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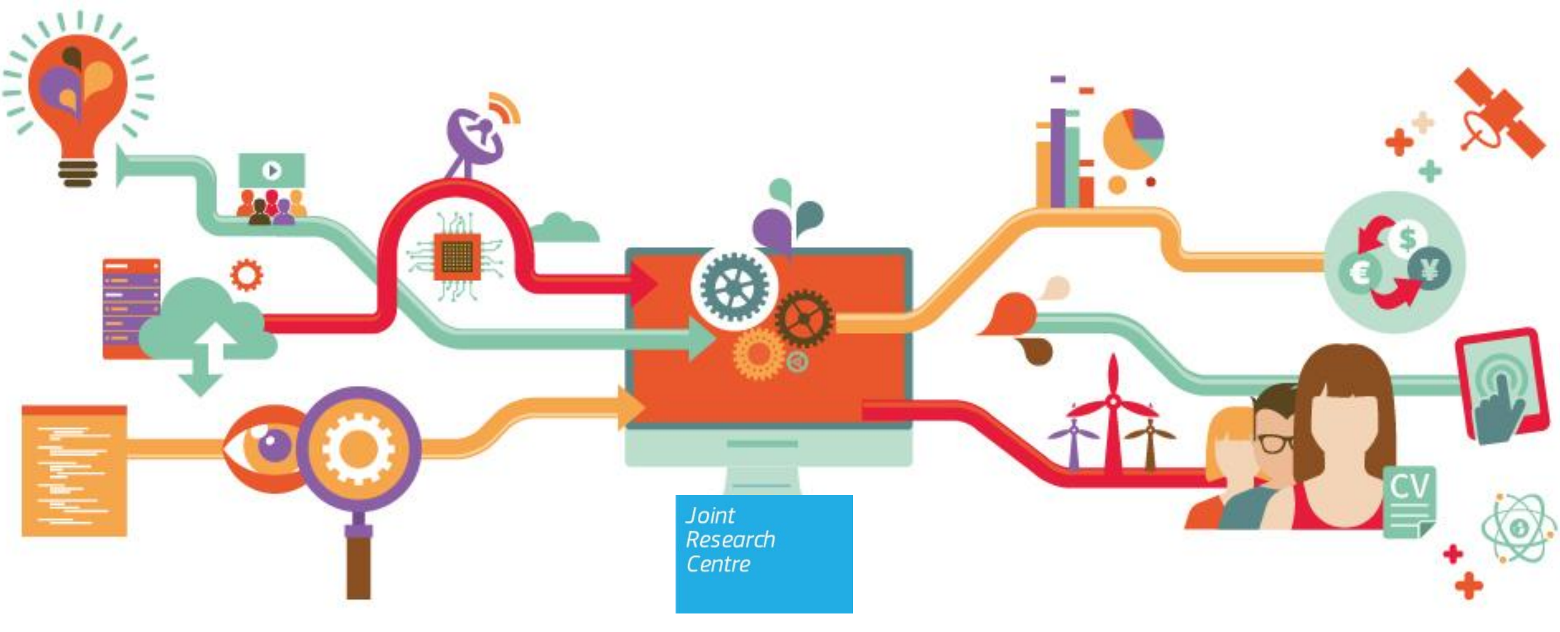

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EU corporate R&D intensity gap: What has changed over the last decade?

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Abstract

This paper contributes with new findings to the literature on corporate research and development (R&D) intensity decomposition by examining the effects of several parameters on R&D intensity and investigating its comparative distribution among top R&D firms, sectors and world regions/countries. It draws on a longitudinal company-level micro-dataset from 2005 to 2013, and uses both descriptive statistics and decomposition computation methods. The results confirm the structural nature of the EU R&D intensity gap. In the last decade the gap between the EU and the USA has widened, whereas the EU gap with Japan and Switzerland has remained relatively stable. The study also uncovers differences in R&D intensity between EU and US companies operating in the sectors more responsible for the aggregate R&D intensity gap. In contrast, the BRIC (Brazil, Russia, India and China) and Asian Tiger countries (Hong Kong, Singapore, South Korea and Taiwan) R&D intensity gap compared to the EU has remained relatively stable, while companies from the rest of the world are considerably reducing such gap. Finally, the study shows a high concentration - sustained over time - of R&D investment in a few countries, sectors and firms, but in the EU there are fewer smaller top R&D firms that invest more intensively in R&D, than in the most closed competing countries.

Keywords: Corporate R&D, decomposition, EU R&D intensity gap, EU R&D policy

JEL Classification: O30; O32; O38; O57

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1. Introduction

Europe is currently facing multiple challenges simultaneously: to resolve the economic crisis, to become more competitive and to create more and better jobs in a sustainable way. The research and development (R&D) activities of companies in the private sector are expected to be play a pivotal role in overcoming these challenges. In fact, R&D expenditure has long been of intense interest to innovation analysts, who have used it as a proxy for innovation inputs and view it as a determinant of growth, productivity and competitiveness. For this reason, R&D intensity targets are one of the main pillars of the European Union's research and innovation policy agenda, namely the Lisbon strategy of 2000 and the related Barcelona target, set in 2003, which states that the EU should spend 3 %[2] of GDP on R&D, two-thirds of which should come from the private sector. The strategy was reiterated and reinforced in the more recent Europe 2020 strategy as in the related European Union Flagship initiative (European Commission, 2010). This initiative emphasises the need to support increased private research and innovation investment and to generate positive demographics (creation and growth) of companies operating in new or knowledge-intensive industries. Such companies play an important role in shaping the dynamics of the economy's sectorial composition, favouring the transition towards a more knowledge-based economy and contributing to overall economic growth, coupled with more and better jobs (for an overview on the subject, see Sheehan and Wyckoff, 2003; Moncada-Paternò-Castello, 2010).

The literature that deals with the deficit in the EU's overall company R&D intensity compared with that of competing economies and the various factors that could explain this gap is extensive (e.g. Dosi, 1997; Pianta, 2005; Erken and van Es, 2007; Moncada-Paternò-Castello *et al.,* 2010; Cincera and Veugelers, 2013).[3] However, much of the research into the main factors that determine corporate R&D intensity seems to address just one main issue – the relative importance of the 'intrinsic' compared with the 'structural' effect[4] – and reaches differing conclusions (Moncada-Paternò-Castello, 2010, 2016a). In contrast, only a limited number of studies reported in the literature have investigated the intensity of corporate R&D by combining several parameters (Ciupagea and Moncada-Paternò-Castello, 2006; Moncada-Paternò-Castello *et al*., 2010; Reinstaller and Unterlass, 2012).

This paper seeks to add to the present literature by addressing three questions:

(i) To what extent does sector composition (the 'structural' effect) affect the aggregate EU R&D intensity gap not only in relation to the USA and Japan, but also in comparison with other competing (and emerging) economies?

(ii) Has the R&D intensity gap changed over time (2005-2013) and, if it has, how has the impact of the main factors affecting that gap changed during the time period under consideration?

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2 This target was set taking into consideration the fact that, at that time, the EU was investing only 1.9 % of its GDP in R&D, whereas Japan was investing 2.7 % of GDP and the USA 2.98 % (European Commission, 2003).

3 The first literature survey on this subject has been recently elaborated by Moncada-Paternò-Castello (2016a).

4 'Intrinsic' refers to firms' R&D intensities level across a wide range of sectors; 'structural' refers to the sector composition of a given economy.

(iii) How has the distribution of R&D investment among top R&D-investing firms and groups of sectors changed in different world regions/countries over time?

This paper uses a novel approach by (a) comparing, for the first time in the literature, micro-data from different editions of the EU Industrial R&D Investment Scoreboard to analyse how the R&D intensity gap decomposition has changed over a long time period (2005-2013) that includes the year(s) of economic and financial downturn; (b) disentangling the differences between competing countries in R&D intensities of sub-sectors (at Industry Classification Benchmark four-digit level (ICB-4)) within the same R&D intensity sector groups that are accountable for most of the R&D intensity gap; (c) comparing data from firms in the EU with data from firms not only in the USA and Japan, but also in some emerging economies such as the Asian Tiger countries (Hong Kong, Singapore, South Korea and Taiwan), Switzerland and the BRIC countries (Brazil, Russia, India and China); and (d) addressing the concentration of corporate R&D with respect to several parameters and their evolution over time.

To our knowledge, there are no studies published in peer-reviewed scientific journals that have considered these characteristics in combination in a comparative analysis.

This study relies on company data accessible from the EU Industrial R&D Investment Scoreboard (hereafter the EU R&D Scoreboard).[5] The EU R&D Scoreboard data are collected from publicly available audited annual reports and company accounts. The main variables considered are firms' R&D investment, net sales and R&D intensity by country/region, industry (sector) and group of sectors. Based on the EU R&D Scoreboard, we compiled a database of micro-data from the EU and non-EU firms that spend the most on R&D and covering the years 2005-2013.[6]

As a main research aim, this paper will identify the structural and specialisation characteristics that explain the differences in aggregate R&D intensity observed between two groups of companies: those located in the EU and those located elsewhere; furthermore, it investigate how these factors and differences have evolved over time. It will also compare the distribution of R&D investment among firms, sectors and countries, and show how this distribution has changed over a nine-year period. This will enable us to assess whether or not firms' R&D intensity growth trends are such that policy targets (such as the Barcelona target) will be met.

This paper is structured as follows. Following this introduction, a review of the literature is presented (section 2). Section 3 introduces the data and samples selected for the analysis and it reports the descriptive statistics, and section 4 gives the decomposition of corporate R&D intensity. Section 5 presents the results of the analysis of the distribution of R&D among top R&D firms, sectors and countries. Section 6 summarises the findings and offers some concluding remarks.

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[5] http://iri.jrc.ec.europa.eu/scoreboard.html

[6] Data are from three editions of the EU R&D Scoreboard survey, those published in 2006, 2010 and 2014, as well as a longitudinal balanced dataset spanning nine years (2005-2013) using company data from the EU R&D Scoreboard editions 2006-2014 to check the robustness of the main decomposition results using the three different Scoreboard editions.

2. Related literature

2.1 Importance of corporate R&D investment and differences in R&D intensity by country

Theoretical studies of corporate R&D activity as a driver for economic prosperity, and the role of technological development in economic growth (Schumpeter, 1942; Solow, 1957; Romer, 1990; Hunt, 2000), suggest that firms generally invest in R&D because provides them with an innovative rent by shifting the revenue and/or cost curve. These extra profits ensure higher overall economic growth.

Empirical evidence (e.g. Griliches, 2000; Griffith *et al*., 2004; Mohnen and Hall, 2013) broadly suggests that engaging in R&D can help firms to innovate and increase productivity, and to improve products or create new products or enter new markets that ensure competitiveness and growth, leading to both private and social benefits, thus entering into the sphere of public policy interest.

Furthermore, Hall *et al*. (2010) show that rates of return on R&D investment are likely to be in the range of 20-30 %. However, firms' returns on R&D investment in terms of innovation and competitiveness differ considerably, depending on the technology intensity of the industrial sector and the product portfolio and/or life cycle (Mairesse and Mohnen, 2005; Kumbhakar *et al*., 2012). In practice, there is an optimum level of corporate investment in R&D that very much depends on the expected returns.

Despite some fears that technological progress destroys jobs, there is firm evidence from several recent studies that, overall, this is not the case. In fact, R&D and innovation usually have a positive and significant effect on employment, and this effect is especially strong in the high-tech sector and in services, but is not significant in the traditional manufacturing sectors (Bogliacino and Pianta, 2010; Bogliacino *et al*., 2012; Harrison *et al*., 2014).

Because of this potential for private and social returns, R&D investment has become a policy target and a proxy measure that can be used to benchmark the socio-economic performance and competitiveness of an economy. In 2003, the EU set a target (to be achieved by 2010, a deadline recently extended to 2020[7]) of increasing investment in R&D from 1.9 % of GDP in 2000 to at least 3 %, of which two-thirds (2 % of GDP) is expected to be contributed by the private sector (up from 1.1 % in 2000).[8] However, more than a decade later, the situation has not improved as expected, especially in the private sector. In fact, 2013 data indicate that in EU-28 overall R&D intensity was still below 2 %, considerably behind that of South Korea, Japan, the USA and China (Table 1).

If we focus on R&D expenditure in the business enterprise sector (BERD) as a proportion of GDP**,** the result for the EU-28 in 2013 was disappointing: 1.26 %, compared with 3.09 % in South Korea, 2.60 % in Japan, 1.96 % in the USA, 2.05 % in Switzerland and 1.51 % in China. Nonetheless, in contrast to Japan and the USA, this figure did at least increase over the period 2008-2013 in the EU, although to a lesser extent than in emerging countries such as South Korea and China (with China overtaking the EU in 2013).

7 The Europe 2020 strategy sets the objective of an R&D intensity of 3 % and most Member States have adopted this figure as their target national R&D intensity by 2020.

8 For comparison, in 2000, the ratio of BERD to GDP (R&D intensity) was 1.8 in the USA and 2.2 in Japan.

Table 1. R&D intensity (as gross domestic expenditure on R&D) by economic sector in the EU-28 and competing economies in 2008 and 2013 – data as % of GDP

	Business enteprise sector		Government sector		High education sector		TOTAL R&D intensity	
	2008	*2013*	*2008*	*2013*	*2008*	*2013*	*2008*	*2013*
EU-28	1.17	1.26	0.24	0.25	0.43	0.47	1.84	1.98
United States	1.97	1.96	0.31	0.35	0.37	0.39	2.65	2.70
Japan	2.72	2.60	0.29	0.28	0.40	0.45	3.41	3.33
Switzerland	2.01	2.05	0.02	0.02	0.66	0.83	2.69	2.90
China	1.08	1.51	0.27	0.32	0.12	0.15	1.47	1.98
Russia	0.66	0.68	0.31	0.34	0.07	0.10	1.04	1.12
South Korea	2.53	3.09	0.41	0.47	0.37	0.41	3.31	3.97

Source*:* Own elaboration from European Commission, EUROSTAT (2015)[9]

The aim of this paper is not to determine the motivations and benefits of R&D investment, or if a particular private or policy target is appropriate. Rather, the scope (and related research questions) of the present investigation is to disentangle the main factors contributing to the EU R&D intensity gap, to identify the dynamics of the R&D investment (gap) over the period under study and to determine how (and to what extent) these factors affected the R&D intensity gap between 2005 and 2013. It also addresses the distribution of R&D investment across countries, sectors and firms. Linked to the focus of this research, the following sections present the theoretical and empirical literature on these specific aspects.

2.2 Structural versus intrinsic effects in R&D intensity

The theoretical foundation of corporate R&D intensity differences, which is determined by firms' own levels of R&D investment and sales (intrinsic effects), is anchored by Schumpeterian arguments that R&D expenditure very much depends on the availability of internal resources, on access to external sources and on high levels of competition regarding innovation in the product market (Aghion and Howitt, 2006).

The theoretical basis of the importance of industry composition and sector characteristics (i.e. the structural effect) in determining the aggregate corporate R&D intensity of a given economy points at the reasons why these inter-industry differences occur. For example, Pakes and Schankerman (1984), whose research is based on the theoretical work of other authors (e.g. Schumpeter, 1942; Griliches and Schmookler, 1963; Scherer, 1982), made the argument that the output of research activities (industrial knowledge) has unique economic characteristics, and they developed a theoretical model showing that R&D intensity depends on a combination of three factors: expected market size and growth in demand; appropriability differences; and technological opportunities.

Empirically, however, we identified divergent findings in the literature concerning the decomposition of the corporate R&D intensity gap between countries, which suggests that caution should be exercised when drawing general conclusions based on individual studies (Moncada-Paternò-Castello, 2010). Summarising a recent first survey of the literature in this

9 Extracted in June 2015 (http://ec.europa.eu/eurostat/statistics-explained/index.php/R_%26_D_expenditure).

field by Moncada-Paternò-Castello (2016a), it is apparent that some studies support the idea that the R&D intensity gap in the EU is mainly due to sectoral composition or 'structural effects' (e.g. Guellec and Sachwald, 2008; Mathieu and van Pottelsberghe, 2010; Moncada-Paternò-Castello *et al*., 2010), while a number of other studies indicate that the EU R&D intensity gap is mainly due to intrinsic effects (Pianta, 2005; Erken and van Es, 2007; Foster-McGregor *et al*., 2013), whilst yet other researchers have found that the R&D gap is due to a mixture of both structural and intrinsic effects (Duchêne *et al.* 2011; Reinstaller and Unterlass, 2012; Stancik and Biagi, 2015).

The review by Moncada-Paternò-Castello (2016a) concludes that the contradictory results of the decomposition of R&D intensity are mainly due to differences in the nature of the data and their comparability and discrepancies resulting from the use of different measurement instruments and indicators – as, for example, if service sectors' data together with the heterogeneity of countries and business structures are considered, rather than to differences in the calculation model/formula used (which for instance do not vary very much in the literature) This finding confirms the results of previous investigation of these aspects by Duchêne *et al*. (2010) and Lindmark *et al*. (2010).

Another stream of the literature investigates the other factors that may have an impact on R&D intensity decomposition parameters. For example, some authors argue that differences in the age, size and dynamics of new, technology-based firms play a role in the overall R&D intensity in a particular country (O'Sullivan *et al*., 2007; Ortega-Argilés and Brandsma, 2010; Cincera and Veugelers, 2013; Moncada-Paternò-Castello, 2016b). Others suggest that the underlying causes of differences in R&D intensity and its decomposition parameters reside in differences in framework conditions: entrepreneurship, intellectual property rights regimes, taxation, access to skills, social security regimes, labour and capital markets (Aghion, 2006; de Saint-Georges and van Pottelsberghe, 2013; Veugelers, 2015).

Finally, it is important to emphasise that the structural composition of the economy has an important impact on a country's overall performance in terms of corporate R&D intensity. Aggregate corporate R&D intensity performance will be lower in an economy with a relatively high proportion of low-R&D-intensity sectors than in an economy with a relatively high proportion of high-R&D-intensity sectors. However, this is not to suggest that R&D investment among firms in a country with an aggregate lower R&D intensity, whichever sector they are in, is necessarily lower than that of similar firms in a country where aggregate R&D intensity is higher.

First hypothesis (**H.1**): *Structural factors continue to play a significant role in the aggregate EU R&D intensity gap, nonetheless within a specific high-R&D-intensity sector, the R&D intensity of EU firms is similar to (or even higher than) that of firms in the EU's main competitor countries.*

2.3 Direction and magnitude of the R&D intensity gap between countries

Productivity underperformance may reflect underperformance in the creation, diffusion and utilisation of new knowledge (Guellec and Sachwald, 2008). The main theoretical argument underpinning this is that a high level of productivity releases resources that can be invested in new knowledge, thus completing the virtuous circle, so new knowledge/technology is the main determinant of productivity improvements and the driver of economic growth

(Schumpeter, 1934; Solow, 1957; Baumol, 1986; Dosi, 1988).[10] Therefore, differences in productivity levels, together with differences in the effectiveness of return on knowledge investment, may determine the differences in R&D intensities among countries. On the other hand, in the Schumpeterian (1934) view of market power and innovation, competition appears to be rather detrimental to innovation and technological progress. These theoretical frameworks could explain the slower rate of productivity and innovation growth in the EU, e.g. in comparison with the USA, coinciding with the emergence of new economies, which rely increasingly on technology and human and financial capital as a basis for competitiveness (Fagerberg *et al.,* 1999; European Commission, 2013; Rincon-Aznar *et al.*, 2014). In addition, other studies suggest that being slow to implement structural industrial change towards highly technology-intensive sectors, and failure to fully exploit the opportunities afforded by ICT opportunities, hamper productivity gains and have a detrimental effect on the R&D/innovation intensity performance of a given economy (van Ark *et al*., 2008; Cardona *et al*., 2013; Cette *et al*., 2015; Ortega-Argiles *et al*., 2015). Modern evolutionary economic theory, in fact, supports a framework of a continuous shift of resources from older to new, emerging, industries, enabled by knowledge accumulation and diffusion (resulting in new technologies, products and services), which positively influences the competiveness of the entire economy (Krüger, 2008; Dosi and Nelson, 2010; Perez, 2010).

These theoretical frameworks would support the theory that the combination of productivity deceleration and slow structural industrial dynamics, together with the rapid rise of new competitors (Chen, 2015), would result in a widening of corporate R&D intensity gaps as well as decreasing the technology export of a given economy in relation to its main direct and emerging competitors. This, in fact, is the case for the EU compared with the USA and emerging competitors, as confirmed by a group of empirical studies on the subject (Duchêne *et al*., 2011; Voigt and Moncada-Paternò-Castello, 2012; Veugelers, 2013; Chung, 2015).

Second hypothesis (**H.2**): *The R&D intensity gap between the EU and its main competitors has widened in the last nine years.*

2.4. Dispersion versus concentration of corporate R&D investment

According to Schumpeterian theory, innovative activities at sector level may be dispersed among a large number of firms that are characterised by 'creative destruction' (Schumpeter Mark I model: Malerba and Orsenigo, 1997). In this case, technological barriers to entry are low and entrepreneurs and new firms play a major role. Alternatively, innovation may be concentrated in just a few innovators that are characterised by 'creative accumulation' (Schumpeter Mark II model: Breschi *et al*., 2000). In this case, sectors are dominated by large established firms and a stable core of innovators and barriers to entry for new innovators are high. Malerba (2005) argues that a high number of technological opportunities, low appropriability, low cumulativeness (at the firm level) along with limited generic knowledge lead to a Schumpeter Mark I pattern. In contrast, high appropriability and high cumulativeness (at the firm level) along with a generic knowledge base lead to a

[10] See Grossman and Helpman (1994) for a discussion on the role of endogenous innovation in the theory of growth.

Schumpeter Mark II pattern. Therefore, we submit that those economies that comprise mainly large and established companies in more traditional sectors, and/or those with limited capacity to create firms that can enter new high-tech sectors and grow rapidly, are operating within a Schumpeter Mark II model. This is the case in the EU, as empirically supported by several studies (e.g. Bartelsman *et al.,* 2005; Stam and Wennberg, 2009; Coad and Rao, 2010) and complemented by other research showing that, globally, corporate R&D is concentrated in a small number of countries, of large companies and of high R&D intensity sectors. (Ciupagea and Moncada-Paternò-Castello 2006; Moncada-Paternò-Castello *et al*., 2010; Reinstaller and Unterlass, 2012; Hirschey *et al*., 2012; Montresor and Vezzani, 2015).

Third hypothesis (**H.3**): *Private R&D is concentrated in a few companies, sectors and countries*.

In summary, in this paper we seek to update and improve our current knowledge of the characteristics and causes of, and trends in, European corporate R&D performance compared to world competitors. We anticipate that the results of our research will support help answer the three research questions posed above.

3. Data and samples selected for the analysis

3.1 Data

Our analysis is based on data drawn from the EU R&D Scoreboard, which have been gathered annually since 2004. The EU R&D Scoreboard data are taken from publicly available audited accounts of each company's consolidated operations worldwide. The full dataset covers the years 2000-2013. The database lists the top corporate R&D investors headquartered all over the EU and R&D-investing companies headquartered outside the EU. The EU R&D Scoreboard covers about 90 % of global private R&D investment worldwide.[11] The 1 000 EU firms that invest the most in R&D together account for almost 95 % of total business expenditure on R&D in the EU.[12]

Companies in the EU R&D Scoreboard include those that are listed on a stock exchange as well as private companies and state-owned companies, but companies that are subsidiaries of another company are excluded, to avoid double counting.

In this report, data are grouped by the sector into which groups of companies are classified, following the definition of the international accounting standard Industry Classification Benchmark (ICB) at the three- or four-digit level.[13] This classification allocates a company's whole R&D investment to the country in which its registered office is located. A discussion on caveats relating to the EU R&D Scoreboard data is provided in section 3.3 and, more extensively, in the Appendix.

The data taken from the companies' published annual accounts refer to a given financial year. As accounting standards permit the financial year to differ from the calendar year, the

11 Based on European Commission (2014, p. 15, footnote 3).

12 94.7 % according to latest (2013) figures from Eurostat (€175.0bn) and the EU R&D Scoreboard (€165.8bn). The figures from the two above-mentioned statistical sources are also comparable at a global level (see Moncada-Paternò-Castello, 2016a).

13 See http://www.icbenchmark.com/.

stated years can include accounts which end on a range of dates from the second part of that year until the first part of the following year. The EU R&D Scoreboard data are nominal and expressed in euros. For companies reporting in a currency other than the euro, currency amounts have been converted to euros at the exchange rates of the latest Scoreboard, and the exchange rate conversion has also been applied to the historical data. In so doing, the EU R&D Scoreboard reports company results in the domestic currency, rather than as economic estimates of current purchasing parity; however, this has no impact on the kind of analyses and estimates upon which we are focusing (Montresor and Vezzani, 2015). Nonetheless, a dataset with deflated monetary values using 2000 as the reference year was analysed to check the robustness of the results obtained (see the Appendix for more information).

3.2 Datasets

For the analytical purposes of this paper, two datasets from the same data source have been used.

The first comprises data from three editions of the EU R&D Scoreboard, i.e. collected in three different years: the 2006 and 2010 editions include data on 2 000 companies and the 2014 edition includes data on 2 500 companies.[14] It is worth noting that the EU and non-EU lists differ in the minimum R&D investment threshold needed to enter the rankings. Furthermore, these three editions do not contain exactly the same number of companies because of company dynamics (entry and exit behaviour to and from the ranking of top private R&D investors and mergers and acquisitions).

Therefore, in order to construct comparable sub-samples of companies from each country/region, we reduced the complete set of companies for each of the three EU R&D Scoreboard editions to approximately 1 250. In this way we could ensure that we could include a sufficient number of firms from each of the countries/regions we wanted to analyse (especially to capture firms from the BRIC and the Asian Tiger countries) and that the samples were representative and with comparable R&D investment (see Moncada-Paternò-Castello *et al.*, 2010). This approach resulted in the following sub-samples: in 2005, 1 247 companies with a minimum total R&D investment of €27.98m; in 2009, 1 247 companies with a minimum total R&D investment of €34.70m; and, in 2013, 1 242 companies with a minimum total R&D investment of €46.70m. All of the firms are among the top 1 250 R&D investors worldwide and all provided data for both R&D expenditure and net sales. These firms account for 98 %, 97 % and 94 % of total R&D expenditure by the complete EU R&D Scoreboard sample in 2005, 2009 and 2013, respectively. Although the samples do not contain exactly the same firms, the comparative analysis of these three datasets allows us to investigate exactly how the factors determining R&D intensity in a comparable sample of top R&D investors have changed over time. The absolute values of monetary data in the three different editions of the EU R&D Scoreboards datasets are not adjusted for inflation. In fact, there is no real need to deflate values as what we present are the ratios (basically R&D/net sales) of three different EU R&D Scoreboard editions that also differ, for instance, in the composition of included firms. Furthermore, although the values

[14] The original full sample comprised, for 2005, data from 2 000 companies with total R&D expenditure of €371bn and net sales of €11 073bn; for 2009, data from 2 000 companies with total R&D expenditure of €402bn and net sales of €12 574bn; and, for 2013, data from 2 500 companies with total R&D expenditure of €540bn and net sales of €16 723bn.

and sector composition of net sales of these companies are not perfectly representative of their economies, they are certainly representative of the sectors where these top global R&D-investing firms operate.

To check the robustness of the results of the analysis of the above-mentioned three different editions of the EU R&D Scoreboard, a second dataset with deflated monetary values was built and used. This is a longitudinal balanced dataset of nine years (2005-2013) corresponding to 1 859 enterprises worldwide taken from several editions of the EU R&D Scoreboard (see the Appendix for further details).

3.3 Main variables and caveat

The main variables considered for the analysis are the company's (R&D) investment, net sale, and sector classification at ICB three- or four-digit level. The ICB sectors have been grouped according to R&D intensity of the sector worldwide following the European Commission (2006-2014) and OECD (1997) approach: high R&D intensity; medium-high R&D intensity; medium-low R&D intensity; low R&D intensity (see the Appendix for further specifications).

Although, in theory, the R&D investment behaviour of top R&D firms could diverge in some respects from total world R&D investment, the differences are unlikely to be substantial considering that such Scoreboard captures almost all global R&D investment by firms.

When using these EU R&D Scoreboard data, a number of factors that potentially affect the interpretation of the figures should be taken into account. In particular, the following should be borne in mind. The original EU R&D Scoreboard figures are nominal and expressed in euros, and deflating the monetary data of these datasets could have some drawbacks. Growth in corporate R&D investment can be organic or due to acquisitions, or a combination of the two. The terms 'EU company', 'US company', 'Japanese company', etc. are used throughout this paper to refer to a company whose ultimate parent company has its registered office in that country or region. Therefore, the EU R&D Scoreboard is a rich and accurate information source about a company's financial effort, but is less accurate when analysing a country's business R&D expenditure (BERD – statistics collected by national statistical offices), although the EU R&D Scoreboard shows similar results at global or a EU level (Moncada-Paternò-Castello, 2016a).

Furthermore, it is very likely that the some top R&D-investing located in some countries or regions are omitted from the EU R&D Scoreboards, for example some companies in the Asian Tiger and BRIC countries and in some of the countries in the Rest of the World (RoW) group. The reasons are mostly historical as public disclosure of companies' data was not always mandatory, especially for companies not listed on the stock markets (e.g. Chinese firms before the privatisation wave of late 2000), and some countries were slow to adopt International Financial Reporting Standards (IFRS) (European Commission, 2014). Unsurprisingly, therefore, this deficiency is more marked in the earliest editions of the EU R&D Scoreboards. More detailed information on the main variables considered for the analysis as well as caveats about the EU R&D Scoreboard data are reported in the Appendix.

3.4 Descriptive statistics

Table 2 reports R&D investment and net sales as a proportion of total R&D investment by EU R&D Scoreboard for each of the years of observation, by sector group and by country.

Table 2. Country R&D investment and net sales by R&D intensity sector[15] as share of total R&D investment by EU R&D Scoreboard firms in 2005, 2009 and 2013

	EU	USA	Japan	Asian Tigers	BRIC	Switzerland	RoW
R&D 2005							
	(*n* = 319)	(*n* = 539)	(*n* = 227)	(*n* = 66)	(*n* = 12)	(*n* = 34)	(*n* = 50)
High	35.3 %	67.5 %	40.3 %	19.9 %	20.9 %	68.4 %	54.8 %
Medium-high	51.2 %	28.7 %	50.2 %	70.9 %	8.6 %	23.8 %	28.0 %
Medium-low	6.3 %	2.3 %	5.5 %	1.2 %	0.0 %	7.8 %	5.3 %
Low	7.2 %	1.4 %	4.0 %	8.0 %	70.5 %	0.0 %	11.9 %
Grand total	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
R&D 2009							
	EU (*n* = 349)	USA (*n* = 447)	Japan (*n* = 238)	Asian Tigers (*n* = 76)	BRIC (*n* = 44)	Switzerland (*n* = 35)	RoW (*n* = 58)
High	34.9 %	69.0 %	38.0 %	26.3 %	33.9 %	68.5 %	49.4 %
Medium-high	48.2 %	25.0 %	52.7 %	62.9 %	16.0 %	21.3 %	15.9 %
Medium-low	7.1 %	4.5 %	4.5 %	3.2 %	0.6 %	10.2 %	15.8 %
Low	9.7 %	1.5 %	4.8 %	7.6 %	49.5 %	0.0 %	18.9 %
Grand total	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
R&D 2013							
	EU (*n* = 354)	USA (*n* = 409)	Japan (*n* = 205)	Asian Tigers (*n* = 77)	BRIC (*n* = 81)	Switzerland (*n* = 38)	RoW (*n* = 78)
High	32.4 %	70.9 %	32.4 %	33.9 %	27.4 %	69.8 %	53.6 %
Medium-high	51.9 %	23.8 %	60.5 %	58.5 %	29.5 %	21.9 %	28.6 %
Medium-low	5.6 %	4.0 %	4.1 %	2.9 %	2.0 %	8.0 %	1.0 %
Low	10.1 %	1.3 %	3.0 %	4.7 %	41.1 %	0.3 %	16.9 %
Grand total	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
Net sales 2005							
	EU (*n* = 319)	USA (*n* = 539)	Japan (*n* = 227)	Asian Tigers (*n* = 66)	BRIC (*n* = 12)	Switzerland (*n* = 34)	RoW (*n* = 50)
High	8.4 %	26.9 %	24.8 %	17.4 %	1.7 %	30.3 %	10.9 %
Medium-high	33.9 %	41.2 %	47.5 %	58.4 %	2.9 %	35.5 %	41.5 %
Medium-low	11.6 %	7.0 %	10.4 %	4.4 %	0.0 %	34.2 %	4.9 %
Low	46.1 %	24.8 %	17.3 %	19.8 %	95.3 %	0.0 %	42.7 %
Grand total	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
Net sales 2009							
	EU (*n* = 349)	USA (*n* = 447)	Japan (*n* = 238)	Asian Tigers (*n* = 76)	BRIC (*n* = 44)	Switzerland (*n* = 35)	RoW (*n* = 58)
High	8.0 %	29.2 %	19.1 %	18.6 %	4.3 %	27.2 %	14.8 %
Medium-high	30.5 %	37.0 %	47.9 %	59.2 %	11.3 %	36.9 %	31.9 %
medium-low	12.8 %	12.4 %	9.1 %	3.4 %	3.0 %	35.9 %	10.6 %
Low	48.7 %	21.5 %	24.0 %	18.9 %	81.4 %	0.0 %	42.7 %
Grand total	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
Net sales 2013							
	EU (*n* = 354)	USA (*n* = 409)	Japan (*n* = 205)	Asian Tigers (*n* = 77)	BRIC (*n* = 81)	Switzerland (*n* = 38)	RoW (*n* = 78)
High	7.9 %	35.7 %	14.3 %	21.3 %	5.3 %	27.3 %	17.1 %
Medium-high	34.4 %	36.3 %	60.3 %	48.8 %	17.7 %	34.7 %	30.5 %
Medium-low	11.2 %	12.2 %	7.1 %	13.4 %	2.0 %	33.1 %	2.2 %
Low	46.6 %	15.7 %	18.3 %	16.5 %	75.0 %	4.8 %	50.2 %
Grand total	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %

Note: Numbers adjacent to the names of countries are the number of companies included in the calculations. Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2006-2014).

In the Appendix, Tables A-1 to A-3 provide more detailed descriptive statistics at four-digit ICB sector level.

[15] Defined as specified in section 3.3 and in the Appendix (Box 1).

The sectorial composition of the countries/regions analysed by sectors' groups is illustrated in Figures 1 and 2, in terms of R&D investment and net sales, the two elements that make up R&D intensity. The two figures show considerable differences in both R&D investment and net sales between sector groups (Figure 1) and countries/regions (Figure 2).

Figure 1 shows that, overall, growth in R&D investment and net sales has been readily stable in the EU sample and irregular in the USA and Japan and that these two countries seem to have suffered the effects of the economic and financial crisis (the USA in 2009 and Japan after 2009).

In terms of growth trends in the groups of sectors within this triad, i.e. the EU, the USA and Japan, the following can be noted. First over the period 2005-2013, US companies in the high-R&D intensity sectors' group increased their lead over other regions in both R&D investment and net sales: in this sectors' group, both R&D investment and net sales were considerably higher in 2013 than 2005 and 2009. Secondly, among EU companies, the sector group that accounted for the greatest proportion of R&D investment over the period of the study was the medium-high R&D intensity sectors' group, and investment in this sector group increased from 2005 to 2009 and from 2009 to 2013. In contrast, however, in the EU sample, the greatest proportion of net sales is accounted for by companies operating in the low-R&D intensity sectors. Finally, the pattern among Japanese companies is similar to that of EU companies, except that the medium-high R&D intensity sectors' group accounted for the highest proportion of both R&D investment and net sales.

Overall, the *structure* of the economic sectors in which top EU R&D investors operate has moved towards higher R&D intensity sectors hardly at all in the three years of observation. In contrast, the size of low-R&D intensity sectors has increased considerably. This dynamic is radically different in the USA, where both R&D investment and net sales have moved towards more high-R&D intensity sectors of the economy.

Figure 2 shows R&D investment and net sales by sector of companies in the Asian Tiger countries, the BRIC countries, Switzerland and the RoW. Generally, there has been a considerable increase in R&D investment, especially in the high- and medium-high R&D intensity sectors, over the three years considered. In, Switzerland the majority of companies' R&D in investment has been the high-R&D intensity sectors. However, total net sales in Switzerland are the lowest among the countries/regions analysed. The largest R&D investment in mid-high tech sectors is made by companies from the Asian Tiger countries, and this increased considerably over the years, as did R&D investment in high-R&D intensity sectors.

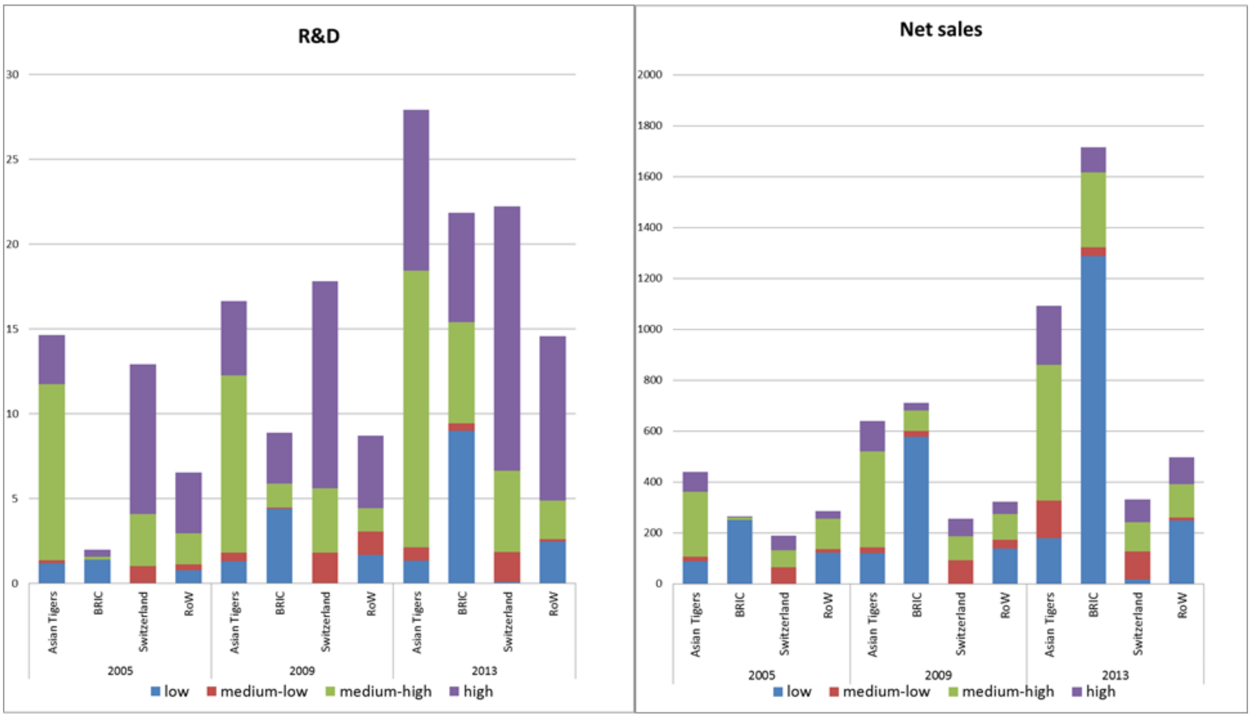
Analysis of the top world R&D-investing companies by sector reveals that in 2013 the EU accounted for the highest proportion of R&D investment in the aerospace and defence sector (6.2 %). In the automobiles and parts sector, the EU, which was previously the leading region, was in second place, with 26.8 % R&D investment, following Japan (28.9 %).

US firms led in the software sector (11.6 %) and Switzerland in pharmaceuticals (66.1 %) and chemicals (7.7 %). Asian Tiger companies accounted for the highest proportion of R&D investment in the semiconductors (14.4 %) and electronic equipment sectors (45.5 %) while companies from the BRIC countries accounted for the highest proportion of R&D investment in telecommunications equipment (21.4 %), gas and oil products (18.4 %), and construction and materials (15.9 %).

Figure 1. R&D investment and net sales in selected years in the EU, the USA and Japan, by sector group[16] (€ millions)

Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2006-2014).

Figure 2. R&D investment and net sales in selected years in the Asian Tiger countries, the BRIC countries, Switzerland and the Rest of the World, by sector group[15] (€ millions)



Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2006-2014).

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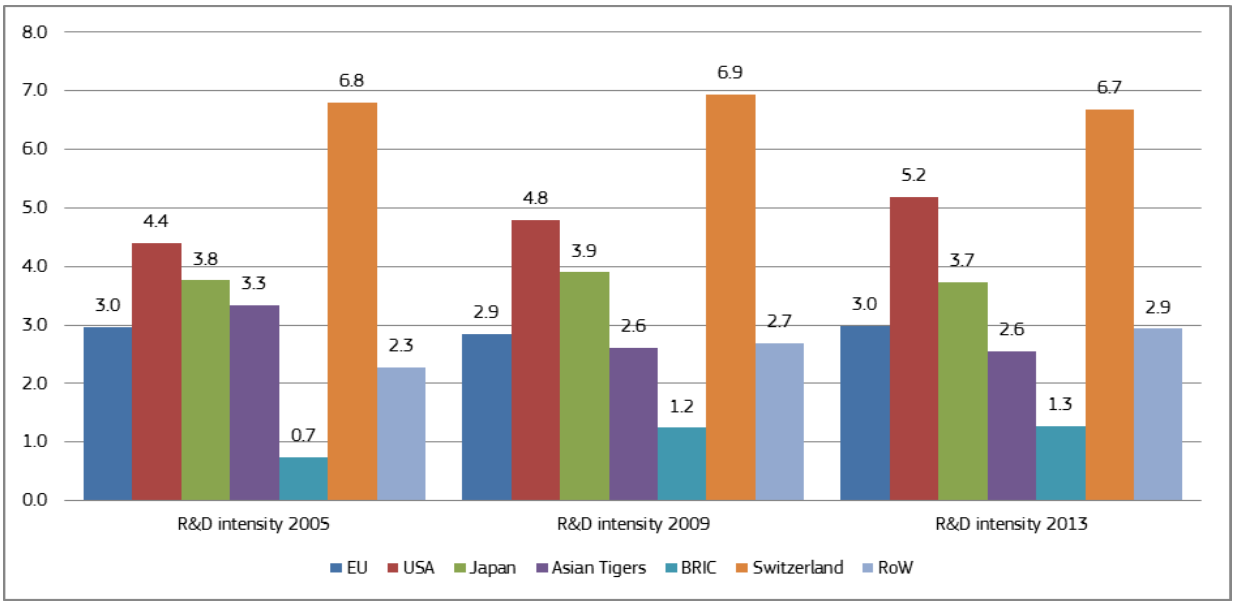
16 Includes only companies in the top 1 250 R&D investors worldwide in terms of R&D investment and net sales (see Table 3 for details).

More information on the shares of R&D expenditure and net sales by sub-sector (four-digit ICB sectors) in the EU R&D Scoreboard can be found in the Appendix (Tables A-1, A-2 and A-3), where it can be appreciated that the global R&D investment (and net sales) is concentrated in ICT-related sectors, in the pharmaceuticals and biotechnology sectors, and in the automobiles and parts sectors.

These data provide evidence of the large difference in net sales between the EU and the USA in the high-R&D intensity sectors, the latter, in 2013, achieving 2.5 times more net sales than the former. This means that, among the total sample of the top 1 250 R&D-investing companies worldwide, US companies are much more represented in high- R&D intensity sectors than EU companies. On the other hand, these figures also indicate that EU companies account for a higher proportion of net sales in the lower R&D intensity (medium- and low-R&D intensity sectors groups) than companies from any other countries/regions.

Figure 3. R&D intensity (R&D/net sales) in selected years by group of countries



Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2006, 2010, 2014).

Therefore, the majority (by net sales) of EU companies in the EU R&D Scoreboard operate in lower-tech sector groups, and this has consequences for total R&D intensity, which is, as a result, greatly influenced by the (lower) level of R&D intensity of the sectors to which these companies belong. This means that the R&D intensity of US firms is generally higher than that of EU companies, as can be seen in Figure 3. This figure also shows that in the EU, Japan and Switzerland R&D intensities remained fairly stable in the three years of observation and in the USA increased by 0.4 points.

4. Decomposition of corporate R&D intensity

4.1 Methodological approach

The descriptive analysis in section 3 seems to suggest that the gap in R&D intensity between the EU and its main competitors, especially the USA, is mainly due to the sectorial composition of the economy rather than a lower level of firms' R&D intensity (i.e. intrinsic effects). The decomposition analysis allows the calculation of the exact size of both effects.

To calculate the relative contributions of each of the two effects to the total difference in R&D intensity between economies, we have followed the decomposition approach of Haveman and Donselaar (2008), Erken and van Es (2007), Lindmark *et al*. (2010) and Le Ru (2012). The approach adopted in this study is also similar to those of van Reenen (1997a, b) and Sandven and Smith (1998), but uses, as a measure of output in a given economy, the share of industry (proxied by net sales - as in Cincera and Veugelers, 2013 -), rather than value added.[17] The approach is the same as that used by Moncada-Paternò-Castello *et al*. (2010)[18]:

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

where:

- X is the first sample (in our case the USA, Japan, Switzerland, the BRIC countries, the Asian Tigers countries or the RoW);
- Z is the second sample (in our case, the EU sample);
- RDI stands for R&D intensity (R&D/*Y*), where *Y* is the overall amount of net sales of companies from all sectors ($\sum y_i$) operating in a given economy; and
- S is the share of the sector *i* in terms of net sales within a given economy (y_i/Y).

Therefore, the aggregate difference in R&D intensity between two economies is equal to the sum of the differences in R&D intensity for all sectors over the period, weighted by their average share of net sales over the same period (intrinsic effect), plus the sum of the differences in output shares of net sales, weighted by their average intensities (structural effect). Therefore, if the share of the R&D-intensive industries within the overall economy of country X is larger than in country Z, the sectorial composition effect is positive for country X and negative for country Z.

4.2 Applying the decomposition to data of three separate EU R&D Scoreboard editions

We applied the R&D intensity decomposition calculations to data from three EU R&D Scoreboard editions, collected in 2006, 2010 and 2014 (1 247 for the year 2005, 1 247 for 2009 and 1 242 for 2013), all of them in the top 1 250 R&D investors worldwide and all providing both R&D and net sales data, as described earlier in section 3.2. It is worth mentioning that each of these three Scoreboards contains a slightly different set of companies as countries enter and exit the ranking of top R&D investors. It therefore

17 This measure of R&D intensity is not intended to be a substitute for R&D to GDP ratio. In fact, the corporate R&D investment to net sales ratio can be a useful complement, improving the overall picture of the private sector's R&D intensity.

18 In the R&D intensity decomposition literature, most authors use similar formulas, while a few authors use different ones. For a review of these formulas, see Moncada-Paternò-Castello (2016a) and, in particular, Appendix A1, p. 33, which includes a table summarising a survey of R&D intensity decomposition formulas.

provides accurate information in particular when studying the evolution of structural effects on corporate R&D intensities.

The results of the decomposition using the EU sample for comparison are shown in Table 3 below and can be summarised as follows.

Table 3. Decomposition of R&D intensities in selected countries/regions using the EU sample for comparison (2005, 2009 and 2013)

		No of companies	**Overall**	Structural	Intrinsic
USA	2005	539	**1.434**	1.832	−0.398
	2009	447	**1.944**	2.666	−0.721
	2013	409	**2.197**	2.917	−0.720
Japan	2005	227	**0.799**	1.163	−0.364
	2009	238	**1.048**	1.579	−0.532
	2013	205	**0.745**	1.286	−0.541
Asian Tigers	2005	66	**0.376**	1.857	−1.481
	2009	76	**−0.245**	3.317	−3.562
	2013	77	**−0.434**	2.743	−3.177
BRIC	2005	12	**−2.220**	−2.286	0.065
	2009	44	**−1.605**	−1.336	−0.269
	2013	81	**−1.714**	−1.106	−0.607
Switzerland	2005	34	**3.840**	3.313	0.527
	2009	35	**4.094**	3.210	0.884
	2013	38	**3.694**	2.502	1.193
RoW	2005	50	**−0.682**	0.176	−0.857
	2009	58	**−0.157**	0.850	−1.007
	2013	78	**−0.053**	0.892	−0.945
Note: number of EU companies: 2005 = 319; 2009 = 349; 2013 = 354					

First, in terms of R&D intensity, EU companies lag behind US, Japanese and, especially, Swiss companies. What is more, the R&D investment gap between the EU and the USA has widened over the period under study, whereas the gap between the EU and Japan and Switzerland has remained stable. In contrast, the R&D investment gap between the EU and the BRIC and Asian Tiger countries is positive, and has remained fairly stable over the three years under examination. However, the EU shows only slightly higher aggregate R&D intensity than countries in the RoW group, and this advantage has clearly reduced during the years of observation.

Secondly, the decomposition figures confirm that the EU presents a negative structural effect compared with all other countries except the BRIC countries. In particular, we observe that the structural gap of the EU in comparison with the USA is, in practice, entirely and increasingly due to the structural effect.

The third, and perhaps most interesting, result of this decomposition computation is the finding that, in terms of intrinsic R&D investment, the EU consistently outperforms all of its competitor economies, except Switzerland, and that intrinsic R&D intensity in fact increases over the period, especially compared with firms from the USA, Japan and the BRIC countries.

However, in the EU, the negative structural effect counteracts the positive effect of corporate R&D investment efforts (intrinsic effect) to a greater extent in any of the regions/countries under examination, except Switzerland.

To check the robustness of the results obtained by the analysis of the three different editions of the EU R&D Scoreboard (2006, 2010 and 2014), a second longitudinal dataset – with monetary data inflation adjusted – was built and used. Overall, the decomposition, when applied to the two datasets, yields very similar outputs, especially with regard to the triad. The Appendix reports the results obtained (Table A-8) and provides further information about the methodological approach.

Table 4 shows the sectors (four-digit ICB code) within the high and medium-high intensity sector groups that contribute most to the positive 'intrinsic effects' of the EU relative to the closest competing economy, the USA. This table reports differences in R&D intensity performance between the EU and the USA as ratios: values > 1 mean that R&D intensity is higher in the EU than in the USA; a value of 2 means that R&D intensity in the EU is twice that in the USA, while a value of 0.5 means the opposite, i.e. R&D intensity in the USA is twice that in the EU. The average absolute values for the EU and the USA are reported in Table A-5 in the Appendix.

Table 4 suggests a positive trend in R&D intensity over the period 2005-2013 among EU firms in some sectors, especially the health care, automobiles and parts, electronics and general industrials sectors, but a negative trend in some other sectors, particularly chemicals and industrial machinery.

Table 4. EU to US ratio of average R&D intensity by sectors (ICB-4) within high and medium-high R&D-intensity-sector groups in 2005, 2009 and 2013

	R&D Intensity			R&D investment			net sales (size)		
Sector (ICB-4)	**2005**	**2009**	**2013**	2005	2009	2013	2005	2009	2013
Pharmaceuticals	**1.036**	**0.995**	**0.960**	0.810	0.732	0.715	0.781	0.735	0.745
Software	**0.852**	**0.983**	**1.047**	0.906	0.679	0.736	1.063	0.691	0.703
Health care equipment and services	**0.610**	**0.609**	**1.179**	0.682	0.816	0.711	1.117	1.339	0.603
Biotechnology	**0.634**	**0.736**	**0.573**	0.361	0.431	0.273	0.570	0.585	0.477
Telecommunications equipment	**1.090**	**0.880**	**1.020**	2.833	3.384	2.025	2.600	3.846	1.985
Semiconductors	**1.120**	**1.135**	**0.964**	1.574	1.926	0.928	1.405	1.696	0.962
Aerospace and defence	**2.813**	**1.968**	**1.778**	1.883	1.462	1.296	0.669	0.743	0.729
Automobiles and parts	**1.207**	**1.366**	**1.458**	1.064	2.019	2.089	0.882	1.478	1.433
Chemicals	**1.420**	**1.198**	**0.569**	1.971	2.048	1.119	1.388	1.709	1.964
Commercial vehicles and trucks	**1.606**	**1.434**	**1.593**	1.099	1.253	1.830	0.684	0.873	1.149
Electronic equipment	**0.913**	**0.808**	**1.841**	0.730	0.737	0.558	0.800	0.912	0.303
General industrials	**1.281**	**1.207**	**1.828**	0.230	0.244	0.415	0.179	0.202	0.227
Household goods and home construction	**0.720**	**1.017**	**1.068**	0.501	0.641	0.866	0.695	0.630	0.811
Industrial machinery	**2.100**	**1.074**	**1.381**	1.365	1.453	1.078	0.650	1.353	0.780
Other sectors [of the full samples]	0.613	0.534	0.435	0.934	0.829	0.705	1.524	1.552	1.621
Total [all sectors of full samples]	0.674	0.595	0.576	1.198	1.142	0.978	1.777	1.920	1.697

Note: Only sectors containing at least five firms and accounting for at least 10 % of the overall R&D expenditure in the EU and the USA over the three years are included in the calculation.

The data in Table 4 also show that overall R&D intensity was greater in the EU than in the USA (i.e. a ratio greater than 1) in 10 out of 14 sectors in 2013, for example in the software and electronic equipment sector, and in some other sectors, for example the general industrials sector, the EU outperformed in all three years although US companies have a much larger share of the market in terms of net sales. In contrast, the biotechnology sector performed much better in the USA than the EU on all parameters and all years under examination, while the opposite is true of the automobiles and parts sector.

Although overall R&D intensity is greater in the EU than in the USA in most of the sectors represented in Table 4, the last row shows that the overall balance is in favour of the USA. Again, this is mostly because there are fewer larger companies operating in high-R&D-intensity sectors in the EU than in the USA.

5. Distribution of R&D across firms, sectors and countries

This section aims to investigate the comparative distribution of R&D investment among the firms in the sample by three main variables[19]: the size of a firm's R&D investment, the sector of activity and the country/world region.

The distribution of R&D intensity by company's R&D size (i.e. the cumulative average R&D intensity) is calculated by summing the R&D investment from the largest to the smallest R&D investors in each country/region and dividing it by the sums of sales. The results are shown in Figure 3,[20] in which the horizontal axes show ranking by R&D investment of the companies in each country (or world region), and the vertical axes show average R&D intensity. Figure 3 shows that the cumulative corporate R&D intensity is asymmetrically distributed, with a significant difference in the degree of concentration between the USA, Japan, the EU and the rest of the countries/regions examined. This suggests that differences in overall R&D intensities also reflect business R&D demographics, i.e. the size of R&D investment by companies. That is, the very big R&D investors are more R&D-intensive than the smaller ones. In the case of the highest ranking companies (the ~10 largest R&D investors in each country) R&D intensity by US firms outperform all firms from its competing economies. In addition, as we move down the rankings, we find a larger group of smaller (by R&D investment) US companies investing more strongly in R&D (by R&D intensity), and in a more consistent way than EU companies, thus raising the overall R&D performance of US companies.

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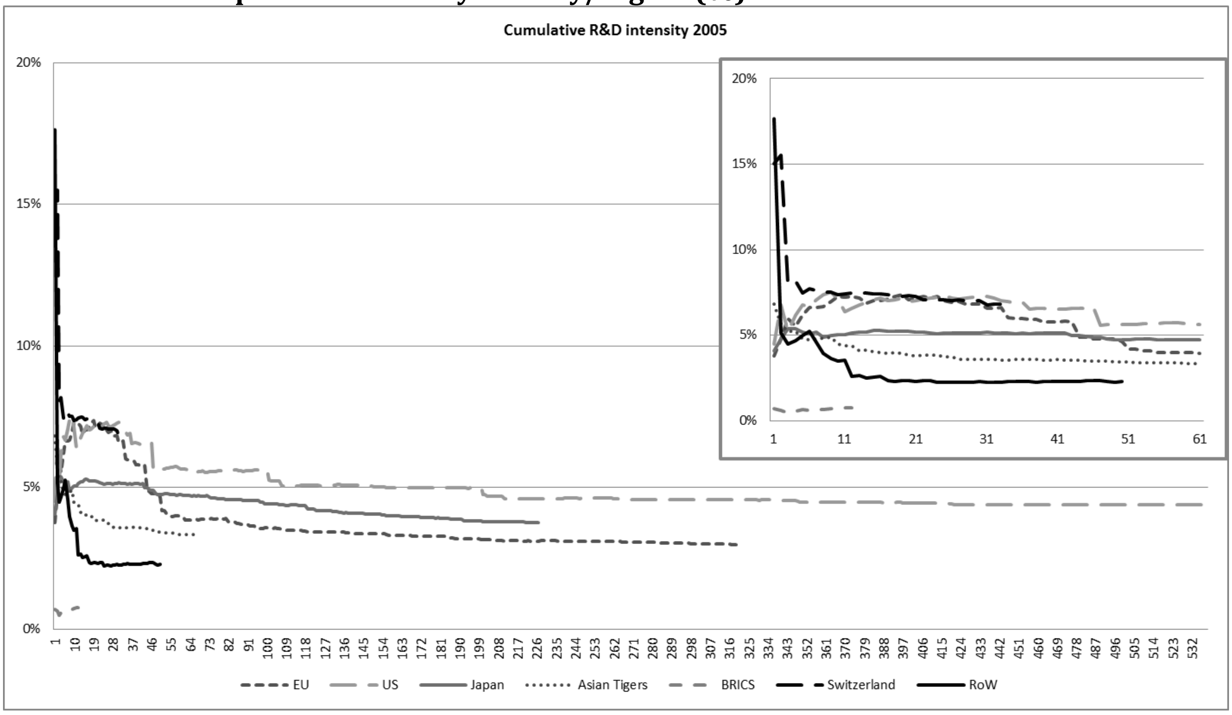
[19] We acknowledge that firm age is another interesting variable affecting R&D concentration. For the related arguments and results, see García-Quevedo *et al.* (2014) and Moncada-Paternò-Castello (2016b).

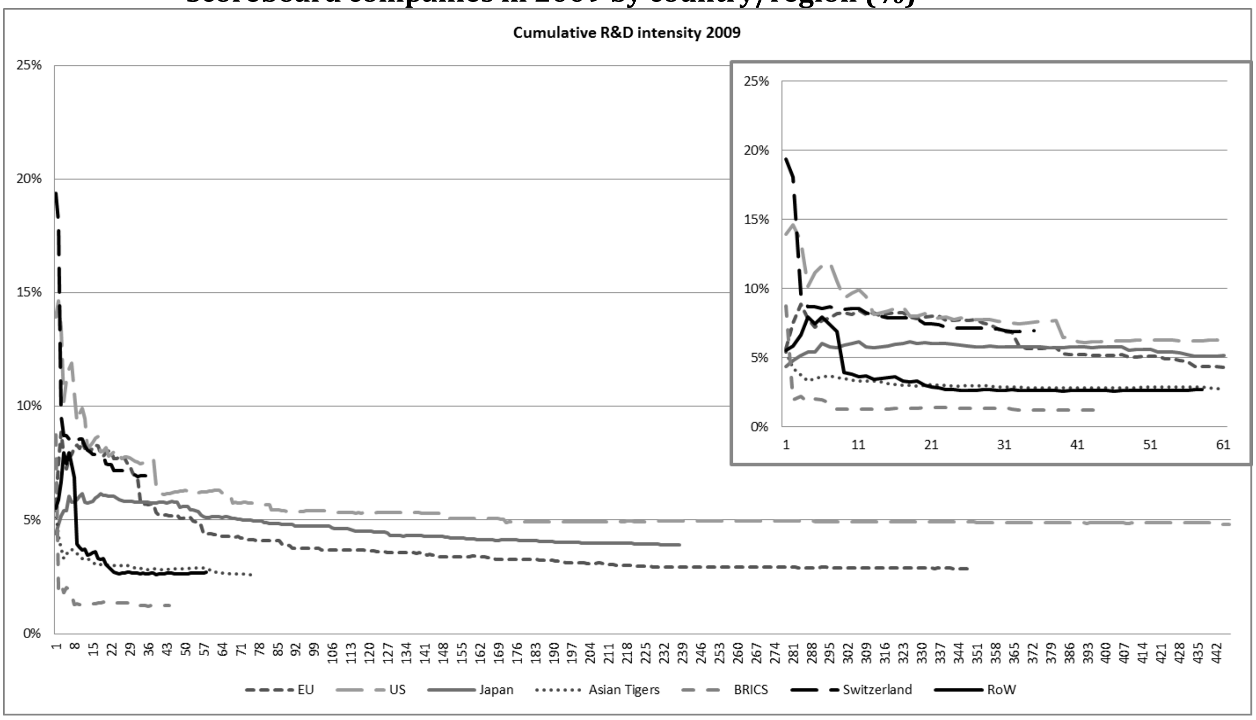
[20] In 2005, as the sample analysed includes only 12 BRIC companies, the graph for BRIC companies stops at 12 on the horizontal axis, while it goes up to 34 for the set of companies from Switzerland, 50 for the RoW, 66 for the Asian Tigers, 227 for Japan, 319 for the EU and 539 for the USA. In 2009, as the sample analysed includes only 44 BRIC companies, the graph for BRIC companies stops at 44 on the horizontal axis, while it goes up to 35 for the set of companies from Switzerland, 58 for the RoW, 76 for the Asian Tigers, 238 for Japan, 349 for the EU and 477 for the USA. In 2013, as the sample analysed includes only 38 companies from Switzerland, the graph for Switzerland companies stops at 38 on the horizontal axis, while it goes up to 77 for the set of companies from the Asian Tigers, 78 for the RoW, 81 for the BRIC countries, for 205 for Japan, 354 for the EU and 409 for the USA.

Figure 3(a). Cumulative average R&D intensity[21] of the samples of EU R&D Scoreboard companies in 2005 by country/region (%)



Note: The value on the *y*-axis is the cumulative R&D intensity; the value on the *x*-axis is the firm's rank according to its R&D investment; more details are given in footnote 19.
Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2006).

Figure 3(b). Cumulative average R&D intensity of the examined samples of EU R&D Scoreboard companies in 2009 by country/region (%)



Note: The value on the *y*-axis is the cumulative R&D intensity; the value on the *x*-axis is the firm's rank according to its R&D investment; more details are given in footnote 19.
Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2010).

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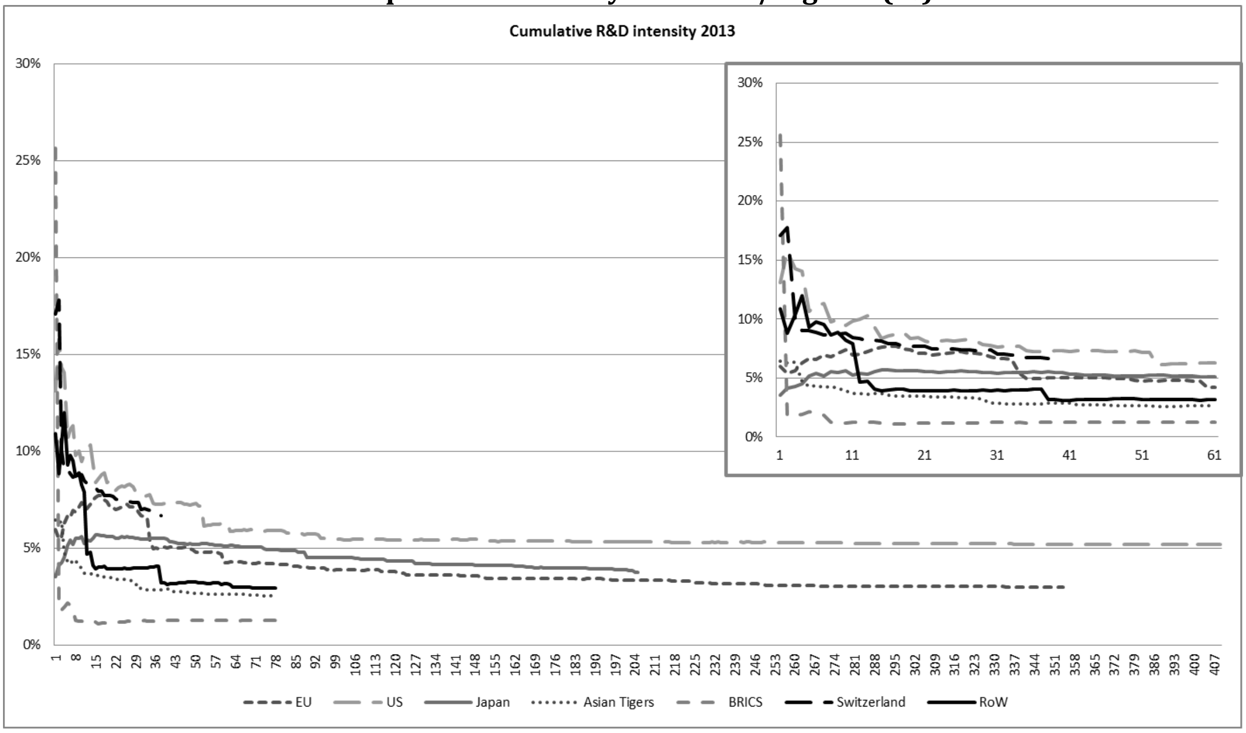
21 Calculated by summing the R&D investment from the largest to the smallest R&D investors in each of the countries and dividing by the cumulative sales. I.e.: the figure plots the weighted average of cumulative R&D intensity for each of the firms by their ranking position of R&D investment in the respective country.

Figure 3(c). Cumulative average R&D intensity of the examined samples of EU R&D Scoreboard companies in 2013 by countries/regions (%)



Note: The value on the y-axis is the cumulative R&D intensity; the value of the x-axis is the firm's rank according to its R&D investment; more details are given in footnote 19.
Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2014).

A comparison of the graphs for 2005, 2009 and 2013 (Figure 3) reveals three general points of interest. The first is that the top 40 R&D investors account for the highest cumulative average R&D intensity. Secondly, the cumulative average R&D intensity of US companies increased in 2013 relative to 2005 and 2009, especially in companies in the top 40 rankings, but also in each of the companies in the ranking from about the 110th place down. In contrast, EU companies in 2013 showed roughly the same behaviour in 2005, resulting in a greater difference in cumulative average R&D intensity between these two years in favour of US companies. Thirdly, in 2013, BRIC companies – with a greater representation than in 2005 – show the lowest cumulated average R&D intensity. Furthermore, moving down the rankings (by R&D investment), companies from the Asian Tiger countries invested more strongly in R&D (by cumulated average R&D intensity) in 2005 than in 2013.

More specifically, the cumulative R&D intensity of EU and US companies drops sharply at particular points as a result of the inclusion in the sample of several large companies with very low R&D intensity both in 2005 and in 2013: for example, cumulative average R&D intensity in the EU falls sharply before the 42nd company in 2005 and the 45th company in 2013 and in the USA before the 35th company in 2005 and the 55th company in 2013 before plateauing.

In 2005, among the 25 largest private R&D investors (from a total of 35 companies) in Switzerland cumulative R&D intensity is higher than in companies from other countries/regions of the same rank, except for one company from the RoW group. However, only the two largest companies from Switzerland among the 38 in the ranking repeat this performance in 2013.

In 2013, the gap in R&D intensity between EU and US companies was narrower only in the case of companies ranked 16 to 35, and it was much wider both above and below these ranks; in 2005, the gap in R&D intensity was narrower only in the case of first 40 companies in each set, after which it widened. In 2013, the top 33 EU companies in terms of R&D investment had a higher cumulative average R&D intensity than the equivalent Japanese companies (this figure was 43 in 2005).

Figure 3 is very telling in two aspects.

First, over the period the curve becomes increasingly skewed towards the origin of the two axes, confirming that R&D intensity is highly concentrated in the top-ranked R&D-investing companies. This also means that the highest ranked R&D investors are likely to operate in sectors of high-high R&D intensity (these sectors have a R&D intensity greater than 5 %).

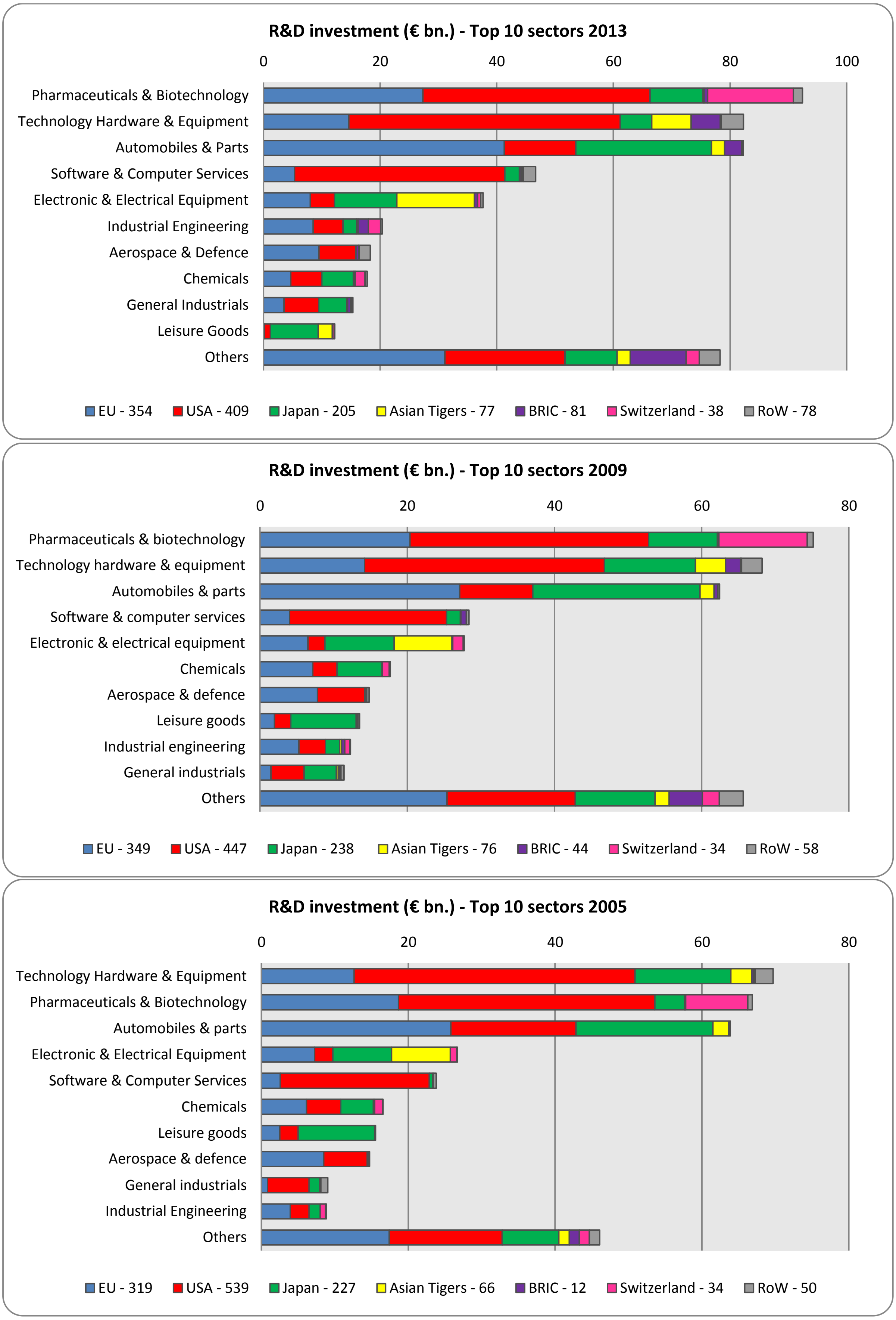
Secondly, and perhaps even more importantly, the curves from the ranking of 60 on the *x*-axis to the right-hand side of the figure show that there is a much smaller proportion of high R&D intensity companies in the EU sample compared to the US one, resulting in an increase in the gap in cumulative average R&D investment. This means that the EU sample includes more companies with lower R&D intensity than, for instance, the US and Japanese samples. In other words, Figure 3 shows that, compared with the EU and Japan, the US sample includes a greater proportion of smaller R&D investors that invest more strongly in R&D (i.e. by R&D intensity): most of US companies holds a cumulative R&D intensity above 5 % in the last two years analysed (i.e. 2009 and 2013), which means that, in contrast to similar EU and Japanese firms, these smaller US R&D investors are mostly operating in high-tech sectors.

Another aspect of note is that only a relatively small number of companies contribute to the total business R&D investment worldwide: of the 2 500 companies included in the EU R&D Scoreboards (editions 2006 to 2014), only a relatively small number account for between 80 and 90 % of global business enterprise expenditure (European Commission, 2006-2014). For example, in 2013 almost half (i.e. 1 247) of the original total sample of 2 500 companies accounted for 94 % of the total R&D investment of the whole sample. Furthermore, despite the rise in R&D investment in emerging economies from 2005 to 2013, only 968 US, EU and Japanese firms together contributed the bulk of R&D investment worldwide in 2013: these 968 firms accounted for €407bn (or 83 %) of the total global figure of €504bn contributed by the 1 242 firms in our sample (see Table A-4 in the Appendix for further descriptive statistics).

Finally, as anticipated in section 3.5, a global R&D investment is concentrated in ICT-related sectors, in the pharmaceuticals and biotechnology sectors and in the automobiles and parts sectors. A quick analysis shows that top four sectors in terms of global R&D investment accounted for 62.8 %, 58.9 % and 60.3 % of R&D investment in 2005, 2009 and 2013, respectively (Figure 4). It is interesting to note that, among these four sectors, the EU leads R&D investment in automobiles and parts, which is the only medium-tech sector; the other three are high-tech sectors and investment in these sectors is led by the USA (Tables A-1 to A-3 in the Appendix provide detailed information on the share of corporate R&D investment by sector and country/world region).

Overall, the trend of R&D investment concentration from 2005 to 2013 shows an increase in its share held by fewer firms from the Triad and a rather stable share held by the four top sectors.

Figure 4. The 10 sectors (ICB-4) with the highest global corporate R&D investment concentration by country/region (2005, 2009, 2013)



6. Summary and conclusions

This paper seeks to increase our understanding of how and why R&D intensity differs in different regions of the world. It confirms that differences in the structural composition of economies play a major role in the R&D intensity gap; it suggests that concentration of R&D investment is an important factor, and it provides new findings. This study is innovative in the methodological approach undertaken and in the results obtained. The research is based on a longitudinal dataset of micro-data for the period 2005-2013 and uses both descriptive statistical analysis as well as a decomposition computation method. These analyses aim to contribute to the literature on the determinants of the EU corporate R&D intensity gap by testing the decomposition effects of several parameters, providing an examination of these phenomena over a nine-year period and giving empirical support to researchers and decision-makers by showing the significance of structural and intrinsic effects as well as the comparative distribution of R&D investment and intensities among top R&D-investing firms, sectors and world regions/countries (the EU, the USA, Japan, the BRIC countries, the Asian Tiger countries and Switzerland).

6.1 Main research findings

Firstly, our analysis shows that R&D investment and net sales growth rates remained steady for the EU sample during the period 2005-2013. The analysis also indicates that, in 2009, annual growth in corporate R&D investment suffered the effect of the economic and financial crisis in most regions/countries, apart from the EU. The effect of the crisis was most evident in the case of the USA, where recovery to the 2005 annual growth level was still proving difficult in 2013. Despite this, in the years considered, US companies show the highest R&D investment figures, followed by companies in the EU and Japan, as a result of which the USA led R&D investment in the high-tech sector group during these years.

Secondly, the R&D intensity gap between the EU and both the USA and Japan was found to be negative and due to the structural composition of the economy (in line with the findings of Moncada-Paternò-Castello *et al*. (2010) and Cincera and Veugelers (2013)), thus confirming our first research hypothesis. Our findings also show that the R&D investment gap between the EU and Switzerland is negative and mostly due to 'structural effects'. Furthermore, we found a negative gap by both BRIC and the RoW countries compared to the EU and that in the years studied, the BRIC countries' gap being due to 'structural effects' while the RoW gap being due to 'intrinsic effects'. Relative to the EU, the Asian Tigers show a negative R&D intensity gap in the first year and a positive R&D intensity gap in the last two years of observation, in all cases mainly due to 'intrinsic effects'.

The third main finding is that the R&D intensity gap between the EU and its main competitors has in part widened in the last nine years (ratifying results by Duchêne *et al.*, 2011; Voigt and Moncada-Paternò-Castello, 2012 and Veugelers, 2013), thus in some extent confirming our second research hypothesis. As an original contribution to the literature, this study indicates that the overall evolution of the R&D investment gap of the EU in comparison an increase in the negative gap with the USA, and a quite stable negative gap compared with Japan and Switzerland. Furthermore, the EU shows a decreasing positive R&D investment gap compared with the BRIC and RoW groups of countries over the three years considered. The Asian Tigers have shifted from a negative R&D intensity gap in comparison with the EU in 2005 to a positive gap in 2009 and an even more positive one in 2013.

The fourth key finding is that in terms of the 'intrinsic effect' EU firms outperform all their competing economies, except Switzerland, and even improve their comparative performance over the period of time examined, especially in comparison with firms from the USA, Japan and the BRIC countries. However, the structural effect outweighs the positive effect of EU corporate R&D investment effort (intrinsic effect) in comparison with all regions/countries considered, except Switzerland. In this context, this study shows that within the high and medium-high intensity sector groups, EU firms in individual sectors often perform much better (in 2013, 10 out of the 14 sectors analysed[22]) in terms of R&D intensity than US companies. As these findings are new in the literature, we also checked the robustness of the above results by implementing a decomposition of the R&D investment gap using a longitudinal balanced dataset (2005-2013) built from several editions of the EU R&D Scoreboard. This further analysis largely confirms and validates the main output of our investigation.

The fifth most relevant finding is that, in the years considered, corporate R&D is asymmetrically distributed, differing significantly between EU and non-EU companies. Overall, the study confirms that the bulk of global private R&D investment is concentrated in high and medium-high sector groups (especially the pharmaceutical and biotechnology, technology hardware and equipment, and automobiles and parts sectors, and software and computer services), in a few countries/regions (especially the USA, the EU and Japan) and in a few companies, confirming our third research hypothesis. The trend analysis indicates a decreasing concentration for both number of companies and R&D investment share of the Triad and an overall rather stable share of R&D investment held by the four top sectors.

Interestingly, R&D intensity is highly concentrated in a small group of the largest R&D-investing firms. These results largely confirm the findings of Ciupagea and Moncada-Paternò-Castello (2006), Moncada-Paternò-Castello *et al.,* (2010) and, in part, Reinstaller and Unterlass (2012), and show that US companies with high cumulative R&D intensity, as is typical of high-tech sectors (i.e. R&D intensity above 5 %), dominate the full range of R&D investment ranking. The analysis of the evolution of the cumulative average R&D intensity of the examined samples represents a novel contribution to the literature. It shows that the bulk of the smaller top US R&D investors improved their cumulative R&D intensity in 2013 with respect to 2005. In contrast, the one of the smaller top EU R&D investors remained largely unchanged. Also, this parameter continues to be lowest in the BRIC region, but in the Asian Tiger countries increased from 2005 to 2013, while in Switzerland was stable over the period.

6.2 Concluding remarks

This study provides new insights into the evolution of corporate R&D by examining one of the factors on which the EU 3 % R&D investment policy target, introduced in 2003, was based.

22 The four sectors in which EU companies performed worse than US companies in 2013 are biotechnology, chemicals, pharmaceuticals and semiconductors.

It confirms that the reason for the EU R&D investment gap, especially relative to the USA, Japan and Switzerland, is mainly structural, and there have been no signs of the changes necessary to achieve the EU policy target for 2020 (Pottelsberghe, 2008; Voigt and Moncada-釣Paternò-Castello, 2012).

Other sources of literature can help us to understand why this phenomenon occurs. Many authors suggest that dynamic changes in the structure of the economy and the associated company demographics with the socio-economic and policy framework conditions are the most important reasons. For example, Mathieu and Pottelsberghe (2010), Foray and Lhuillery (2010) and Moncada-Paternò-Castello (2010) argue that there have been more dynamic changes in the structure of the US economy than in the EU economy in the last two decades. The economy in the USA moved in favour of higher-R&D-intensity sectors in particular, in ICT-related sectors, to a larger extent than in the EU, and this, in turn, was a major contributor in the difference in overall R&D intensity between the EU and the USA.

The findings of this study clearly show that EU companies have only a weak presence, in terms of market share, in the high-tech sectors compared with their most direct competitors; most of these sectors have been created in the last few decades (e.g. biotech, software, internet) by new firms. Cincera and Veugelers (2013) and Moncada-Paternò-Castello (2010, 2016b) claim that younger and smaller US companies are more present – and show a greater capacity to grow – in high-R&D intensity sectors than similar companies in the EU. Such companies, if numerous and if they prosper in the (new) high-R&D intensity sectors, are able to drive the shift in the economic structure of a given country, hence reinforcing its technology base.

Therefore, when taking action to decrease the EU R&D intensity gap, policy-makers should not consider only horizontal policy options across all sector and firm typologies. Tailored policies that address the barriers to the creation of new (high risk and oriented to solve societal problems) R&D and innovation-intensive sectors and companies (favouring new/young entrants) should be also considered.

This study shows that the EU corporate R&D investment mostly in medium-R&D intensity sectors (which dominated structure of the EU economy) is less sensitive to a global economic and financial downturn. Furthermore, larger European companies in lower and more traditional R&D intensity sectors (such as automobiles and parts and industrial engineering and machinery) have to be acknowledged for their capacity to compete (and lead) on a global level. Hence, EU policy measures should be also directed towards established (large/medium) firms operating in less R&D-intensive sectors to enable them not only to carry quality R&D themselves but also to absorb R&D results from other, more R&D intensive, sectors. In doing so these companies will be better prepared to exercise a leading role in the development process of the next technological generations and in the creation of the future knowledge-intensive industries.

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Appendix

Caveats of the EU R&D Scoreboard data[23]

Before introducing the variables used in this study, we must point out that when using the EU R&D Scoreboard data for comparative analyses there are a number of factors that should be taken into account because they potentially affect the interpretation of the figures. In particular, the following should be borne in mind:

i) The EU R&D Scoreboard figures are nominal and expressed in euros, with all foreign currencies converted at the exchange rate prevailing on 31 December of the reporting year. Financial indicators consolidated from companies' activities in different currency areas are influenced by fluctuations in exchange rates. This has an impact on firms' relative placing in the world rankings based on these indicators. Moreover, the ratios between indicators or the growth rate of an indicator may be affected.

ii) Deflating the monetary data of these datasets has some drawbacks. It should be noted that, in practice, most firms in the EU R&D Scoreboard dataset are multinational; therefore, they have operations and sales in many countries all over the world. These firms' R&D investments are, in general, largely executed in their home countries (essentially, at the location of the company headquarters). In this context, if a deflator such as percentage of GDP of the firm's home country is applied for a given year equally to R&D investment, sales and profits, additional elements of data distortion are introduced. However, if the variables are not deflated, a different problem arises as all variables would increase over time (i.e. all variables will have a common trend due to inflation).

iii) Growth in corporate R&D investment can be organic, due to acquisitions, or a combination of the two. Consequently, mergers and acquisitions may explain sudden changes in the R&D growth rates and rankings of specific companies. They are likely to have less effect on R&D intensities since most acquisitions involve companies in the same sector.

iv) Other important factors to take into account are differences in the various countries' (or sectors') business cycles, which may have a significant impact on companies' investment decisions as well as the adoption of the International Financial Reporting Standards (IFRS).[24] It should also be noted that, although the accounting standards lead to a certain standardisation in the data reported, companies still have some choice over what they declare as R&D. This can have important impacts.

v) Company location versus R&D investment location: The terms 'EU company', 'non-EU company', 'US company', 'Japanese company', etc., are used throughout this report to refer to a company whose ultimate parent has located its registered office in that country or region. In fact, the EU R&D Scoreboard does not show where exactly the R&D investment is executed. It is a rich and accurate information source about a company's financial effort, but is less accurate when analysing a country's business R&D expenditures (the business

23 Source: European Commission (2006-2014).

24 Since 2005, the European Union has required all listed companies in the EU to prepare their consolidated financial statements according to IFRS (see: Regulation (EC) No 1606/2002 of the European Parliament and of the Council of 19 July 2002 on the application of international accounting standards at http://eurlex. Available at: europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002R1606:EN:HTML).

enterprise expenditures in R&D – BERD – statistics collected by national statistical offices[25]), although it shows similar overall results at EU level. An extensive discussion on these and other aspects of using the EU R&D Scoreboard compared with other data sources is offered by Moncada-Paternò-Castello (2016a).

Description of the main variables considered for the analysis

The selection of variables is motivated by the research goals – i.e. answering the research questions/testing the above-mentioned hypotheses – and is supported in the literature, e.g. Lindmark, Turlea and Ulbrich (2010), Moncada-Paternò-Castello et al. (2010) and Cincera and Veugelers (2013). The main variables considered in the study are:

(i) Corporate research and development (R&D) investment. According to the EU R&D Scoreboard methodology, this is the cash investment funded by companies themselves. It excludes R&D undertaken under contract for customers such as governments or other companies. It also excludes the companies' share of any associated company or joint venture R&D investment. Disclosed in the company's annual report and accounts, it is subject to the accounting definitions of R&D. For example, a definition is set out in International Accounting Standard (IAS) 38 'Intangible assets' and is based on the OECD (2002) 'Frascati' manual.26

(ii) Net sales follow the usual accounting definition of sales, excluding sales taxes and shares of sales of joint ventures and associates. For banks, sales are defined as the 'Total (operating) income' plus any insurance income. For insurance companies, sales are defined as 'Gross premiums written' plus any banking income.

(iii) Sectors' classification: ICB (Industry Classification Benchmark) at the three-digit level, corresponding to sectors in which each company states its main activity lies. The ICB is an industry classification taxonomy launched by Dow Jones and FTSE in 2005 and now owned solely by FTSE International. It is used to segregate markets into sectors within the macro-economy. The ICB is used globally (though not universally) to divide the market into increasingly specific categories, allowing investors to compare industry trends between well-defined sub-sectors. We grouped industrial sectors according to R&D intensity, and following the European Commission (2006-2014) and OECD (1997) approach (see Box 1).

[25] For a comparison between EU R&D Scoreboard with BERD statistics, see Box 1 (p. 26) in Moncada-Paternò-Castello *et al*. (2010).

[26] Research is defined as original and planned investigation undertaken with the prospect of gaining new scientific or technical knowledge and understanding. Expenditure on research is recognised as an expense when it is incurred. Development is the application of research findings or other knowledge to a plan or design for the production of new or substantially improved materials, devices, products, processes, systems or services before the start of commercial production or use. Development costs are capitalised when they meet certain criteria and when it can be demonstrated that the asset will generate probable future economic benefits. Where some or all of R&D costs have been capitalised, the additions to the appropriate intangible assets are included to calculate the cash investment and any amortisation eliminated.

Box 1. Grouping of industrial sectors according to R&D intensity of the sector worldwide.

High R&D intensity sectors (R&D intensity above 5 %) include, for example, pharmaceuticals and biotechnology; health care equipment and services; technology hardware and equipment; software and computer services; and leisure and goods.

Medium-high R&D intensity sectors (R&D intensity between 2 % and 5 %) include, for example, aerospace and defence; automobiles and parts; electronics and electrical equipment; industrial engineering and machinery; chemicals; personal goods; household goods; general industrials; and support services.

Medium-low R&D intensity sectors (R&D intensity between 1 % and 2 %) include, for example, food producers; beverages; travel and leisure; media; oil equipment; electricity; and fixed line telecommunications.

Low R&D intensity sectors (R&D intensity less than 1 %) include, for example, oil and gas producers; industrial metals; construction and materials; food and drug retailers; transportation; mining; tobacco; and multi-utilities.

Source: European Commission (2014) following the OECD (1997) approach.

Note: In contrast to the approach to the data taken in the 2014 edition of the EU R&D Scoreboard, the aerospace and defence sector has been classified as medium-high as its global R&D intensity results averaged less than 5 % over the three years considered. In fact, this sector was in the medium-high sector group in the 2006 and 2010 editions of the EU R&D Scoreboard.

For this study, Hong Kong, Singapore, South Korea and Taiwan have been grouped as 'the Asian Tigers', with Brazil, Russia, India and China as the 'BRIC.' countries; ROW denotes 'Rest of the World'.

Table A-1. R&D investment and net sales as a proportion of the total, by sector (four-digit ICB sector) and country/region in 2013

4-digit ICB code	4-digit ICB sector in the Scoreboard	EU - 354		US - 409		Japan - 205		Asian Tigers - 77		BRIC - 81		Switzerland - 38		RoW - 78	
		Share of R&D	Share of Net sales	Share of R&D	Share of Net sales	Share of R&D	Share of Net sales	Share of R&D	Share of Net sales	Share of R&D	Share of Net sales	Share of R&D	Share of Net sales	Share of R&D	Share of Net sales
0530	Oil & Gas Producers	1.8%	18.6%	0.8%	14.4%	0.3%	5.6%	0.9%	7.1%	18.4%	52.3%			4.0%	34.5%
0570	Oil Equipment, Services & Distribution	0.2%	0.4%	0.9%	2.2%			0.8%	9.7%	0.7%	1.5%	0.9%	3.3%		
0580	Alternative Energy	0.3%	0.2%	0.1%	0.1%										
1350	Chemicals	3.0%	4.3%	2.9%	4.2%	6.7%	6.7%	0.6%	0.8%	0.7%	3.0%	7.7%	7.9%	2.5%	7.7%
1730	Forestry & Paper	0.1%	0.4%			0.2%	0.5%								
1750	Industrial Metals & Mining	0.7%	2.9%	0.1%	0.5%	1.2%	4.0%	1.4%	3.9%	1.7%	2.3%			0.8%	0.9%
1770	Mining	0.2%	1.2%							2.7%	2.0%				
2350	Construction & Materials	0.7%	3.0%	0.3%	0.5%	0.9%	3.1%	0.6%	0.8%	15.9%	17.1%	0.3%	4.8%	1.5%	2.9%
2710	Aerospace & Defence	6.2%	3.2%	3.5%	5.6%					2.2%	0.5%	0.3%	0.2%	13.1%	4.3%
2720	General Industrials	2.3%	1.2%	3.2%	5.1%	6.0%	9.2%	0.5%	1.1%	2.2%	2.0%	1.0%	3.0%	1.2%	7.7%
2733	Electrical Components & Equipment	4.2%	2.7%	0.1%	0.2%	6.5%	6.2%	2.3%	1.1%	0.8%	0.2%	1.9%	2.9%	1.2%	1.1%
2737	Electronic Equipment	1.0%	0.4%	2.2%	2.6%	6.7%	4.2%	45.5%	29.2%	1.6%	0.4%	0.5%	0.5%	1.6%	1.3%
2753	Commercial Vehicles & Trucks	2.2%	1.3%	2.3%	3.6%	1.1%	1.2%	0.3%	1.0%	3.2%	1.5%	2.3%	3.4%		
2757	Industrial Machinery	3.3%	2.8%	0.5%	1.1%	1.7%	2.3%	0.7%	3.4%	4.9%	2.3%	7.0%	14.0%	2.1%	1.7%
2770	Industrial Transportation	0.2%	1.2%							0.4%	0.2%				
2790	Support Services	0.7%	0.8%	0.5%	0.4%	0.2%	0.8%							2.9%	1.9%
3350	Automobiles & Parts	26.8%	14.7%	6.7%	9.2%	28.9%	25.9%	8.2%	11.7%	13.2%	7.7%	0.2%	0.5%	1.6%	1.8%
3530	Beverages	0.2%	0.8%	0.3%	1.4%	0.6%	1.3%								
3570	Food Producers	1.3%	1.8%	0.6%	2.6%	0.7%	1.1%	0.2%	0.7%			6.4%	23.8%	1.0%	2.2%
3720	Household Goods & Home Construction	0.9%	1.1%	1.3%	2.9%	0.3%	1.1%					0.3%	0.2%		
3740	Leisure Goods	0.1%	0.1%	0.6%	0.5%	10.2%	4.4%	8.7%	4.0%	0.3%	0.04%	1.2%	0.6%	0.6%	0.1%
3760	Personal Goods	0.9%	1.0%	0.3%	1.2%	0.8%	0.9%	0.5%	0.5%			0.7%	2.1%	0.9%	1.1%
3780	Tobacco	0.2%	0.4%	0.3%	1.3%	0.5%	0.8%								
4530	Health Care Equipment & Services	1.6%	1.1%	3.7%	5.3%	1.1%	0.6%					0.8%	0.6%	1.2%	0.3%
4573	Biotechnology	0.7%	0.1%	5.7%	1.1%									2.3%	0.8%
4577	Pharmaceuticals	17.1%	3.8%	15.6%	5.8%	11.3%	2.1%	0.6%	0.7%	2.8%	0.5%	66.1%	25.4%	8.4%	4.0%
5330	Food & Drug Retailers	0.2%	1.0%												
5370	General Retailers	0.4%	2.9%	1.2%	2.0%							0.2%	3.2%		
5550	Media	0.4%	0.7%	0.1%	0.02%	0.3%	0.5%								
5750	Travel & Leisure	0.2%	0.9%	0.1%	0.03%	1.4%	1.9%			0.7%	0.04%			1.6%	2.0%
6530	Fixed Line Telecommunications	2.6%	4.1%	0.6%	2.7%	2.1%	3.5%	2.0%	3.0%	1.4%	0.5%	0.5%	2.8%		
6570	Mobile Telecommunications	0.2%	0.9%	0.1%	0.1%									0.5%	2.5%
7530	Electricity	1.1%	5.0%	0.03%	0.2%	0.3%	4.1%	1.7%	4.7%						
7570	Gas, Water & Multi-utilities	0.5%	5.9%	0.04%	0.1%	0.2%	1.2%			0.2%	0.3%				
8350	Banks	4.3%	6.2%							1.7%	0.9%			8.8%	8.7%
8532	Full Line Insurance	0.1%	0.2%												
8570	Life Insurance	0.1%	0.1%											0.8%	0.3%
8633	Real Estate Holding & Development													0.5%	0.4%
8770	Financial Services	0.3%	0.1%	0.1%	0.2%										
8980	Equity Investment Instruments			0.03%	0.04%										
8990	Nonequity Investment Instruments					0.2%	0.02%								
9533	Computer Services	0.7%	0.2%	3.4%	2.6%	3.1%	2.5%			0.5%	0.3%			1.7%	0.1%
9535	Internet	0.1%	0.03%	4.7%	1.7%			0.3%	0.05%					7.8%	2.4%
9537	Software	2.7%	0.5%	11.6%	4.0%					1.0%	0.04%	1.1%	0.3%	5.2%	1.3%
9572	Computer Hardware	0.7%	0.2%	6.5%	8.4%			8.4%	12.1%	1.5%	0.8%	0.5%	0.5%	0.5%	0.1%
9574	Electronic Office Equipment	0.04%	0.02%	0.3%	0.5%	4.8%	2.7%								
9576	Semiconductors	2.4%	0.4%	11.6%	3.2%	1.6%	0.5%	14.4%	4.0%					12.5%	1.7%
9578	Telecommunications Equipment	6.4%	1.3%	7.1%	2.6%	0.3%	1.5%	1.5%	0.6%	21.4%	3.6%			13.3%	6.2%
	Grand Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2014).

Note: Numbers (*n*) following the names of countries/regions are the *n* of companies included in the calculations.

Table A-2. R&D investment and net sales as a proportion of the total, by sector (four-digit ICB sector) and country/region in 2009

4-digit ICB code	4-digit ICB sector in the Scoreboard	EU - 349		US - 447		Japan - 238		Asian Tigers - 76		BRIC - 44		Switzerland - 35		RoW - 38	
		Share of R&D	Share of Net sales	Share of R&D	Share of Net sales	Share of R&D	Share of Net sales	Share of R&D	Share of Net sales	Share of R&D	Share of Net sales	Share of R&D	Share of Net sales	Share of R&D	Share of Net sales
0530	Oil & gas producers	1.9%	14.5%	0.9%	15.2%	0.4%	5.1%	0.6%	5.8%	29.8%	62.5%			3.9%	21.3%
0570	Oil equipment, services & distribution	0.1%	0.3%	1.0%	1.7%			1.4%	0.8%			0.8%	2.4%		
0580	Alternative energy	0.2%	0.2%	0.04%	0.1%									0.5%	0.3%
1350	Chemicals	5.9%	4.8%	2.4%	4.0%	6.9%	6.9%	0.4%	0.4%			5.1%	6.5%	1.6%	6.5%
1730	Forestry & paper	0.2%	0.6%			0.1%	0.8%								
1750	Industrial metals & mining	0.7%	2.9%	0.1%	0.5%	1.5%	5.2%	1.8%	3.5%	0.6%	1.5%			2.3%	3.9%
1770	Mining	0.2%	1.5%			0.1%	0.3%			9.2%	3.1%				
2350	Construction & materials	0.9%	3.1%	0.2%	0.7%	1.4%	4.3%	1.3%	2.7%	9.2%	13.4%			2.0%	0.8%
2710	Aerospace & defence	6.4%	3.2%	4.7%	7.6%	0.1%	0.04%	0.2%	0.4%	1.1%	0.5%	0.6%	0.4%	3.7%	5.3%
2720	General industrials	1.2%	1.1%	3.3%	6.2%	5.0%	4.7%	1.5%	2.9%	1.7%	2.4%	1.3%	5.5%	4.8%	16.0%
2733	Electrical components & equipment	4.6%	2.7%	0.5%	1.0%	3.7%	3.4%	2.5%	1.9%			6.4%	11.5%		
2737	Electronic equipment	0.8%	0.3%	1.2%	0.7%	7.0%	4.3%	44.6%	35.4%	1.3%	0.6%	1.7%	0.8%	1.2%	1.8%
2753	Commercial vehicles & trucks	1.8%	1.0%	1.9%	2.6%	1.0%	1.1%	0.9%	3.9%	2.4%	0.8%	1.9%	3.3%		
2757	Industrial machinery	2.5%	2.4%	0.7%	1.2%	1.2%	1.7%	0.7%	0.9%	2.4%	1.4%	2.0%	6.2%	1.0%	0.5%
2770	Industrial transportation	0.2%	1.7%												
2790	Support services	0.5%	0.8%	0.4%	0.5%	0.1%	0.4%			0.7%	0.01%				
3350	Automobiles & parts	22.4%	11.4%	7.3%	8.6%	25.8%	21.5%	11.5%	12.6%	5.9%	5.3%			2.3%	1.3%
3530	Beverages	0.1%	0.6%	0.2%	1.1%	0.6%	1.1%								
3570	Food producers	1.4%	1.9%	1.2%	4.2%	0.7%	1.2%					8.4%	28.3%	0.5%	2.5%
3720	Household goods & home construction	1.0%	1.1%	1.6%	3.0%	0.5%	1.6%					0.2%	0.2%		
3740	Leisure goods	1.6%	0.6%	1.6%	0.8%	10.1%	6.6%	1.4%	1.0%					2.4%	1.3%
3760	Personal goods	0.7%	1.2%	0.5%	1.3%	0.6%	0.8%	0.6%	0.7%	0.5%	0.2%	2.1%	2.4%		
3780	Tobacco	0.1%	0.4%	0.3%	1.4%	0.4%	2.3%								
4530	Health care equipment & services	1.5%	1.0%	3.9%	2.6%	1.1%	0.6%					0.3%	0.4%	1.2%	0.3%
4573	Biotechnology	0.6%	0.1%	5.4%	1.1%	0.4%	0.1%					0.3%	0.01%	2.2%	0.9%
4577	Pharmaceuticals	16.2%	3.2%	18.4%	6.0%	10.3%	1.9%			2.0%	0.4%	67.2%	26.2%	7.3%	3.2%
5330	Food & drug retailers	0.1%	2.0%	0.3%	5.1%	0.05%	0.5%								
5370	General retailers	0.3%	2.0%	1.3%	0.9%							0.2%	2.0%		
5550	Media	1.0%	1.2%	0.1%	0.03%	0.5%	1.1%							4.6%	2.8%
5750	Travel & leisure	0.1%	0.1%	0.3%	0.2%	0.7%	1.5%							0.8%	0.2%
6530	Fixed line telecommunications	3.8%	6.2%	0.5%	3.0%	2.3%	3.5%	1.9%	2.5%	0.6%	3.0%	0.8%	3.2%	10.2%	5.0%
6570	Mobile telecommunications	0.3%	1.2%			0.2%	1.2%	0.9%	1.4%					1.0%	3.7%
7530	Electricity	1.0%	4.8%			1.0%	5.7%	2.5%	4.8%					0.8%	2.5%
7570	Gas, water & multiutilities	0.5%	5.7%			0.2%	1.0%			0.7%	0.9%				
8350	Banks	3.5%	9.2%					0.5%	0.7%					9.0%	10.4%
8530	Nonlife insurance	0.1%	0.3%												
8570	Life insurance	0.1%	1.1%												
8770	Other financials	0.3%	0.3%	0.1%	0.1%									0.5%	0.3%
9533	Computer services	0.6%	0.3%	3.0%	2.7%	2.1%	1.6%			3.3%	0.1%				
9535	Internet			2.3%	0.9%			0.3%	0.03%	1.1%	0.2%			0.9%	0.3%
9537	Software	2.7%	0.5%	10.3%	3.3%					4.1%	0.6%			3.2%	0.7%
9572	Computer hardware	0.1%	0.02%	4.8%	6.0%	6.9%	4.9%	8.7%	13.6%			0.5%	0.5%	8.2%	2.3%
9574	Electronic office equipment	0.2%	0.1%	0.5%	0.5%	5.0%	2.4%								
9576	Semiconductors	2.7%	0.4%	11.1%	2.7%	2.0%	0.8%	15.6%	3.7%	1.3%	0.1%	0.2%	0.1%	7.2%	0.8%
9578	Telecommunications equipment	8.7%	1.9%	7.6%	2.4%	0.1%	0.2%	0.2%	0.2%	22.1%	3.0%			16.6%	5.1%
	Grand Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2010).
Note: Numbers (*n*) following the names of countries or regions are the *n* of companies included in the calculations.

Table A-3. R&D investment and net sales as a proportion the total by sector (four-digit ICB sector) and country/region in 2005

		EU - 319		US - 539		Japan - 227		Asian Tigers - 66		BRIC - 12		Switzerland - 34		RoW - 50	
4-digit ICB code	4-digit ICB sector in the Scoreboard	Share of R&D	Share of Net sales	Share of R&D	Share of Net sales	Share of R&D	Share of Net sales	Share of R&D	Share of Net sales	Share of R&D	Share of Net sales	Share of R&D	Share of Net sales	Share of R&D	Share of Net sales
0530	Oil & gas producers	1.8%	20.0%	0.7%	16.2%	0.1%	1.9%			48.6%	75.7%			4.5%	29.2%
0570	Oil equipment, services & distribution	0.1%	0.3%	0.7%	1.5%										
1350	Chemicals	5.8%	4.8%	3.1%	5.5%	6.4%	7.0%	1.1%	1.4%			8.5%	10.2%	0.6%	1.7%
1730	Forestry & paper	0.2%	1.2%	0.1%	1.7%	0.2%	0.9%								
1750	Industrial metals	0.8%	3.6%	0.2%	0.9%	1.0%	3.1%	1.5%	6.7%					4.2%	9.7%
1770	Mining	0.1%	1.4%							12.0%	4.1%				
2350	Construction & materials	0.6%	2.5%	0.2%	0.7%	1.1%	3.6%							1.9%	0.8%
2710	Aerospace & defence	8.0%	2.9%	3.9%	5.9%	0.1%	0.04%			4.0%	1.2%			3.2%	4.7%
2720	General industrials	0.8%	0.7%	3.8%	6.6%	2.1%	3.2%					1.1%	1.3%	14.5%	24.5%
2733	Electrical components & equipment	6.1%	3.3%	0.4%	0.9%	1.4%	1.6%	6.7%	5.9%			4.8%	10.1%		
2737	Electronic equipment	0.7%	0.4%	1.2%	0.8%	10.1%	6.5%	47.9%	37.2%			1.9%	1.0%	1.6%	1.4%
2753	Commercial vehicles & trucks	1.5%	1.1%	1.5%	2.6%	0.7%	0.9%					2.1%	3.1%		
2757	Industrial machinery	2.2%	2.2%	0.2%	0.8%	1.4%	2.4%					3.4%	7.4%	2.1%	3.1%
2770	Industrial transportation	0.3%	2.5%			0.2%	1.0%	1.0%	3.6%						
2790	Support services	0.2%	0.1%	0.5%	0.5%	0.1%	0.4%							3.2%	5.1%
3350	Automobiles & parts	24.3%	16.0%	11.4%	13.4%	26.7%	22.6%	14.7%	13.3%	4.6%	1.7%			2.2%	0.7%
3530	Beverages					0.4%	1.0%								
3570	Food producers	1.6%	2.7%	0.3%	0.9%	0.6%	0.9%					7.5%	30.9%		
3720	Household goods	0.7%	1.1%	1.6%	2.6%	0.5%	1.6%					0.7%	1.5%		
3740	Leisure goods	2.3%	0.9%	1.7%	1.0%	14.9%	8.3%	0.3%	0.4%					1.0%	0.3%
3760	Personal goods	0.6%	1.0%	0.6%	1.4%	0.6%	0.6%	0.5%	0.6%			1.1%	0.9%		
3780	Tobacco	0.1%	0.4%	0.6%	2.6%	0.4%	1.8%								
4530	Health care equipment & services	1.1%	0.7%	3.4%	2.0%	0.2%	0.1%					1.1%	1.2%	0.6%	0.5%
4573	Biotechnology	0.6%	0.1%	4.6%	0.8%	0.4%	0.2%					4.6%	1.2%	3.1%	0.6%
4577	Pharmaceuticals	17.0%	3.4%	18.7%	5.8%	5.4%	2.0%			7.0%	0.5%	61.2%	26.7%	6.3%	1.9%
5330	Food & drug retailers	0.3%	1.9%	0.3%	4.1%										
5370	General retailers	0.03%	0.3%	0.6%	0.9%	0.2%	0.2%								
5550	Media	1.2%	1.4%	0.2%	1.1%	0.5%	1.1%								
5750	Travel & leisure	0.2%	0.1%	0.2%	0.2%	0.1%	0.5%							0.6%	0.3%
6530	Fixed line telecommunications	3.3%	6.5%			3.4%	5.3%	1.2%	4.4%			0.3%	3.3%	5.3%	4.9%
6570	Mobile telecommunications	0.3%	1.5%	0.1%	1.1%			2.9%	2.5%					1.4%	3.0%
7530	Electricity	0.9%	2.2%			1.2%	6.0%	2.6%	7.0%						
7570	Gas, water & multiutilities	0.3%	3.6%	0.03%	0.1%	0.2%	0.8%			9.9%	15.5%				
8350	Banks	1.4%	4.6%												
8530	Nonlife insurance	0.2%	0.3%												
8570	Life insurance	0.1%	0.8%												
8770	Other financials	0.1%	0.1%	0.1%	0.03%										
9533	Computer services	0.3%	0.2%	3.5%	2.6%	0.1%	0.1%	0.2%	0.2%					1.9%	1.3%
9535	Internet			0.7%	0.3%									0.7%	0.2%
9537	Software	2.1%	0.5%	9.4%	2.6%	0.6%	0.4%							4.1%	0.8%
9572	Computer hardware	0.05%	0.03%	6.1%	5.4%	15.1%	11.3%	8.5%	11.5%			0.6%	0.8%	4.7%	0.8%
9574	Electronic office equipment	0.2%	0.1%	0.5%	0.5%	1.1%	0.7%								
9576	Semiconductors	3.1%	0.5%	11.5%	3.2%	1.6%	0.9%	10.7%	5.2%	3.4%	0.4%	1.0%	0.4%	4.5%	0.5%
9578	Telecommunications equipment	8.6%	1.9%	7.5%	2.7%	0.9%	0.8%	0.3%	0.1%	10.5%	0.9%			27.9%	4.0%
	Grand Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2006).
Note: Numbers (*n*) following the names of countries or regions are the *n* of companies included in the calculations.

Table A-4. R&D investment and net sales by country of the sample analysed with regard original samples of the three EU R&D Scoreboards editions (2005; 2009; 2013)

2013

Country/region (no of firms)	*R&D investment (%)*	*R&D investment (€bn)*	*Net sales (%)*	*Net sales (€bn)*
EU (354)	95.3 %	154.3	87.4 %	5164.5
US (409)	94.5 %	182.3	91.6 %	3516.4
Japan (205)	94.2 %	80.6	81.9 %	2160.2
Asian Tigers (77)	90.1 %	27.9	80.3 %	1092.7
BRIC (81)	85.1 %	21.8	88.8 %	1715.6
Switzerland (38)	97.0 %	22.2	96.2 %	332.2
RoW (78)	84.4 %	14.6	71.1 %	496.2
Grand Total* (1242)	***93.8 %***	**503.6**	***86.6 %***	**14477.9**

2009

Country/region (no of firms)	*R&D investment (%)*	*R&D investment (€bn)*	*Net sales (%)*	*Net sales (€bn)*
EU (349)	93.4 %	121.3	78.7 %	4254.3
USA (447)	98.7 %	136.1	98.5 %	2837.3
Japan (238)	99.3 %	88.0	97.3 %	2256.5
Asian Tigers (76)	98.3 %	16.6	98.9 %	638.4
BRIC (44)	98.3 %	8.9	97.5 %	710.5
Switzerland (35)	99.5 %	17.8	98.5 %	256.1
RoW (58)	97.9 %	8.7	97.7 %	322.8
Grand Total* (1247)	***97.1 %***	**397.3**	***89.7 %***	**11275.9**

2005

Country/region (no of firms)	*R&D investment (%)*	*R&D investment (€bn)*	*Net sales (%)*	*Net sales (€bn)*
EU (319)	94.1 %	106.2	79.5 %	3583.3
USA (539)	99.2 %	149.8	98.2 %	3406.8
Japan (227)	99.6 %	69.8	98.3 %	1855.7
Asian Tigers (66)	100.0 %	14.6	100.0 %	438.4
BRIC (12)	97.3 %	2.0	93.6 %	263.5
Switzerland (34)	99.4 %	12.9	98.5 %	189.5
RoW (50)	97.2 %	6.5	97.0 %	286.3
Grand Total* (1247)	***97.7 %***	**361.8**	***90.5 %***	**10023.6**

Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2006, 2010, 2014).

*The total of the truncated sample as a proportion of the total of the original full sample.

Note: The original full sample comprised, for 2005, data from 2 000 companies with a total R&D expenditure of €371bn and net sales of €11 073bn; for 2009, data from 2 000 companies with a total R&D expenditure of €402bn and net sales of €12 574bn; and, for 2013, data from 2 500 companies with a total R&D expenditure of €540bn and net sales of €16 723bn.

For information, taking as reference the overall sample of 2 500 firms in 2013, the R&D investment was distributed as follows: EU 30.1 %, USA 36 %, Japan 15.9 %, together totalling 82 %. The RoW represented 18% of the global R&D investment (of which Switzerland 4.2 %; South Korea 3.8 %; China 3.7 %; Taiwan 1.8 %; Canada 0.7 %; and other countries 3.7 %).

Table A-5 Average R&D intensity, R&D investment and net sales performance of EU firms compared with US firms by specific sector (ICB-4) within high and medium-high R&D intensity sector groups in 2005-2013

	Average R&D Intensity						Average R&D investment (€m)						Average size of net sales (€m)					
	EU			USA			EU			USA			EU			USA		
Sectors ICB-4	2005	2009	2013	2005	2009	2013	2005	2009	2013	2005	2009	2013	2005	2009	2013	2005	2009	2013
Pharmaceuticals	14.7	14.6	13.4	14.2	14.7	14.0	666.8	654.1	849.5	823.4	894.0	1187.7	4 536.6	4 482.6	6 336.2	5 805.8	6 096.8	8 503.2
Software	13.4	14.6	15.6	15.7	14.8	14.9	174.3	222.1	346.2	192.5	327.1	470.6	1 301.9	1 524.5	2 219.0	1 224.9	2206.9	3 158.3
Health care equipment and services	4.5	4.4	4.3	7.3	7.2	3.6	98.2	142.8	176.5	144.1	175.0	248.1	2 205.6	3 252.9	4 128.6	1 974.5	2 430.1	6 841.7
Biotechnology	17.1	17.1	15.1	26.9	23.2	26.4	59.7	75.7	92.1	165.4	175.7	337.3	349.5	442.8	608.9	613.7	756.8	1 276.7
Telecommunications equipment	13.2	13.3	14.6	12.1	15.1	14.3	908.2	1173.3	1098.7	320.6	346.7	542.5	6 865.0	8 848.1	7 532.0	2 640.4	2 300.3	3 794.2
Semiconductors	17.4	22.0	18.1	15.6	19.4	18.8	360.7	469.3	409.6	229.2	243.7	441.3	2 068.7	2 129.2	2 256.8	1 471.9	1 255.4	2 345.1
Aerospace and defence	8.2	5.8	5.8	2.9	3.0	3.3	653.6	520.2	634.0	347.1	355.9	489.2	7 925.2	8 951.9	10 952.3	11 841.9	12 050.7	15 029.1
Automobiles and parts	4.5	5.6	5.5	3.7	4.1	3.8	955.0	1179.5	1504.1	897.8	584.2	720.0	21 204.5	21 154.7	27 279.5	24 051.9	14 311.1	19 042.0
Chemicals	3.5	3.5	2.0	2.5	2.9	3.6	306.3	340.8	330.5	155.4	166.4	295.5	8 688.6	9 735.5	16 228.4	6 259.0	5 696.3	8 260.8
Commercial vehicles and trucks	4.0	5.1	5.2	2.5	3.5	3.3	271.6	366.8	690.3	247.2	292.8	377.2	6 755.2	7 237.2	13 177.3	9 874.7	8 287.1	11 473.5
Electronic equipment	5.8	6.3	8.1	6.3	7.7	4.4	82.5	92.4	112.5	113.1	125.5	201.4	1 429.3	1 476.8	1 386.0	1 786.9	1 619.2	4 569.5
General industrials	3.2	3.1	6.0	2.5	2.6	3.3	93.0	122.6	350.5	405.0	501.4	844.6	2 871.8	3 936.3	5 858.7	16 024.4	19 438.4	25 808.3
Household goods and home construction	2.0	2.5	2.5	2.7	2.5	2.3	110.7	169.4	275.2	221.3	264.3	317.6	5 625.0	6 664.6	11 067.5	8 088.5	1 0573.7	13 640.4
Industrial machinery	2.9	3.0	3.5	1.4	2.8	2.5	95.7	123.6	153.8	70.1	85.1	142.7	3 342.1	4 132.5	4 376.7	5 141.2	3 055.3	5 608.5
All other sectors	1.1	1.1	1.1	1.8	2.0	2.6	205.3	211.8	256.2	219.7	255.4	363.3	18 673.3	19 691.7	22715.9	12 255.8	12 684.3	14 010.3
Total (full sample)	3.0	2.9	3.0	4.4	4.8	5.2	332.8	347.6	435.8	277.9	304.4	445.7	112 32.8	12 189.8	14 588.9	6 320.6	6 347.4	8 597.6

Note: Only sectors containing at least five firms and accounting for at least 10 % of the overall R&D in the EU and in the USA over the three years have been included in the calculation.

Decomposition using a longitudinal dataset (2005-2013)

The dataset

To check the robustness of the results obtained by the analysis of the three different editions of the EU R&D Scoreboard (2006, 2010 and 2014), a second dataset was built and used. The dataset was built by starting with the 2 500 firms listed in the 2014 EU R&D Scoreboard edition (2013 data) and keeping only those firms that had in each and every previous edition of the EU R&D Scoreboard both R&D and net sales data back to the edition of 2006 (2005 data) as well as the ORBIS-Bureau van Dijk database.

This balanced dataset allowed us to capture how the R&D investment of individual companies changed over the nine-year period of observation. The monetary data in this balanced dataset were adjusted for inflation. The deflation was done using the GDP deflators published by World Bank[27] and using 2000 as the reference year, taking the same approach used by Montresor and Vezzani (2015)[28] on a dataset these authors built from the same data source (i.e. the EU R&D Scoreboard).

In the end, complete data for each of the nine years were available for 1 859 firms, and the longitudinal dataset includes 907 companies from the 2006 EU R&D Scoreboard 2006 (73 %), 995 companies from the 2010 EU R&D Scoreboard (80 %) and 1 023 companies from the 2014 EU R&D Scoreboard (82 %) Therefore, differences are due to missing data for at least one of the nine years considered because of the different composition of the EU R&D Scoreboard editions.

Tables A-6 and A-7 and Figure A-1 show descriptive statistics of the balanced dataset.

Figure A-1 shows the global R&D investment and net sales annual growth rates of the longitudinal dataset 2005-2013, marked by a decrease in 2009 in both parameters due to the financial and economic downturn.

Applying the decomposition to the longitudinal dataset of EU R&D Scoreboards

We applied the decomposition to the data for three years (2005, 2009 and 2013) from the longitudinal balanced dataset of nine years (2005-2013), which comprised data for 1 859 enterprises worldwide taken from several editions of the EU R&D Scoreboard. Overall, when comparing the data of the three different EU R&D Scoreboards with those of the balanced dataset, there is a similar general trend in the parameters analysed, but in most cases, parameters are lower for the companies in the longitudinal dataset than for those of the three different EU R&D Scoreboards.

The balanced dataset, however, allows us to capture how the R&D investment of individual companies has changed over the nine-year period of observation, thereby providing accurate information that is particularly useful for studying the evolution of the ‘intrinsic effect’ in the R&D intensity gap.

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27 http://data.worldbank.org/indicator/NY.GDP.DEFL.KD.ZG/countries/all?display=default

28 See page 384, footnote 7.

Table A-6. Descriptive statistics of the sample by main world regions/countries – balanced dataset 2005-2013

	All firms		EU		USA		Japan		Switzerland		BRIC		Asian Tigers		RoW	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
R&D	213.1	642.7	231.6	665.5	216.3	623.4	261.6	695.7	334.4	1120.1	109.2	183.7	141.3	630.8	72.2	153.4
Net sales	6 339.2	17 343.2	8 255.9	21 177.3	4 390.0	14 507.4	7 960.3	16 954.4	5 053.5	11 118.7	10 854.3	30 288.3	5687.9	13 435.4	2 812.7	8 089.2
Operating profit	585.3	1 989.1	623.3	2060.2	626.6	2178.2	463.8	1 330.7	821.6	2 183.2	950.2	2281.0	438.3	1705.9	469.0	2 385.9
Employees	25 412.9	54 585.4	34 359.2	64 202.3	18 099.8	40 013.9	21 614.9	41 946.1	25 255.5	55 973.4	32 532.4	78 775.7	60 299.1	13 4610.6	194 61.9	51 923.4
Capital expenditure	438.8	1713.6	664.4	2 208.3	290.0	1 439.9	494.0	1 639.3	280.0	555.9	916.2	3 172.0	461.3	1 427.3	165.9	756.8
R&D intensity	*1.078*	*27.221*	*2.527*	*48.790*	*0.888*	*9.055*	*0.045*	*0.049*	*0.063*	*0.046*	*0.045*	*0.067*	*0.042*	*0.039*	*0.066*	*0.069*
Number of firms	1 859		473		619		366		56		68		156		121	

Table A-7. Descriptive statistics of the sample by R&D intensity sectors – balanced dataset 2005-2013

	All firms		High R&D intensity		Medium-high R&D intensity		Medium-low R&D intensity		Low R&D intensity	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
R&D	213.1	642.7	254.2	707.7	204.1	682.3	153.0	277.1	113.1	162.4
Net sales	6339.2	17343.2	2937.7	8206.5	5950.8	15065.0	10561.6	15635.2	19812.6	37691.4
Operating profit	585.3	1989.1	387.5	1572.5	465.8	1335.0	1388.5	2648.7	1398.1	4019.3
Employees	26070.2	56111.9	15672.2	39615.0	26276.9	53109.7	47487.4	81428.3	50809.8	84063.7
Capital expenditure	438.8	1713.6	144.7	508.3	333.5	1268.2	877.0	1901.7	2107.7	4387.2
R&D intensity	*0.851*	*23.169*	*1.930*	*35.480*	*0.062*	*0.340*	*0.029*	*0.044*	*0.013*	*0.013*
Number of firms	1859		792		760		124		183	

Figure A-1. Global R&D investment and net sales annual growth rates – longitudinal dataset 2005-2013

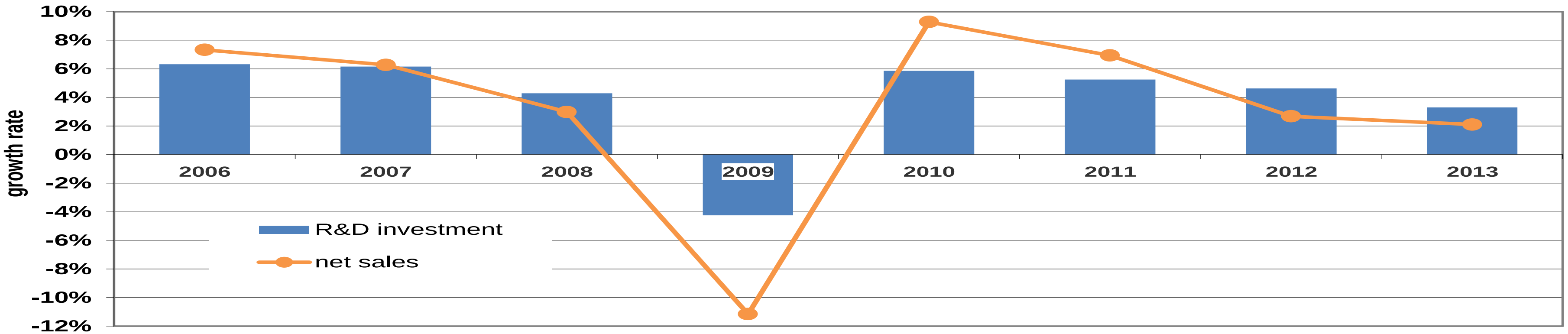

Table A-8 provides the result of this decomposition calculation. Comparing the data for the USA and the EU, we can confirm that the reason for the R&D intensity gap remains structural and very little changes over the years (as one would expect – the data come from the same companies competing in the same sectors of operations) and that the order of magnitude of the R&D intensity gap is in most cases very similar to what was reported in Table 3 (section 4.2). Moreover, the decomposition of this longitudinal dataset confirms that, in terms of 'intrinsic effects', EU companies outperform all of their competing economies (apart from Switzerland).

Overall, the results from the decomposition applied to the two datasets are very similar, especially comparing the results for the EU, the USA and Japan. For the other country groups, the results are also generally similar, although sometimes sample variations lead to changes in the results.

In fact, in contrast to the results in section 4.2 and the data in Table 3, in Table A-8 the 'intrinsic effect' advantage of EU companies is slightly eroded over time when compared with the USA, BRIC and the RoW. There are a number of possible reasons for this, but they mainly stem from the different characteristics of the two datasets (e.g. the number of companies in the dataset, their size and sectorial composition, the use of nominal as opposed to real values, and so on). However, there is one possible further interpretation of the slight difference in the trend in the results of the 'intrinsic effect': it could be due to the increased competition for R&D investment from other EU companies (or companies from other regions, such as from the RoW) in the same sectors and in other more R&D-intensive sectors.

Table A-8. Decomposition of R&D intensities in selected countries/regions using the EU sample for comparison and applied to three years of the longitudinal dataset (2005-2013)

		No of companies	**Overall**	Structural	Intrinsic
USA	2005	619	**1.347**	2.011	–0.664
	2009	619	**1.867**	2.624	–0.757
	2013	619	**2.121**	2.586	–0.465
Japan	2005	366	**0.512**	1.303	–0.791
	2009	366	**0.758**	1.338	–0.581
	2013	366	**0.481**	1.322	–0.841
Asian Tigers	2005	156	**–0.250**	2.220	–2.470
	2009	156	**–0.654**	2.800	–3.454
	2013	156	**–0.321**	2.626	–2.946
BRIC	2005	68	**–2.130**	–1.037	–1.093
	2009	68	**–1.762**	–0.946	–0.816
	2013	68	**–1.799**	–1.158	–0.642
Switzerland	2005	56	**2.545**	2.050	0.494
	2009	56	**3.720**	2.402	1.318
	2013	56	**3.813**	2.457	1.355
RoW	2005	121	**–1.479**	0.264	–1.743
	2009	121	**–0.783**	0.869	–1.651
	2013	121	**–0.239**	1.112	–1.351

Note: number of EU companies: 437.

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