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Business R&D investments in the EU: Main dynamics and economic effects

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Abstract. *Research and development expenditures are known as drivers of innovation and productivity. This paper aims at investigating two interrelated aspects of business R&D investments in the EU: the main features and trends in business R&D investments and their impact on company's performance. The results from preceding descriptive analysis on the most recent dynamics in the EU's R&D investments indicate the persistence of several characteristics highlighted also in the literature, such as an increasing business R&D intensity gap between the EU and its main competitors, large differences registered in the total R&D investment intensity across EU countries, sectors and firms and industrial R&D concentration at the level of a few players. The positive impact of R&D investments on company's performance in terms of net sales and operating profit is shown by conducting several econometric models. We also investigate whether the size has an effect on the R&D investments performed by companies exploiting data from the EU industrial R&D investment Scoreboard.*

Keywords: company, research and development, EU Scoreboard, innovation, performance.

JEL Classification: O12, O16.

1. Introduction

Research and development (R&D) expenditure has been intense used in innovation analysis as a proxy for innovation inputs and viewed as a determinant of economic growth and productivity. Investments in research and other intangible assets (education, ICT, skills development, management capacity etc.) are essential to support knowledge creation and that can be transformed to higher-value-added innovations.

Being identified as source of innovation and performance, one of the pillars of the European Union's policy agenda states that the EU should move towards a stronger public research and to make it more attractive to private investment in research and innovation. This would allow the EU to bridge the growing gap in the levels of research investment between Europe and its main trading partners (European Commission, 2003). Also, the Innovation Union is one of the 7 flagship initiatives of the *Europe 2020 strategy* for smart, sustainable and inclusive growth. The Innovation Union plan aims to make Europe into a world-class science performer, to remove obstacles to innovation like expensive patenting, market fragmentation, slow standard-setting and skills shortages, and to revolutionize the way public and private sectors work together, notably through innovation partnerships between the European institutions, national and regional authorities and business.

The comparative analysis of innovation performance in the EU countries that aim at assessing relative strengths and weaknesses of national innovation systems, as well as industrial research monitoring activity were set up as parts of the action plan. In this context, scoreboards were building to evaluate trends in R&D investment. The EU Scoreboard of top R&D-investing companies is published annually and monitors the top 1000 R&D investors financed by company's funds, regardless the place where the R&D is performed. R&D investments allow firms to develop new products, processes or services. For this reason, the EU Scoreboard allows the inputs to this process to be monitored and facilitates comparisons with other companies operating in the USA, Japan or other parts of the world.

This paper aims at investigating the main features and trends of business R&D investments in the EU and their impact on company′s performance. Firstly, we conduct a descriptive analysis on the most recent trends in R&D investments in the EU and third countries. While overall average European R&D intensity (ratio of R&D investment to GDP) lags behind the one registered by its competitors, the top EU industrial companies invest annually more in R&D and are among the most important players on the world market. Exploiting the latest micro-data from the EU Industrial R&D Investment Scoreboard, we investigate R&D investment patterns by examining the distribution of R&D investments among sectors and countries. R&D concentration at the level of a few countries, sectors and companies creates analysis opportunities regarding the impact of R&D on company's performance. The positive impact of R&D investments on company's performance in terms of net sales and operating profit is shown by conducting several econometric models. We also investigate whether the size has an effect on R&D investments of the companies.

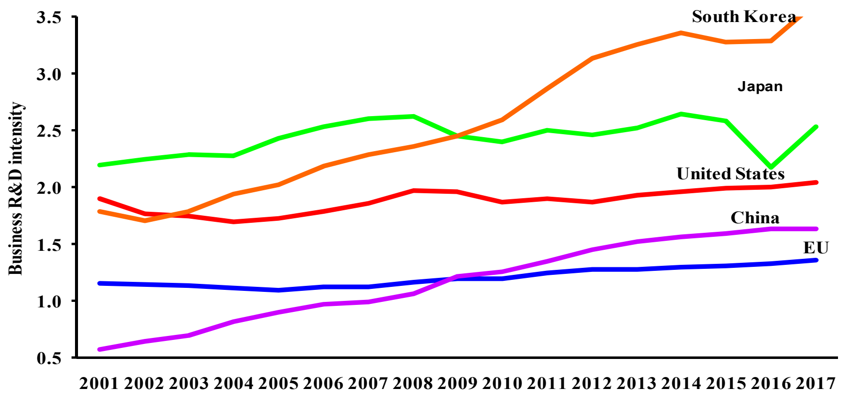
2. Dynamics in the EU's business R&D investments

Europe is a global player in research and innovation activity, leading in public investment in R&D and in its stock of researchers. It is also a front runner in scientific production, including high-quality of scientific publications. The EU accounts for less than one fifth of the world's R&D investment, but a quarter of global public R&D investment and one third of all high-quality scientific publications (European Commission, 2018a).

However, several factors can explain Europe's difficulty to transform its scientific leadership into leadership in innovation, mainly related to underinvestment in research activities.

Europe's *investment in business R&D* is less than one fifth of global business R&D investment. Although there is a slightly upward trend in business R&D intensity registered in the last decade, Europe's business R&D intensity has been shrinking over time due to the rising share of other economies, notably China. One quarter of global business R&D expenditure is performed in China and its business R&D intensity has nearly tripled since 2000, progress that is rivaled only by South Korea. In fact, business R&D intensity stood at 1.36% in 2017 in the EU, in comparison to 2.04 in the United States and 3.62% in South Korea (Figure 1), reflecting an increasing business R&D intensity gap between the EU and its main competitors.

Figure 1. *Business R&D intensity by region (R&D as % of GDP)*



Source: Eurostat.

The EU is not on track to reach the Europe 2020 strategy target of 3% of GDP invested in R&D. By 2020, the EU aims to reach an overall R&D intensity of 3% (2% for business R&D intensity) through different national targets. While R&D expenditures have increased in most member states over the last decade, it is unlikely that the EU target of 3% of GDP will be met by 2020. EU R&D intensity only increased from 1.83% of GDP in 2008 to 2.06% in 2017 and it is considerably behind that of South Korea, Japan and United States. There are various national targets of R&D intensity (as it is shown by European Commission – Eurostat; EIB, 2018 etc.). As of 2017, Denmark, Germany, Czech Republic and Cyprus were the EU countries to have reached their national Europe 2020 strategy target.

Large differences are registered in the total R&D investment intensity across EU countries, especially between those in the EU's core and periphery. For instance, in 2017 Romania allotted 0.5% of the GDP to R&D, which was below the EU average of 2.06% and it was the lowest share among the member states. This puts Romania in a group of countries where the R&D expenditure was below 1% of the GDP in 2017, namely Latvia (0.51%), Malta (0.55%), Cyprus (0.56%), Bulgaria (0.75%), Croatia (0.86%), Lithuania (0.88%) and Slovakia (0.88%). The countries that spent the most on R&D were Sweden (3.33%) and Austria (3.16%), followed by Denmark (3.06%) and Germany (3.02%).

The large dispersion of R&D intensity and its dynamics is mainly driven by business R&D expenditures and reflect several low investors stagnating and some high investors accelerating as well as some Central and Eastern European countries increasing their R&D levels. The highest EU business R&D intensity growth rates over 2007-2017 are registered in Bulgaria, Poland, Greece, Slovakia, Cyprus and Hungary, all of which had growth rates at least four times higher than the EU average. Although the business R&D intensities of all of these member states were below the EU average in 2017, the gap with the EU average has narrowed considerably since 2007.

Business R&D expenditures registered 54.8% of the gross domestic expenditure on R&D in 2008 in the EU, but the situation has not improved much almost a decade later. The share of business R&D expenditures in 2017 in the EU was lower than that in the United Sates (63.6%) and in South Korea (74.7%) as we show in Table 1. This indicates that, to catch up with its main competitors, the EU will need to create a better framework and provide the right incentives for supporting more R&D activities by the business sector.

Table 1. *Gross domestic expenditure on R&D by source of funds in the EU-28 and competing economies (as % of total)*

Region/country	Business enterprise sector		Government sector		Higher education sector		Private non-profit sector	
	2008	2017	2008	2017	2008	2017	2008	2017
EU-28	54.8	56.6	33.8	29.5	1.0	0.9	1.6	1.6
China	71.7	76.5	23.6	19.8	n.a.	n.a.	n.a.	n.a.
United States	62.5	63.6	30.4	22.8	2.9	3.6	3.2	3.9
Japan	78.2	78.3	15.5	19.8	5.1	5.3	0.7	0.8
South Korea	72.9	74.7	25.4	21.6	1.0	0.6	0.4	0.3

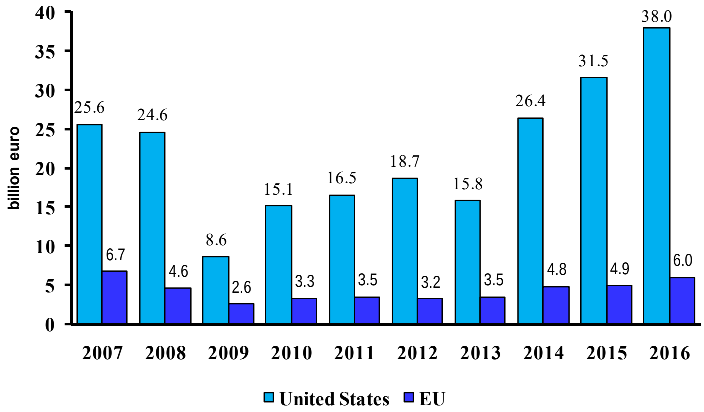
Source: Eurostat.

Table 1 also illustrates that the percentage of R&D expenditure financed by government sector is much higher than the corresponding shares for the United States (22.8%), South Korea (21.6%), China and Japan (19.8%). This reflects a higher reliance and a stronger role of public research in many EU countries (European Commission, 208a*)*. The highest share of R&D expenditures in the government sector was recorded in Latvia (47.7%), followed by Greece and Portugal (42.6%) in 2016.

The differences in business R&D investment across EU member states are only partly driven by the industry specialization of each country. The variation is also due to differences in the business environment, access to finance, human capital and the skills of the labor force (EIB, 2018).

There is a *low access to risk-taking capital* in the EU. Venture capital companies play an important role in providing financing to start-up and risky projects. However, Europe's venture capital market remains largely underdeveloped in comparison to the United States at all phases of the innovation process: from inception, to development and scale-up, from seed-capital, early- and later-stage development funds to mezzanine bridges. Figure 2 shows that the EU's venture capital market lags far behind that in the United Sates in terms of venture capital raised. In addition, the EU's market is largely dominated by Unaided Kingdom, which remained far away Europe's leading venture capital magnet, followed by Germany and France. Also, there is a large dispersion in terms of venture capital investment levels in Europe, as well as in their dynamics with low investments stagnating registered in several CEE countries (Diaconu, 2017).

Figure 2. *Venture capital raised (billion euro) in the EU and the United States*



Note: Data from HR, CY, MT, SI, SK were not included.
Source: Invest Europe, NVCA / Pitchbook.

Business R&D investment is characterized by high concentration, with a small number of countries, sectors and companies accounting for a large share of R&D expenditures. The 1000 EU firms that invest the most in R&D together account for more than 90 % of total business expenditure on R&D in the EU. In addition, major European companies are among the most important players on the world market, while the overall average EU R&D intensity lags behind the one registered in its main competitors.

3. Investment trends and economic effects in companies that invest the most in R&D in the EU

3.1 Main characteristics of major R&D investors in the EU

The EU Industrial R&D Investment Scoreboard comprises information on R&D investment made by each company included in the 1000 top companies registered in the EU ranked by their investment in R&D. According to European Commission (218b), the 1000 companies have invested more than €8 million in R&D in 2017/2018, and of these 1000, 577 appear in the world top 2500. The total R&D for the EU 1000 is shown in

Table 2, alongside other indicators of business performance. The EU 1000 companies have a total R&D of €206.3 bn in 2017/2018 and they raised most of financial indicators over time, not only R&D investments, but also net sales, capital expenditures, R&D intensity and capital intensity. Profitability also increased mainly in the last period and to a lesser extent the number of employees. Although the change in capital expenditure was higher than the change in R&D investment, *R&D investments per company and R&D intensity registered a constant increase.*

Table 2. *Overall business performance of 1000 R&D Scoreboard companies based on 2012-2018 data*

Indicators	2011/2012	2013/2014	2015/2016	2017/2018
R&D investment (€ m)	152,920.9	165,759.8	193,220.7	206,288.5
R&D investment/company (€ m)	152.91	165.76	193.22	206.88
Change in R&D investment over previous year (%)	9.4	8.4	16.7	5.5
Net sales (€ m)	6,361,329.0	6,302,425.3	6,033,828.7	6,365,624.6
Change in net sales over previous year (%)	1.1	-1.8	-4.3	5.5
Capital expenditure (€ m)	278,570.7	370,850.4	335,119.6	373,680.4
Change in capital expenditure over previous year (%)	12.5	33.12	9.63	11.50
Employees (number of persons)	20,968,150	19,975,761	19,251,802	21,308,605
Change in number of employees over previous year (%)	-4.6	-0.1	3.6	10.7
R&D investment per employee (€)	7,293	8,298	10,037	9,681
Net sales/Employee (€)	30.3	31.6	31.3	29.9
R&D investment/Net sales (%)	2.4	2.6	3.2	3.2
Capital expenditure/Net sales (%)	4.4	5.9	5.6	5.9
Operating profit/Net sales (%)	9.8	6.8	6.7	10.0

Source: author's calculations based on the 2010-2018 EU 1000 Scoreboard.

However, as in the previous periods, the last Scoreboard data display the persistence of *industrial R&D concentration by company, country and sector*, as one of the major characteristics of R&D in the EU. That means that a small number of companies, countries and sectors perform a large share of R&D investment. Table 3 shows that there are 899 companies in the top 10 member states that accounted for 97% of the total R&D investment performed in the EU 1000 group in the period 2017/2018. Moreover, the general performance in terms of net sales one year growth appears to be positively correlated with R&D one year growth, but more influenced by the number companies operating in the same country. The German companies made the largest contribution to the performance of the 1000 EU companies, registering 6.3% R&D one year growth and 6.5% net sales one year growth.

Table 3. *R&D trends for companies placed in the top 10 EU member states*

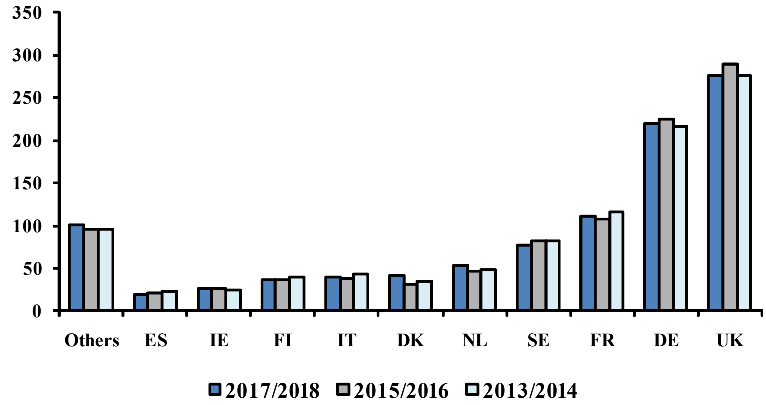
Country	Number of companies	R&D in 2017/2018 (€bn)	R&D share within EU (%)	R&D one year growth (%)	Net sales one year growth (%)
Germany	219	81.3	39.4	6.3	6.5
UK	275	30.5	14.8	6.9	16.2
France	111	29.0	14.0	8.2	9.1
Netherlands	53	18.5	8.9	0.6	5.3
Sweden	77	9.5	4.6	6.1	4.5
Ireland	27	8.5	4.1	-3.8	-1.1
Italy	39	6.5	3.2	9.5	6.3
Finland	36	6.4	3.1	1.1	5.2
Denmark	42	5.3	2.6	1.7	3.8
Spain	20	4.6	2.2	2.4	8.3

Country	Number of companies	R&D in 2017/2018 (€bn)	R&D share within EU (%)	R&D one year growth (%)	Net sales one year growth (%)
Top 10 EU countries	899	200.2	97.0	5.2	8.4
Other EU	101	6.1	3.0	13.0	11.2
Total EU	1000	206.3	100	5.4	8.5

Source: European Commission (2018b), p. 66.

The concentration of R&D by country is shown in Figure 3. 68% of the total R&D is the result of companies based in Germany, UK and France in 2017/2018 and this fact seems to persist. The aggregate indicator in each country is dependent on the figures of a small number of companies in the Scoreboard or the concentration of R&D at the level of a few firms. For example, five German automotive companies account for 45% of German R&D in 2017/2018.The data prove the importance of the investment behavior of a few large players for the country and sector R&D mix (Zaman and Goschin, 2012).

Figure 3. *R&D concentration by country within the 1000 EU companies, 2013-2018*



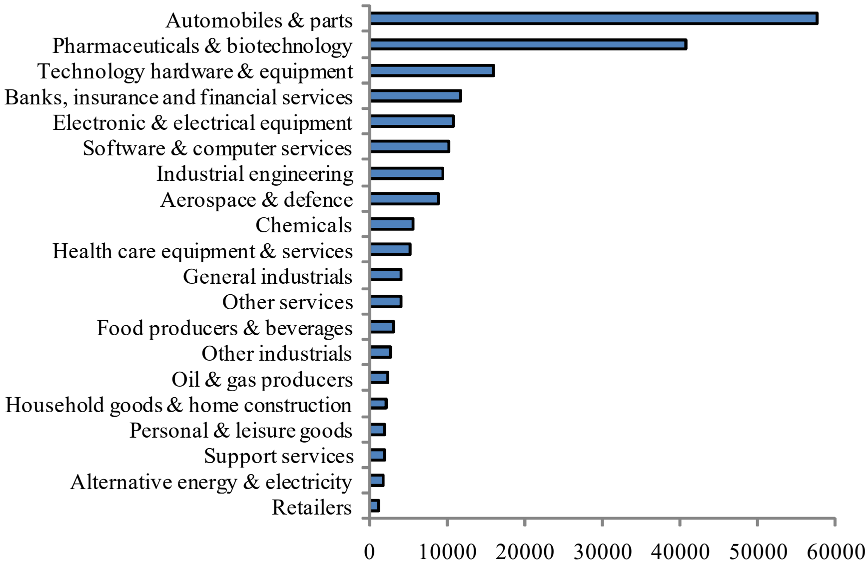
Source: European Commission 2016, 2017 and 2018b.

R&D investments are particularly *concentrated at the level of a few sectors* (Figure 4), such as automotive and aerospace, pharmaceuticals, technology hardware and equipment that account for more than 56% of the total R&D in the 1000 EU Scoreboard firms in 2017/2018. A similar concentration of R&D in a relatively small number of industrial sectors have been observed over the last 14 years (Ciupagea et al., 2003; Moncada-Paternò-Castello et al., 2006; Moncada-Paternò-Castello et al., 2010; Zaman and Goschin, 2012; Moncada-Paternò-Castello, 2016; European Commission, 2017, 2018b; EIB 2018).

According to the European Commission (2018a), there are three main technological areas where R&D is developing new and improved products for the future: biotechnology, software/AI (artificial intelligence) and new/improved materials. Examples of new developments in these three areas include cancer immunotherapies, gene and stem cell therapies, software robots to automate back office processes, graphene and solid state batteries. Autonomous electric vehicles provide an example involving two of these areas (software/AI and new materials. Biologically compatible structures that facilitate the sustained release of hormones or enzymes provide another example involving two areas.

A third example is digital health and the use of AI in drug discovery, in planning clinical trials and in diagnostics.

Figure 4. *R&D (€m) concentration by sector within the 1000 EU companies, 2017/2018*



Source: author's calculation based on the EU Industrial R&D Investment Scoreboard data.

However, in comparison with the USA, the EU is identified as having higher shares of R&D in medium-tech sectors that play a key role in shaping the EU R&D investments (see, for instance, Moncada-Castello, 2016, in which R&D intensity is examined and investigates its comparative distribution among firms, sectors and countries using the EU Industrial R&D Scoreboard data from 2005 to 2013 and the ICB sectoral classification). In this respect, the structural and intrinsic effects that impacted the EU's R&D intensity gap are analyzed. The structural composition of the economy is identified as the major factor impacting the EU's intensity gap, i.e. the prevalence of medium R&D intensity sectors in the EU's industrial structure. This is why, in the last decade, the EU was criticized for its slow dynamics toward high and medium high sectors of the economy. The intrinsic factor also play a major role in shaping the EU's R&D intensity gap in terms that the EU firms outperformed all their competing economies, but its importance in influencing the EU' R&D intensity gap is lower than the structural effect. That means that the most important share of the gap comes from the EU industrial mix, rather than from the individual RD intensity.

Coad (2017) observes that firms in the EU R&D Industrial Scoreboard for the years 2000-2015 display a large amount of heterogeneity in R&D intensities among firms in the same sector and the heterogeneity persists over time. That means that firms in the same sector cannot have always similar patterns of innovation activity. Some low tech firms have relatively high R&D intensities, while some high tech firms perform low R&D intensities. These findings have policy implications. In comparison with other studies that suggest that national R&D intensity targets should be reached by adjusting the economic structure toward more R&D intensive sectors, it is recommended that the adjustment should be made by stimulating firm's entry in high tech sectors and encouraging incumbent firms their R&D within their sectors as well.

The EU Industrial R&D Investment Scoreboard data display *the highest share of very large firms* of the total sample (Table 4); the very large ones (71.5%) performed the 96.29% of the total R&D investments, 99.52% of total capital expenditures and obtained 99.12% of total net sales. They are the most capital intensive. In the 2017/2018 sample, large firms are the most R&D intensive and, to a lesser extent, capital intensive. SMEs invest less of their net sales in R&D than large firms. Also, SMEs and large firms are more R&D intensive than capital intensive. Large firms are the most R&D intensive in the sample.

Nonetheless, when we analyze the R&D and capital expenditure costs, as well as the R&D/Capital expenditures ratios, we can illustrate better the investments patterns of each group. We compute R&D and capital expenditure costs as R&D/(Operating profit + R&D + Capital expenditures) and also Capital expenditures/(Operating profit + R&D + Capital expenditures). These ratios indicate the investment average effort of the total available funds made by each group. From this perspective, SMEs appear more R&D oriented when compared to large and very large firms. The last ratios related to the two types of investments efforts lead to the same pattern. Also, the percentage of R&D investment of the total investments effort is the highest in SMEs and decreases as firm's size increases.

Table 4. *R&D and capital investments, net sales, R&D and capital intensities performed by companies in the EU Industrial R&D Investment Scoreboard 2017/2018, by size class*

Type of firm by size		Small and medium-sized firms	Large firms	Very large firms	Total
% of total companies		15.20%	13.30%	71.50%	100.00%
R&D investments	€m	4,218.2	3,432.9	198,637.4	206,288.5
	% of total	2.04%	1.66%	96.29%	100.00%
Capital expenditures	€m	858.9	935.2	371,886.3	373,680.4
	% of total	0.23%	0.25%	99.52%	100.00%
Net sales	€m	36,706.6	19,119.4	6309,798.6	6365,624.6
	% of total	0.57%	0.30%	99.12%	100.00%
R&D intensity		11.49%	17.95%	3.14%	3.20%
Capital expenditures intensity		2.34%	4.89%	5.89%	5.87%
R&D cost		148.59%	78.02%	16.44%	16.69%
Capital exp. cost		6.80%	21.25%	30.79%	30.72%
R&D / Capital expenditures		4.91	3.67	0.53	0.55
R&D × 100 / (R&D + capital expenditure)		83.08%	78.59%	34.82%	35.57%
Capital expenditure × 100 / (R&D + capital expenditure)		16.92%	21.41%	65.18%	67.43%

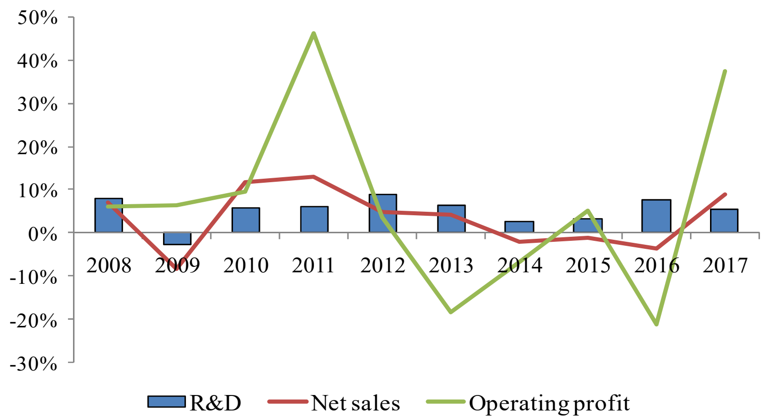
Source: author's calculations based on the 2017/2018 EU Industrial R&D Investment Scoreboard. We consider that small and medium-sized firms have 5-250 employees; large firms have 251-1000 employees and very large firms have more than 1000 employees.

The extent to which firm's investments impact their economic performance can vary across firms and economic sectors. There is an extensive literature associated with the impact of firm's size on its R&D behavior (see, for instance Ortega-Argilés and Brandsma, 2008 for a review of the literature). The same authors analyze the impact of firm's size on R&D intensity taking into account the firm's operating sectors. Using data from the top R&D

investors from the 2006 EU Industrial R&D Investment Scoreboard they conclude that smaller sized companies tend to spend a larger proportion of their income from sales on R&D and this result is independent of sectoral composition.

With respect to the trends in R&D, net sales and operating profit registered by the 1000 Scoreboard companies over a longer period of time, Figure 5 reveals several features. R&D shows positive trends for most of the 10 years period. Also, the growth rate of R&D investment has been significantly higher than the growth rate of net sales (except for the last year, when net sales have recovered strongly). Over the last year, companies' capital expenditures have improved, following several of negative performance or stagnation (European Commission, 2018b). Moreover, the growth rate of operating profit has improved as a response to the increase in net sales. Figure 5 reveals also two other important features: the major R&D players are continuous R&D investors and there seem to be a stronger positive correlation between R&D and net sales than between R&D and operating profit.

Figure 5. *One year R&D investments, net sales and operating profit change by the 1000 Scoreboard companies*



Source: the EU Industrial R&D Investment Scoreboard.

3.2. Economic effects of R&D investments in the 1000 EU companies

Statistics on R&D investments are often used to compare investment in innovation across countries and firms. R&D investment is viewed, in general, as an input in innovation activity, particularly in product innovation (Antonucci and Pianta, 2002), while capital expenditures are mainly involved in process innovation (Vaona and Pianta, 2008).

Firm productivity is associated with both R&D and capital investments, but the correlation can be affected by the performance of innovative firms. Factors such as product and market regulations, the development of capital markets to finance innovation, the protection of intellectual property rights, the nature of complementarities between investments in physical assets and intangible assets can also affect firm performance.

In order to investigate the relationship between firm's investments and the corresponding economic effects, we use data from the 2016-2018 EU Industrial R&D Investment

Scoreboard which centralizes micro-data on R&D investments, capital expenditures, net sales, operating profit, number of employees, market capitalization and profitability for each firm. Table 5 offers the description of each variable available in the data.

Table 5. *Variables included in the analysis to select the best regression models*

Variable	Description	Unit of measurement
RDexp	R&D expenditures funded by the company is the total R&D performed within a territorial unit that has been funded by the private or public companies.	€m
Capex	Capital expenditure is expenditure used by a company to acquire or upgrade physical assets such as equipment, property, industrial buildings.	€m
Opprofit	Operating profit is calculated as profit (or loss) before taxation, plus net interest cost (or minus net interest income) minus government grants, less gains (or plus losses) arising from the sale/disposal of businesses or fixed assets.	€m
Netsales	Net sales follow the usual accounting definition of sales, excluding sales taxes and shares of sales of joint ventures & associates.	€m
Profitability	Profitability is operating profit as percent of net sales.	%
Marketcap	Market capitalization is the share price multiplied by the number of shares issued at a given date.	€m
Emp	Number of employees is the total consolidated average employees or year-end employees if average not stated.	persons

Source: European Commission (2018b).

We present the results our econometric analysis in two parts.

First of all, we search for the best model that is able to explain the economic effects resulted from the investment efforts made by firms, using the entire sample of R&D investors. Second of all, we investigate whether the size matter for R&D. In this respect we engage two different sets of regression equations. We select net sales and operating profit as economic effects and dependent variables.

Between the independent variables used for the study, R&D expenditures and capital expenditures show the strongest impact on net sales and operating profit. That means that firms with higher R&D and capital expenditure will have increased net sales and operating profit. The research hypothesis investigated here is listed as follows: firms with high R&D and capital expenditures have improved net sales and/or operating income.

From this perspective, our approach is not new. Hsu et al. (2013) investigate the impact of R&D capability on firm's financial performance by using historical data of Taiwanese companies from 2000 to 2011, and find that firm's R&D investments rate impact net sales; firms with a high level of R&D rate have better stock returns and net sales, but such firms do not have an advantage in terms of operating income. These results can indicate that higher R&D investments increase operating costs which, in turn, decreases operating income despite increased net sales.

Using the EU Industrial R&D Investment Scoreboard data, Zaman and Goschin (2012) show that, although the economic crisis and slow recovery limited the firms' financing capacity to R&D, firms registered an increase in the R&D investments in 2008-2010, leading to an increase in their net sales. Also, the R&D growth rate positively impacted the net sales growth rate. These results reveal success cumulativeness in innovation activity, which capture the extent to which "success breeds success" (Dosi and Nelson, 2009) demonstrated in the study to maintain itself, even in adverse market conditions with respect to financing and demand.

Parcharidis and Varsakelis (2007) find that the effect of R&D investments on profitability becomes positive after a period with decreasing returns. Using data from companies listed at Athens Stock Exchange for the period 1995-2000, the result obtained can be induced by production costs that tend to increase in the short-run, because new product development or new processes need time to show results.

We use the EU Industrial R&D Investment Scoreboard micro-data under the year of analysis draw from 2016-2018. Our analysis of R&D activity and its economic effects in the selected sample proceeds in the following equations:

$$Y_{it} = \alpha_0 + \sum_j \alpha_1 Z_{jit} + \varepsilon_{it} \quad (1)$$

where
Y_{ij} – the dependent variable, net sales or operating profits (in €m);
Z_{ij} – the independent (exogenous) variables;
α_j are the parameters that summarize the *j* factor contribution to the dependent variable;
t stands to the year and *i* for the company;
ε_{it} is an independently and identically distributed error term for *i* and *t* with zero mean and variance σ^2.

Because the purpose of our analysis is to select the best regression model that is able to explain the relationships established between the variables analyzed, we tried building several models. We started the analysis with all variables considered and removed the weakest predictor at every step, respectively the independent variable that determines the smallest reduction of Fisher statistics. The parameters of the models were estimated using Ordinary Least Squares and the estimated regression coefficients, alongside their corresponding standard errors and the values of standard econometric tests, are shown in Table 6. Only the statistically significant variables were preserved in the final specification of each econometric model.

Table 6. *Regression analysis results for the years 2017/2018 and 2016/2017 – whole sample*

Models: t =2017/2018 t-1 = 2015/2016	Independent variables					Tests				
Model 1 *Y = Net sales* (t)	RDexp (t)	Capex (t)	Emp (t)	Marketcap (t)	Intercept	Obs.	Adj. R^2	F	Prob	Durbin-Watson
Coefficient	4.140 (0.000*)	9.049 (0.000*)	0.083 (0.000*)	0.039 (0.000*)	191.273 (0.582*)	940	0.868	1,098	0.000	1.793
Std. error	0.438	0.252	0.007	0.022	346.954					
Model 2 *Y=Opprofit* (t)	RDexp (t)	Capex (t)	Emp (t)	Marketcap (t)	Intercept	Obs.	Adj. R^2	F	Prob	Durbin-Watson
Coefficient	0.345 (0.000*)	0.681 (0.000*)	0.009 (0.000*)		154.173 (0.001*)	940	0.546	363.900	0.000	1.914
Std. error	0.070	0.039	0.001		48.369					

Model 3 *Y=Net sales* (t-1)	RDexp (t-1)	Capex (t-1)	Emp (t-1)		Intercept	Obs.	Adj. R^2	F	Prob	Durbin-Watson
Coefficient	4.827 (0.001*)	7.470 (0.001*)	405.290 (0.001*)		-136.68 (0.474*)	898	0.999	3,665	0.001	2.194
Std. error	0.299	0.144	3.527		90.603					
Model 4 *Y=Opprofit* (t-1)	RDexp (t-1)	Capex (t-1)	Emp (t-1)		Intercept	Obs.	Adj. R^2	F	Prob	Durbin-Watson
Coefficient	0.437 (0.001*)	0.344 (0.001*)	11.221 (0.001*)		12.260 (0.001*)	898	0.994	52,782	0,001	1.826
Std. error	0.059	0.029	0.701		37.723					

Source: author's calculations. *Significant at 5%.

The results from the first model referring to the year 2017/2018 indicate that the net sales are positively influenced by increases in the R&D investments, in capital investments and in the number of employees as well as in the market capitalization. The operating profit is positively influenced by investing in R&D activities, as well as in fixed assets and by increasing the number of employees. The influences of R&D and capital expenditures on the net sales and operating profit is positive in the year 2017/2016 as well, meaning that firm's performance can be explained by the increase in R&D and capital expenditures and number of employees. Only the variation in exogenous variables under the year of analysis is found to be statistically important ($p < 0.05$). R&D and capital expenditures from t-1, t-2 and t-3 do not influence net sales and operating profit in year t. The models 1-4 are statistically significant and explain in a very large proportion the variability in net sales and operating profit ($R^2 = 0.868; 0.546; 0.999; 0.994$).

Looking within the whole group of top R&D investors, the role of company size in R&D can be analyzed. We investigate whether size has an effect on the R&D investments of the companies. The group consists of companies with established records of sales, R&D and capital expenditure. We carry out regressions of the net sales in firms on the size of firms, separately for each size class, considering the total number of employees a measure of firm′s size. The results are shown in Table 7:

Table 7. *Regression analysis results for the years 2018/2017-2016/2015 by firm's size class Dependent variable – Net sales; Independent variable – Rdexp; Capex.*

Dependent variables and tests	Small and medium-sized firms *Y = Net sales*	Large firms *Y = Net sales*	Very large firms *Y = Net sales*
RDexp	5.460 (0.000)*	1.925 (0.000)*	7.593 (0.000)*
Capex	15.859 (0.000)*	1.117 (0.085)*	8.867 (0.000)*
Intercept	-83.828 (0.000)*	107.703 (0.000)*	2,313.432 (0.000)*
F	95.76	8.177	2,831
Prob.	0.000*	0.000	0.000
Adjusted R^2	0.520	0.058	0.815
Durbin Watson	2.138	1.864	1.713
Obs.	176	234	1,038

Source: author's calculations. *Significant at 5%.

The R&D and capital expenditures show positive and significant coefficients in all groups of firms. However, firms belonging to the very large group seem to be in a better position to innovation through R&D than SMEs and large firms. The impact of R&D investments on the net sales is greatest at the level of very large firms. This fact confirms the market power that very large firms have, including ensuring them legal protection which can provide short-run market power to create an incentive to invest in R&D.

4. Conclusions ad policy implications

Given the large differences in R&D investment across EU countries, there is scope for public policy to intervene on several fronts to incentivize R&D investment. In addition, public intervention can be justified not only because firm performance is positively related with net sales or operating profit in firms, but due to the positive externalities that are typically associated with R&D spending and innovation outputs.

The EU's strength in science is an important asset, but it will not be enough if the EU does not put in place the right enabling conditions and business climate for stronger and more impactful, breakthrough and deep-tech innovation activity. Overcoming the EU's limitations to reap the full benefits of the new wave of innovation needs a concerted effort across stakeholders, including research institutions, regulators, businesses and governments at regional, national and EU level. Addressing the EU's innovation challenges requires a coordinated effort from all stakeholders in all member states at different levels that need to upgrade their efforts to boost investment in innovation and other intangible assets, such as education and skills development and ICT, and build a backdrop that incentivizes the development and uptake of innovation (European Commission, 2018b).

In recent years, the EU has adopted many measures to strengthen its innovation capacity. However, the EU needs to reinforce its policy efforts in order to establish a framework for stronger and more impactful innovation creation and diffusion, against the backdrop of today's rapidly changing innovation dynamics and enhanced uncertainty.

The EU needs investments to cover the whole science-innovation spectrum, from basic research to breakthrough innovation, as well as education and skills. While member states benefit from different fiscal spaces for public investment, those able to do so should invest more in intangible assets. The EU is strong in incremental innovation and medium-tech (e.g. transport, health or energy sectors) innovation and needs to boost R&D investments particularly business R&D investments, an area which EU notably lags behind. In addition, public R&D investment will benefit from moving away from supporting specific fields towards more comprehensive mission-oriented policy approaches that maximize the impacts of public R&D and galvanize private investment.

The average size of the top R& investors among EU-based companies is rather very large than large. Although they invest less form their net sales in R&D and have a lower R&D cost (Table 4), they can better exploit the results from their investments than SMEs (Table 7). In order to become a competitive global player, EU needs particularly to incentivize the innovation in SMEs by boosting sufficient access to risk capital. Public efforts to invest and leverage private risk capital are crucial. Initiatives like the Capital Markets Union or the creation of a pan-European Venture Capital "Fund of Funds" aiming at making European capital markets deeper, broader, better integrated and with greater capacity to leverage business resources will help bridge this gap.

Continuing structural reforms that allow markets to react better and faster to the changes that innovations bring to the markets and which facilitate the entry, as well as the orderly exit of firms, will help reallocate resources towards the most innovative and productive companies, avoiding the negative lock-in of resources in unproductive and zombie companies (European Commission, 2018b).

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