lack of research skills in the future.

The European Commission's *Survey on Business Trends in R&D Investment* shows that one of the most important factors determining the location of a firm’s R&D activities is the availability of researchers, followed by market access, access to specialised R&D knowledge and a predictable legal framework for R&D. This result is further supported by other empirical evidence, based on surveys (The Economist, 2004) and country-level aggregate data (Jones and Teegan, 2003). It appears that firms are setting up R&D activities in foreign locations in order to tap into sources of scientific excellence worldwide.

This trend is echoed by results from a Canadian study (Barber, 2003), which looked at the characteristics of companies with a research intensity of between 3 and 50%.[3] A number of characteristics distinguished this community of companies, most significantly that many of them have already experienced shortages of human capital as an inhibitor to growth.

It seems, therefore, that the supply of creative science and engineering talents serves close attention by policymakers, especially in view of the internationalisation of R&D. Innovation depends on people, hence on having an adequate supply of creative talent to undertake more R&D. If this creative talent is not available, then no matter how much money you 'throw' at R&D, it will do no good. Wherever creative talent goes, innovation and economic growth are sure to follow (Romer, 2000; Florida, 2004).

There is an argument, therefore, for government policies to support programmes that directly increase the supply of scientific and engineering talent, rather than the demand for it (Romer, 2000). The reasoning is simple: if the demand for science and engineering talent is increased and the supply of such talent remains fixed, the result is more likely to be an increase in researchers' salary, rather than an increase in the total *amount of inputs* that go into the process of R&D. And it is the latter that is required if growth and innovation are to be achieved.

The EU enjoys a fairly adequate supply of scientists and engineers overall, although there may be surpluses and shortages in regions and areas of expertise (e.g. high level of unemployment of young PhD holders in France, shortage of ICT related specialist in Germany and the German government's 'green card policy' to attract experts from abroad). So, while greater efforts to ensure that there is an appropriate supply of creative talent in the EU do not appear to be a priority, the point remains that any policy initiative encouraging greater investment in industrial R&D needs to keep constraints on the supply side in mind.

Even if the supply of researchers is regarded as sufficient, the exploitation of research results may be hampered by the weakness of university-industry relations. There is evidence that proximity and established cluster type relations between universities and companies continue to play a role, in spite of expectations that physical distance would be a factor of declining significance for the exchange of information in modern society (Döring and Schnellenbach, 2006). This would suggest that policies stimulating R&D should leave sufficient room for measures encouraging firms to be imaginative in their use of research results.

2. R&D investment by companies and private R&D in sectors

The Member States have different economic structures and there are large differences between the levels of R&D in each sector. There are many sectors of economic activity, in

[3] Those with research intensities above 50% are considered to be new start-ups which are not guaranteed to last in the long run.

particular in services, that report low R&D intensities and only a few, mostly high tech, sectors in manufacturing that are characterised by high intensities.[4]

For companies that want to compare their R&D and innovation performance with companies of a similar size operating in the same sector the available sources of information are limited.

The *EU Industrial R&D Investment Scoreboard* shows that large EU based companies spend as much on R&D as their counterparts based elsewhere. However, it also reveals that the EU is less well represented in the high-tech and emerging sectors of the world economy. Among the top R&D investors the variation in R&D relative to sales between companies operating in the same sector is much less than the variation between sectors.

Company R&D performance

A clear finding of the *2005 EU Industrial R&D Investment Scoreboard* is that the top EU companies tend to perform at least as well in terms of R&D investment as their counterparts outside the EU. For example, there are more EU than US companies among the top 50 R&D investors in the world. Eighteen EU companies account for 36% of the total R&D investment of the top 50 companies in the world, while 17 US companies account for 35% and 12 Japanese companies for 23%. Furthermore, there are few sectors where there is not at least one EU company in a leading position – even in highly R&D intensive (R&D investment / net sales) sectors such as IT Hardware and Electronics & Electrical Equipment.

The main message that emerges is that, even though there may be good reasons for governments to support R&D in large companies, these companies cannot be expected to raise R&D intensities much above their main competitors. Individual companies may lose competitiveness if they invest below the sector average, but it is by no means clear that there are positive returns for any investment above the sector average, especially in the short term. Thus, companies can actually over-invest in R&D without gaining market share. The question that remains is whether investing in research would enable EU-based companies to increase their market shares at the expense of their competitors elsewhere in the world.

At the heart of these questions lies the debate on the effects of R&D on corporate performance. The conventional wisdom is that greater investments in R&D will lead to better performance at the firm level and, at an aggregate level, should lead to greater economic growth and productivity. There is some evidence supporting this view in the 2004, 2005 and 2006 editions of the *EU Industrial R&D Investment Scoreboard*, which finds a correlation between changes in profitability and changes in R&D investment among EU companies. Further empirical evidence and econometric studies backing up this line of argument can be found in Guellec & van Pottelsberghe (2001); DTI (2005); Ulku (2004); and Mairesse & Mohnen (2004).

Company size

[4] The differences in R&D intensities between countries can be attributed to differences in sectoral structure and differences in the R&D intensities of the sectors (the "intrinsic" part). Calculations by Bart van Ark (based on the work of Hugo Erken and Martin Ruiter, Ministry of Economic Affairs, The Netherlands, July 2005) suggest that the intrinsic effect dominates the structural effect in most Member States. However, the outcome of such calculations turns out to be rather sensitive to the level of disaggregation.

There are too few EU based companies with high R&D intensities which are comparable in size and sales volume to the top investors in the world (*EU Industrial R&D Investment Scoreboard*, European Commission, 2005). There is a scarcity in Europe of medium-to-large companies in which R&D drives growth. There may also be a problem of successful innovative enterprises that stay relatively small.

Regional analyses of R&D and innovation suggest that SMEs are particularly sensitive to spillovers from university and public research undertaken in the region, more so than large firms. It is interesting to note that SMEs tend to rely more on inputs which have R&D embedded in them. In other words, they use products and services that are the result of R&D conducted elsewhere. There are also small innovative companies that depend heavily on the demand from big R&D intensive companies nearby. Feldman (1994) concludes that smaller firms make use of external sources of R&D as additional inputs in order to compensate for a lack of resources compared to larger firms. This is not to say that such firms are not innovative. As a survey of 1800 firms in three German regions shows, knowledge spillovers have a positive impact on the number of patents applied for by SMEs (Döring and Schnellenbach, 2006).

In terms of policy analysis further study is needed on the dynamics of company development. The questions that have to be addressed include: why is the segment of R&D intensive medium-large companies in the EU smaller in relative terms than in other economies? Are there specific obstacles related to R&D which make it unattractive for smaller companies to grow? Should remedies be found in research policies or rather in improving the framework conditions?

Service sectors

There are some new emerging R&D-intensive sectors, such as market-exposed services (leisure & hotels, media & entertainment, health, software, internet) and biotechnology (*EU Industrial R&D Investment Scoreboard*, European Commission, 2005). These sectors include some which may drive the world economy in the future, as has been the case with ICT R&D investment in recent decades. In some of these sectors the EU companies account for a relatively small share of R&D investment and sales compared to their overall proportion of total figures worldwide, which may be an issue of concern.[5] The main policy question is whether support to R&D in services needs to be fully assimilated to schemes to support R&D in manufacturing. R&D in services has grown rapidly, albeit from a low base in recent years. However, the horizon of R&D investment is typically much shorter than in manufacturing, as is the window for using R&D output.

The services sector is essential in a modern economy and fundamental for the competitiveness of the EU in view of its share (over 60%) of the overall value added of the economy. Moreover, services provide a large proportion of employment. They can make a significant contribution to the EU's industrial R&D investment in the future, closing the gap with other developed economies, where the proportion of total corporate R&D accounted for by services already surpassed 25% some time ago.

At first sight, it would appear that reshaping the sectoral composition of the EU and modernising its industrial fabric would be required in order to achieve two thirds of the 3%

[5] The RENESER Project produced a report for DG MARKT on Research and Development Needs of Business Related Service Firms, combining data analysis with company case studies and interviews.

target. There are indeed examples of strategic views on the structure of industry that have guided the development of knowledge based economies. Support to and promotion of specific R&D fields has, for instance, been part of industrial policy in Singapore and Hong Kong (Young, 1992). In Europe, government involvement in the creation of Airbus and in the turnaround of Nokia could serve as examples. However, there are few examples in the service sector of governments trying to second guess the markets and mould companies into winners. Within the EU the opening up of the services market could be a greater incentive to R&D use than national government strategies to pick winners.

Low tech sectors

The main drivers of technological progress in the knowledge-based economy are the highly R&D-intensive sectors. Therefore, most of the attention of technology policy is focused on them. However, a number of recent studies demonstrate the need to reassess the importance of low R&D-intensive sectors for economic growth and employment and the role of research and innovation on those sectors (Sandven & Smith, 2005; Mairesse & Mohnen, 2004).

In the first place, low R&D-intensive sectors play an important role in employment and job creation in the EU (Sandven & Smith, 2005). So, any increase in R&D in those sectors can have a big impact on productivity and economic growth.

Part of the inter-sectoral effect of R&D is captured by spillovers. The rates of return to R&D are higher at sectoral level than at firm level, but also higher when estimated at the level of total manufacturing value added and again at the level of GDP. This suggests that it is not only the sectoral composition of GDP but also the spillovers between sectors that need to be taken into account when analysing the differences between countries' R&D intensities.

3. Concentration and internationalisation

While R&D is concentrated in advanced industrial economies and at favourable locations within the larger countries, the advantages of physical location may be diminishing with the increasing speed and globalisation of information flows around the world and with easier access to the knowledge built up through R&D. This raises the question of whether policymakers would more usefully focus on making their country an attractive location for R&D or somewhere with easy access to knowledge generated elsewhere. The question of how to reap the benefits of R&D output generated by FDI, either inward or outward, remains a major challenge for the EU and the Member States.

The internationalisation of industrial R&D

Domestic R&D is far from the only source of knowledge exploited in the economic activities of a given country. A companion European Commission report, the *Annual Digest of Industrial Research* (European Commission, 2006c), deals with the internationalisation of industrial R&D.

In an increasingly global marketplace in which research activity can be outsourced to foreign affiliates, it is debatable whether BERD needs to be carried out in the home market and whether it is the best or only route to a competitive, knowledge-based economy?

Whether the EU becomes a more competitive, knowledge-based economy may largely depend on innovation including its ability to absorb knowledge produced elsewhere and use it productively. In other words: EU companies need to innovate – but this innovation will not necessarily depend on domestic R&D efforts.

Much innovation hinges on tacit knowledge, which is difficult to transfer and apply elsewhere than where has been created and it is held. If a significant number of firms engage in R&D activity in a specific foreign location, a given firm should be able to benefit from knowledge spillovers generated in that location by establishing R&D activities there. This knowledge can then be transferred to the home country and utilised to improve products and processes.

A study by Griffith et al. (2004) concluded that foreign research labs located in the US benefit from spillovers, which eventually leads to an improvement in home country productivity. UK firms which established a high proportion of inventors based in the US benefited disproportionately from growth in the US R&D stock over a period of ten years. Specifically, the total factor productivity of UK firms would have been at least 5% lower in 2000 had it not been for R&D growth in the US in the 1990s. The effects were particularly strong for industries which had 'the most to learn', i.e. where their total factor productivity gap with the US was biggest.

But countries cannot expect to be able to benefit from international spillovers without ever having to produce highly R&D intensive products or services themselves. At some stage they will need to move to the production of high technology exports as continuous innovation without R&D becomes more and more difficult (in one way or another a country needs to pay for R&D 'imports'). Even though much embedded knowledge can be 'bought', there are clear advantages to being a producer of technologies, particularly in the field of ICT (where the EU lags behind the US). As Amable (2000) points out, countries which produce these technologies witness a faster diffusion of new technologies, and also benefit from higher productivity growth than countries not specialising in them.

The primary factor driving asset-exploiting R&D activities abroad is presumed to be the potential of the host market. For asset-augmenting activities, on the other hand, it is the presence of a highly skilled labour force. The *Survey of Business Trends in R&D Investment*, a companion study by the European Commission (2006b), shows how both these factors are very prominent among firms, suggesting that both motives continue to co-exist.

However, if research policy is to adapt to a world where the phenomenon of R&D internationalisation is growing relentlessly, it will need to learn more about this process and its implications, be they positive (e.g. benefiting from R&D undertaken abroad) or negative (e.g. loss of high-quality jobs at home). Some aspects are already known. For example, technology flows from the subsidiary firm – located abroad – to the parent company – located at home – are correlated with the degree to which the subsidiary firm is embedded in the local context and the degree to which it is integrated with the rest of the organisation (OECD, 2005a).

In sum, it is important to highlight that the internationalisation of R&D offers opportunities as well as challenges for innovation in the EU. As such, fears that the EU is experiencing a 'hollowing out' miss the point. Some R&D investment moves to foreign countries, including to the emerging economies of China and India, but much of the knowledge flows back. In the end, what is important is the amount of innovation that takes place in the EU and the degree to which it (a) needs to rely on domestic R&D and (b) is capable of benefiting from international spillovers. A broader framework needs to be developed, building on what is known about the processes involved in the internationalisation of industrial R&D, in order for the EU to have a research policy that adapts to an increasingly interconnected and borderless world.

What determines decisions by firms on the location of R&D?

The R&D expenditure of foreign-controlled firms in the OECD countries more than doubled in the period 1995-2003. This is much higher than the increase in foreign-controlled turnover (OECD, 2006). Although in absolute terms R&D remains small in comparison to foreign direct investment, the internationalisation of R&D is one of the most dynamic features of globalisation. Broad-based surveys of Swedish companies (ITPS, 2005; Hakkala and Zimmermann; 2005) show an increase in R&D performed abroad from 15-25% in 1995 to 40% in 2003.

International organisations are using survey results in the absence of a full and coherent set of data on R&D invested by multinationals at home and abroad. According to the UNCTAD (2005) survey, although the bulk of the R&D conducted abroad takes place in other developed countries, with the US and the UK as the favourite destinations, many of the responding companies also carry out R&D in developing and emerging economies. China (first) and India (third) are among the most favoured future destinations, with the US taking second place.

The OECD (2005) reports on surveys carried out in 2004 by the European Industrial Research and Management Association (EIRMA) on 40 multinationals, and in 2005 on 229 US and EU multinationals, financed by the Kaufman Foundation and the US National Academies. Both aim to identify the factors that make the home and destination countries attractive places in which to conduct R&D. The quality of research personnel, the level of intellectual property rights protection and the presence of universities are the most positively quoted factors, whereas cost considerations are lower down the list. These findings broadly match those from other studies. In addition it is found that high growth potential and low R&D costs play a more significant role for the location of R&D activities in emerging economies, where multinationals aim at improving products and services rather than develop new technologies.

Policies to increase R&D in the private sector can aim at increasing existing R&D as well as at attracting R&D from elsewhere. The first will have positive spillovers to other countries; the second may divert R&D activities away from those countries. From a Community point of view, such policy competition may be beneficial if it improves the efficiency of the policies of the Member States but harmful when it leads to relocation for rent seeking reasons by entrepreneurs. The negative effects should be minimised by greater exchange of information and coordination of policies affecting research and innovation between the Member States.

Results from the *Survey on R&D Investment Business Trends in Sectors* (European Commission, 2006c) give an indication of the importance of several factors determining where to locate a firm's R&D activity. Among these factors are several framework conditions. With some variation between sectors of economic activity, the results suggest that policy predictability and proximity factors are more important determinants of R&D location than costs, including those of complying with legal and regulatory requirements.

The main factors are related to market conditions (i.e. characteristics of the goods-and-services market, the labour market and the market for R&D). This is the case of 'market access', 'high availability of researchers' and 'access to specialised R&D knowledge and results'. Government policies have a strong influence on these factors, although the favourable effects and their perception by market participants take considerable time to emerge.

The surveyed companies also emphasise factors that reflect the predictability and stability of government policy. They fall under the category of framework conditions. This is the case of 'macroeconomic and political stability', 'predictable framework for R&D', and 'R&D cooperation opportunities' (e.g. with public research organisations).

Firms in engineering and machinery display the characteristics of the 'old economy', where geographical distance is still relevant. They value being physically close to other company activities and close to suppliers. The cost of researchers is considered more important in this sector than in others.

Firms in the pharmaceuticals and biotechnology favour 'macroeconomic and political stability' and a 'predictable legal framework for R&D'. Firms in the chemicals sector value being in close proximity to other companies' activities. In this regard, it is worth noting that the chemical and pharmaceutical industries were found to be the most internationalised in terms of R&D in the UNCTAD (2005) survey.

It would be useful to extend this analysis to sectors that are not usually considered to be highly R&D intensive and to companies that are below the critical size for carrying out their own R&D. There is some indication that the proportion of companies that make innovative use of knowledge, including the results of R&D carried out elsewhere, is rising. This would call for a sharper focus of R&D policies on such issues as the cooperation between firms and the strengthening of university-industry links.

4. Policy orientations and reflections on directions to take

The location where R&D is carried out is determined in part by the attractiveness of a country for foreign investment and for research. For some goods and services the proximity to markets still plays a role, but with the globalisation resulting from increasing trade and faster information flows this factor tends to become less decisive. The greater mobility of researchers both within and between countries also makes it more difficult for companies to keep the results of their own research in-house and makes them rely more on outside research, including research from foreign sources. This strengthens the arguments in favour of international collaboration on research.

While the concepts of open innovation and industrial ecology[6] do not produce clear handles for national policymaking, they do emphasise that domestic R&D capacity is needed to attract international business. Even if the R&D activities of the top R&D investors among

[6] Rod Coombs and Luke Georghiou – A New "Industrial Ecology" – Science, Vol. 296, 19 April 2002; Henry W. Chesbrought – "The Era of Open Innovation" - MIT Sloan Management Review, Vol. 44, No. 3, Spring 2003.

multinational companies are unlikely to be moved and stay within a country, the production and sales activities may generate spin-offs to domestic firms that have an R&D content.

There are many types of policies by which the government affects company decisions and strategies regarding research and innovation, including for example:

- The funding of public research organisations and programmes, including the stimulation of science-industry linkages.
- Direct fiscal support through grants and tax credits.
- Public procurement and other demand-side policies.
- The finance available for innovative business activities.
- The labour supply for science, technology and research oriented jobs.
- Intellectual property registration and protection.
- Policies which affect the business, concerning product market regulation and labour market legislation.

The Lisbon strategy recognises that the overall level of R&D is a good yardstick for the capacity of an economy to turn the results of science and research into the commercially viable production of goods and services. This is because R&D leads to innovation but also because it enables firms to pick up knowledge spillovers. The importance of spillovers is well covered by the literature and the empirical evidence on spillovers incorporated in macroeconomic models is largely responsible for the favourable effects of stimulating investment in R&D in simulations with such models.

The level of R&D is an outcome of a long process rather than a policy target that is achievable in the short term. Increases in R&D expenditure will need to be accompanied by other measures and an improvement in the framework conditions to be successful.[7] Otherwise, the innovation process can easily run into the sand when it encounters constraints, in particular constraints on the supply of scientists and highly skilled personnel. There are many factors, captured under the general heading of framework conditions, which in the short term may act as constraints on the success of policy measures aimed at raising R&D. The most tangible of these are: ease of finance, macroeconomic stability, foreign exposure, market regulations, and property rights legislation. However, the attitudes towards entrepreneurship and risk taking and other less measurable socio-economic factors have a role to play as well.

The Lisbon agenda and the setting of the Barcelona objective have made R&D a major focus of the strategy for growth and jobs in the EU. This has renewed the interest in the role of technological change and R&D in economic growth, a topic that is well covered in the economic literature. There is a growing recognition that countries need to continue to invest in human capital and to build up an internal capacity for research to be able to benefit from R&D, even if conducted elsewhere.

[7] Maher and Andersson (2000) call for a search for good corporate governance practices, which should be based on an identification of what works in specific countries and for an examination of the conditions in which these practices can be transferred to other countries. They find that reliance on debt financing can impinge upon the development of a vibrant and thriving SME sector. The empirical evidence also suggests that R&D investment is adversely affected when the main source of outside finance is debt. Countries with liquid equity markets tend to invest more in R&D activity and high tech start-ups. This suggests that policy-induced changes in governance and debt-equity mixes could be an instrument to kill two birds with one stone: stimulate R&D activity and create a thriving economy on the basis of small and innovative enterprises.

The Member States have very different levels of R&D, measured by expenditures as a percentage of GDP, with even greater variations between regions within those countries. A large part of the differences can be explained by differences in economic structure. In fact, the bulk of the expenditures are made by relatively few companies, mostly producing goods in sectors such as car manufacturing and pharmaceuticals. However, aiming for an increase in R&D and the greater use of its results does not make these companies the main subject of analysis.

Much of the increase in R&D in recent decades has been in information technology, in which European IT producing companies are considered to have been less successful. It is interesting to ask why, but again the main policy interest may be different. In many sectors, IT has changed the window for the exploitation of new ideas. It has become more difficult to contain the benefits within borders. Consequently, the policy interest has moved to open innovation and greater cooperation across borders.

The emphasis on the worldwide use of R&D highlights the economic differences between countries. The role of R&D in generating economic growth in advanced economies is different from that in countries that are still catching up. At the technology frontier there is little to be gained from just adopting the methods developed elsewhere and in-house R&D is of crucial importance in some sectors. In emerging economies, the gains to be made from introducing new products and services and adapting to existing technology are much larger.

The sector structure of an economy is not independent from the level of development, these being a trend towards services in more advanced economies. Moreover, the size distribution of companies within each sector and within the economy as a whole will change over time. Any policy aiming at R&D and innovation therefore needs to be closely coordinated with policies in other areas, notably affecting labour market conditions and competition.

Surveys show that the factors that favourably influence the location of R&D would largely be the same as the factors which attract business: a high demand for innovative products and a sufficient supply of highly educated personnel. The European economy would benefit from greater researcher mobility, better regulation (including product standardisation where necessary), less red tape, better access for innovators to the financial market, and, in general, better framework conditions to promote a more research- and innovation-minded society across the EU.

Seville, 25 January 2007

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Abstract

This paper addresses a series of key policy questions in industrial R&D. It questions whether EU growth suffers from underinvestment in R&D, or whether the lack of R&D is a reflection of more general imperfections of the single market. It also elaborates on the finding that EU companies in sectors with traditionally high levels of R&D spend as much on R&D as their competitors. This is combined with evidence from surveys showing that lack of funding for R&D is not the most binding constraint for investing companies. It also builds on the notion that the internationalisation and outsourcing of R&D appears to carry on regardless of differences in government financial support. One conclusion, therefore, is that market-oriented reforms and complementary policies to improve the structure of the European economy may be more effective in raising R&D expenditures - and in generating growth through innovation - than direct incentives.

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