

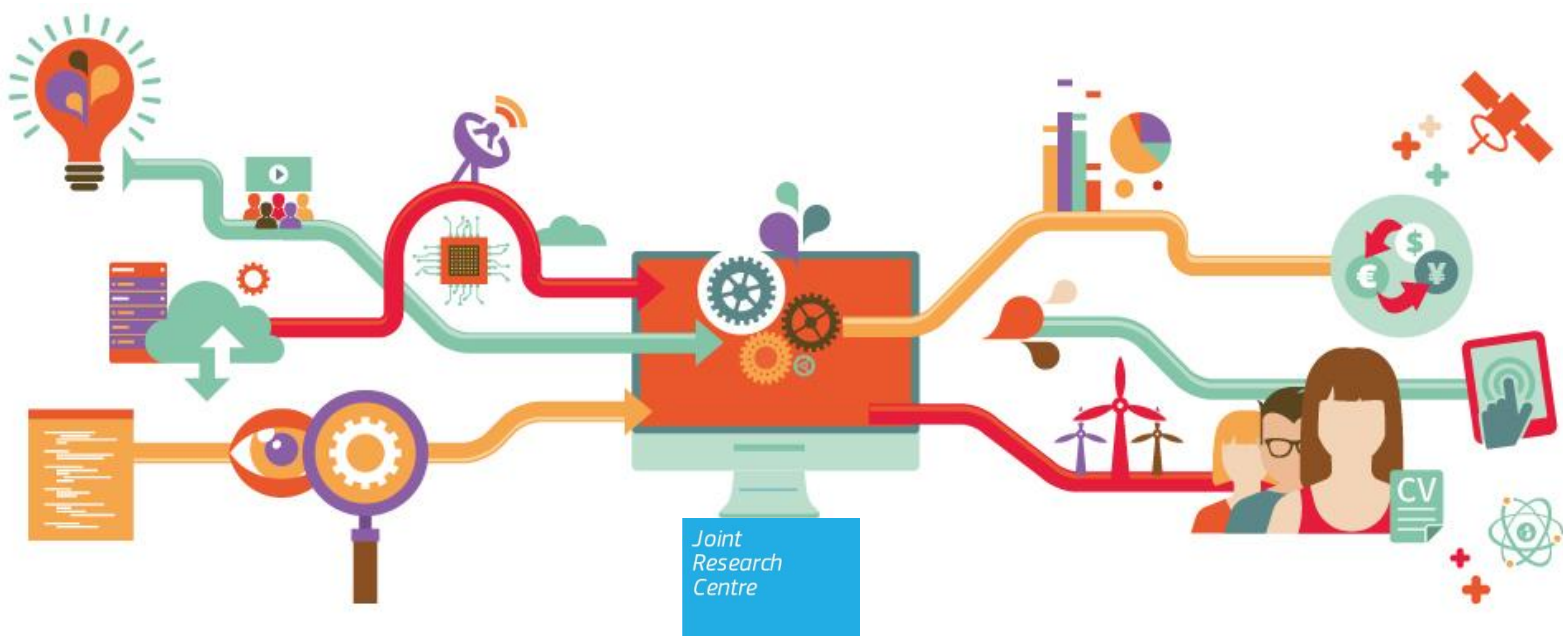
## JRC TECHNICAL REPORTS

# Corporate R&D intensity decomposition: Theoretical, empirical and policy issues

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# Corporate R&D intensity decomposition: Theoretical, empirical and policy issues <sup>1</sup>

Pietro Moncada-Paternò-Castello

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## Abstract

*Research and development (R&D) indicators are increasingly used not only to facilitate international comparisons, but also as targets for policies stimulating research. An example of such an indicator is R&D intensity. The decomposition method of R&D intensity was conceived with the aim of evaluating aggregate R&D intensity and explaining the differences in R&D intensity between countries. For policy purposes, it is particularly important to determine whether the differences are intrinsic (e.g. due to firms' underinvestment in R&D) or structural (e.g. due to differences in the sectors that make up an economy).*

*Despite its importance for analytical purposes, the theoretical and methodological framework enabling decomposition of corporate R&D intensity has been elaborated only recently, and it is still not commonly used in the literature. Moreover, examination of the R&D intensity of firms in different industries and at different layers of aggregation leads to mixed results, the reasons for which are not fully understood.*

*This paper aims to review the theoretical and methodological frameworks of corporate R&D intensity decomposition and how it is applied in the literature in order to determine the policy implications of empirical results that at first sight may seem to be contradictory. More specifically, this paper surveys the literature to determine (i) the theoretical framework of determinants of corporate R&D intensity, (ii) the methodologies that have been put in place to decompose corporate R&D intensity and the empirical results reached and (iii) the likely reasons for the contrasting results. Finally, the paper points out the possible policy implications and suggests some potential avenues for future research in this area.*

**Keywords:** corporate R&D intensity gap; decomposition; literature survey; R&D policy

**JEL Classification:** O30; O32, O38; O57; F23; R39

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## 1. Introduction

Research and development (R&D) intensity indicators are increasingly used not only to facilitate international comparisons, but also as targets for policies stimulating research. The two goals are, of course, intimately linked; it makes little sense to set a quantitative policy target unless it is known whether it is high or low compared with economies at similar stages of development.

In fact, R&D expenditures have long been an important concern for innovation analysts, who have used them as proxies for innovation inputs and have considered them to be a determinant of growth, productivity and competitiveness. For this reason, R&D intensity targets are one of the main objectives of the European Union's research and innovation policy agenda, namely the Lisbon Strategy, devised in 2000, and the related Barcelona Target, set in 2003 (which states that the EU should spend 3% of gross domestic product (GDP) on R&D, two-thirds of which should come from the private sector). A benchmarking exercise performed at the time revealed that the EU was not performing at the same level as its main competing economies, notably the USA and Japan. In the EU, only 1.9% of GDP was being invested in R&D, compared with 2.7% in Japan and 2.98% in the USA; in other words, there was an 'R&D intensity gap' (European Commission, 2003). As a result, a target for EU R&D intensity was set in an effort to close the gap (Sheehan and Wyckoff, 2003).

More recently, the importance of the Barcelona Target has been reiterated and reinforced in the Europe 2020 strategy, part of the EU flagship initiative (European Commission, 2010a), which supports an increase in private research and innovation investment and puts the emphasis on the importance of policies positively affecting the demographics (creation and growth) of companies operating in new/knowledge-intensive industries. One of the approaches that has been developed and used by scholars and policy analysts to investigate the EU R&D intensity gap, and to determine the extent to which it is attributable to differences in R&D investment between countries, sectors, or even firms, has been the 'decomposition' of the R&D intensity gap into its major economic determinants. Actually, the decomposition methodology for the R&D intensity gap was originally conceived with the aim of evaluating the extent to which changes in aggregate R&D intensity can be explained by changes in industrial structure (van Reenen, 1997).

Despite the significance of the analytical purpose, the theoretical framework and the methodology needed to decompose countries' R&D intensity have been elaborated only recently, and are still not extensively used in literature. According to Becker and Hall (2013), the literature on the determinants of R&D investment in industry sub-groups, as well as on sectoral decomposition of such determinants, is rather limited. Yet the results of the decomposition studies of corporate R&D intensity are often contradictory (Moncada-Paternò-Castello et al., 2010).

The micro-macro statistical issue is a major topic for economic policy research. In fact, the analysis of micro-level statistics allows the evaluation of the characteristics of an economic system at the most accurate (unitary) scale. Aggregate micro-level statistics can, in turn, be particularly useful for understanding industry and macro-level dynamics, and thus are extremely valuable for policy design, monitoring and evaluation. Despite this, large-scale application of aggregate micro-level statistics is still limited, especially in the field of the

knowledge economy, for different reasons but mostly because the available information is limited and inhomogeneous owing to measurement problems and some conceptual and methodological differences (De Panizza and De Prato, 2009; Bjørnskov and Foss, 2016) (2).

The examination of firms' R&D intensity in industries and at different layers of aggregation leads to results that are mixed and not completely understood. For policy purposes, it is particularly important to determine whether the differences between countries/regions are intrinsic, for example due to firms' underinvestment in R&D (something that can be expected to be relatively easily changed), or structural, for example attributable to the sector composition of an economy (change in which is likely to require more effort and time).

This paper aims to contribute to the literature by offering the first survey of scientific studies on the decomposition of corporate R&D intensity.

The main question that this paper aims to answer is whether the differences in corporate R&D intensity arising from decomposition studies at country level are sector specific, firm specific or data/methodological specific. A second question that this research aims to answer is what the policy significance is of empirical results regarding corporate R&D that at first sight may seem to be contradictory.

This study will (i) survey the literature on the main determinants of corporate R&D intensity and the methodologies used to decompose corporate R&D intensity and their main empirical results (section 2); (ii) discuss the main findings, including the possible reasons for the contrasting results and the implications for the quality of the comparisons derived (section 3); and (iii) suggest the relevance of the findings for policies and some potential avenues for future research in this area (section 4).

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(<sup>2</sup>) According to Bjørnskov and Foss (2016), other micro-macro problems are common to many economic studies. These include the use of detailed micro-level data beyond case studies towards meso- and macro-statistical interests, the interaction between macro-level institutions and policies and firm-level responses and, in particular, the potentially complex interactions between different institutions and policies.

## **2. Literature review: theoretical and methodological frameworks — empirical results**

In this section, the theoretical and empirical literature on the main determinants of corporate R&D is introduced. The central objective of investigation of this paper is then tackled by elaborating on the concept and purpose of decomposing corporate R&D intensity, and presenting the empirical decomposition results from the surveyed literature on the subject.

### **2.1. Theoretical framework of the determinants of corporate R&D intensity**

Before presenting the literature of the main determinants of corporate R&D intensity, a general theoretical framework of reference is provided.

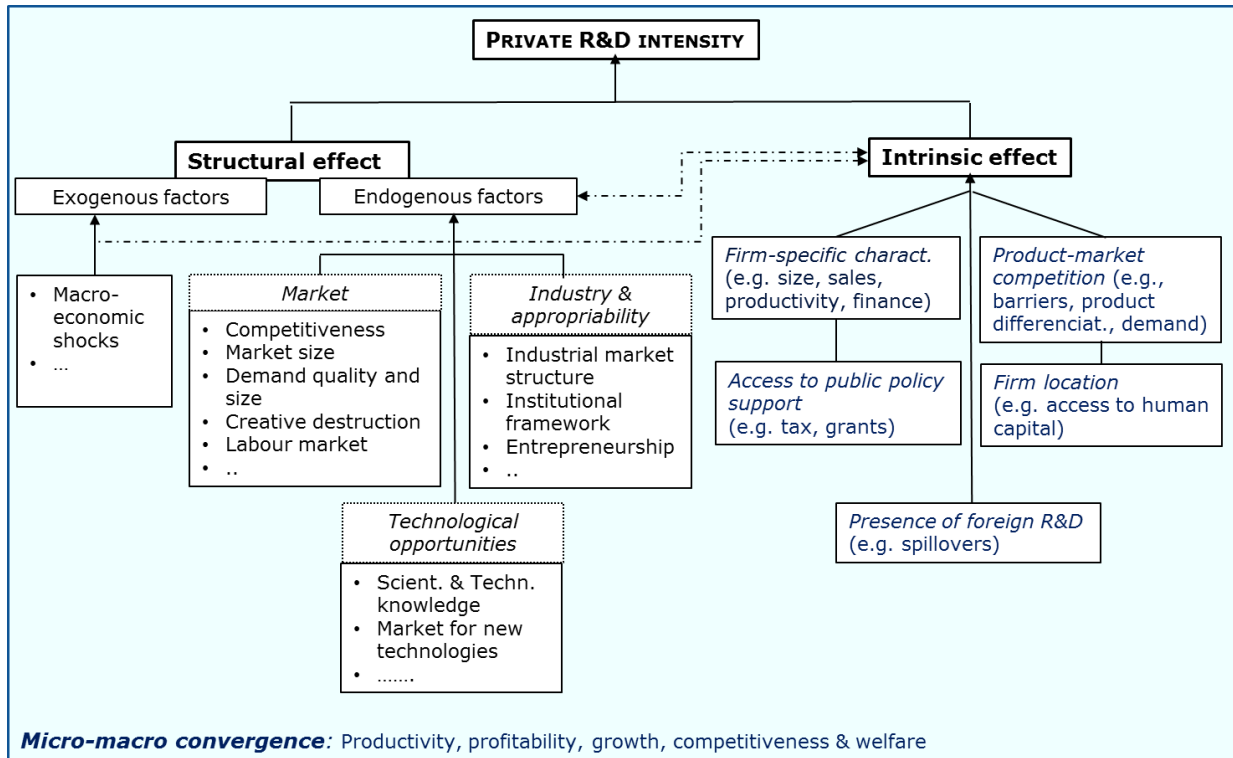
Economic theory indicates that knowledge development (Schumpeter, 1949) and technical change (Solow, 1957) are the major sources of productivity growth in the long term. R&D is a major source of technical change (Romer, 1990; Guellec and van Pottelsberghe de la Potterie, 2001), and this is recognised as a key element for increasing the knowledge base and, with it, the growth, productivity and competitiveness of an economy (Mowery and Rosenberg, 1989; Coccia, 2008). In fact, most of the arguments in favour of policies targeted at raising the level and efficiency of R&D rely on the assumption that there are close links between R&D investment and micro- and macro-economic performance (Mitchell, 1999; Bilbao-Osorio and Rodríguez-Pose, 2004; Griffith et al., 2004; Kafouros, 2008). The effects of ‘micro–macro convergence’ of private and public (social) drivers in the implementation and promotion of corporate R&D activities are visible the potential returns not only in productivity, but also in profitability, sales, market capitalisation, employment growth, competitiveness and socio-economic welfare (see, for example, Morbey and Reithner, 1990; Griliches, 1994; Cincera et al., 2009a; Hall et al., 2010).

As regards the firm-level dimension, the theoretical framework of determinants of corporate R&D intensity is graphically summarised in Figure 1, which illustrates that the total corporate R&D intensity of a given economy (country) depends on both the structural (sector) composition effect and intrinsic effect (Pakes and Schankerman, 1984; Erken, 2008; Mathieu and van Pottelsberghe de la Potterie, 2010; Becker and Hall, 2013).

We consider that the structural factors affecting an economy can be exogenous or endogenous. Endogenous factors are characteristics typical of a given industry sector(s), while exogenous factors are usually external to the sector(s) and the country’s macro-economic system.

Intrinsic factors are those that determine the characteristics of the firm(s) and its behaviour, for example the firm’s knowledge, financial capacity or strategy and its R&D investment.

**Figure 1. Theoretical framework of determinants of corporate R&D intensity**



*Source:* Author's elaboration from Pakes and Schankerman (1984), Erken and van Es (2007), Mathieu and van Pottelsberghe de la Potterie (2010) and Becker and Hall (2013).

However, structural endogenous factors are also, at least to some extent, dependent on intrinsic factors (Erken and van Es, 2007) <sup>(3)</sup>. In other words, the sectoral structure of a country depends on not only, for example, historical industrial footprints, but also (especially) on the country's aggregate capacity to be successful in technological development or in competition for technology markets and on its collective capacity for R&D-led growth. We should add that structural factors can influence firm-intrinsic factors; for example, although firms' access to government funding for R&D depends on their strategy and their ability (intrinsic factors) to successfully obtain such funding, it is conditional on such public incentives being available in the first place (structural factor).

The literature attempting to determine reasons for differences in R&D investment and intensity between economies is extensive. In the following sub-sections, we report the main findings from this literature, focusing on only three main arguments: (i) productivity as one of key drivers that links structural and intrinsic factors, (ii) structural endogenous factors and (iii) the intrinsic factors determining corporate R&D intensity.

**i) Productivity as one of the main micro–macro drivers for corporate R&D activity**

The literature suggests that a virtuous circle exists, whereby competitiveness promotes R&D and technological development, leading to productivity gains, which in turn increases profitability, which then releases resources that can be used to invest in (more) R&D. Essentially, in accordance with endogenous Schumpeterian growth theory, productivity growth is positively influenced by R&D expenditure (Schumpeter, 1949; Griliches, 1994;

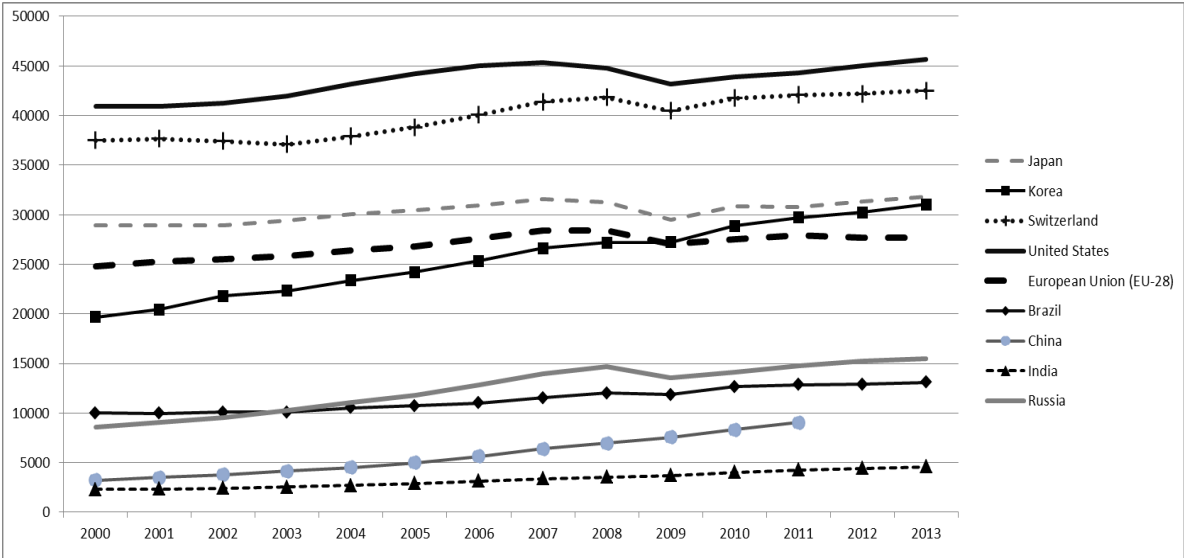
<sup>(3)</sup> For more information on this relationship, see Erken and Donselaar (2006).

Zachariadis, 2003; Guellec and Sachwald, 2008). As Mathieu and van Pottelsberghe de la Potterie (2010) put it, the underpinning concept is that firms' return on R&D investment can be achieved through a higher level of productivity as a result of an accelerated rate of technological change. The increased effectiveness (due to higher productivity) of R&D investment (or 'effective' rate of return to R&D), together with a higher propensity to invest in R&D, allows for greater competitiveness of firms and of the economy as a whole. Therefore, heterogeneity of both sectors and firms should be taken into account as this explains the substantial differences in the rate of productivity return to R&D investment (Cincera *et al.*, 2009b, Ortega-Argilés *et al.*, 2010; Montresor and Vezzani, 2015).

In practice, micro- and macro-productivity returns to R&D (like the other drivers mentioned previously, such as profitability, growth, etc.) enable the possible convergence of objectives of the intrinsic and structural factors.

Unfortunately, the EU faces a productivity gap compared with its main competitors, and this has widened since the financial economic crisis that started in 2007, as can be seen in Figure 2, which shows productivity over the period 2000–2013 measured as GDP per capita.

**Figure 2. GDP per capita in the EU-28 and selected countries in 2000–2013**



Source: author's own elaboration of data from OECD (2015) (4).

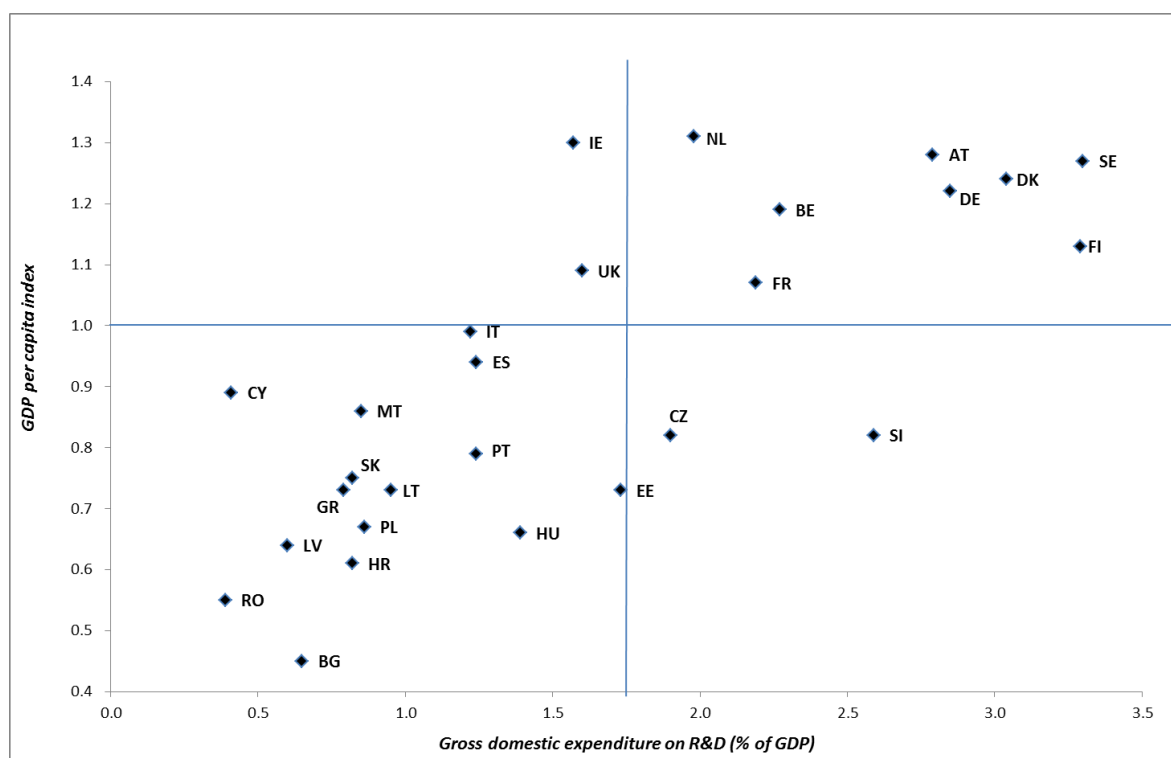
Note: data on the y-axis are in US dollars, constant prices, 2005 purchasing power parities.

Figure 2 shows average productivity among the EU-28 countries, and thus does not disguise dissimilarities in the degree of development of different EU countries. This dissimilarity can be seen in Figure 3, which reports productivity (as GDP per capita) and R&D efforts/intensities (R&D expenditure as a percentage of GDP) in the different EU-28 countries in 2013

(4) Data extracted on 6 March 2015 from <http://stats.oecd.org/>



**Figure 3. GDP per capita and R&D intensity in EU-28 countries in 2013**



Source: author's own elaboration of data from European Commission (Eurostat) (2015) (5).

Notes: EU-28 average productivity = 1 (index of reference); based on purchasing power standards per capita. The EU-28 GDP per capita in 2013 at current prices was EUR 26,600. The EU-28 R&D intensity (gross domestic expenditure on R&D as a proportion of GDP) was 1.98%. For a better graphical representation, data for Luxembourg (GDP per capita index = 2.57; R&D intensity = 1.16%) are not plotted in the figure.

It should be remembered that a firm's R&D investment can be either pro-cyclical or counter-cyclical and that R&D investment also depends on a firm's business cycle and their business characteristics (Voigt and Moncada-Paternò-Castello, 2009; Arvanitis and Woerter, 2014). Stephan (2004) stressed that the high-tech firms usually adjust their R&D expenditures less to the business cycle in contrast to low- and medium—tech ones. These are micro-level factors that, when analysed at the aggregate (macro-) level, could make between-country comparisons more difficult.

#### ii) Sector composition (or structural) factors

Industries are characterised by, among other things, very different levels of R&D investment relative to their output, and it should be noted that, in the absence of country-specific differences, differences in aggregate R&D intensities between countries reflect the mix of industries in particular countries (Moncada-Paternò-Castello and Smith, 2009).

(5) Data extracted on 8 March 2016 from [http://ec.europa.eu/eurostat/statistics-explained/index.php/R\\_%26\\_D\\_expenditure](http://ec.europa.eu/eurostat/statistics-explained/index.php/R_%26_D_expenditure) and [http://ec.europa.eu/eurostat/statistics-explained/index.php/National\\_accounts\\_and\\_GDP](http://ec.europa.eu/eurostat/statistics-explained/index.php/National_accounts_and_GDP)

The advanced economies of the world may be similar in terms of basic economic indicators (e.g. income levels), but they differ significantly in terms of their technological specialisations and hence industrial structures. These industrial structures, which influence aggregate corporate R&D intensity, can be affected by exogenous factors, such as the economic and financial shocks caused by global events, for example a financial downturn, a global oil crisis or a war.

The theoretical basis for the effects of industry composition and sector characteristics (i.e. the endogenous structural effects) on the aggregate corporate R&D intensity of a given economy gives a clue as to why these inter-industry differences occur. Pakes and Schankerman (1984), based on the theoretical work of other authors (e.g. Schumpeter, 1950; Griliches and Schmookler, 1963; Scherer, 1982), while arguing that the output of research activities (industrial knowledge) exhibits unique economic characteristics, developed a theoretical model indicating that R&D intensity depends on the combination of three factors: expected market size and growth in demand, appropriability differences and technological opportunities.

Taking stock of this theoretical literature and complementing it with other studies (namely Erken and van Es, 2007; Mathieu and van Pottelsberghe de la Potterie, 2010; Becker and Hall, 2013), we classify the endogenous structural factors as market factors, technological opportunities factors and industry and appropriability factors. These factors are interlinked. *a) Market factors* refer, in particular, to the competitiveness level, the expected size of the market and/or the demand (quality, size) inducement, the level of higher education and the degree of labour market mobility (Pakes and Schankerman, 1984; Saxenian, 1996; Lundvall and Borrás, 2005; van Pottelsberghe, 2008; Mathieu and van Pottelsberghe, 2010; Aghion *et al.*, 2014).

*b) Technological opportunities* are based the availability and the cost (efficiency) of producing scientific and technical knowledge in different areas or industrial sectors. These factors also include the size and the homogeneity of the market for new technologies, for example the patent system (Foray and Lhuillery, 2010; de Saint-Georges and van Pottelsberghe de la Potterie, 2013). These authors argue that the key function of knowledge dissemination/adoption is to enable firms to rely on efficient R&D and innovation economic systems.

*c) Industrial and appropriability factors* include historical track record, sector capital specificity, industrial market structure, the level of industry–university collaboration, ‘creative destruction’ and entrepreneurial ability (success) and the general institutional framework (e.g. industrial policy, public R&D expenditures and infrastructures) in which firms operate. Abundant empirical studies (Cohen and Lorenzi, 2000; Aghion, 2006; van Pottelsberghe, 2008; Veugelers, 2015) have identified various other structural factors that contribute to countries’ R&D levels.

### iii) Intrinsic factors

The theoretical foundation of corporate R&D intensity differences, which is determined by a firm’s own levels of R&D investment and sales (intrinsic effects), finds a solid anchorage in the Schumpeterian arguments that R&D intensity differences very much depend on the availability of internal resources, access to external sources and high levels of product

market competition on innovation (Aghion and Howitt, 2006). Becker and Hall (2013) suggest five types of key intrinsic determinants of private-sector R&D expenditures: firm-/industry-specific economic and financial factors, product market competition, public policies, location and endowment, and the presence of foreign R&D.

#### *(1) Firm-/industry-specific factors*

The theoretical explanation underpinning firms' motivation to invest in R&D is centred on the expected (positive) return. Among the key investment sources and determining factors of such investment are cash flow and sales, especially when firms have difficulty relying on external funds; these arguments have a solid theoretical Schumpeterian foundation (Aghion and Howitt, 2006). We can therefore distinguish two main specific factors: the benefits from R&D and the costs of R&D. As regards the former, there is a rich literature indicating a positive correlation between R&D investment and a company's sale growth (Morbey and Reithner, 1990), while other studies have shown a strong link between R&D investment and productivity (see literature cited in 'Productivity as one of the main micro-macro drivers for corporate R&D activity'). More recent studies have found that the potential for increased profitability as a result of R&D investment is a key factor determining a firm's private R&D investment (Hall *et al.*, 2010).

As far as the cost of R&D is concerned, and in particular the ability of firms to access sources of finance, demographics play a relevant role, since access to finance probably depends upon a firm's age and size. The empirical results of the effect of cash flow on R&D investment are mixed. Most studies report a significant positive effect (e.g. Hall *et al.*, 1998; Cohen, 2010; Cincera and Ravet, 2010), especially in the case of more technology-intensive and/or smaller firms (Cincera *et al.*, 2015), but some authors report insignificant effects (e.g. Harhoff, 2000; Bond *et al.*, 2003). However, the effect of sales on R&D investment is likely to be positive (van Reenen, 2007; Borisova and Brown, 2013). Ortega-Argilés and Brandsma (2010), Cincera and Veugelers (2013) and Stancik and Biagi (2015) found that the size of R&D-intensive firms plays a role in explaining the overall R&D intensity gap between the EU and the USA. In both economies, R&D intensities tend to be higher in smaller firms, but the effect is more significant in the USA than in the EU. One reason for the high R&D intensity in the USA is the large number of small and medium-sized enterprises (SMEs) operating in strongly performing R&D sectors, notably those concerned with information and communications technology (ICT). These results are, in part, confirmed by a recent study by Moncada-Paternò-Castello (2016b) showing that the age distribution of top R&D investors is strongly related to the sector (and technology) in which these firms operate. In summary, age and size will affect the net private return to R&D but are not drivers of R&D *per se*.

#### *(2) Product market competition*

This has already been identified in Schumpeterian growth theory (Aghion and Howitt, 2006) as a factor having possible mixed effects on R&D investment. In fact, a high level of market competition may undermine incumbent firms' incentive to innovate because these firms are less efficient in exploiting innovation investment (Romer, 1994; Acs *et al.*, 2009). In contrast, other streams of empirical literature (Geroski, 1990; Damanpour, 2010; Ayyagari *et al.*, 2012) have found market competition to have a positive effect on innovation, because firms

use R&D as a strategic investment to combat or prevent competition. In addition, Aghion *et al.* (2002) found that the relationship between product market competition and innovation forms an inverted U-shape: the escape competition effect dominates at low initial levels of competition, whereas the Schumpeterian effect dominates at higher levels of competition.

A possible explanation of these controversial results is provided by Wu (2012) and Kubick *et al.* (2014). They argue that a low level of competition, attributable to a small number of large incumbent firms and high barriers to access facing new entrants, provides little incentive to invest in R&D. The greater the access and the less differentiated the product, the greater is the incentive to achieve an advantage through R&D. On the other hand, in highly competitive markets, the time for innovation is short and the potential gains from R&D could be small and highly uncertain. The situation is different for every country and sector, and such structural differences need to be taken into account before asserting that any deficiencies in terms of R&D are intrinsic to the country.

### *(3) Access to public policy support*

Tax credits and direct subsidies for R&D have positive effects on firms' R&D investment, but they also bring the threat of crowding-out/substitution effects (Bloom *et al.*, 2002; Guellec and van Pottelsberghe de la Potterie, 2005; Hall *et al.*, 2016).

### *(4) Firm location*

Firm location is an important factor as a firm's R&D investment increases with its proximity to universities and a skilled labour force (Vivarelli, 2013; Capello, 2014; Amoroso *et al.*, 2015). *A priori*, one would expect the economic structure of a particular country to be less important to investment in R&D than intrinsic qualities such as national incentives (e.g. taxes, grants). Yet the annual surveys of EU R&D Scoreboard companies, conducted since 2005, clearly indicate that, as reported in Moncada-Paternò-Castello *et al.* (2011) and Cincera *et al.* (2012), for these companies, the principal factors influencing R&D investment are, in order of importance, (a) access to specialised R&D knowledge, (b) the availability of researchers and (c) proximity to other company activities (e.g. production). In addition, the survey results show that top R&D investors' main reasons for locating R&D in China and India are market size and growth, together with the availability of R&D personnel (Tübke *et al.*, 2015).

### *(5) Presence of foreign R&D*

Studies of the role of foreign R&D as driver of domestic R&D investment show mixed results. For example, Gorg and Greenaway (2003), Moncada-Paternò-Castello *et al.* (2011) and D'Agostino and Santangelo (2012) have suggested that domestic R&D and innovative activity can be augmented by competition because this leads to knowledge spillovers from foreign firms. However, the same authors argue that greater competition reduces the propensity of domestic firms to invest in R&D investment because return on investment, in terms of profitability, is expected to be lower.

Therefore, both the *intrinsic* and *structural* components of corporate R&D intensity in a given economy are determined by a number of factors that could be macro or micro in nature or origin. In fact, it should not be forgotten that structural differences are the result

of decisions by individual firms over a long period of time. Their performance and strategy may be influenced by government policy, but the focus on intrinsic factors may also remove the main impediments to corporate R&D.

### 2.2. Concept and purpose of decomposing corporate R&D intensity

The literature comparing private-sector R&D intensity in competing economies in different countries or regions of the world (e.g. EU vs. USA), and the various factors that influence it, is extensive. Much of the scientific effort devoted to studying this phenomenon seems to address one main issue: whether the R&D intensity differences between countries are the result of companies' different behaviour in R&D (*intrinsic effect*) or are mainly due to the structure of the economy (*structural effect*). In other words, the question is: are differences in overall R&D intensity due to differences in the investment behaviour of the companies within a particular country, compared with similarly positioned companies in other countries, or do they simply reflect differences in the structure of the economy that cannot be remedied in the short term?

Thus, the methodology for decomposing the R&D intensity gap has been conceived to evaluate the extent to which changes in aggregate R&D intensity can be explained by a change in industrial structure or by a change in R&D intensity of a given industry, and also for benchmarking purposes.

In one of the seminal works to analyse corporate R&D intensity, van Reenen (1997) defined decomposition as 'a straightforward accounting exercise'. Box 1 reports three examples of basic equations frequently used in the decomposition of corporate R&D intensity, while Table A1 in the Annex reports the full list and the further details of main methodological approach — including main formulas and data sources used, the counties/regions compared, and the main results — of 15 recent studies on the decomposition of private R&D intensity.

**Box 1. Examples of basic equations frequently used when decomposing R&D intensity**

$$\Delta r_{total} = \sum_i \Delta r_i \bar{s}_i + \sum_i \bar{r}_i \Delta s_i$$

where R&D intensity  $r_i$  is the proportion of value added devoted to R&D ( $R\&D_i/VA_i$ ) and  $s_i$  is each industry's share of total value added ( $VA_i/\sum_i VA_i$ ) for  $i = 1 \dots N$  industries. The bars denote a time mean (average over  $T$  years). The  $\Delta$  values are changes over time (for  $T$  years). *Source: van Reenen (1997)*

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$$RDI_X - RDI_Y = \sum_i RDI_{Z,i} (P_{X,i} - P_{Y,i}) + \sum_i P_{X,i} (RDI_{X,i} - RDI_{Y,i})$$

where  $RDI$  represents the extent of private R&D intensity ( $R\&D/VA$ ) and  $P$  is the share of the value added,  $i$  indicates the sector,  $X$  stands for the country/region  $X$  and  $Y$  represents the countries/regions with which country  $X$  is compared. *Source: Erken and van Es (2007)*

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$$RDI^y - RDI^o = \sum_i RDI_i (w_i^y - w_i^o) + \sum_i w_i (RDI_i^y - RDI_i^o)$$

where  $RDI$  is R&D intensity, defined as R&D investments divided by net sales. Superscripts  $y$  and  $o$  denote, respectively, "yollies" (young leading innovators) and "ollies" (old leading innovators), subscript  $i$  denotes industry,  $w_i^y$  denotes the share of the sector accounted for by the total number of young firms and  $w_i^o$  denotes the share of the sector account for by total number of old firms. *Source: Cincera and Veugelers (2013)*

### 2.3 Decomposition of corporate R&D intensity: empirical findings

The divergent findings in the literature concerning the causes of the R&D intensity gap between EU and US companies suggest that caution should be exercised when drawing general conclusions based on individual studies (Moncada-Paternò-Castello, 2010).

There is one group of researchers (e.g. Dosi, 1997; Pianta, 2005) who are more inclined to consider that the EU R&D deficit is generally the result of companies' underinvestment in R&D (*intrinsic effect*). For example, more recently, Erken and van Es (2007) examined the differences in business R&D between 14 EU countries and the USA in 36 sectors over a 17-year period using OECD-STAN<sup>(6)</sup> and ANBERD<sup>(7)</sup> data. They concluded that the contribution of sector composition to the R&D funding gap between the EU and the USA was very low, whereas the intrinsic effect was undoubtedly responsible for the private R&D gap. They also argued that, if only manufacturing sectors are taken into account, corporate R&D intensity does not differ much between the USA and the EU. They suggest that the R&D gap is due mainly to institutional differences, including, for example, a lower level of government support for research activities in the EU.

In contrast, other researchers have concluded that the gap is mainly due to the structure of the economy (i.e. sectorial composition or *structural effect*). This is true of one of the first empirical studies (Scherer, 1967), which demonstrated that most R&D intensity can be explained by industry fixed effects. Later work by Cohen *et al.* (1987) showed that the sector in which firms operate accounts for half of the R&D intensity differences across firms. More recently, Ab Iorwerth (2005) undertook a detailed decomposition<sup>(8)</sup> of differences between Canadian and US R&D intensities across industries. He used the OECD-STAN database for industrial analysis and the OECD Research and Development Expenditure in Industry database and found that Canada's low aggregate R&D performance hides high research intensities in some research-intensive industries. Nonetheless, the results also indicated that the smaller relative size of these industries — together with the low R&D intensities in motor vehicle and service industries — accounted for the weak aggregate performance in Canada compared with the USA. Likewise, for the EU versus US comparison, Ciupagea and Moncada-Paternò-Castello (2006), O'Sullivan (2007) and Guellec and Sachwald (2008) suggest that the European private R&D investment deficit is mainly due to a sectoral composition effect. These authors found that the R&D intensity difference could be attributed to the fact that the ICT sector is smaller in the EU than in the USA. In fact, in the EU the ICT sector accounts for a relatively much smaller proportion of overall business expenditure on R&D than it does in the USA.

This conclusion confirms the findings of GFII (2007), of the European Commission (2007, 2008), and of Moncada-Paternò-Castello *et al.* (2010) and Cincera and Veugelers (2013), who based their analyses on samples from the EU R&D Scoreboard data. Moncada-Paternò-

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(6) OECD stands for Organisation for Economic Co-operation and Development; STAN stands for 'STructural ANalysis Database'.

(7) ANBERD stands for Analytical Business Enterprise Research and Development database.

(8) He used the *Bennet decomposition* following Diewert (2005).

Castello *et al.* (2010) found that the structural effect accounted for 85% of the gap between the EU and the USA, with only 15% being attributable to the intrinsic effect <sup>(9)</sup>.

Moncada-Paternò-Castello *et al.* (2010) also analysed the distribution of R&D among the top R&D-intensive firms and found that in the EU R&D investment is concentrated in a relatively smaller number of firms operating in sectors that are generally of lower R&D intensity than the USA. Cincera and Veugelers (2013) investigated the role of the older and younger firms in the corporate R&D intensity gap between the EU and the USA and found that 55% of the EU gap is accounted for by greater R&D intensity in younger US firms, and this is almost entirely due to the different sectoral composition in the two economies.

Furthermore, Stančik and Biagi (2015), who used EU R&D Scoreboard data (2002–2010) to decompose the R&D intensity gap, found that R&D intensity is lower in the EU than in the USA, Japan or the Asian Tiger countries, but higher than in the BRIC countries (Brazil, Russia, India, China). The authors concluded that the former finding can be attributed to structural effects, whereas the latter is the consequence of both higher R&D intensity within sectors and sectoral composition. Focusing on the R&D intensity gap between the EU and the USA and using firm-level data. These authors also found that there is strong between-sector variation and some evidence of within-sector variation, although not always in favour of the USA.

Several studies carried out in the last decades indicate that economic and technological specialisation is one of the main factors underpinning the EU R&D investment gap. For example, some have investigated the reasons for the commonly observed pattern that R&D investments in Europe as a whole are generally lower than in the USA. Although Pavitt and Soete (1982) found that one of the main factors underpinning this phenomenon was the high degree of international specialisation in individual EU Member States, a more recent study found that technological capabilities in the EU showed a tendency towards convergence between 1998 and 2008 compared with the USA (Fagerberg *et al.*, 2014). These results indicate that social capabilities, such as a well-developed public knowledge infrastructure, condition the growth of technological capabilities. Moncada-Paternò-Castello (2016b) complemented these finding by suggesting that the EU firms are less able than USA companies to create high-tech sectors or join them quickly, and, therefore, to fully exploit the growth opportunities offered by first mover advantages.

Van Ark *et al.* (2003) observed that, in the USA, expenditure on R&D outside the manufacturing sector has been increasing since the mid-1990s and now accounts for about one-third of total R&D expenditure, up from less than one-fifth in 1995. So, although the manufacturing sector still accounts for the majority of R&D expenditure, its share is declining. These authors also note that growth in services R&D has been slower in Europe than in the USA, and has still not reached 20% of total R&D. At least part of this gap is probably explicable by the fact that ICT diffusion has been slower in Europe than the USA.

Mathieu and Van Pottelsberghe de la Potterie (2010) limit their analysis of R&D intensity to 20 manufacturing sectors, concluding that BERD <sup>(10)</sup> intensity is mainly driven by the degree of specialisation in R&D-intensive industries. This finding supports the argument that a sectoral composition effect is the cause of the low EU R&D intensity. This study

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<sup>(9)</sup> A complete discussion of these aspects is offered by Moncada-Paternò-Castello (2016a).

<sup>(10)</sup> BERD stands for Business Enterprise Expenditure on R&D.

focused on 10 European Member States and considered a range of data that covered the period from 1991 to 2002. The findings suggest that specialisation in sectors of high R&D intensity is the reason why R&D intensity is higher in some of the EU Member States than in others.

More recently, Reinstaller and Unterlass (2012), using BERD panel data, analysed the development of R&D intensity in the EU-27 countries and some other relevant non-EU countries over the period 2004–2007. They found that changes in aggregate BERD figures were driven by structural changes and by changes within same sector with rather different speed of changes depending on countries and sectors.

Gumbau-Albert and Maudos (2013) used the EU-KLEMS<sup>11</sup> database to calculate R&D capital stock (rather than R&D expenditures) with the aim of investigating differences in the technological capital intensity of various industries in the EU-11 countries and the USA. They found a technological gap in favour of the USA until the mid-1990s because of the greater accumulation of technological capital in most of the productive sectors considered. However, from 1995 onwards a change in productive specialisation occurred: a significant drop in the relative importance of lower technology-intensive industries in the EU-11 economy was accompanied by a significant drop in the relative importance of some medium technology-intensive industries in the USA, leading to a reduction in the technological gap between the EU and the USA. Gumbau-Albert and Maudos (2013) also found that differences in the productive structure of European countries explain most of the differences in technological capital intensity. Another recent decomposition analysis (Foster-McGregor *et al.*, 2013) found that differences in the R&D intensity (defined as the expenditure of manufacturing firms on R&D relative to manufacturing value added) of manufacturing firms in seven EU Member States and the USA and Japan are mainly driven by the intensity effect. Industry structure (composition effect) plays a role in some EU Member States but is never the primary factor. However, the authors suggest that the relative importance of the composition effect and the intensity effect in a decomposition exercise depends on the level of aggregation of the industries, and they recognise that a more detailed industry breakdown would assign greater importance to the composition effect, assuming that companies in the same sub-sector are closer in terms of R&D intensity.

Other studies find some clear path of mixed (intrinsic *together* with structural) effects. A recent study by Belitz *et al.* (2015) based on OECD data at two-digit level analysed the difference between private-sector R&D intensity in Germany and a selection of OECD countries. These authors found that the structural effect and the behavioural (intrinsic) effect play more or less equally important roles in explaining the differences between Germany and other OECD countries with regard to private-sector R&D intensity. Furthermore, they found that, although Germany often suffers from the behavioural effect, at the same time it usually benefits from the structural effect; both effects are strongly driven by a few particularly research-intensive industries. Another interesting paper comes from Lindmark *et al.* (2010), who compared two data sets — EU R&D Scoreboard micro-data and BERD statistics — to decompose EU and US R&D intensities. They concluded that about half of the overall R&D gap between the EU and the USA lies in the ICT sector. In turn,

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(<sup>11</sup>) EU-KLEMS stands for EU level analysis of capital (K), labour (L), energy (E), materials (M) and service (S) inputs



this ICT R&D gap has two facets. BERD data suggest that the gap is largely intrinsic: R&D intensity is lower in the EU than in the USA in several sub-sectors, even though ICT sector size and composition are quite similar. In contrast, company data from the EU R&D Scoreboard suggest that the gap is instead structural: the sector size and composition of sub-sectors differ greatly, whereas R&D intensity is similar <sup>(12)</sup>.

In this context, it should be emphasised that the high-tech sectors are important not only because companies in them invest at a higher R&D intensity but also because, in such sectors, the link between R&D and productivity is greater and more significant (Ortega-Argilés and Brandsma, 2010). Nonetheless, Janger *et al.* (2011) decomposing R&D intensity at EU country level, found that some countries specialise in knowledge-intensive structures, but some other countries, despite focusing on less knowledge-intensive structures, present high R&D intensities.

Table A1 in the Annex summarises the results of most recent studies on the decomposition of private R&D intensity.

### 3. Discussion

The literature survey reported above describes clearly contradictory results. But why are the analyses of the EU R&D gap reported in the literature controversial? The contradictory findings regarding the causes of the R&D intensity gap between companies in the EU and the USA or other competing countries suggest that some methodological problems make it difficult to converge on generally accepted measures of structural and intrinsic effects. The decomposition of the R&D deficit into these two components has been shown to be highly sensitive to the level of data specificities. More importantly, in the case of studies considering both manufacturing and service sectors, the results lack robustness because of the widely recognised problems in comparing service sector R&D data between, for example, the USA and the EU, which are subject to very different statistical norms (Erken and van Es, 2007; Duchêne *et al.*, 2010). Therefore, the results of different studies seem to be highly sensitive to the level of detail at which industries are compared (Jaumotte and Pain, 2005), on whether or not service sectors are taken into consideration together with manufacturing (Erken and van Es, 2007) and on the data used and methodologies adopted (Pianta, 2005). This would suggest that it is worthwhile exploring a different methodological approach: perhaps the pairwise comparison of company performances in different countries is the way to go.

Moncada-Paternò-Castello *et al.* (2010) argue that the conclusions of these studies cannot necessarily be applied to all countries and all economies because of the possible heterogeneity in R&D intensities and industrial structures: the '*intrinsic*' effect may dominate in some countries whereas the '*structural*' one dominates in others. According to Lindmark *et al.* (2010), one factor that could explain the contradictory decomposition results is international flows of R&D and value added: companies tend to allocate a larger share of their value added and a smaller share of R&D outside their home markets. In sub-sectors with a large number of large US companies, these flows are unbalanced, and (BERD) R&D intensities are thus higher in the USA than in Europe, all else being equal.

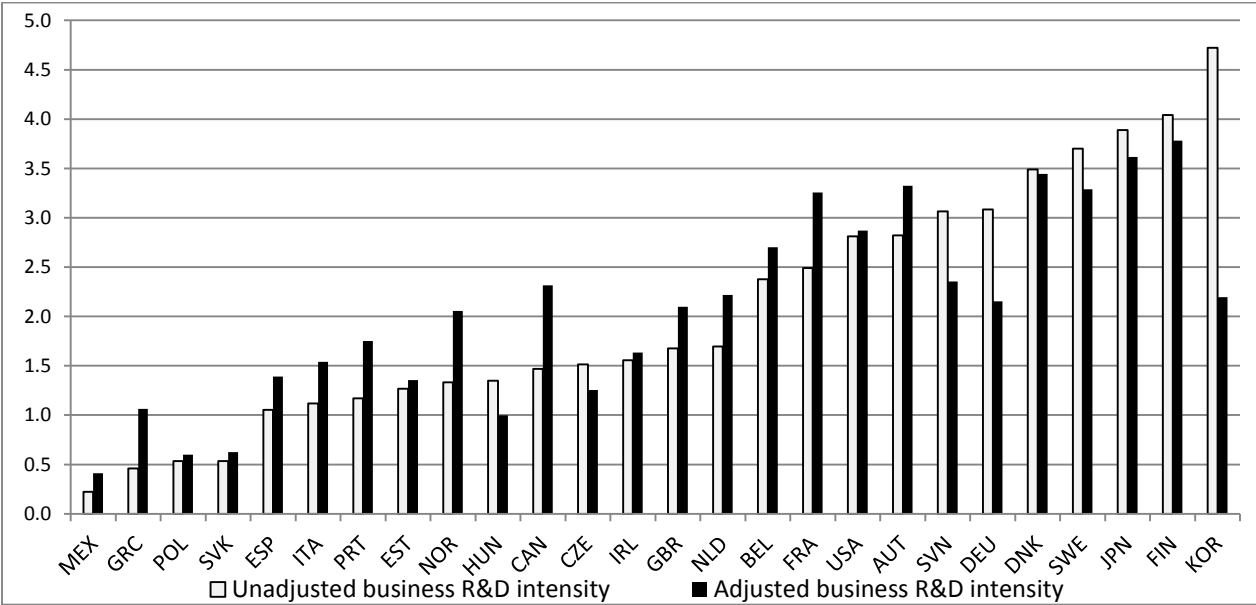
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<sup>(12)</sup> Another reason could be that the top R&D investors are just more similar, even if they are in different sub-sector classifications.

Similar results were obtained by Hernandez *et al.* (2013), who investigated the EU-US R&D gap by analysing BERD statistics (national intramural business expenditures in R&D) and EU R&D Scoreboard data. They found that, based on EU R&D Scoreboard data, the R&D intensity performance of individual EU-based companies is similar to that of their US counterparts because of the constraints imposed by global competition. However, according to the national statistics, industrial activities located within the boundaries of the EU are much less R&D intensive than those located within the boundaries of the USA, especially in key high-tech sectors (e.g. ICT). The EU R&D Scoreboard data capture the R&D invested by EU or US companies all over the world, whereas BERD statistics relate to national and foreign companies that perform R&D in the boundaries of the given territory (see Box 2 for more information on such differences). Therefore, the authors argue, the industrial (production and R&D) activities of foreign-controlled companies play a pivotal role in the discrepant results obtained using these two datasets.

There are other cases of discrepancies in the calculation of business R&D intensities depending on the approach adopted. For example, following one of the first examples by the French Ministry for education and research (Le Ru, 2012), it is only in recent editions of the Science, Technology and Industry Scoreboard (OECD, 2015) that the OECD has recognised the role of structural differences between countries in the calculation and comparison of their R&D intensities, and overcome it by adjusting the R&D intensity using the OECD industrial structure — the sectoral share of OECD value added for the given year (2013) — as adjusted, common weights across all countries. Instead, the unadjusted measure of BERD intensity is an average based on each country’s actual sector shares. The different results between the two measurements of R&D intensity are shown in Figure 4.

**Figure 4: Business R&D intensity (%) in OECD countries adjusted for industrial structure, 2013**



Source: OECD Science, Technology and Industry Scoreboard 2015 (OECD, 2015).

As mentioned earlier, one of the most important causes of this apparent discrepancy in corporate R&D intensity decomposition, according to the literature, is the nature of the data

used, and especially the way in which data are collected. To give more explicative insides on data differences, Table 1 summarises the statistical features of data sources most frequently used in analyses of EU corporate R&D intensity decomposition.

There are several studies that exhaustively discuss the detailed statistical differences between data, ranging from the definitions of R&D to the methodologies to collect the information. As this survey article is focused on the decomposition of R&D, we remit to such literature for both the statistical explanation of different data and the estimation of the extent to which these differences affect the quality of any comparison.

Examples of authors who have investigated the statistical characteristics in depth include Poti *et al.* (2007), who compared BERD and the Community Innovation Survey (CIS), and O'Mahony and Timmer (2009), who compared the EU-KLEMS with the CIS. Azagra Caro and Grablowitz (2008) investigated the differences between BERD and the EU R&D Scoreboard, while Cozza (2010) complemented national statistical data on business R&D with EU R&D Scoreboard data.

These studies suggest that international comparison at sector and micro-level is not always possible<sup>(13)</sup> because of often deep methodological differences, but different sources frequently bring an extremely useful complementarity of information.

In fact, there are recent promising works that not only try to use different sources of private sector R&D data, but also combine them with additional datasets to bring a previously missing dimension to the economic and policy analyses of innovation. To give a few examples, Dernis *et al.* (2015) combined EU R&D Scoreboard with patent data to disentangle the technological profile of firms' R&D investment, while Alstadsæter *et al.* (2015) looked into the effects of top corporate R&D income taxation from the tax advantage of patent boxes. Amoroso *et al.* (2015) combined EU R&D Scoreboard data with the *fDi Markets* database<sup>(14)</sup> to assess the ability of labour markets to attract knowledge-intensive and manufacturing greenfield FDI. Other authors combined micro-data from BERD (among others) with those from the EU's R&D Framework Programme to disentangle the delocalisation patterns in university-industry interaction (Azagra Caro *et al.*, 2013), whereas Ciriaci *et al.* (2015) matched ANBERD<sup>15</sup> data with patent data from the Worldwide Patent Statistical Database (PATSTAT) and the OECD Patent Quality Indicators databases to estimate the innovation impact of the vertical integration of knowledge-intensive business services (KIBS) into manufacturing industries.

It worth mentioning that there are new, ambitious and promising institutional initiatives, such as the 'framework regulation integrating business statistics' – FRBS (European Commission, 2016a), which aim to harmonise statistics, establishing a common legal framework for the systematic collection, compilation and dissemination of European business statistics.

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(13) They argue that, for example, the distinction between national and foreign investment within the extramural R&D category, or of the actual R&D expenditures of multinationals' investment, would allow for a much better demographic distribution of data.

(14) *fDi Markets* is an on-line database maintained by fDi Intelligence, a division of the Financial Times Ltd. fDi Intelligence collects available information on investments since 2003 and monitors cross-border investments in all sectors and countries worldwide, relying on firms data and media sources.

(15) Is the "Analytical Business Enterprise Research and Development" database of the OECD

**Table 1. Brief description of data sources most frequently used in EU corporate R&D intensity decomposition.**

| <i>Data sources / Characteristics</i> | <b>EU R&amp;D Scoreboard</b>   | <b>BERD</b>   | <b>ANBERD</b>  | <b>CIS</b>   | <b>EU-KLEMS</b>   |
|---------------------------------------|--|---|--|--|---|
| <i>Monetary flows</i>                 | All R&D financed by a particular company from its own funds, regardless of where that R&D activity is performed        | All R&D expenditures by those parts of companies located within the EU, regardless of where the funds for that R&D activity come from   | As BERD database but for missing data includes a number of estimations   | As BERD database, plus includes a number of estimations  | R&D investments are considered as capital stock (and not as expenditure) and are incorporated in Gross Fixed Capital Formation <sup>(a)</sup> ; R&D is specifically considered to be a production asset |
| <i>Sample</i>                         | Top R&D-investing companies  | A stratified sample, covering all large companies and a representative sample of smaller companies with no size threshold   | Completes BERD with information from national statistical offices and with estimations and sector re-classifications for internationally comparable data | As BERD, but confined to selected industries and to firms with 10 employees or more  | Like ANBERD (STAN), this uses additional sources such as national accounts, industry surveys, labour force surveys and capital formation surveys  |
| <i>Statistical Unit</i>               | Companies: subsidiaries counted within the consolidated group; R&D systematically attributed to the registered offices | Business enterprises' subsidiaries are counted separately; R&D is attributed to headquarters or registered offices. Statistics for enterprises are compiled at national level and for local units at regional statistics level (NUTS 2 level) | As BERD  | Business establishments. The survey is carried out at the enterprise level. Firms that organise business activities into separate units can be sampled several times | At detailed industry level per country but also provides higher-level aggregates (e.g. total economy, total market, services and total goods production)  |
| <i>Data collection frameworks</i>     | International Accounting Standard (IAS) 38   | Frascati Manual   | Frascati Manual  | Oslo Manual  | System of National Accounts (2008 SNA)  |
| <i>Geographical area</i>              | World  | EU Member States and candidate Countries, EFTA Countries, Russian Federation, China, Japan, United States   | 34 OECD countries and six non-member economies (China, Romania, Russia Federation, Singapore, South Africa, Taipei)                                      | EU-28 Member States  | 25 EU countries, as well as Australia, Japan and the US   |
| <i>Data category</i>                  | Audited company account data — companies above a minimum R&D threshold   | R&D statistics via surveys of sampled companies sent by national statistical offices  | R&D statistics obtained from surveys of sample companies plus a number of estimations  | Innovation statistics surveys of sampled firms sent by national statistical offices  | Extends ANBERD (STAN) with data from national accounts  |
| <i>Economic sectors</i>               | International Classification Benchmark (ICB)   | Statistical classification of economic activities (NACE) revision 2   | International Standard Industrial Classification (ISIC) revision 4   | Statistical classification of economic activities (NACE) revision 2  | International Standard Industrial Classification (ISIC) revision 4  |

(a) A flow value, defined as the total value of a producer's acquisitions, less disposals of fixed assets.

Source: Own elaboration from OECD (2002, 2012), European Commission (1997, 2007, 2008, 2016a, 2016b), Azagra Caro *et al.* (2008) and O'Mahony and Timmer (2009)

A few more points about the use of R&D intensity as a statistical indicator need to be made. As we have seen, aggregate R&D intensity indicator is affected not only by the industrial structure, but also by characteristics (demographics, business cycle) of the pool of firms that make up that structure, and by other structural factors and intrinsic factors, as seen in section 2.1.

It is worth remembering that, despite policy targets and the related socio-economic objectives, companies should not be tempted to overinvest in R&D, that is to invest more than 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.

The definition of R&D intensity as an indicator of country or company performance is another important aspect to mention. First of all, the numerators and denominators could be different in nature. For example, the numerator is either firms' R&D investment or business enterprise expenditure on R&D — BERD; the former data are captured from firms' financial accounts and the latter from surveys (for detailed differences see Box 2).

**Box 2. Comparing the EU R&D Scoreboard with Business enterprise Expenditure on R&D (BERD)**

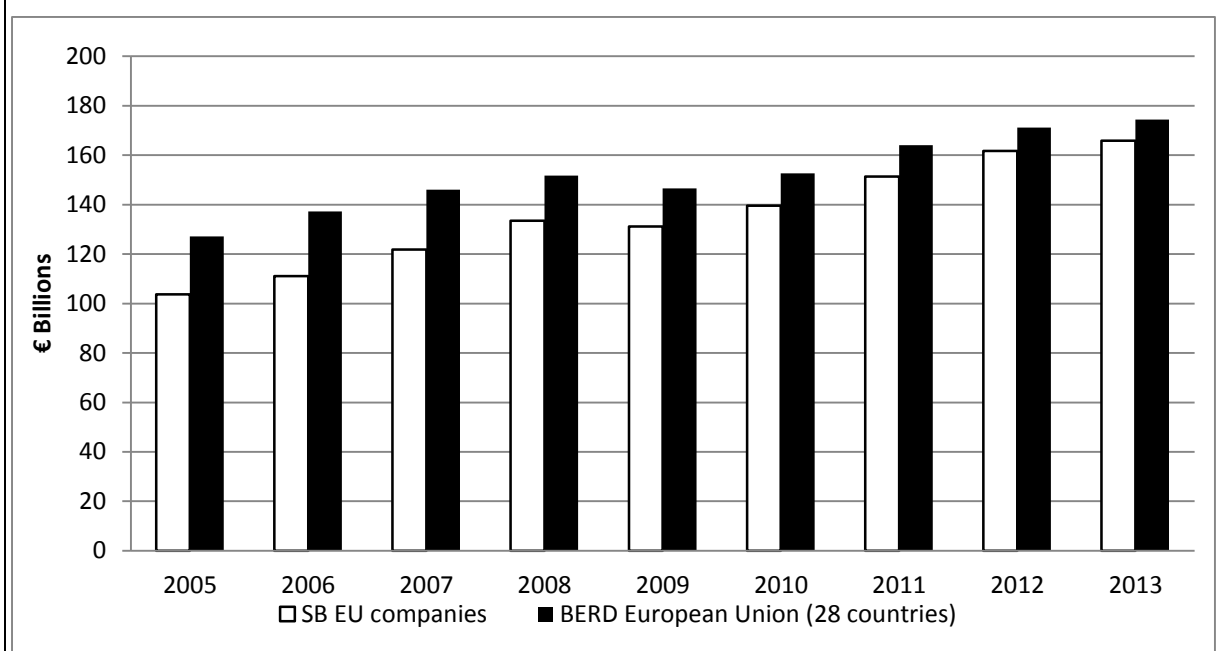
The data used for the EU Industrial R&D Investment Scoreboard are different from those provided by statistical offices, for example BERD data collected by national statistical agencies. The Scoreboard refers to all R&D financed by a particular company from its own funds, regardless of where that R&D activity is performed. The Scoreboard therefore presents an indicator of a particular corporation's global financial commitment to R&D. BERD, on the other hand, refers to all R&D activities performed by businesses within a particular territory (and therefore includes small parts of many global businesses), regardless of the location of the business's headquarters, and regardless of the sources of finance. In summary, the distinction between Scoreboard and BERD data can be seen overall as 'global corporate funding' versus 'activity within a geographical area'.

Furthermore, the Scoreboard collects data from audited financial accounts and reports. BERD typically takes a stratified sample, covering all large companies and a representative sample of smaller ones. Additional differences lie in the definition of R&D intensity (BERD uses the percentage of value added, whereas the Scoreboard measures it as the R&D/sales ratio) and the sectoral classification they use (BERD follows NACE, the European statistical classification of economic sectors, while the Scoreboard classifies companies' economic activities according to the Industrial Classification Benchmarking (ICB) classification).

It is difficult to compare the Scoreboard figures and BERD data directly (Moncada-Paternò-Castello *et al.*, 2010). Even if both were fully comprehensive and accurately measured, the global measurements would still differ, as BERD includes non-company sources of R&D finance, and because the measurements refer to different samples of firms. Non-company sources of R&D finance can be significant: for example, government-financed BERD is approximately twice as high in the USA — both in absolute terms and as a proportion of GDP — as in the EU-25. This is an important fact that is often overlooked when examining the differences in BERD intensities between the USA and the EU (Dosi *et al.*, 2005). Lepouri (2006) underlines that BERD is not suited to mapping funding channels and cross-border flows, especially concerning companies.

These two types of measure are complementary and therefore both are useful for policy-makers seeking a complete picture of private R&D investment trends and patterns. At the most aggregate level (e.g. world, EU) of private R&D the two data sources provide similar results (Figure 5).

**Figure 5. R&D in the European Union: EU R&D Scoreboard and BERD data (2005–2013)**



*Source: Calculations from Eurostat and EU R&D Scoreboard data, following the approach of the Hernandez et al. (2013)*

Although EU R&D Scoreboard data are more appropriate for the examination of the investment in R&D by a company or group of similar companies, these data give policy-makers and others some insight into companies' global R&D commitments and their relationship to firm-level economic outcomes. This focus indicates how much firms, rather than the parts of firms within particular national territories, are investing in R&D and in which industries the most R&D-active companies operate. BERD data, in contrast, are more accurate for territorial analysis of private R&D activities, although they are revealing only if the data components of inward and outward flows of R&D investment and production (added-value) are available and taken into consideration<sup>(16)</sup>. These aspects are enormously important when drawing the correct policy implications<sup>(17)</sup>.

Furthermore, in statistical macro- or meso-analysis for policy-makers, the denominator is either GDP or value added, whereas firms' sales or value added are used by corporate and financial analysts to benchmark their competitiveness with peers at corporate or product/service levels. The differences are substantial. Firms' sales are used by corporate and financial analysts to evaluate their level of financial effort (R&D investment) in relation to their market size (sales) and to compare this with the financial effort of their main competitors. Firms also use value added (defined as sales minus the cost of bought-in goods and services) to measure the economic health created by a company as a whole or by a given

<sup>(16)</sup> In a pilot study of statistics, the European Commission (2010b) demonstrated that using data from the EU R&D Scoreboard and adding aggregate values from national business R&D statistics allows novel insights into the internationalisation of business R&D process. Unfortunately, these micro-data are not made available by the majority of statistical offices in the EU.

<sup>(17)</sup> For example, an exhaustive explanation and empirical demonstration of the relevance of companies' cross-border activities in the evaluation of the EU-US intensity gap using BERD or the EU R&D Scoreboard data, and the apparent discrepancy of results, is provided in Ch. 7, pp. 53–62, in op. cit. as European Commission (2013).

product/service and to identify differences (if any) from a competitor(s). In contrast, GDP or value added is utilised in statistical macro- or meso-analysis by policy-makers and policy analysts as the denominator of the R&D intensity ratio to monitor territorial competitiveness. However, these measures reflect two very different aspects: GDP is measure of the value of all final goods and services produced, whereas value added in most industries consists in the value of the contribution of the factors of production - mainly capital, wages and remuneration of knowledge - and is used in macroeconomics to compare different sectors of the economy.

These differences could, as seen earlier, account for some mismatch of results when comparing aggregate R&D intensities, depending on the definition of R&D intensity and the data used in the calculation.

Moreover, something that the private-sector R&D intensity indicator does not consider is the complex — but important — issue of the efficiency and the effectiveness of R&D investment (Cincera *et al.*, 2009). GDP accounts for economic output and the BERD/GDP measures effort (the part of private-sector economic activities devoted to R&D), not R&D efficiency or effectiveness (Godin, 2007).

Nor does private-sector R&D intensity take into account different companies' strategy, as in the case of some sub-sectors, such as the pharmaceutical or biotechnology sectors, which require firms to invest heavily in R&D but in which sales may be very low for several years until new products can be successfully introduced.

Finally, there are issues concerning the interpretation of R&D intensity indicators over time, as countries enter or leave economic cycles at different points, and grow at different but fluctuating rates (Meister and Verspagen, 2006). It is not surprising that fluctuations (global or country specific) in growth, together with differences in the structure of national economies and in their ability to resist the undesired effects of a economic and financial downturn, not forgetting different national economic priorities (as in developing economies, or in some new EU Member States), could lead to some turbulence in the R&D/GDP (value added or firm' sales) ratio. Such economic evolutions could either hamper or facilitate the capacity of one country relative to one to continue to invest in R&D; it could also result in a higher or lower intensity ratio simply because the value of the denominator falls or rises.

Therefore, when using R&D intensity as a policy target or to compare R&D/GDP (value added or firms' sales) ratios in different economies (also within the EU), especially over a relatively short time span, one should proceed with caution, particularly if policy measures are likely to result from such comparisons. In this case, the relevance of R&D intensity goes beyond the mere academic discussion.

These arguments indicate very clearly that the nature of data, and their comparability, together with the heterogeneity of countries and business structures, the timing of economic cycles, corporate strategies, and possible differences — even though not substantial — in the calculation formulas used have to take into account in the analysis of R&D intensity decomposition and its interpretation (see Table A1 in the Annex for the main methodological approach, including formulas and data sources, of studies investigating the decomposition of private R&D intensity).

## 4. Summary and conclusions

Research and development (R&D) indicators are increasingly used not only to facilitate international comparisons, but also as targets for policies stimulating research. An example of such an indicator is R&D intensity. The decomposition methodology of quantifying R&D intensity was conceived with the aim of evaluating the extent to which changes in aggregate R&D intensity can be explained by a change in industrial structure (*structural effect*) or by a change within a given industry (*intrinsic effect*).

The micro-macro statistical issue is a major topic for both firms and policy-makers because of the convergence of interests in terms of outputs (i.e. private and social returns). Micro-level statistics allow evaluation of the characteristics of an economy at the unitary (firm) scale as well as at industry and macro-level when such data can be aggregated.

Despite the significance of the analytical purpose, the theoretical and methodological framework needed to decompose countries' R&D intensity has been elaborated only recently, and is still not widely used in the literature, which in turn shows rather contradictory results: some methodological problems make it difficult to converge on generally accepted measures of structural and intrinsic effects. We believe that a more accurate approach to explore is to compare the corporate R&D intensity performances of similar companies in different jurisdictions, the accuracy of which would increase as more and better-quality data become available.

The results of this study clearly show that R&D intensity as a policy target and the comparison between different characteristics of corporate R&D intensity ratios belonging to different economies should be handled with care, particularly with respect to the policy measures that result from such comparisons. This implies that policy-makers and analysts, depending on the question they want to address, should be careful to choose the appropriate data source and methodology.

For example, global corporate R&D funding can best be analysed using EU Scoreboard data to interrogate the global R&D performance and economic competitiveness of European multinationals at the level of firms. BERD data are more accurate for territorial analysis of private R&D activities. Furthermore, in the R&D intensity ratio, the denominator utilised in statistical macro- or meso- analysis by policy-makers is either GDP or value added, whereas corporate and financial analysts use firms' sales or value added to benchmark their competitiveness against peers at the corporate or product/service level.

Additionally, there is a key issue about the interpretation of corporate R&D intensity data. Examples have been given of the counter-cyclical or cyclical behaviour of companies depending on their level of competitiveness and distance from the technological frontier. Moreover, corporate R&D intensity does not capture the efficiency and effectiveness of R&D investment, nor the business/technological characteristics or strategy of firms.

These aspects are enormously important when drawing the correct policy implications. The relevance of the methodological approach and the interpretation of results go beyond mere academic discussion and the contradictory results suggest that policy-makers and researchers should not rely on information from a single source or indicator but should combine data from complementary sources when available.



Generally, if deficient R&D intensity is *intrinsic* in nature, it can be remedied by policy-makers in a relatively short period. In contrast, if the R&D intensity problem is *structural*, resulting from sectoral composition, it is much less sensitive to governmental policy and broader and deeper longer-term measures will be needed.

The findings of this first literature survey on corporate R&D intensity decomposition also indicate that further research should consider addressing the shortage of good-quality data (e.g. should provide more complete micro-data that also allow homogeneous company - and country - comparability; R&D expenditure inflows and outflows), the shortage of investigations relying on longer time series and on longitudinal (balanced) datasets, and the shortage of studies that include more independent variables (which may explain more accurately the determinants of sector composition and of intrinsic effects) and investigate the development of more sophisticated statistical and econometric models.

However, it needs to be kept in mind that even the most sophisticated methods can only produce meaningful results when the basic data are complete and correct. As long as they are not, there will be a trade-off between the geographic extension and the depth of the analysis. These limitations should be made explicit in the advice to policy-makers and, in their turn, they would be advised not to overstate the policy implications beyond what is being nonsense by the quality and the multidimensionality of the data.

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ANNEX — Table A1. Overview of objectives, methodology, data sources and findings of 15 recent studies on private R&D intensity decomposition

| Author(s), year          | Objective of decomposition  | Decomposition: main equation used   | Data sources; measure of R&D and of the economy's output; year(s) of observations  | Main results  |
|--------------------------|---|---|--|---|
| Van Reenen (1997)        | To break down the aggregate shifts in R&D intensity into 'between'/intrinsic and 'within'/structural effects of UK vs. competing countries and manufacturing vs. non-manufacturing industries | $\Delta r_{total} = \sum_i \Delta \bar{r}_i \bar{s}_i + \sum_i \bar{r}_i \Delta s_i$ <p>The R&amp;D intensity <math>r_i</math> is the proportion value added devoted to R&amp;D (<math>R\&amp;D_i/VA_i</math>) and <math>s_i</math> is each industry's share of total value added (<math>VA_i/\sum_i VA_i</math>) for <math>i = 1, \dots, N</math> industries. The bars denote a time mean (average over <math>T</math> years). The <math>\Delta</math> values are changes over time (for <math>T</math> years)</p>                                 | BERD of UK vs. other G7 countries, 1974–1991; value added  | UK manufacturing industries have been slower to increase their R&D intensities than their G7 counterparts. The main reason for this is not the different pattern of industrial restructuring in the UK compared with elsewhere (either a shift away from manufacturing or shifts between industries within the manufacturing sector), but an intrinsic ('within') effect    |
| Sandven and Smith (1998) | To identify country and sector effects in BERD intensity  | $I_{m,j} = \sum_{i=1}^n \bar{I}_i w_{i,j} + \sum_{i=1}^n (I_{i,j} - \bar{I}_i) \cdot w_{i,j}$ <p><math>I_{m,j}</math> = <math>I</math> stands for R&amp;D intensity and <math>m</math> stands for manufacturing in country <math>j</math><br/> <math>\bar{I}_i</math> = is the typical (median) benchmark of the R&amp;D intensity in industry <math>i</math><br/> <math>w_i</math> = is the share (weight) of total manufacturing value added of industry <math>i</math></p>   | BERD of 13 EU countries in 1991; value added   | Large countries have higher R&D intensities than small countries, and R&D intensity is affected by the industrial structure. Moreover, a strong positive association was found between economy size (GDP) and the <i>structure component</i> : the larger the economy, the more the industrial structure is favourable to a high R&D intensity in manufacturing.            |
| Ab Iorwerth (2005)       | To examine R&D intensity performance across industries between Canada and the USA   | <p>Aggregate gap is given by the sum of (a) the intensity effects:</p> $\sum \left( \frac{R \& D_i^{Cnd}}{VA_i^{Cnd}} - \frac{R \& D_i^{US}}{VA_i^{US}} \right) * 1/2 \left( \frac{VA_i^{Cnd}}{GDP_i^{Cnd}} - \frac{VA_i^{US}}{GDP_i^{US}} \right)$ <p>and (b) the structural effects, given by:</p> $\sum \left( \frac{VA_i^{Cnd}}{GDP_i^{Cnd}} - \frac{VA_i^{US}}{GDP_i^{US}} \right) * 1/2 \left( \frac{R \& D_i^{Cnd}}{VA_i^{Cnd}} - \frac{R \& D_i^{US}}{VA_i^{US}} \right)$ <p>Note: uses a Bennet decomposition following Diewert (1998)</p> | OECD-STAN database for Industrial Analysis and the OECD Research and Development Expenditure in Industry database – Canada and US data – value added | Canada's low aggregate R&D performance hides high research intensities in some research-intensive industries. Nonetheless, the results also indicated that the smaller relative size of these industries — together with the low R&D intensities in the motor vehicle and service industries — accounted for the weak aggregate performance in Canada compared with the USA |
| Erken and van Es (2007)  | To disentangle differences in business R&D between the EU-15 and the USA, which are broken down into a sector composition effect and an intrinsic effect                                      | $RDI_X - RDI_Y = \sum_i RDI_{Z,i} (P_{X,i} - P_{Y,i}) + \sum_i P_{X,i} (RDI_{X,i} - RDI_{Y,i})$ <p><math>RDI</math> represents the extent of private R&amp;D intensity (R&amp;D/VA), <math>P</math> stands for the share in the value added, <math>i</math> indicates the sector, <math>X</math> stand for country/region <math>X</math> and <math>Y</math> stands for the countries/regions with which country <math>X</math> is compared (as Van Velsen, 1988; Hollanders and Verspagen, 1998)</p>  | BERD of the USA and 15 EU countries in 1987–2003; value added  | Differences in the structure of EU compared with the USA play only a minor role in explaining the R&D gap. Instead, the European R&D shortfall is mainly caused by a negative intrinsic effect, meaning that companies in the EU spend less on R&D than their US peers in the same sectors  |

| Author(s), year | Objective of decomposition  | Decomposition: main equation used  | Data sources; measure of R&D and of the economy's output; year(s) of observations | Main results   |
|-----------------|---|--|---|--|
| Erken (2008)    | <p>(a) To analyse the effect of sector composition and intrinsic effects on private R&amp;D expenditure in the Netherlands, OECD countries (average) and the EU-15 compared with the USA</p> <p>(b) To examine the <i>factors</i> that affect the <i>sector composition</i> of the Netherlands</p> <p>(c) To examine the <i>factors</i> that affect the <i>intrinsic effects</i> of the Netherlands</p> | <p>(a)</p> $RDI_X - RDI_Z = \sum_i RDI_{Z,i} (P_{X,i} - P_{Y,i}) + \sum_i P_{X,i} (RDI_{X,i} - RDI_{Y,i})$ <p>(as Erken and van Es, 2007)</p> <p>(b)</p> $STR_{i,t} = \alpha + \beta \left( STR_{i,t-1} - \alpha - \sum_i f_i DUM_i - \varphi(LAB_{i,t-2}) \right) + \gamma(INT_{i,t-1} + PUB_{i,t-1}) + \varphi(LAB_{i,t-1}) + \sum_i f_i DUM_i + e_{i,t}$ <p><i>STR</i> represents the sector composition effect as a percentage of total value added</p> <p><i>LAB</i> symbolises the relative unit labour costs vis-à-vis competitors in other OECD countries</p> <p><i>INT</i> represents the intrinsic effects a percentage of total value added</p> <p><i>PUB</i> denotes the difference in public R&amp;D intensity between the Netherlands and the OECD average</p> <p><i>DUM</i> are country dummies.</p> <p>The indices <i>i</i> and <i>t</i> refer, respectively, to countries and years (fixed effects model using OLS)</p> <p>(c)</p> $RD_{i,t} = \alpha_i + \beta_i X_{i,t} + \delta_i D_{i,t} + e_{i,t}$ <p><i>RD<sub>i,t</sub></i> represents the R&amp;D intensity of countries, firms or industries (<i>i</i>) at time <i>t</i>. <i>RD<sub>i,t</sub></i> is modelled as a function of a constant term <math>\alpha_i</math>, a vector of explanatory variables <i>X<sub>i,t</sub></i> and dummy variables (firm-, country- or industry-specific fixed effects) <i>D<sub>i,t</sub></i>. The error term is denoted by <i>e<sub>i,t</sub></i>.</p> | GGDC 60-Industry database, OECD STAN and ANBERD database; value added             | <p>(a) Differences in the structure of EU compared with the USA play only a minor role in explaining the R&amp;D gap. The European R&amp;D shortfall is mainly caused by a negative intrinsic effect, meaning that companies in the EU spend less on R&amp;D than their US peers in the same sectors</p> <p>(b) All the explanatory variables (INT, PUB and LAB) have a significant impact on the sector composition effect</p> <p>(c) The most important explanation behind the R&amp;D gap (mostly intrinsic effects) is provided by institutional differences between the EU-15 and the USA</p> |

| Author(s), year                               | Objective of decomposition   | Decomposition: main equation used  | Data sources; measure of R&D and of the economy's output; year(s) of observations   | Main results  |
|---|--|--|---|---|
| Moncada-Paternò-Castello <i>et al.</i> (2010) | To examine whether there are significant differences in private R&D intensity performance between the EU and the US and, if so, why. | $RDI_X - RDI_Z = \sum_i RDI_{Z,i} (S_{X,i} - S_{Z,i}) + \sum_i S_{X,i} (RDI_{X,i} - RDI_{Z,i})$ <p><i>X</i> refers to the sample to be compared (EU, Japanese and the Rest of the World sample)</p> <p><i>Z</i> is the other sample in the comparison (the USA)</p> <p><i>RDI</i> stands for R&amp;D intensity (R&amp;D/<i>Y</i>); the value of '<i>Y</i>' is the overall amount of net sales of companies operating in a given sector.</p> <p><i>S</i> is the share of the sector <i>i</i> in terms of net sales within a given economy (<i>y<sub>i</sub>/Y</i>).</p> | 2008 edition of the EU Industrial R&D Investment Scoreboard<br>R&D intensity defined as R&D investments divided by <i>net sales</i> | The lower overall corporate R&D intensity for the EU is the result of sector specialisation (structural effect) — specialisation in sectors of high R&D intensity (especially ICT-related sectors) is stronger in the USA than in the EU  |
| Lindmark <i>et al.</i> (2010)                 | Decomposing ICT R&D intensity of EU vs. USA by Size Factor and Intensity Factor  | $\left( \frac{R \& D^{ICT}}{GDP} \right)^{US} - \left( \frac{R \& D^{ICT}}{GDP} \right)^{EU} =$ <p>the US-EU deficit</p> $\frac{(VA^{ICT})^{US}}{(GDP)^{US}} * \left\{ \frac{(R \& D^{ICT})^{US}}{(VA^{ICT})^{US}} - \frac{(R \& D^{ICT})^{EU}}{(VA^{ICT})^{EU}} \right\}$ <p>the deficit due to the R&amp;D intensity factor +</p> $+ \frac{(R \& D^{ICT})^{EU}}{(VA^{ICT})^{EU}} * \left\{ \frac{(VA^{ICT})^{US}}{(GDP)^{US}} - \frac{(VA^{ICT})^{EU}}{(GDP)^{EU}} \right\}$ <p>the deficit due to the ICT sector size factor</p>                                    | BERD for ICT sectors EU and US; year 2005; VA and GDP   | The higher R&D intensity of the US ICT sector can be largely attributed to the higher US R&D intensity compared to EU of the sub-sectors IT Equipment, Measurement Instruments and Computer Services. Therefore, no sub-sector is particularly responsible for the smaller <i>size</i> of ICT sector. |

| Author(s), year                                     | Objective of decomposition  | Decomposition: main equation used   | Data sources; measure of R&D and of the economy's output; year(s) of observations                    | Main results   |
|---|---|---|--|--|
| Mathieu and Van Pottelsberghe de la Potterie (2010) | To evaluate the extent to which national industrial structure affects country rankings based on aggregate R&D intensity | $RI_{ijt} = \beta_{ij} + \varphi_i T \quad (1)$ $RI_{ijt} = \alpha_i I + \varphi_i T \quad (2)$ $RI_{ijt} = \beta_{ij} + \alpha_i I + \varphi_i T \quad (3)$ <p>(1) The links of country specificity to the variance in R&amp;D intensity</p> <p>(2) The links of sector-specific impact on the R&amp;D intensity</p> <p>(3) The simultaneous effects of national and industry-specific factors</p> <p>The control variables are time dummies, country dummies and/or industry dummies.</p> <p><math>RI, J, I</math> and <math>T</math> are, respectively, the business R&amp;D intensity (total R&amp;D expenses divided by value added), country-industry- and time-specific vectors of dummy variables.</p> <p><math>\beta_i</math> and <math>\beta_j</math> are the vectors of parameters to be estimated. Equations are estimated by the OLS method.</p> | BERD from OECD ANBERD database, years 1991–2005. R&D intensities: total R&D expenditures/value added | The econometric analysis performed on a cross-country cross-industry panel dataset suggests that accounting for industrial structure substantially affects the traditional country rankings. |

| Author(s), year                      | Objective of decomposition   | Decomposition: main equation used   | Data sources; measure of R&D and of the economy's output; year(s) of observations             | Main results  |
|--------------------------------------|--|---|---|---|
| Reinstaller and Unterlass (2012)     | The comparison of structural and country effects of business R&D intensities across countries <i>over time</i> (i.e. as Sandven and Smith (1998) + over time!)   | $I_{m,j,t+1} = \sum_{i=1}^n \bar{I}_{i,t} w_{i,j,t} + \sum_{i=1}^n (I_{i,j,t} - \bar{I}_{j,t}) \cdot w_{i,j,t}$ <p>Sector and country effects in base year <math>t</math>,</p> $+ \sum_{i=1}^n I_{i,j,t} (w_{i,j,t+1} - w_{i,j,t})$ <p>change effects over time period <math>\Delta t</math>,</p> $+ \sum_{i=1}^n (I_{i,j,t+1} - I_{i,j,t}) \cdot w_{i,j,t}$ <p>changes of sectoral R&amp;D intensities over time, and</p> $+ \sum_{i=1}^n (I_{i,j,t+1} - I_{i,j,t}) (w_{i,j,t+1} - w_{i,j,t})$ <p>changes in sectoral R&amp;D intensities (i.e. as Sandven and Smith (1998) + <i>over time</i>)</p>  | BERD of 27 EU countries; value added  | Changes in aggregate BERD figures are driven by 'within' (sectoral R&D intensity) and 'between' (structural change) effects with rather different intensity. For instance, Germany experiences structural change towards more technology-intense industries, whereas the United Kingdom experiences the inverse development pattern. Countries such as Denmark, Austria or Sweden, on the other hand, experience mostly a change in R&D intensities 'within' given industries |
| Foster-McGregor <i>et al.</i> (2013) | To compare the R&D intensity in the manufacturing sector as an indicator of the intensity of innovative activity, measured as the business expenditure of manufacturing firms on R&D relative to manufacturing value added | $R\&D_c^m - R\&D_w^m = \sum_i (va_{i,c} - va_{i,w}) \cdot R\&D_{i,w}$ $+ \sum_i (R\&D_{i,c} - R\&D_{i,w}) \cdot va_{i,w}$ $+ \sum_i (va_{i,c} - va_{i,w}) \cdot (R\&D_{i,c} - R\&D_{i,w})$ <p>where <math>R\&amp;D^m</math> is R&amp;D intensity in the manufacturing sector; <math>R\&amp;D_i</math> is R&amp;D intensity in industry <math>i</math>. Subscript <math>c</math> denotes countries and subscript <math>w</math> denotes the global average, which for this purpose is the average of the nine countries included in the decomposition exercise. The valued added shares of manufacturing are denoted by <math>va</math>. (following Eaton <i>et al.</i>, 1998)</p> | OECD ANBERD, World Input-Output Database (WIOD), 2007-2008; value added<br>Seven EU countries | This decomposition shows that the differences in the R&D intensity of firms across the seven EU Member States and US and Japanese firms at the manufacturing level are mainly driven by the intensity effect. The industry structure (composition effect) plays a role in some of the seven Member States but is never the primary factor.  |

| Author(s), year                  | Objective of decomposition   | Decomposition: main equation used   | Data sources; measure of R&D and of the economy's output; year(s) of observations  | Main results  |
|----------------------------------|--|---|--|---|
| Gumbau-Albert and Maudos, (2013) | To analyse the relative importance of country effect and specialisation effect when explaining the differences and evolution in the technological effort of the USA and the EU | <p>(a) Analysis of specialisation:</p> $\frac{K_t^A}{Y_t^A} - \frac{K_t^B}{Y_t^B} = \sum_{j=1}^J \theta_{jt}^B \left( \frac{K_t^A}{Y_t^A} - \frac{K_t^B}{Y_t^B} \right) + \sum_{j=1}^J (\theta_{jt}^A - \theta_{jt}^B) \frac{K_t^B}{Y_t^B} + \sum_{j=1}^J (\theta_{jt}^A - \theta_{jt}^B) \left( \frac{K_t^A}{Y_t^A} - \frac{K_t^B}{Y_t^B} \right)$ <p>R&amp;D capital stock/GVA ratio, is called <math>K/Y</math>; A and B are the two economic areas to be analysed (USA and EU-11, respectively), <math>t</math> is the year and <math>j</math> the sector and <math>y</math> measures the specialisation or production structure proxied by the weight of the GVA in each sector <math>j</math> in total</p> <p>(b) Contribution of structural change:</p> <p>As (a) but the terms A and B are replaced by time dimensions <math>T</math> and 0 (initial and final year, respectively).</p> | Use the EU-KLEMS database for 12 countries and 16 industries, 1980–2003. They analyse the differences in technological capital intensity as R&D capital stock to gross value added (GVA) ratio — and not R&D expenditures/G VA | There was a technological gap in favour of the USA until the mid-1990s. Since 1995 a change in productive specialisation has occurred, with a significant drop in the weight of lower technology-intensive industries in the EU-11 economy, as well as a significant drop in the weight of some medium technology-intensive industries in the USA, accounting for the reduction in the technological gap between the EU and the USA. The authors also found that the differences in the productive structure of EU countries explain most of their differences in technological capital intensity   |
| Cincera and Veugelers (2013)     | To calculate exact size of the EU vs. US difference in R&D intensity between younger firms and older to determine if it is due to structural or intrinsic effects              | $RDI^y - RDI^o = \sum_i RDI_i (w_i^y - w_i^o) + \sum_i w_i (RDI_i^y - RDI_i^o)$ <p>RDI is the R&amp;D intensity, defined as R&amp;D investments divided by net sales. Superscripts <math>y</math> and <math>o</math> denote, respectively, <i>yollies</i> and <i>ollies</i>, subscript <math>i</math> denotes industry, <math>w_i^y</math> is the share of the sector accounted for by the total number of young firms and <math>w_i^o</math> is the share of the sector accounted for by the total number of old firms</p>   | 2008 edition of the EU Industrial R&D Investment Scoreboard. R&D intensity defined as R&D investments divided by <i>net sales</i>  | Both structural and intrinsic effects are positive, reflecting, respectively, that, compared with <i>ollies</i> , <i>yollies</i> are more present in R&D-intensive sectors and are more R&D intensive within sectors. But the structural effect is four times greater, thus confirming the importance of the sectoral structure. The smaller of young firms in the EU accounts for about one-third of the EU–US differential in R&D intensity, while 55% of the differential is because young leading innovators in the EU are less R&D intensive than their US counterparts. Further analysis shows that this is almost entirely due to a different sectoral composition |

| Author(s), year          | Objective of decomposition  | Decomposition: main equation used  | Data sources; measure of R&D and of the economy's output; year(s) of observations                                    | Main results  |
|--------------------------|---|--|--|---|
| Stancik and Biagi (2015) | To analyse R&D intensity gap decomposition on EU versus US, Japan, Asian Tigers and BRIC. | $RDI_t^A - RDI_t^B = \sum_i (RDI_{it}^A - RDI_{it}^B)w_{it}^{AB}$ $+ \sum_i w_i (w_{it}^A - w_{it}^B)RDI_{it}^A$ <p>where <math>RDI_{it}^A</math> is the R&amp;D intensity of sector <math>i</math> in year <math>t</math> in region <math>A</math> (defined as R&amp;D investment over sales) and <math>w_{it}^A</math> denotes the share of sector <math>i</math> in year <math>t</math> sales within region <math>A</math> total sales. The first term in equation represents the intrinsic effect while the second term is the structural one.</p> <p>In practice, region <math>A</math> is always the EU-22 (which is the reference region) while region <math>B</math> is either, the USA, Japan, the BRIC countries or the Asian Tigers</p> | Microdata from the EU Industrial R&D Scoreboards covering the period 2002–2010.<br>Total sales in the region/country | The EU is less R&D intensive than the USA, Japan or the Asian Tiger economies, but more R&D intensive than the BRIC countries. The former result is due to structural effects, while the latter being consequence of both higher R&D intensive activities within sectors and sectoral composition.<br>The analysis also shows that the EU is, on average, less R&D intensive than the USA (by about 2 percentage points) and that this gap has tended to increase over time |

| Author(s), year             | Objective of decomposition   | Decomposition: main equation used   | Data sources; measure of R&D and of the economy's output; year(s) of observations   | Main results   |
|-----------------------------|--|---|---|--|
| Belitz <i>et al.</i> (2015) | To analyse the difference between the private-sector R&D intensities of Germany and the OECD countries | <p>The difference in private R&amp;D intensity between two countries</p> <p><math>(FI_{DEU} - FI_{Other\ country})</math> is decomposed into two components, a structural component (<math>\Delta_{ST}</math>) and a behavioural component</p> <p><math>(\Delta_{VH}): FI_{DEU} - FI_{Other\ country} = \Delta_{ST} + \Delta_{VH}</math></p> <p>The structural component (<math>\Delta_{ST}</math>) captures the share of that difference that is attributable to differences in the relative sizes of industry sectors in the two countries. It is derived from the difference in sectoral weightings — measured here based on the relevant sector's share of value added and the R&amp;D intensity of that sector in the other country. The weighted R&amp;D intensities are aggregated across all available sectors:</p> $\Delta_{ST} = \sum_i FI_{Other\ country} (SHARE_{i\ DE} - SHARE_{i\ Other\ country})$ <p>where <math>i</math> = sector, two-digit sector code</p> <p>The behavioural component (<math>\Delta_{VH}</math>) measures the share of the total difference that is attributable to divergent R&amp;D behaviour (R&amp;D intensity) within a sector. It is derived from the sectoral difference in R&amp;D intensity between two countries, which is weighted with the relevant German sector's share of value added. The weighted sectoral differences are aggregated across all available sectors:</p> $\Delta_{VH} = \sum_i SHARE_{i\ DE} (FI_{i\ DE} - FI_{i\ Other\ country})$ <p>where <math>i</math> = sector, 2-digit sector code.</p> <p>NOTE: The decomposition technique used here is based on Ronald Oaxaca and Alan Blinder's work on wage differentials. R. Oaxaca, "Male-female wage differentials in urban labour markets," <i>International Economic Review</i> 14 (3) (1973): 693–709. A. Blinder, "Wage Discrimination: Reduced Form and Structural Estimates," <i>Journal of Human Resources</i> VII (4) (1973): 436–455.</p> | Sector-level (two-digit) data from the OECD for 2011 or 2010<br>R&D intensities measured as a ratio of R&D expenditure to value added — attributed to different patterns of investment behaviour in the relevant industries (intrinsic effect) or to different economic structures — as industry shares in total value added vary from country to country | On the whole, the structural effect and the behavioural (intrinsic) effect play more or less equally important roles in explaining the differences between Germany and other countries with regard to private-sector R&D intensity. Although Germany often suffers from the behavioural effect, it usually benefits from the structural effect. Both effects are strongly driven by a few particularly research-intensive industries |



| Author(s), year                  | Objective of decomposition  | Decomposition: main equation used  | Data sources; measure of R&D and of the economy's output; year(s) of observations   | Main results  |
|----------------------------------|---|--|---|---|
| Moncada-Paternò-Castello (2016a) | To investigate (i) whether the explanation for the lower overall corporate R&D intensity of the EU vis-à-vis the competing (and emerging) economies lie mainly in an "intrinsic" vs. a "structural" effect; (ii) how (if) R&D intensity gap and its main determinants has changed over the 2005-2013 period by world regions/countries. | $RDI_t^A - RDI_t^B = \sum_i (RDI_{it}^A - RDI_{it}^B)w_{it}^{AB} + \sum_i w_i (w_{it}^A - w_{it}^B)RDI_{it}^A$ <p>where:</p> <ul style="list-style-type: none"> <li>- X refers to one of the two samples to be compared (in our case the US the Japanese, the Switzerland's, the BRIC's, the Asian Tigers's or the Rest of the World sample)</li> <li>- Z is the other sample in the comparison (in our case, the EU sample)</li> <li>- RDI stands for R&amp;D intensity (R&amp;D/Y); the value of "Y" is the overall amount of net sales of companies operating in a given sector.</li> <li>- S is the share of the sector i in terms of net sales within a given economy (y<sub>i</sub>/Y).</li> </ul> | Micro-data from the EU Industrial R&D Investment Scoreboard - covering the years 2005-2013 - of top 1250 R&D investing companies worldwide. | <p>The results indicated that the EU R&amp;D investment gap is structural, that the EU gap has broadened in the last decade vs. the US; the gap is negative and with a quite stable evolution vs. Japan and Switzerland. Such EU gap is positive and with quite stable evolution vs. BRIC and Asian Tigers groups, while the companies from the rest of the world are sensibly narrowing their R&amp;D intensity deficit.</p> <p>The analysis also shows that sector-by-sector within the same high and medium-high intensity sectors groups, the EU firms perform often much better (in 10/14 sectors analysed) in R&amp;D intensity than the US ones.</p> <p>Finally, the study shows that there is a concentration of R&amp;D investment by countries, sectors and firms, with a fewer population of smaller EU R&amp;D investors that invest more strongly in R&amp;D vis-à-vis main benchmarking regions/countries</p> |



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