# 1. The role of public research in economic development

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*There is considerable variation in the level of technological development across the EU's Member States, which in turn means that the role of research and development (R&D) in furthering their development differs significantly depending on the country's position in relation to the technology frontier. This calls for a differentiated understanding of the drivers of technological upgrading and, thus, for a differentiated understanding of the role of R&D in this process. In this context, we explore in more detail the role of public R&D, a topic that has not been subject to systematic review.*

*We start with a review of the literature on the effects of public R&D on productivity and growth. We summarise the main stylised facts and show that our understanding of the benefits of public R&D is limited, and that a broader approach is needed which takes account of a wider range of benefits from public R&D. Specifically, we explore these issues in the context of Central and Eastern Europe (CEE) and Southern Europe as two EU 'catching-up' regions. We show that the links between science and industry in these regions are stronger than is commonly assumed, but that we need a better understanding of the nature of these links and their intensity.*

## 1.1 Introduction

Research and technological development, both public and private, are important long-term drivers of growth and economic development. Historical evidence shows that public research, in interaction with firms, constitutes one of the main drivers of catch-up processes (Mazzoleni and Nelson, 2007) and that technology development and innovation are the outcomes of intensive interaction between market actors and public sources of knowledge (Mazzucato, 2011).

However, the relationship between public and private R&D changes in the course of economic development. As national income increases, the share of R&D conducted and funded by the business sector also increases. During this process, the role of public R&D changes. From initially facilitating the absorptive capacity of domestic industry and other sectors (agriculture, health, defence and education), public R&D increasingly contributes to a further technology upgrading of the Business Enterprise Sector (BES).

The benefits of public R&D are not always obvious to all policy actors. As the level of public R&D is the outcome of a political process with arguments centring on the benefits of public R&D, which includes both measurable economic benefits to the business sector and difficult-to-measure benefits such as quality of life, health, security, etc., these benefits need to be well known and well understood.

In this chapter, we explore the role of public R&D from a long-term growth perspective, with special reference to the less developed EU countries and regions. For countries that operate close to, or at, the technology frontier and where growth is based on R&D and innovation, the role of public R&D in reducing technological uncertainties and building a body of knowledge to support future growth seems obvious. However, in the case of economies that are behind the technology frontier and where business sector demand for public R&D is weaker, the role of public R&D is not always obvious or well understood. This is a particularly important policy issue for the CEE and Southern EU economies, which are major recipients of EU Structural Funds directed mostly towards supporting R&D and innovation activities.

The special focus on the less developed EU countries is justified by the fact that these countries need to address specific challenges in their catch up processes. Their business sectors are typically of low R&D intensity, and

Foreign Direct Investment (FDI) and technology imports play an important Part In their technology upgrading, which calls for a different role for public R&D.

In Section 2, we provide a brief review of the literature on the effects and benefits of public R&D. We summarise the major stylised facts that emerge from this research and discuss its policy relevance. Section 3 discusses the role of public R&D in the EU with special reference to the CEE and South EU economies. We highlight similarities and differences in public and private R&D across three EU 'mega regions': EU South (Greece, Cyprus, Malta, Portugal, Spain and Italy), EU CEE ('new' Member States from CEE), and the 'EU North' (the remaining EU12 developed economies).

## 1.2 Public R&D: Role, effects and benefits

Historical evidence shows that catching-up, to a large extent, depends on an effective public research and higher education system (Mazzoleni and Nelson, 2007). The effects of R&D have been explored in depth by measuring its benefits based on rates of return or output elasticities with respect to R&D as inputs. We provide a brief review of this literature, focusing in particular on the benefits derived from public R&D.

### 1.2.1 Challenges related to measuring the returns from R&D investments and the specificity of public R&D

Measuring the returns to public R&D investment poses a number of particular challenges. First, R&D activities lead to intangible knowledge and ideas, which are known to be non-rivalrous and non-excludable. For private actors, patent protection is aimed at delaying free use or imitation, thus enabling innovators to capture a fair share of the rents from their inventions. Publicly funded research, on the other hand, is aimed at stimulating the generation of knowledge which becomes a public good that is shared widely.

Second, public R&D investments in health, quality of life, environment, social protection, defence, etc., are aimed at broader socioeconomic impacts that do not increase GDP directly. This means that such R&D investments should be treated in a different way even though they do contribute to providing a basis for a range of private activities in these areas (Sveikauskas 2007).

Third, the benefits from R&D are not limited to the original investors, but also accrue for competitors, other firms, suppliers, customers and to society at large. For example, private returns to the firms that initiated research may be negative, but other firms can build on these results which might lead to R&D with high social returns.

A conventional argument for public investment in R&D and, especially, public support for private R&D, is based on the assumption of poor appropriability from private investment in R&D. It is assumed that the difficulty for firms to appropriate all the benefits of their R&D activities is the main cause of private underinvestment in R&D, which, in turn, justifies public R&D or public support for private R&D.

Measuring the rates of return from R&D is based on a production function logic which treats R&D as an input along with capital and labour. This approach has the advantage that it can be used to generate quantitative estimates of how much R&D contributes to growth. Research on measuring the private returns to R&D has received impetus with the availability of large datasets and panel data econometrics which address the issues of simultaneity and unobservable factors that are inherent in such data. The most recent comprehensive survey was carried out by Hall et al. (2010).

In a nutshell, while it is clear that public R&D plays an important role in economic growth and convergence, its effects on growth are not easy to demonstrate. Estimates of the effects of public R&D are rather scarce, and much less reliable than those related to private R&D.

### 1.2.2 Private and social returns to R&D

Hall et al. (2010) conclude that, due to the stochastic nature of R&D outcomes, there is no single private 'rate of return'. Nevertheless, there is agreement that estimates of the private and social rates of return to privately funded R&D are large and positive for many countries, falling mostly in the range of (10%) 20% to (30%) 50% (Hall et al., 2010; Nadiri, 1993).

The social returns to R&D are large and exceed the private returns by a substantial margin (Griliches, 1995): 50% to 100%. Sveikauskas (2007) provides a review of the evidence on rates of return and suggests that the private return to R&D is around 25%, while the social return is 65%. The social returns are almost always substantially greater than the private returns and frequently are unequal among trading partners and industries. This is confirmed by a recent meta-survey by Kokko et al. (2015).

At the macro level, an OECD (2004) study shows that there is a clear positive link between private sector R&D intensity and growth of per capita gross domestic product (GDP) in the OECD economies. However, there is no clear-cut relationship between public R&D activities and growth, at least in the short term (OECD, 2004). The authors explain these results, pointing to the specificity of public R&D, i.e., important interactions between public and private R&D as well as difficult-to-measure benefits from public R&D (e.g., defence, energy, health and university research) (OECD, 2004).

Bouis, Duval and Murtin (2011) provide an update to this work based on a large sample of 40 countries over a more recent period. The results of their growth regressions show that expenditure on R&D has a positive effect on output per capita, as suggested by previous studies based on a smaller sample of countries. However, the estimated coefficient is significantly lower than in previous studies (0.06 compared to 0.15 in the 1980s and 1990s).

At the country level, Kokko et al. (2015) review the literature on the growth effects of R&D investment with special reference to the EU. They conduct a meta-analysis and conclude that the growth effects of R&D do not differ between the US and the EU, which includes high and low R&D spending countries. However, they show that the relationship is less significant in all specifications. They suggest that better utilisation of R&D investments in the US compared to the EU is due to lower private sector investment and weaker public-private sector linkages.

### 1.2.3 Explaining the lower rates of return to public R&D

A stylised fact in econometric research on spillovers is that the rates of return to public R&D are lower or less significant than in the case of private R&D [32] (see Griliches, 1986; Levy and Terleckyj, 1989; Lichtenberg and Siegel, 1991; Mansfield, 1980; Nadiri and Mamuneas, 1994 and references cited in Hall et al. 2010; Sveikauskas, 2007; and Kokko et al., 2015). However, we should bear in mind that this stylised fact holds if public R&D investments are considered to be identical in nature to private investments, which is a somewhat dubious assumption.

Apart from this important caveat, the explanations for the lower rates of public R&D differ. First, the conventional explanation is that private firms may be less efficient if their R&D is based on public funding or if this funding is used to support 'far from the market' research. Second, government R&D may be in areas that are far from the market (defence) or operate in a mixed mode such as in the case of health. Third, the aim of public R&D is rather to generate indirect and not direct benefits, by establishing a basis for R&D activities by firms and public organisations (universities, hospitals, etc.). Fourth, it is often claimed that public R&D is directed towards more risky areas with reduced rates of return. However, when the research is successful, the returns to basic

[32] There is a dearth of evidence on rates of return or elasticities of public R&D with respect to growth and productivity, for countries behind the technology frontier. See the survey by Hall et al. (2010) and the literature review in this chapter.

R&D can be higher than the returns to applied or developmental research (Griliches, 1986; Link, 1981; Mansfield, 1980). Fifth, there may be government overinvestment, which can lead to 'overcrowding' and lower returns. The EU's smart specialisation policy is aimed at avoiding exactly this kind of problem.

### 1.2.4 Types of benefits of public R&D: Beyond econometric approaches

Although econometrics dominates assessments of the effects of R&D, including public R&D, the complexity of the relationship between public R&D and growth demands alternative approaches. Econometric approaches are based on a simple production function model of the R&D system. They assume that R&D inputs and outputs can be reduced to information. However, the evidence shows that the links between publicly funded R&D and industry are more complex and, to a large extent, indirect. On this basis, Martin et al. (1996) and Salter and Martin (2001) (see also Martin and Tang, 2006) develop a classification of the benefits of public research, which demonstrates the variety and complexity of its impacts. Salter and Martin (2001: 520) distinguish the following types of benefits:

1. **Increasing the stock of useful knowledge;**

   Public R&D increases the stocks of knowledge available to firms. Publications represent important sources of learning for firms in sectors such as pharma, but it is knowledge, not just information, that is of most value to firms. Since public research is far from the market it stimulates and enables firms to focus on near-to-the-market research, acting as a complement rather than a substitute. This requires familiarity with the most recent published work, and informal contacts, joint R&D and networking (Arundel et al., 1995).

2. **Training skilled graduates;**

   Skilled graduates in many industries are seen as the primary benefit flowing to firms. They bring complex problem solving skills, new methodologies and the capacity to perform R&D. This transfer varies across areas and is dependent on where key competencies in specific technology areas reside.

3. **Creating new scientific instrumentation and methodologies;**

   Instrumentation drives scientific progress (De Sola Price and Bedini, 1967). The development of new instrumentation and methodologies is an important outcome of public R&D, and is especially significant in some sectors.

4. **Forming networks and stimulating social interaction;**

   Industries are social communities, and effective technology networking in industry includes academic networks. Links with academia are important for industries that are directly dependent on science. Also, in industries where graduates are an important source of new knowledge, networking may be more informal based on alumni networks. In some sectors, networks are maintained largely through attendance at exhibitions and conferences. Martin and Salter (2001) review the literature on the localised nature of R&D collaborations, which are reflections of geographical, cultural or institutional proximity.

5. **Increasing the capacity for scientific and technological problem-solving;**

   The problem solving capabilities in the public R&D sector complement its role of provider of general scientific knowledge. This expertise is embodied in individual contracts and collaborations between universities, public research organisations (PROs) and individual firms, and is frequent in applied R&D areas.

6. **Creating new firms.**

   The creation of new firms through spinoffs is generally seen as one of the major and desirable benefits of public R&D. However, despite the policy hype it would seem to be a less important benefit of public R&D (Brown and Mason, 2014).

In this section, we have discussed the difficulty of demonstrating, in an unambiguous quantitative manner, the benefits of public R&D. This difficulty is related to the methodological assumptions in the econometric approaches commonly used, which are unable to capture the specific features of R&D, and especially public R&D.

However, the available literature clearly shows that there is a market failure justifying public support for R&D. Work on the effects of R&D shows that the social rates of return on R&D are much higher than the rates of private R&D investment, which suggests substantial under-investment in R&D by the private sector. If we take the differences in the private and social rates of return to R&D at face value, then as Griffith (2000: 11) points out ‘we should optimally be spending on R&D a share of GDP two to four times larger than we are currently’. The significant gap between the private and social rates of return on R&D is in line with the market failure model which considers the reluctance of entrepreneurs to invest in new knowledge for fear that knowledge will ‘leak out’ and, thus, not be fully appropriated, to be a major problem.

## 1.3 Public R&D in the context of the EU28

In this section, we explore the trends in and the role of public R&D and interaction between public and private R&D in the context of the EU28. The EU is one the world’s most developed regions. However, this ignores the substantial differences in R&D and innovation capacities across the EU28 countries. For the purposes of this chapter, three EU28 ‘mega-regions’ will be defined:

- North: Sweden, Finland, Austria, Germany, Denmark, Belgium, Luxemburg, France, the Netherlands, Ireland, UK
- South: Italy, Spain, Portugal, Malta, Greece, Cyprus
- CEEC: Slovenia, Czech Republic, Estonia, Hungary, Lithuania, Slovakia, Poland, Croatia, Latvia, Bulgaria, Romania

The differences in capacities between these mega-regions are illustrated in Figure II-1-1, which shows the differences between the three EU regions in terms of GERD per capita, transnational patents and S&T papers, in 2013.

**Figure II-1-1** **Gross domestic expenditure on R&D (GERD), transnational patents and S&T articles per inhabitant in the three EU ‘mega-regions’**

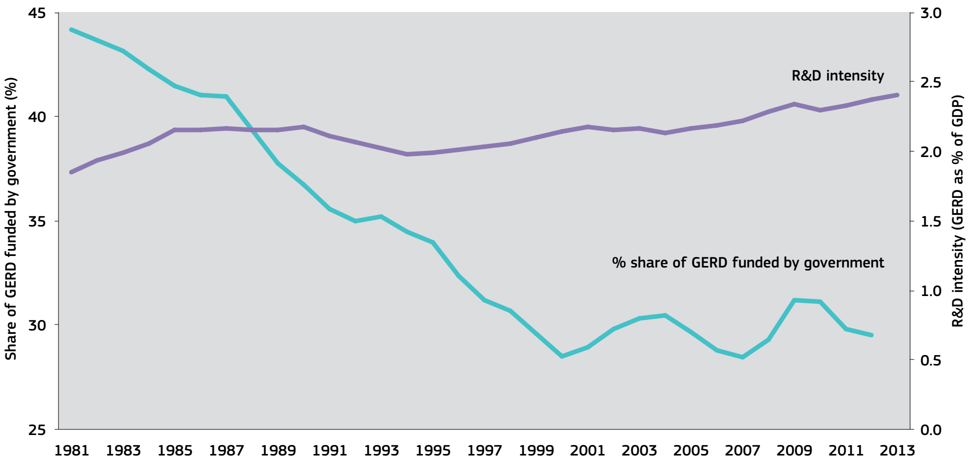
| | GERD per inhabitant PPS€ 2013 | Transnational Patents per million population 2012 | S&T articles per million population 2013 |
|---|---|---|---|
| EU - North | 723 | 228 | 727 |
| EU - South | 203 | 36 | 356 |
| EU - CEE | 197 | 13 | 249 |

Science, Research and Innovation performance of the EU 2016
*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies
*Data:* Eurostat, WIPO, World Bank

### 1.3.1 Trends in public and private R&D

The share of GERD funded by national governments has been continuously declining across the OECD since the beginning of the 1980s. This is usually ascribed to the ending of the Cold War and strained budgetary conditions, but it seems that this trend has a deeper structural basis. The decline started before 1989 and seems to be unrelated to budgetary conditions and economic growth. The decline in the share of government funding started in the 1980s, while at the same time the overall GERD/ GDP share has been rising in most countries. This is due largely to increased R&D in the business sector, which accounts for the majority of expenditure in the OECD countries. However, the decline in the share of government funded GERD halted at the turn of century and now appears to have stabilised.

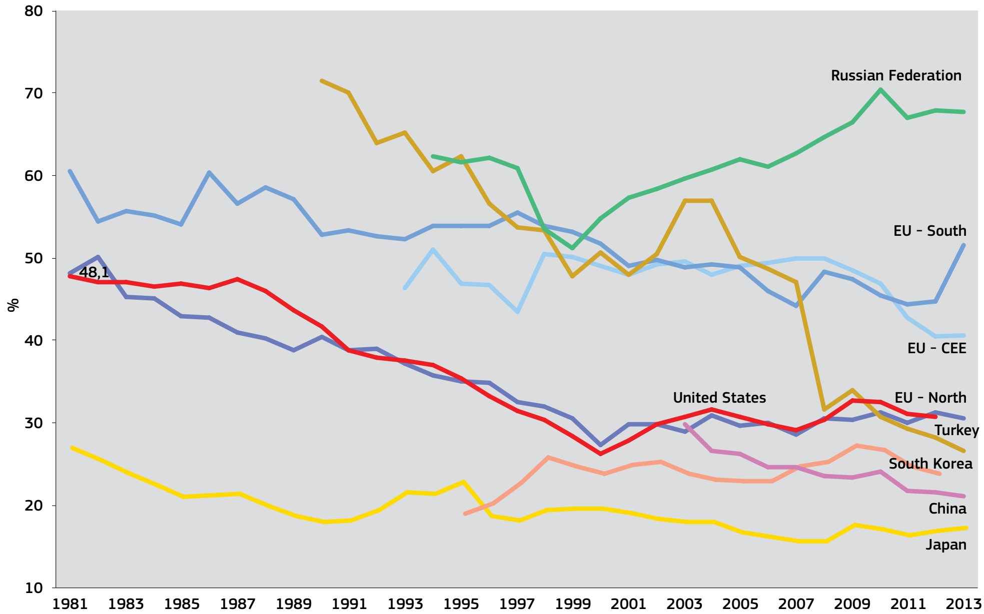
**Figure II-1-2** **R&D intensity and share of GERD funded by government (%) in OECD countries, 1981-2013**




Science, Research and Innovation performance of the EU 2016
*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies
*Data:* OECD

Figure II-1-3 shows this overall trend for the OECD countries disaggregated across different countries and the three EU regions defined above. In the EU North and US, the decline in government funded R&D has halted and its share is gradually increasing again. The trend is similar in Korea and, after 2008, in Japan. China shows a continuously declining share of government funded R&D, but an increasing overall GERD. In Russia, the role of government funding increased after 1999. EU CEE and EU South show higher shares of government funding compared to EU North, differences that we explore in greater detail later.

**Figure II-1-3** **Share of GERD funded by government (%), 1981-2013**

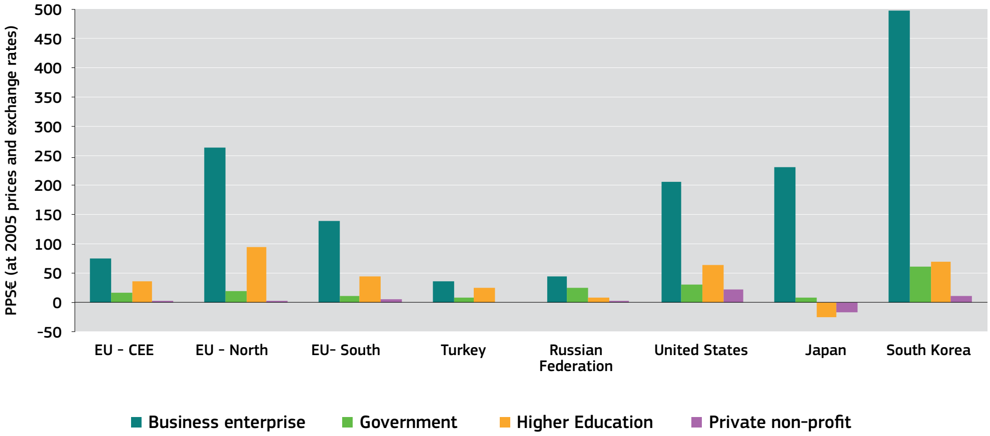



Science, Research and Innovation performance of the EU 2016

*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies
*Data:* Eurostat, OECD

Next, we look at changes in relative funding of GERD across the four institutional sectors. The biggest increases in R&D funding can be observed in the Business Enterprise Sector in the EU and other countries. The biggest increases in higher education funding can be found in North EU. South EU and CEE EU have invested more in the higher education than in the government sector and so the government sector share continues to be in decline. Korea has increased its investment per capita in both the government and higher education sector quite considerably.

**Figure II-1-4** **GERD by sector per head of population in PPS€ at 2005 prices and exchange rates - difference between 2011 and 1991 in absolute values**



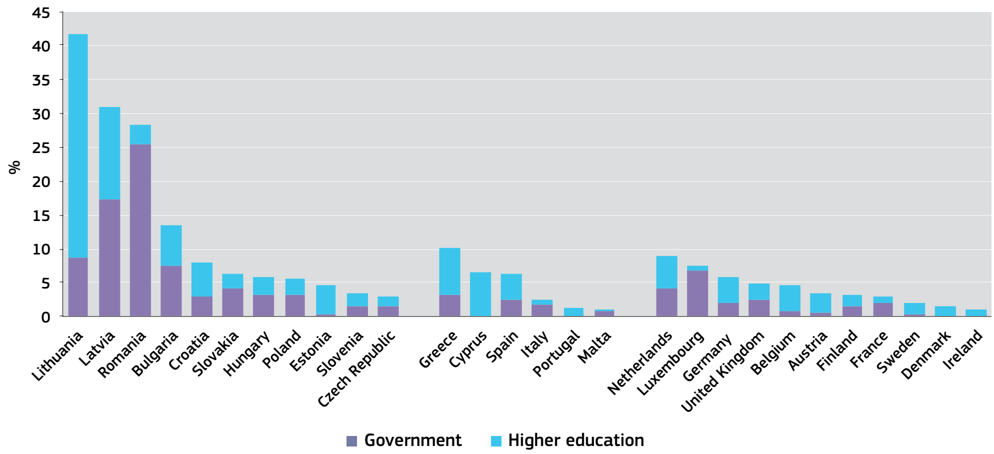

| | EU - CEE | EU - North | EU - South | Turkey | Russian Federa-tion | United States | Japan | South Korea |
|---|---|---|---|---|---|---|---|---|
| Business enterprise | 75.8 | 263.1 | 139.0 | 36.0 | 44.2 | 205.7 | 231.5 | 496.6 |
| Government | 16.0 | 18.9 | 10.6 | 9.1 | 25.8 | 31.0 | 8.0 | 59.6 |
| Higher Education | 36.4 | 94.5 | 43.0 | 26.0 | 9.2 | 62.6 | -24.2 | 70.1 |
| Private non-profit | 0.5 | 0.7 | 6.3 | : | 0.2 | 21.3 | -17.3 | 11.9 |

Science, Research and Innovation performance of the EU 2016
*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies
*Data: Eurostat*

## 1.3.2 Business funding of public R&D

The funding of public R&D by the business sector is one way to measure the intensity of public-private interactions. The share of business funding used to support public R&D points to the importance of external R&D in an R&I system and the role of PROs and higher education institutions in company's innovation activities. Figures II-1-5 and II-1-6 show that the share of business sector funding going to public R&D is slightly higher in EU South and much higher in EU CEE compared to EU North. This may be due to weaker business R&D which relies more on public R&D to compensate for its own low R&D capabilities.

**Figure II-1-5** **Share of business enterprise funding of R&D going to public (government and higher education) sector R&D, 2012**




Science, Research and Innovation performance of the EU 2016
*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies
*Data:* Eurostat

There are quite substantial differences in reliance on public R&D between the EU CEE and the EU North. This is largely due to the strong reliance of two Baltic States (Lithuania and partly Latvia) on university R&D and the reliance on PROs in Romania. However, when looking at median values, EU CEE is still more reliant on public R&D than the EU North while the EU South lies somewhere in between (Figure II-1-6).

**Figure II-1-6** **Share of business enterprise funding of R&D going to public sector R&D, 2012**

| | Government | Higher education | Total |
|---|---|---|---|
| | | Average | |
| **EU - CEE** | 6.9% | 6.9% | 13.8% |
| **EU - South** | 2.2% | 3.6% | 5.8% |
| **EU - North** | 2.5% | 2.1% | 4.7% |
| | | Median | |
| **EU - CEE** | 3.1% | 3.0% | 6.3% |
| **EU - South** | 1.3% | 2.5% | 4.4% |
| **EU - North** | 1.4% | 1.8% | 3.3% |

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*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies
*Data:* Eurostat

A higher share of business funding going to public R&D would be expected in economies with a high share of large firms with more linkages to public R&D. In addition, external R&D-industry links are more developed in more science-intensive sectors such as semiconductors, computers, communications equipment, drugs, organic chemicals, plastics, petroleum refining, pulp and paper (Klevorick et al., 1995; Cohen et al., 2002). However, these are all areas where EU CEE and EU South tend not to have comparative advantages (see Radosevic and Yoruk, 2014). Their economies are dominated by medium and small sized enterprises and comparatively smaller shares of large enterprises. So, the higher relative intensity of public R&D-enterprise sector links in the EU CEE noted above suggests that the nature of these links may be different. Demand from firms for the services of public R&D organisations is not less intensive in less developed EU economies, but it is probably different in nature.

## 1.4 Role of public research in technology upgrading

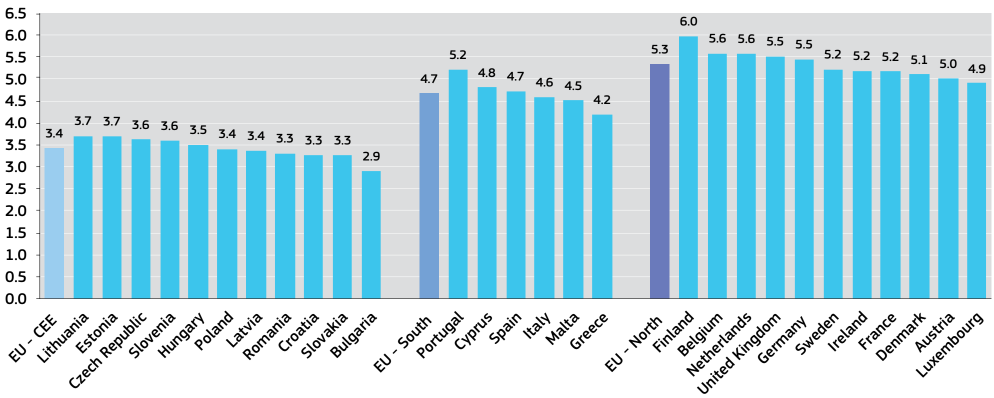
The latest research on public R&D, in countries that are catching up, shows that the role of public R&D can be understood only in relation to firms' changing capabilities (Albuquerque et al., 2015). So, in order to fully understand the role of public R&D, we need to take account of the evolution of the capabilities of both local public R&D (Eun et al., 2006; Liefner and Schiller, 2008) and of local firms.

In the early stages of catch up what matters is not only firms and their links to FDI but also their links with universities and PROs, which are important for linking the national innovation system to international flows of science and technology. For example, Ribeiro et al. (2015, Table 8.6) show that more than half (64%) of the institutional citations in US firms' patents are to domestic organisations. Domestic sources account for 39% of institutional citations in Europe, and 26% in Japan. The pattern is different for countries that are catching up, e.g., in the case of China only 6% of citations were from domestic sources.

This illustrates the importance of foreign sources of knowledge for development, and the greater shift towards domestic sources as countries upgrade technologically and the importance of local sources of knowledge increases. Thus, it is important to assess the quality of the R&D and innovation infrastructure, which should adjust over time to the technological upgrading of firms.

Figure II-1-7 presents a subjective assessment of the quality of R&D and innovation infrastructure in the EU, which shows big differences among the three EU regions.

**Figure II-1-7 Quality of R&D and innovation infrastructure[1] in the EU, 2014-15**




Science, Research and Innovation performance of the EU 2016

*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies
*Data:* World Economic Report, Global Competiveness Report Database
*Note:* [1]Based on a subjective assessment of the business community and calculated as average quality of education, availability of scientists and engineers, availability of research and training services, and quality of scientific research institutions.

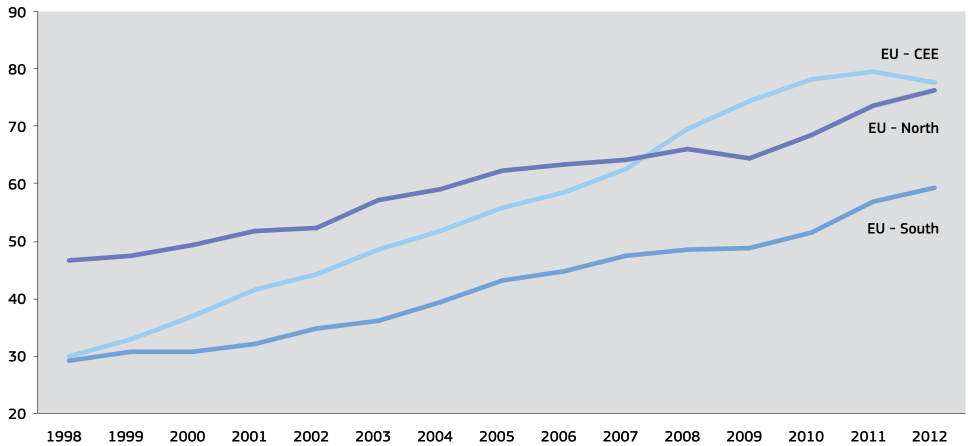
Figure II-1-7 shows that, particularly in EU CEE, firm upgrading is constrained not only by factors internal to the firm, but also by the poor quality of the R&D and innovation infrastructure. These indices suggest that in EU CEE the public R&D infrastructure is not yet adjusted to firms' technology upgrading needs. The infrastructure quality in EU South appears to be better.

Historical experience shows that in order for public R&D to contribute to catch-up, its research was oriented towards 'an actual or potential user-community' and R&D programmes were geared 'to help solve problems, and advance technology, relevant to a particular economic sector' (Mazzoleni and Nelson, 2007: 1525). Also, research conducted outside universities, in dedicated application-oriented laboratories, typically played an important role in this process (Mazzoleni and Nelson, 2007: 1526). In view of this experience it is important to note that PROs seem to be losing their position in public R&D systems in the EU and especially in EU CEE and EU South (Figure II-1-4). This evolution may be worrying given the increasing need for mission oriented R&D related to 'grand challenges' for which universities are not necessarily the best equipped.

Figure II-1-8 shows that there has been a quite intensive process of expansion of higher education in EU CEE. The annual rate of increase in the number of graduates per 1000 population aged 20-29 was 7.1% in EU CEE, 5.2% in EU South and 3.6% in EU North in the period from 1998-2012. This has led to a situation where, on average, EU CEE now has more graduates per 1000 population aged 20-29, than EU North.

This may have effects on the capacity of universities to facilitate technology upgrading of the economy. In EU CEE, the large increases in the number of university students are putting a strain on universities' knowledge generation and knowledge utilisation functions (Radosevic and Kriuacione, 2007). Coupled with limited budgets, this has endangered the balance between the three university missions of teaching, research and knowledge exchange. It would seem that, despite individual success stories, universities are not the key promoters of linkages in the national innovation systems of CEECs.

**Figure II-1-8** **Total graduates (ISCED 5-6) per thousand population aged 20-29, 1998-2012**

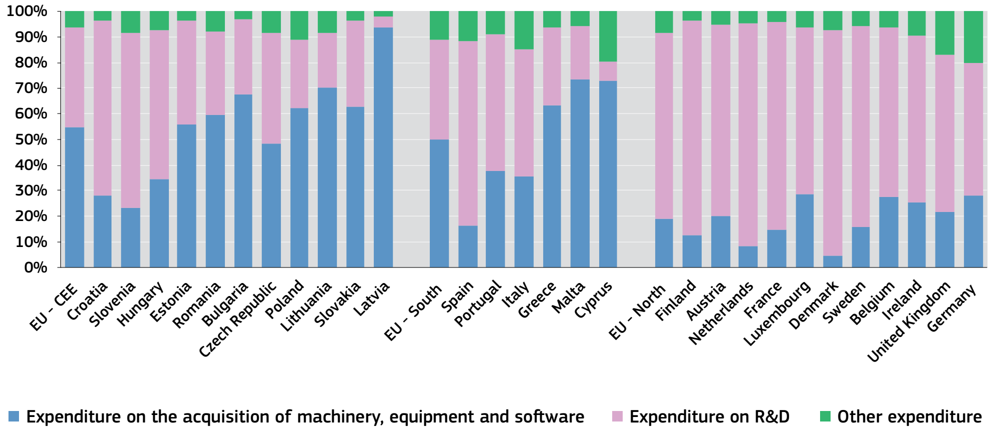





*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies
*Data:* Eurostat

The structure of innovation expenditures across the EU shows significant differences across the three EU regions (Figure II-1-9). Innovation in EU CEE and EU South consists more of acquisition of new machinery, equipment and software, and relatively little of R&D activities. This would be expected given the lower share of continuously active R&D firms in EU CEE and EU South. It also suggests that demand for external R&D and, thus, for public R&D is relatively less intensive in the EU periphery compared to EU North.

**Figure II-1-9** **Structure of innovation expenditure, 2010-2012**

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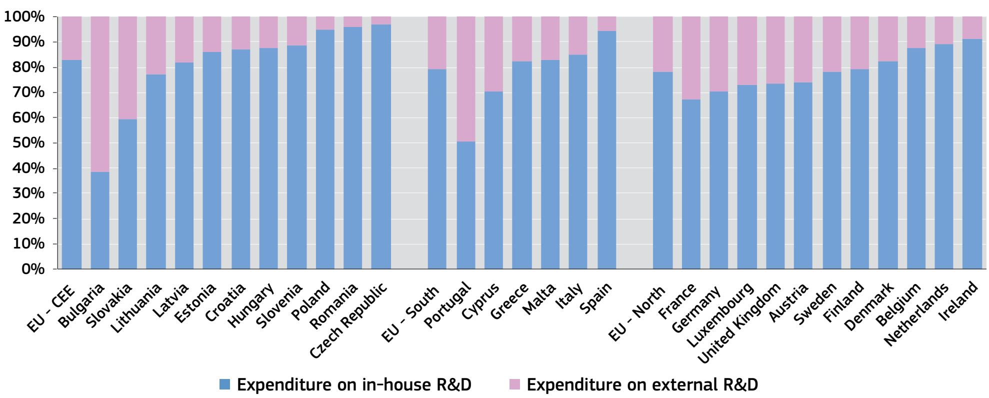
*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies
*Data:* Eurostat

Figure II-1-10 decomposes expenditures on R&D into in-house R&D and external R&D. We are interested in whether the share of external R&D is significantly different across the three regions. In terms of averages, the differences are small (17% to 22%). In terms of the median share of external R&D, the more developed the region the higher the share (13% CEE, 18% South and 22% North). However, there seem to be no significant regional differences in the balance between enterprises' internal vs. external R&D activities, which suggests that, despite a lower share of R&D active enterprises in less developed EU regions, the proportion of R&D expenditures on external R&D is similar.

**Figure II-1-10** **Distribution (%) of R&D expenditure between in-house R&D and external R&D, 2012**

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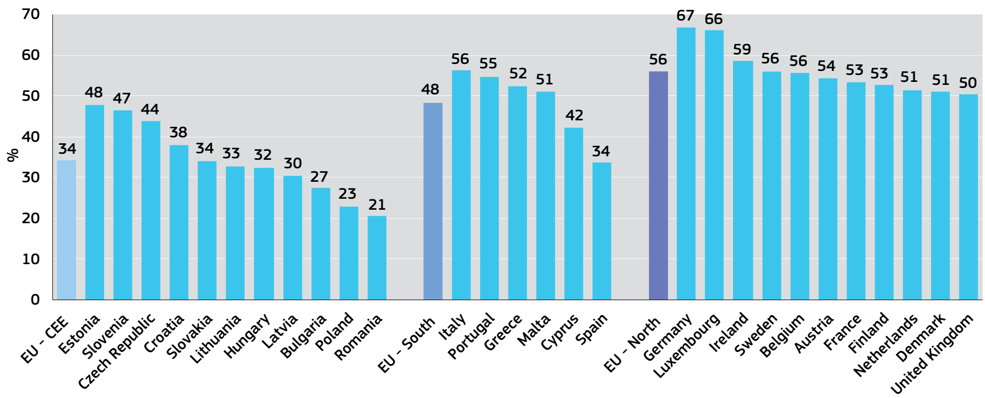
*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies
*Data:* Eurostat

## 1.5 Industry — Public R&D links in the EU

Innovation surveys are important for understanding the role of public R&D and the nature of industry-public R&D links in the EU. Public R&D is an information input for innovation activity. A better understanding of the innovation process in the EU gives some idea of the relationships between firms and public R&D across the EU.

Innovation frequency differs significantly across the three EU regions (see Figure II-1-11 and Figure II-1-12). Innovation frequency is higher in EU North compared to EU CEE although there is less difference with EU South. Presumably, the higher share of inventors is representative of a potentially higher demand for public R&D.

**Figure II-1-11** **Share of innovative firms[1] in total firms (%), 2010-2012**




Science, Research and Innovation performance of the EU 2016

*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies
*Data:* Eurostat
*Note:* [1]Data on innovation refer to core innovation activities which exclude Sectors: A (Agriculture, forestry and fishing) and N (Administrative and support service activities).

**Figure II-1-12** **Descriptive statistics based on shares of innovative enterprises, 2010-2012**

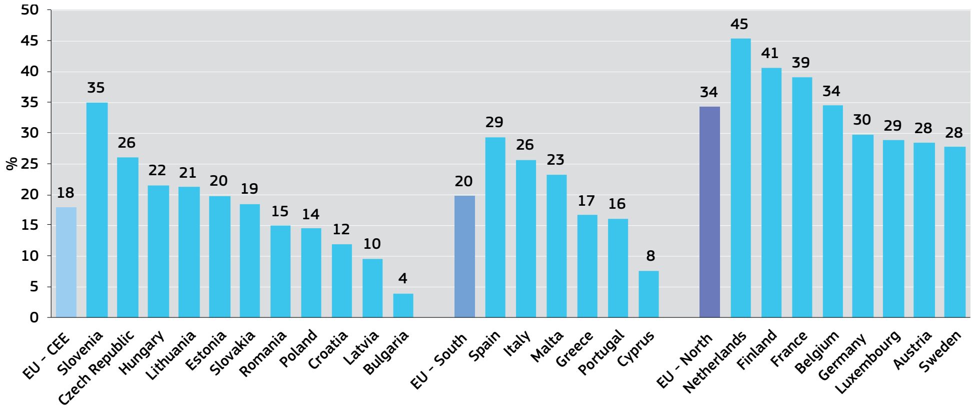
| | EU - North | EU - South | EU - CEE |
|---|---|---|---|
| Max | 67% | 56% | 48% |
| Min | 50% | 34% | 21% |
| Range (max-min) | 17% | 22% | 27% |
| Median | 54% | 52% | 33% |
| Average | 56% | 48% | 34% |

Science, Research and Innovation performance of the EU 2016

*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies
*Data:* Eurostat

An important feature of the innovation processes in the EU periphery compared to the developed EU12, is the share of enterprises which engage in continuous in-house R&D activity. Figure II-1-13 shows the average shares of such enterprises based on three innovation surveys (2008, 2010 and 2012), in terms of regional averages. It can be seen that it is not only the higher shares of innovators, but also higher shares of firms continuously engaged in R&D that differentiate the three EU regions.

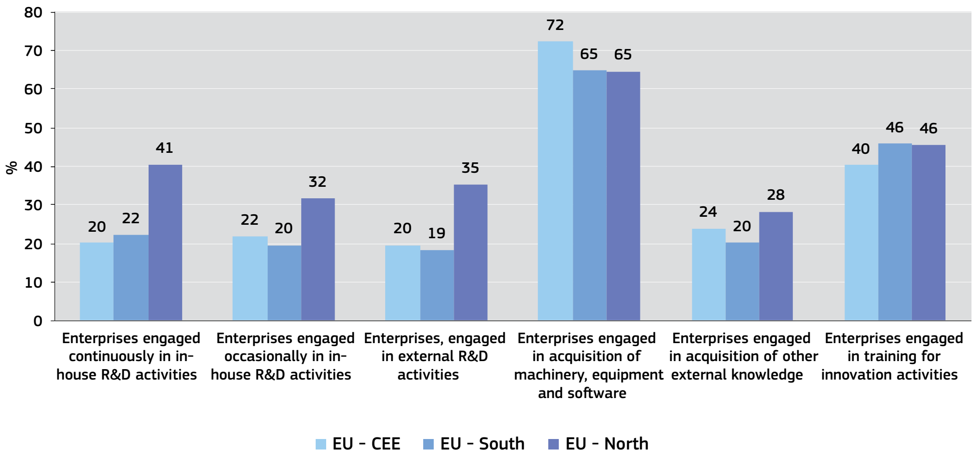
**Figure II-1-13** **Share (%) of enterprises engaged continuously in in-house R&D activities - average 2008-2012**




Science, Research and Innovation performance of the EU 2016
*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies
*Data:* Eurostat

In 2012, the share of firms with continuous R&D activity was twice as high in the EU North as compared to the EU periphery (see Figure II-1-14). Also, the share of enterprises that engage in external R&D is significantly higher in EU North compared to EU South and EU CEE. Differences in other types of innovation activity are less pronounced. The biggest difference is in the frequency of R&D active firms and the extent to which they are engaged in external R&D activities. EU North has more continuously R&D active firms and more frequent engagement in external R&D activities, a significant part of which consists of agreements with public R&D organisations.

**Figure II-1-14** **Share (%) of enterprises involved in different types of innovation activity, 2012**



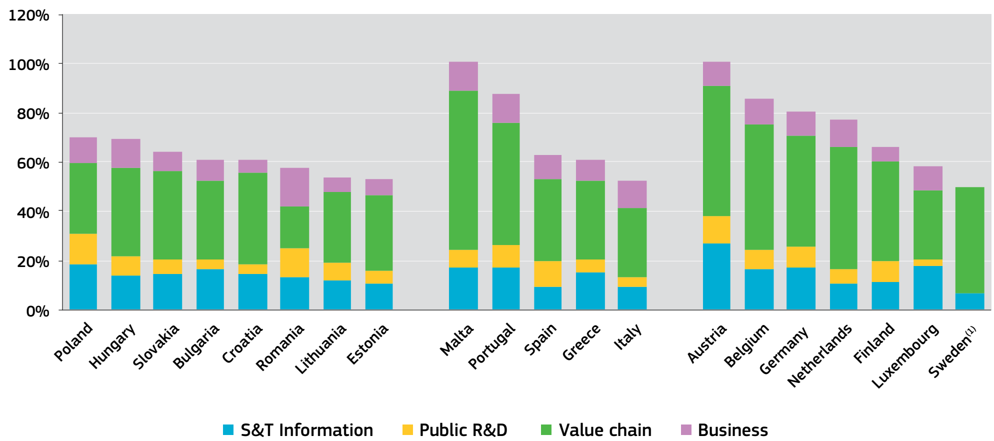

Science, Research and Innovation performance of the EU 2016
*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies
*Data:* Eurostat

A simple correlation analysis suggests that the correlation between enterprises with continuous in-house R&D activities and those engaged in external R&D activities is 0.76, which suggests that these two activities are complementary.

The different sources of information for innovation can be categorised as: S&T information (conferences, trade fairs and exhibitions; scientific journals and trade/technical publications), public science organisations (universities and government, public or private research institutes), value chains (clients and customers; suppliers of equipment and materials) and business sources (professional and industry associations; consultants and commercials labs).

Figure II-1-15 depicts the percentages of firms that consider specific sources of information as highly important across different groups. It shows that, on average, the importance of external sources of information is slightly higher in the EU North compared to EU South, and considerably higher than in EU CEE. Also, value chains are the most frequent source of information followed by conferences, exhibitions and journals (Figure II-1-16). Public R&D and business sources are less important sources of information. However, the indirect importance of public R&D as an important generator of R&D knowledge through journals and other publications, and participation in conferences and professional associations should be noted. If this indirect or 'spillover role' of public R&D is included, the importance of public R&D for innovation processes in the enterprise sector is much higher**.** Finally, the importance of different sources of information is very similar across countries and across regions.

**Figure II-1-15** **Share (%) of enterprises that consider information from different external sources as highly important for innovation, 2012**




Science, Research and Innovation performance of the EU 2016

*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies

*Data:* Eurostat

*Note:* (1)SE: Information on public scientific organisations is not available.

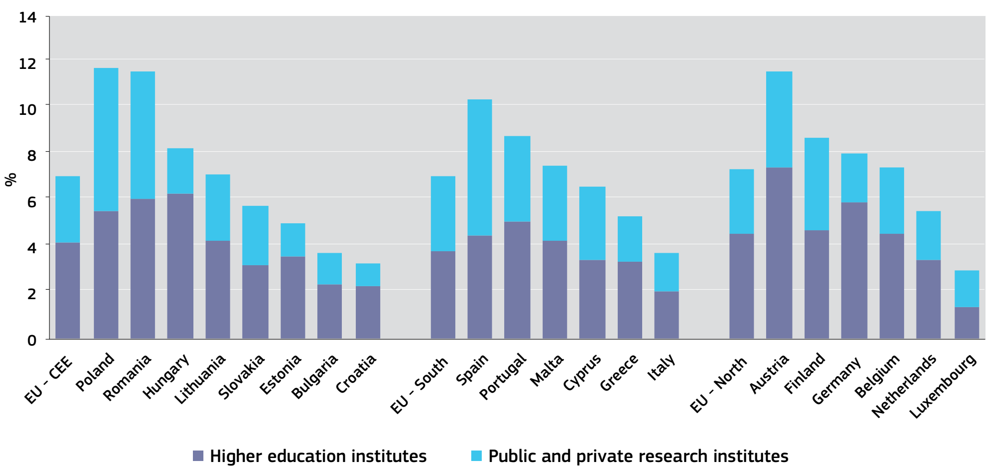
**Figure II-1-16** **Percentage of enterprises considering information from different external sources as highly important for innovation, 2012 (median)**

| | S&T information | Public R&D | Value chain | Business | Total |
|---|---|---|---|---|---|
| EU - CEE | 14.9% | 7.1% | 32.1% | 8.3% | 62.4% |
| EU - South | 16.2% | 7.1% | 41.7% | 11.2% | 76.2% |
| EU - North | 16.7% | 7.5% | 45.5% | 9.5% | 79.2% |

Science, Research and Innovation performance of the EU 2016
*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies
*Data:* Eurostat

Finally, we examine firms' assessments of whether they regard public R&D (universities and PROs) as highly important sources of innovation. Data from innovation surveys shows that there are no major differences in that respect across the three EU regions, and that those differences that do exist are largely intra-regional. The overall importance of public R&D is surprisingly similar across the three mega regions in terms of both PROs and universities (Figure II-1-17). So, similar to the proportions of R&D expenditure on external R&D across countries and regions, we do not observe a lower frequency of importance of external sources of information including public R&D organisations across the different regions. This picture of the importance of public R&D seems to be a permanent feature since there are no significant changes across the most recent three innovation surveys.

**Figure II-1-17** **Share (%) of firms that consider public and private research institutes and higher education institutes as important sources of information for innovation, 2012**




Science, Research and Innovation performance of the EU 2016
*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies
*Data:* Eurostat

In summary, innovation surveys show that the frequency of innovators is higher in the developed part of the EU compared to EU CEE and South. The share of continuous R&D innovators is also much higher in EU North and, accordingly, a higher proportion of them engage in external R&D. The share of R&D expenditure is also much higher in EU North compared to EU CEE and EU South. In the latter regions, much innovation expenditure is for acquisition of equipment, machinery and software.

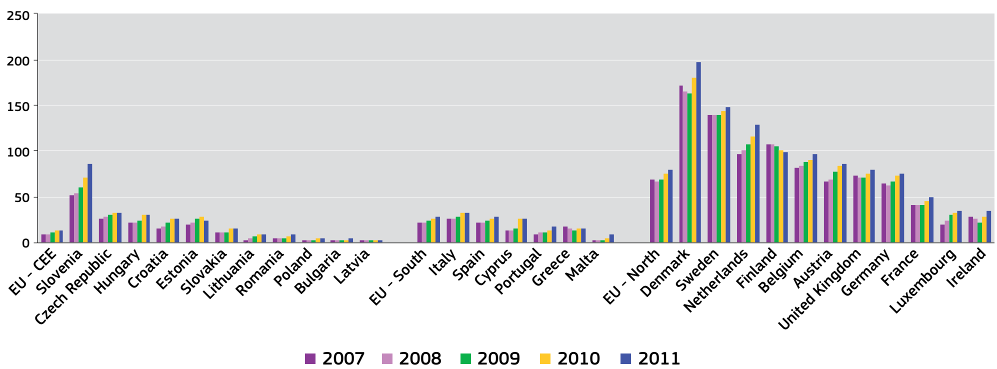
However, differences with respect to the share of external R&D expenditure and the frequency of importance of PRO and universities as sources of information for innovation, are much smaller and are not significant across the three regions. So, despite lower R&D intensity of innovation activities and lower intensity of demand for external R&D, the less developed EU regions have similar expenditure shares for external R&D. Also, information or knowledge from external R&D providers such as PROs and higher education institutions is equally important for EU CEE, EU South and EU North.

The above suggests that the usual argument that science-industry links in less developed regions of the EU are less intensive does not bear close scrutiny. It is usually assumed that science-industry links are quite undeveloped in catching up contexts. However, Albuquerque et al. (2015) and evidence from the EU would tend to disprove this assumption. Evidence from innovation surveys in catching up economies shows that innovative firms regard universities as highly important sources of information, to a similar or even higher extent than in developed countries. For example, in the 2008 Brazilian innovation survey, 6.8% of innovative firms regarded universities as highly important sources of information (Albuquerque et al., 2015), which is very close to the median value of 7% for the three EU regions. Also, there is no significant difference between developed and developing countries in the ranking by firms of the importance of sources of innovation [33].

Such evidence questions the notion that in catching up countries public-business R&D links are missing or weak. In our view, this assumption arises because the relation between public R&D and the business sector has been reduced to the mere commercialisation of R&D. This report provides evidence to support the view that science-industry links in less developed parts of the EU are not less intensive, but they are different.

In the EU context, the difference in the nature of the science-industry links between EU North, EU CEE and EU South is sufficient to merit further attention. There seem to be fewer upstream and research cooperation links, and more downstream S&T and innovation services links. Figure II-1-18 shows that the intensity of upstream cooperation in the form of joint publications between PROs/ universities and the business sector are a much less developed form of cooperation in the EU CEE and EU South compared to the EU North. However, there is a process of convergence underway: the number of co-publications per million population increased in 2007-2014 by 54% in CEE EU, 42% in EU South and 16% in EU North.

**Figure II-1-18** **Public-private co-publications per million population, 2007-2011**




Science, Research and Innovation performance of the EU 2016
*Source:* DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies
*Data:* Innovation Union Scoreboard

[33] E.g., correlation of the importance of sources of information for innovation between the US and India is 0.886 (Al Albuquerque et al., 2015, Table 5.6).

## 1.6 Conclusions: How to harness the potential of public R&D to support economic development

Our review of the literature on the role of public R&D in development shows that it is difficult to demonstrate its benefits in an unambiguous, quantitative manner. We reviewed various benefits of public R&D, and the differentiated role of public R&D in development in the context of the EU, which includes a diversity of R&D and innovation activities. Scattered, unsystematic evidence allows only tentative conclusions about the benefits of public R&D which differ across different groups of countries according to their technological development and distance from the technology frontier. The benefits of public R&D have a somewhat different ordering in catching up countries when compared to technology frontier economies.

Although we do not have systematic evidence of these benefits, training of skilled graduates is probably the most important benefit from public R&D in the less developed EU. The quality of higher education is especially important for ‘knowledge-based industrialisation’ and has been rather overlooked in the process of ‘massification’ of higher education that occurred in the first decade of 2000 (Dakowska and Harmsen, 2015). Also, increasing scientific and technological problem solving capacity should be high on the policy agenda. At the same time, we observe a gradual, but increasing pressure towards the achievement of scientific excellence, which is not always locally relevant. Funding criteria tend to be based on academic output, which does not contribute to improved local relevance. The challenge for policy is how to prioritise locally relevant but internationally excellent R&D (see Radosevic and Lepori, 2009).

The evidence in this chapter casts doubt on the commonly held view that relationships between PROs and universities and industry are less important for firms in less developed EU regions. This is in line with new evidence on science-industry links (Albuquerque, 2015; Schiller and Lee, 2015). Science-industry links are important at all stages of economic development, but similarly intensive links should not be mixed up with similarities or differences in their nature.

The first policy message from our analysis is that there is a need to redress the balance in the importance of channels of interaction and the benefits of public R&D in the less developed EU. Commercialisation and the aim of creation of new firms through public R&D has been over-estimated as a growth enhancing factor in the less developed EU economies, compared to other channels (Brown and Mason, 2014). Similar to other emerging economies (Albuquerque et al, 2015), the policy focus on commercialisation is too narrow in the context of CEE and South EU. The establishment of technology transfer offices to promote the commercialisation of existing inventions in a linear way should not be the major policy focus in this area. Such programmes, which are modelled on different contexts, ignore the needs of local firms and the capabilities of local public R&D organisations, which are much more focused on S&T problem solving.

The second important policy issue is whether countries will be able to develop specific roles for PROs as opposed to universities. As countries upgrade technologically, it might seem that the role of universities increases and the role of PROs decreases. However, new challenges related to climate change and energy transition may require a much greater role for more narrowly focused PROs (Mazzucato, 2015). It will be important for EU CEE and EU South to identify technology and mission-specific roles for their PROs. More advanced technology upgrading will require good support for small- and medium-sized, technology-intensive enterprises and firms. Some countries have plans to try to replicate the Fraunhofer model in response to this need.

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