Research and development activities in Belgium: A snapshot of past investment for the country's future

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by Saskia Vennix

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ABSTRACT

Recent changes in the accounting legislation regarding the accounting and disclosure of research and development (R&D) expenditure in the financial statements have triggered this research on the importance of this kind of activities and their impact at microeconomic level. Using survey data, a solid sample of 1,964 R&D companies was compiled. Based on this sample, some of the main characteristics of R&D firms are presented, such as sector of activity, age, geographic location, etc. In 2016, these 1,964 R&D entities together employed nearly 279,000 people and generated € 45 billion of value added, which represents 6 % of Belgium's domestic employment and 10.6 % of the country's gross domestic product. By means of statistical techniques, the microeconomic impact of R&D efforts on average annual growth of value added, average annual employment growth and average annual growth of labour productivity is investigated. Following this research, the conclusion is that R&D investment has generally had a positive impact on average annual growth of value added and average annual employment growth for periods of four years or longer. In a shorter timespan (less than four years), such a positive impact of R&D involvement could not be demonstrated. For the average annual growth of labour productivity, no evidence of any difference between the R&D and the non-R&D group was found.

JEL classification: D22, J21, L25, O33.

Key words: microeconomic data, corporate R&D, firm performance, employment, value added, Belgian firms

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INTRODUCTION

Numerous scientific studies have demonstrated a positive relationship between research and development (R&D) expenses and performance. The literature addressing this topic is extensive. Chauvin and Hirschey (1993) and Bae and Noh (2001) demonstrated that R&D investment has a consistent and positive effect on a firm's market value. This conclusion was affirmed by Ehie and Olibe (2010) for both manufacturing and service firms in the US, based on an empirical analysis covering the period 1990-2007. Moreover, R&D expenditure facilitates an entity's future growth opportunities (Bae and Noh, 2001). The reasons for this include the fact that R&D seems positively correlated with productivity (Morbey and Reithner, 1990; Parisi *et al*., 2006), sales growth (Morbey and Reithner, 1990; Del Monte and Papagni, 2003) and financial performance. Crépon *et al.* (1998) even developed a model – also known as the CDM model – that demonstrates a link between research, innovation and productivity at the firm level. Peters *et al.* (2013) also quantified linkages between a firm's R&D investment, product and process innovations, and future productivity and profits.

Anagnostopoulou and Levis (2008) extended previous research and, from their large dataset of UK listed companies for the period 1990-2003, found evidence supporting the relationship between R&D intensity (different proxies were used) and growth in sales and gross income, but only in the case of R&D-intensive industries. Ayaydin and Karaaslan (2014) evidenced a positive effect of R&D intensity (defined as R&D expenditure in relation to net sales) on firms' financial performance (measured by return on assets) for a sample of 145 manufacturing companies in Turkey for the 2008-2013 period. Based on a selection of (formerly) publicly listed companies from the Netherlands, Belgium and Luxembourg, Beld (2014) also concluded that firms' financial performance (return on assets) is boosted by R&D investment. Although Vithessonthi and Racela (2016) argued that investing in R&D is likely to benefit a firm in the long run, they found a negative short-run impact of R&D on a company's financial performance (measured as return on assets and return on sales), for a sample of listed US companies over the period 1990-2013. Allocation of significant resources to R&D obviously detracts from immediate profitability.

At macro level, it is often argued that innovation and R&D might have an adverse impact on employment. As this might indeed be a direct consequence of radical technological change, studies (Van Reenen, 1997; Edquist *et al*., 2001) have provided empirical evidence that this is compensated by positive employment effects at the firm level, resulting from increasing demand for products due to the fall in prices (as technological innovation leads to a decrease in production costs) or due to higher wages and/or from additional investment due to higher profits. However, at an aggregate level, a business stealing bias might exist, meaning that job expansion at the firm level is at the expense of competitors' employment. Using a dataset covering 25 manufacturing and service sectors for 16 European countries over the period 1996-2005, Bogliacino and Vivarelli (2010) found that R&D expenditures have an overall job-creating effect. Harrison *et al.* (2014) also observed that innovation stimulates employment, and estimated that the maximum reallocation due to business stealing amounts to one third of the net employment created by product innovators.

Policymakers have also recognised the importance of R&D for obtaining a sustainable competitive advantage. R&D does not only yield productivity and other competitive benefits to companies (such as new products, improved products, new applications for existing products, etc.), its spillover effects are also beneficial to economies. In 2000, the European Union (EU) was already aware of the need to boost R&D in order to face growing international challenges and to secure the EU's economic competitiveness. This resulted in a strategy – also known as the Lisbon strategy – to become the most competitive and dynamic knowledge-based economy in the world. One of the means to reach this goal was to raise overall R&D investment to 3 % of gross domestic product (GDP). Until now, this objective has not been met, but the EU reaffirmed this goal in its Europe 2020 strategy. The Europe 2020 strategy sets the target of improving the conditions for innovation, research and development, among other things, with the aim of reaching the 3 % objective by 2020, of which two-thirds must be derived from the private sector.

Recent provisional figures from Eurostat indicate that the EU's ratio of R&D expenditure to GDP – also referred to as R&D intensity – has risen slightly to 2.2 % in 2017, which is still far below the 3 % target. According to provisional figures, Belgium's R&D intensity remained just below the 2.6 % level in 2017. In a recent publication, Clerbois *et al.* (2018) estimate that Belgian R&D efforts must rise at an average annual rate of 7.61 % during the period 2015-2020 in order to reach the 3 % target. Following the calculations by Clerbois *et al.*, such an average annual growth rate exceeds the actual average annual growth rate observed between 2002 and 2015. Based on Eurostat data, the average annual growth rate for the period 2013-2017 remains below the 7.61 % level as well. This implies that our country will have to shift to a higher gear if it intends to meet the 3 % objective by 2020.

Belgium, however, performs better than the European average. The European Innovation Scoreboard 2018[1] considers Belgium as a strong innovator, mentioning firm investment and attractive research systems as two of the country's strengths. Companies active in R&D and innovation are especially attracted by the high quality of Belgian education and research facilities, the availability of skilled workers, and various tax incentives for R&D investment. As far as this last point is concerned, policy makers have made efforts to create an environment that stimulates and attracts R&D investment. These tax incentives include a partial (80 %) exemption from advance payment of the withholding tax on the wages of researchers with at least a master's degree, and a tax deduction of 13.5 % (or 20.5 % spread over several years) for investment in patents or assets that aim to promote R&D in new products and advanced technologies that are not detrimental to the environment or that reduce any negative effects on the environment. Since 2018, following the corporate income tax reform, the payroll tax exemption for R&D staff is extended to holders of certain bachelor degrees (biotechnology, industrial science and technology, nautical science, product development, etc.), albeit it limited to 40 % for 2018 and 2019. From 2020, it will be increased to 80 % as in the case of master's degrees. The withholding tax exemption measure offers the advantage that it reduces the net employee expenses for the companies concerned, without lowering the gross R&D salaries and therefore the R&D intensity. Expanding these fiscal measures, the government affirms that it is determined to strengthen Belgium's position as an R&D country. According to a working paper[2] published by the Federal Planning Bureau, Belgium now has the most generous R&D tax incentives relative to GDP out of all the OECD countries.

For accounting periods starting on or after the 1st of January 2016, the transposition into Belgian law of Directive 2013/34/EU of the European Parliament and of the Council of 26 June 2013 on the annual financial statements, consolidated financial statements and related reports of certain types of undertaking implemented significant changes in companies' financial reporting regulations. One of these changes relates to the accounting and disclosure of R&D expenditure in the financial statements. Therefore, three years after the entry into force, now is the time to study the topic of R&D expenses in Belgium in greater depth. More specifically, the aim of this paper is to provide a picture of the Belgian corporations that invest part of their resources in R&D: what are their activities? Where are they located? Do they belong to a Belgian or a foreign group? How many people do they employ? How much value added do they generate? Additionally, the goal is to assess the growth performance of Belgian companies active in R&D compared to a non-R&D group. Since most Belgian R&D companies belong to a group (cf. section 1.7) and R&D activities are sometimes even organised in separate legal entities, it does not seem correct to link these activities to the performance of the company alone. Indeed, the knowledge acquired, new products or new technology will be used by all companies within the group and therefore benefit all of them. Since many of these group companies are located all over the world, it is impossible to directly link the Belgian R&D activities to the financial performance of each of these entities. Moreover, groups may have several R&D centres located in different countries. As a result, this paper focuses on the direct impact for the Belgian

[1] https://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en

[2] Dumont (2019).

economy: do R&D companies experience stronger average annual growth in value added, employment and labour productivity compared to their peers not active in R&D?

Annex 1 mentions the changes in the financial reporting legislation in order to explain the R&D-related information that can be retrieved from the most recent financial statements of Belgian companies. However, the definition of R&D applicable to the financial statements (accounting perspective) differs from the official statistical definition of R&D (policymaking perspective, used for instance to measure whether the criterion of 3 % has been met). This topic is elaborated in detail in the annex to explain why the standardised financial statements could not be used as a unique data source to determine the R&D activity of Belgian companies.

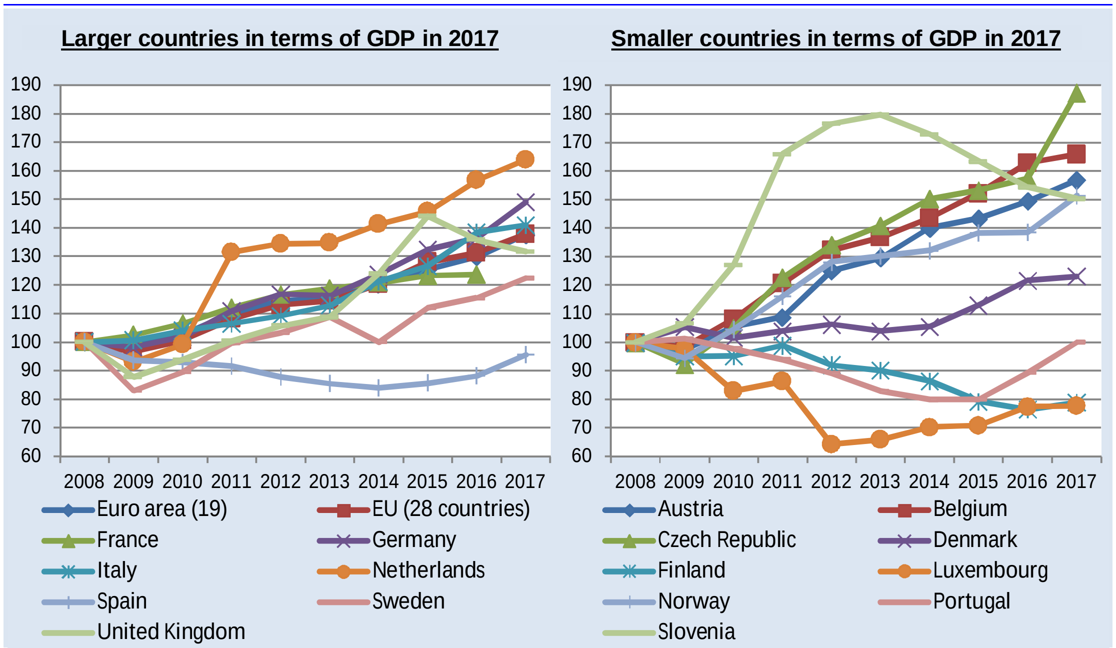
1 PORTRAIT OF CORPORATE R&D INVESTMENT IN BELGIUM

1.1 INTRODUCTION

According to the OECD terminology[3], gross expenditures on R&D are analysed per implementing agent or by location of the activity. They include business expenditures on R&D (companies and collective research institutes, which is in fact the main scope of this study), government expenditures on R&D (all units of federal, regional and local government and other government bodies such as public not for profit organisations), higher education expenditures on R&D (universities, research institutes controlled by universities, higher education institutions) and not for profit organisations expenditures on R&D (both partly public and private organisations and international organisations). For most industrialised countries, the business enterprise sector accounts for the largest share of R&D expenditures. The business sector comprises[2] resident financial and non-financial corporations, branches of non-resident enterprises, and resident non-profit institutions that are market producers of goods or services, or provide services for businesses.

In the Belgian business enterprise sector, a total of € 7.7 billion[4] was spent on R&D in 2017. In comparison with the year 2008, corporate R&D spending has increased by 65.8 %. Compared to other major R&D investor countries, Belgium's performance ranked second (Chart 1). Countries such as Bulgaria, Cyprus, Poland and Slovakia have a higher growth rate, but their level of R&D investment per capita remains relatively low. The nine-year growth rate of corporate R&D expenditure stood at 38 % for both the EU and the euro area.

CHART 1 R&D EXPENDITURE BY THE BUSINESS ENTERPRISE SECTOR
(current prices, index 2008 = 100)



Source: Eurostat. The majority of the 2017 figures are provisional. No 2017 figures available for France at the time of finalisation of this paper.

In view of the scale of R&D investment in Belgium, especially that originating from the business enterprise sector, and the significant growth over the past couple of years, this topic merits a more detailed analysis.

3 OECD (2015).

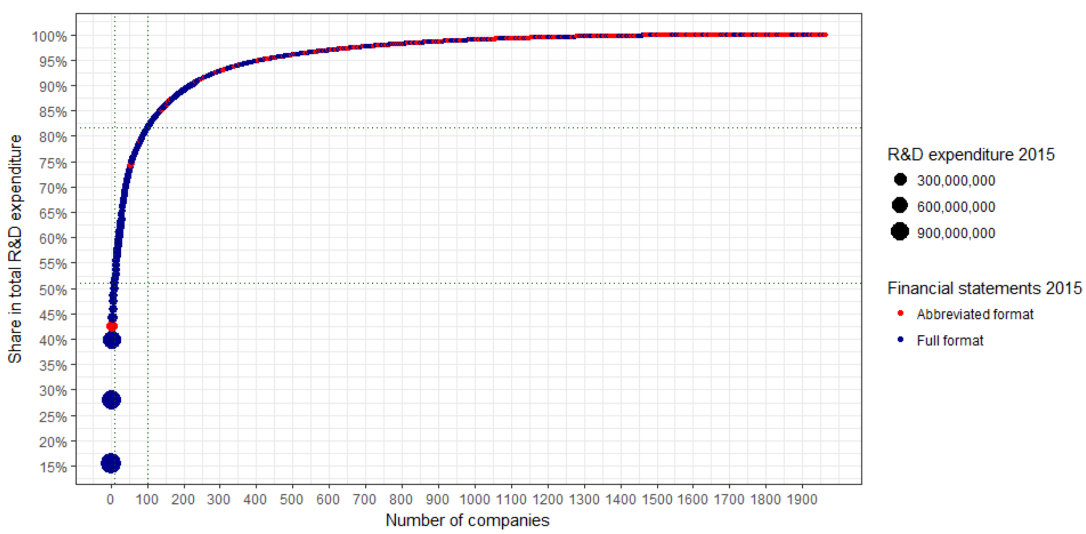
4 Provisional Eurostat figure for the year 2017.

1.2 CONSTRUCTION OF THE SAMPLE

In order to provide a portrait of Belgian companies investing in R&D, it is obviously necessary to define a sample. The total population of Belgian R&D-investing companies is not known. Annex 1 clearly shows that information from the financial statements cannot be used to determine the amount of a firm's R&D expenditure. The biannual survey performed by the Belgian Science Policy Office's (Belspo) scientific and technical information department commissioned by the OECD and Eurostat, in close cooperation with regional and community partners, is therefore used as a source for R&D expenditure at micro level. This survey is organised every two years among Belgian companies and aims to provide an overview of Belgium's scientific potential. The most recent results available cover the period 2015[5].

Respondents to the survey reporting intramural and/or extramural[6] R&D expenditure for both 2014 and 2015 were linked to standardised financial statements for periods ending in 2014, 2015 and 2016. Only those companies that filed either a full or an abbreviated format for three consecutive years (i.e. 2014 to 2016) were included in the sample. Employment activities (NACE code 78), which comprise in particular temporary employment agencies, as well as education activities (NACE code 85) were removed, due to their specific characteristics and atypical behaviour. 1,964 companies from the Belspo R&D survey could be linked to their respective 2014, 2015 and 2016 annual accounts[7]. Mapping failures were due to financial institutions, insurance companies and foreign companies that do not file standardised financial statements, bankruptcies, late filing, extended accounting periods, etc. The analysis took account of both full and abbreviated formats, irrespective of the length of the accounting period and the closing date of the financial statements.

CHART 2 CUMULATIVE DISTRIBUTION OF R&D EXPENDITURE IN 2015



Source: Belspo survey data, NBB (own calculations).

Out of the 1,964 companies in the R&D sample[8], 1,092 – i.e. 55.6 % – filed a full format for the accounting period 2015, whereas the remainder – i.e. 44.4 % – filed an abbreviated format. The 1,092 companies filing a full format in 2015 spent on average 4.1 % of their operating revenue on R&D (R&D intensity) in 2015. The median R&D intensity, however, equalled only 1.7 %. R&D intensity cannot be calculated for corporations filing an abbreviated or micro format since the majority

[5] More information about the Belspo survey data is given in section 4 of Annex 1.

[6] A definition of intramural and extramural R&D is provided in section 3 of Annex 1.

[7] Financial statements filed up to mid-October 2018 have been taken into account.

[8] Checks were made for companies covered by the R&D sample and explicitly mentioned in this study to verify that their R&D activity can be retrieved from other sources (financial statements and/or website). As a result, no confidentiality issues arise.

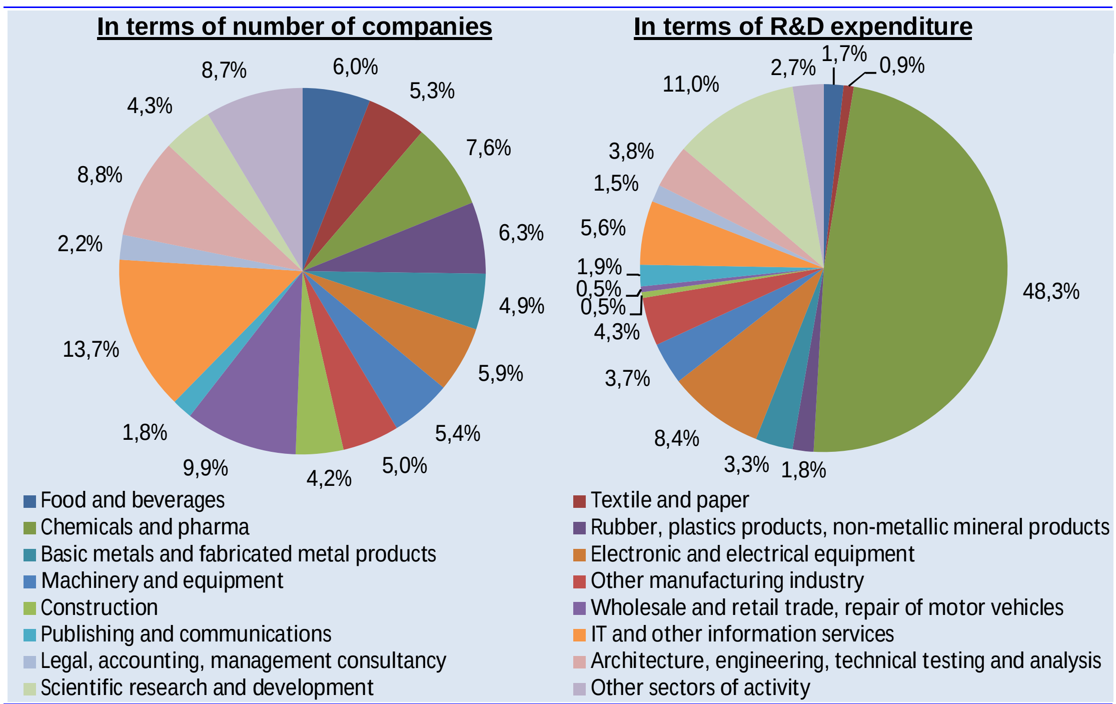
of them do not disclose figures related to revenue. The 1,964 companies together invested € 7.4 billion[9] in R&D activities, which means on average € 3.75 million per company. However, in the Belgian business sector, R&D activities are highly concentrated with the top 10 companies in terms of R&D investment accounting for more than half of all R&D expenditure in 2015 (Chart 2). The top 3 even account for 40 % of total R&D investment. The hundred companies spending the largest amounts on R&D together represent 82 % of all reported R&D expenses.

1.3 SECTORS OF ACTIVITY INCURRING R&D EXPENDITURE

The activity sector[10] that is best represented among the companies that incurred R&D costs in 2015 is the IT sector (Chart 3). However, the IT sector accounts for only 5.6 % of total R&D expenditure. On average, each IT company invests € 1.5 million. 9.9 % of the R&D companies are active in the trade sector, whereas they account for only 0.5 % of all R&D expenditure. The average R&D cost per trade company - € 0.2 million – remains far below the overall average.

In terms of R&D budgets, the chemicals and pharma industry is the most important sector. Chemical and pharma companies account for 48.3 % of all R&D expenditure. Unsurprisingly, this is mainly due to the pharmaceutical companies, even though only 27 of them are included in the sample; that small number is in fact the reason why they have been grouped together with the chemicals industry, to ensure that the figures calculated in the next sections are meaningful. The average R&D spending in 2015 amounts to € 114.3 million among the pharmaceutical firms, while it is just € 3.8 million among the chemical companies.

CHART 3 SHARE OF SECTORS OF ACTIVITY IN R&D EXPENDITURE IN 2015



Source: NBB, Belspo survey data (own calculations).

[9] Both intramural and extramural expenses are taken into account, which implies that certain R&D activities might be included twice in this figure, namely those R&D activities that are outsourced and for which the subcontractor is included in the sample too. Since the analysis in this section is made at micro level, this double-counting is not an issue. On the contrary, it is best to take into account all R&D expenses, in order to get a clear picture of the scale of R&D at company level.

[10] Annex 2 contains the definition of the different sectors of activity in terms of NACE codes.

Often closely connected to the pharma sector, especially in the case of biotechnology firms, the scientific R&D sector ranks second in terms of the amounts involved. The sector accounts for another 11 % of the overall R&D expenditure, which implies that the average R&D cost incurred per scientific R&D company – € 9.6 million – is also well above the overall average.

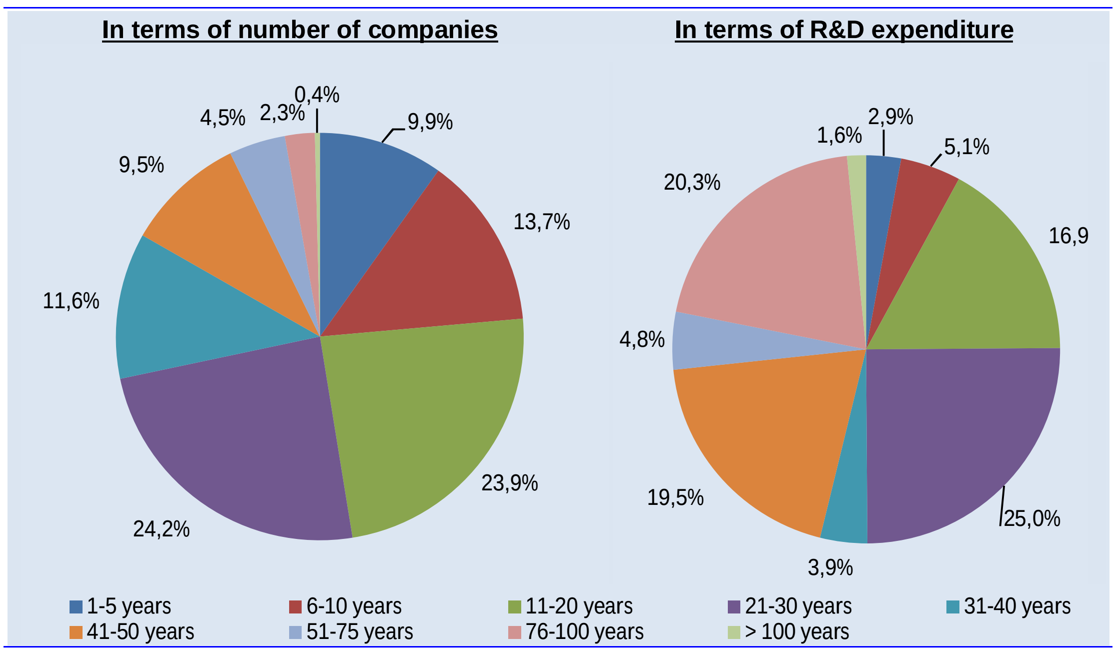
In Eurostat's classification of the manufacturing industries according to technological intensity[11], not only the pharmaceutical industry but also the manufacture of computer, electronic and optical products[12] is categorised as a high-technology industry. In Chart 3, this branch is grouped together with the manufacturers of electrical equipment[13], a medium-high technology industry. The figures do provide some evidence for these classifications. 5.9 % of the companies in the sample are classified in the electronic and electrical equipment industry, whereas they report 8.4 % of the R&D investment. Furthermore, average R&D spending is clearly higher in the electronic equipment industry (€ 7.3 million) than in the electrical equipment industry (€ 1.8 million).

Other manufacturing industry includes the manufacture of other transport equipment[14]. In the sample, this industry sector is mainly composed of manufacturers of aircraft and spacecraft and related machinery[15], another high-technology industry according to Eurostat's classification. The figures support this view as the average R&D investment amounted to € 12.3 million in 2015. This average figure is relatively high for manufacturers of basic metals[16] too (€ 8.9 million), despite the fact that Eurostat considers this branch as a medium-low-technology industry.

1.4 AGE OF R&D COMPANIES

Using the most recent year of the Belspo survey (i.e. 2015) as the reference year, R&D companies from the sample are between 1 and 143 years old.

CHART 4 AGE DISTRIBUTION OF R&D COMPANIES



Source: NBB, Belspo survey data (own calculations).

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[11] http://ec.europa.eu/eurostat/statistics-explained/pdfscache/6384.pdf
[12] NACE code 26.
[13] NACE code 27.
[14] NACE code 30.
[15] NACE code 30.3.
[16] NACE code 24.

Almost half of the R&D companies are between 1 and 20 years old, but Chart 4 reveals that they do not account for the majority of the R&D costs. Until the age of 10, R&D budgets remain relatively small. Companies over 40 years old seem to be able to spend the most resources on R&D. Although they only represent 16.8 % of the sample, they account for 46.2 % of the aggregate R&D expenditure. If the top 3 companies spending the most on R&D are removed from the sample (as they distort the figures to some extent), the average R&D costs incurred in 2015 per group of companies aged 40 or younger varies between € 1.1 million and € 2.7 million. This average increases to € 2.8 million for the group between 41 and 50 years old, to € 4 million for the group between 51 and 75 years old, to € 7.7 million for the group between 76 and 100 years old, and even to € 14.7 million for the group older than 100.

The few companies older than 100, are nearly all active in manufacturing industry. Those older than 50 are best represented in the chemicals and pharma industry (16.1 % of these firms are older than 50), the manufacture of rubber, plastic products and non-metallic mineral products (13.7 %), the other manufacturing industry (13.3 %) and the metal industry (12.4 %). Young companies (at most 10 years old), on the other hand, are relatively better represented in the scientific R&D sector (61.2 % of these firms are no more than 10 years old), legal, accounting and management consultancy activities (41.9 %), the IT sector (39.8 %) and architecture, engineering, technical testing and analysis activities (37.0 %).

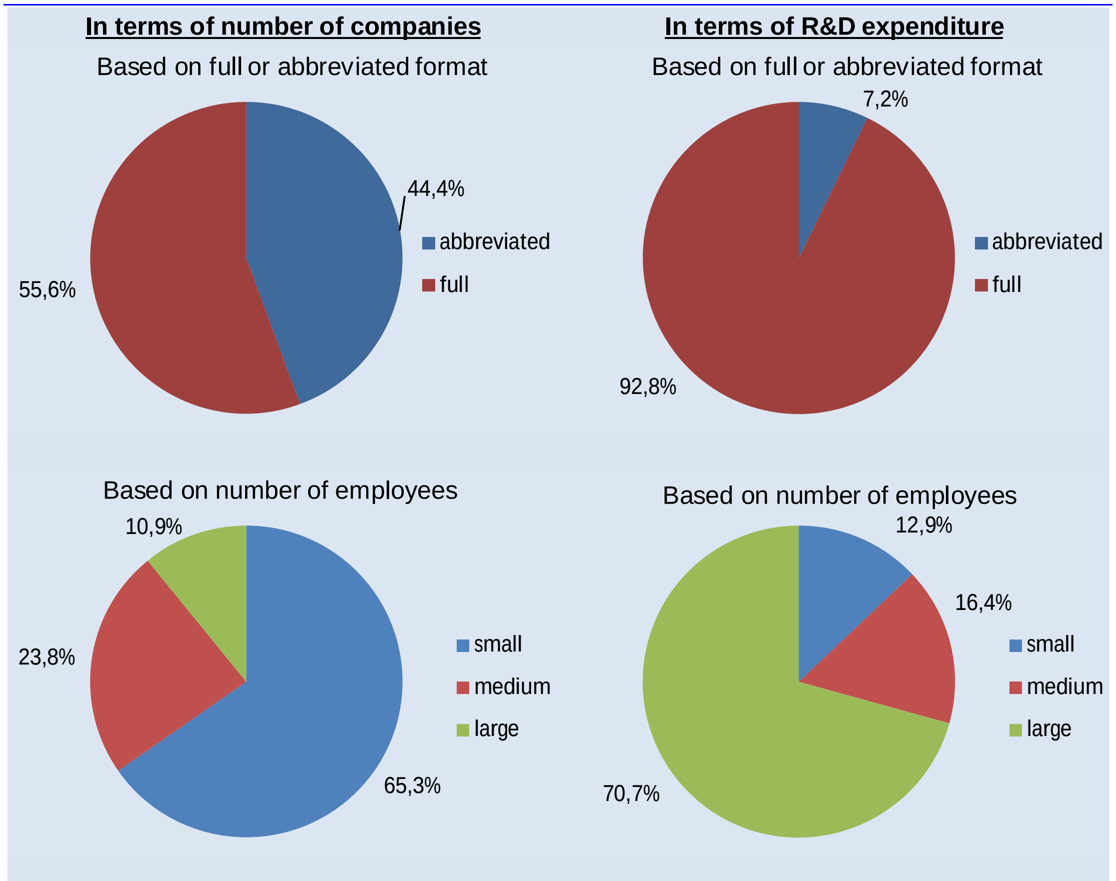
If the sample of 1,964 companies active in R&D is compared to all other Belgian corporations filing standardised financial statements for the period 2014-2016, it can be stated that the R&D firms under review are in general somewhat older. Indeed, the median age of the R&D sample is 22, compared to 14 for all other Belgian entities. This observation is confirmed in all sectors of activity, except scientific R&D. Here, the median age equals 9 for both populations. The difference in median age is largest in the construction sector (14 years) and the metal industry (10 years).

1.5 SIZE OF R&D COMPANIES

As Chart 5 shows, R&D activities are not confined exclusively to large companies. Since the accounting definition for large and micro-entities cannot be applied because turnover information is often missing from financial statements in the abbreviated format, other size criteria had to be used. The upper graphs in Chart 5 are based on the type of annual accounts filed for the accounting year 2015. 44.4 % of the sample of R&D companies filed an abbreviated format for the year 2015. However, they account for only 7.2 % of all R&D expenditure in 2015. Therefore, the majority of R&D costs are reported by entities filing financial statements according to the full format.

The outcome of using a size criterion based on the average number of employees expressed in full-time equivalents is displayed in the lower graphs of Chart 5. Here, three size classes are distinguished: small, medium and large. Small companies are defined as those employing at most 50 people. Medium-sized firms are defined as those having more than 50 but maximum 250 staff members. Finally, large entities are defined as those having a workforce of more than 250 employees. Based on this definition, nearly two-thirds of the R&D sample are small companies, yet they generate only 12.9 % of the R&D expenses. Large firms make up the smallest group, but they accounted for 70.7 % of total R&D expenditure in 2015.

CHART 5 R&D COMPANIES BY SIZE CLASS



Source: NBB, Belspo survey data (own calculations).

1.6 GEOGRAPHIC LOCATION OF R&D COMPANIES

Belgium is geographically classified according to a hierarchical system introduced by the French in 1796. The municipalities are the basic units. At a higher level, these are grouped into 43 administrative districts. Chart 6 provides a visual representation of the administrative districts according to the number of R&D companies located there, based on the address of the registered office and/or the address of the establishment where the main R&D activities take place. The majority of R&D companies are located in one of Belgium's major economic centres. The Ghent and Antwerp districts are home to the largest number of R&D companies, 191 (9.7 %) and 185 (9.4 %) respectively. Brussels Capital and Hasselt rank equal third with 116 R&D firms each. There are several possible reasons for this, one being the presence of a university or other important educational institute (e.g. Ghent, Antwerp, Brussels, Hasselt, Leuven, Kortrijk). Turnhout and Halle-Vilvoorde on the other hand, are known as alternative locations for firms that want to avoid the congestion problems of the metropolitan environment (Antwerp and Brussels respectively).

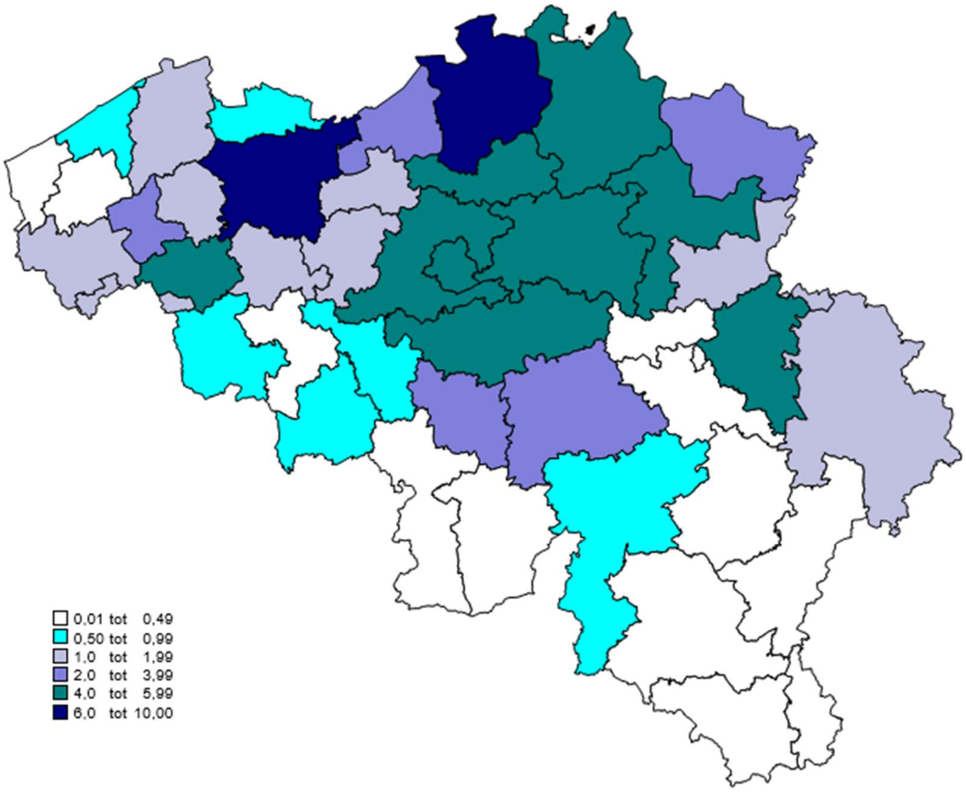
In April 2018, the University of Namur published a working paper[17] highlighting the variations in R&D activities among the three Belgian Regions. Even expressed in relation to gross domestic product, the Flemish Region is the leader, whereas the Brussels Capital Region lags behind. Indeed, Chart 6 shows that the main R&D activities of 6 % of the R&D companies under review are located in the Brussels Capital Region, yet this Region generates 18 % of Belgium's GDP[18]. The first Walloon

[17] Clerbois et al (2018).

[18] Period 2013-2016.

district – Nivelles – occupies the ninth position in the ranking, being the main location of 5.1 % of the companies active in R&D. Among the 18 districts where less than 1 % of the R&D firms are registered, only four are Flemish districts. Aggregating the number of entities to the level of the provinces, the largest numbers of R&D companies are registered in Antwerp (19 %), East-Flanders (18 %) and West-Flanders (14 %). The provinces of Luxembourg and Namur, on the other hand, are home to the smallest number of companies active in R&D, at 1 % and 3 % respectively.

CHART 6 GEOGRAPHIC DISTRIBUTION OF R&D COMPANIES
(based on administrative districts, figures in %)



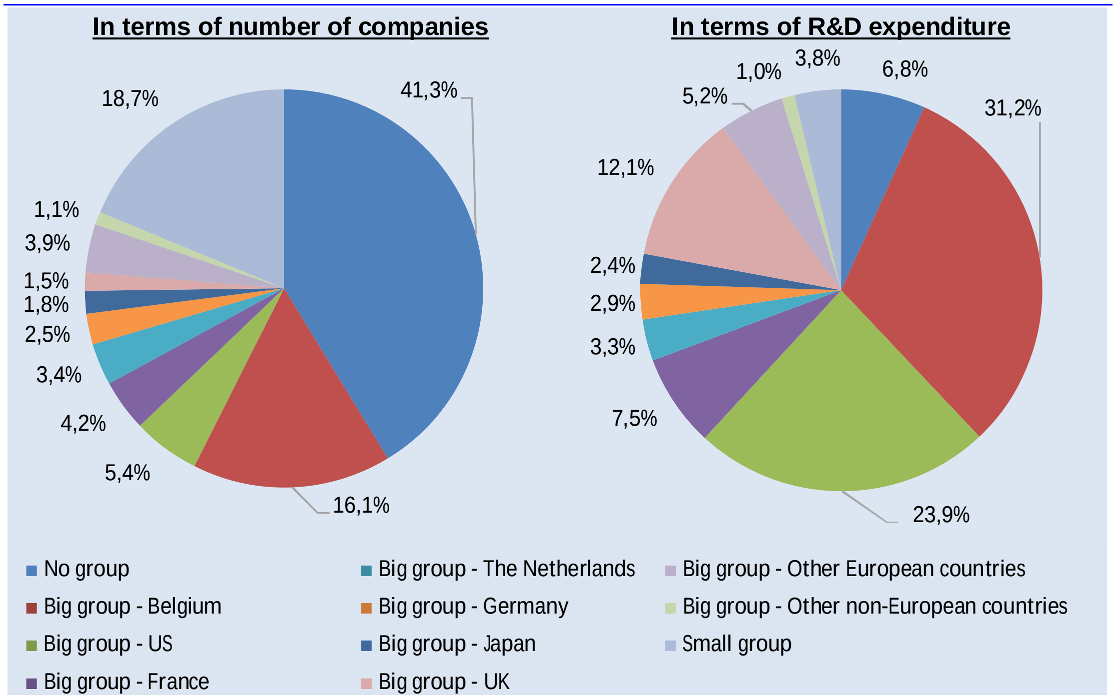
Source: NBB, Belspo survey data (own calculations).

A more detailed breakdown by sector of activity shows that IT companies active in R&D are relatively well represented in Ghent and Nivelles. Architecture, engineering, technical testing and analysis firms active in R&D are relatively more common in Leuven. R&D entities from the chemical and pharmaceutical sector are relatively more prevalent (in terms of number of entities) in Turnhout and Mechelen.

1.7 GROUP STRUCTURES

It seems obvious that the larger the company, the more resources it has at its disposal to invest in R&D activities. In general, standalone firms – not belonging to a group – have fewer resources available for investment compared to entities belonging to a group structure, either as a subsidiary or as a parent entity. In the sample of 1,964 R&D companies, those forming part of a group were identified on the basis of information available in the firms' statutory financial statements. For each company belonging to a group, the group was also classified as small or big. For the purpose of this study, the size criterion for the group is not based on actual group revenue or total asset value, as this group information is not always easily available. For practical reasons, the group size criterion therefore concerns whether or not consolidated financial statements are drawn up. Finally, in a group structure, the group's nationality was also identified according to the location of the registered office of the ultimate parent (headquarters).

CHART 7 R&D COMPANIES ACCORDING TO THEIR GROUP STRUCTURE



Source: NBB, Belspo survey data (own calculations).

As Chart 7 shows, 41.3 % of the R&D companies under review do not belong to a group. These standalone entities accounted for only 6.8 % of total R&D expenditure in 2015. A similar observation applies to R&D firms that are part of a small group. They account for 18.7 % of the companies studied, but they only represent 3.8 % in terms of the amount spent on R&D activities. Nearly all of them are Belgian groups, which means that the ultimate parent is located in Belgium. 89.4 % of all R&D expenses are incurred by only 40.0 % of the companies. They are all part of a big group. Belgian big groups are best represented, both in terms of number of groups (16.1 %) and R&D costs incurred (31.2 %). Based on the R&D sample, US groups seem best represented among the foreign big groups with R&D activities in Belgium. They account for 23.9 % of the R&D expenditure. They include many multinationals such as Janssen Pharmaceutica (part of Johnson & Johnson), Procter and Gamble (P&G's largest R&D centre related to laundry products and other detergents is located in Strombeek-Bever), Pfizer (R&D centre for Phase I studies on the site of the Erasmus hospital in Anderlecht), etc. UK groups with R&D activities in Belgium are not so numerous (1.5 %), but they do account for a considerable share of R&D expenditure (12.1 %). That is obviously related to the presence of GlaxoSmithKline in Belgium. Groups headquartered in neighbouring countries (France, the Netherlands, Germany and Luxemburg) also seem to regard Belgium as a good place to develop R&D activities. Indeed, Belgian R&D companies related to such groups represent 10.9 % of the total number and 15.1 % in terms of the costs incurred.

1.8 DOMESTIC EMPLOYMENT IN R&D COMPANIES

The 1,964 companies reporting intramural and/or extramural R&D expenditure for the period 2014 as well as for the period 2015, and linked to their respective 2014, 2015 and 2016 financial statements, together employed nearly 279,000[19] people in 2016 (Table 1), which represents 6 % of Belgium's domestic employment[20]. This implies a rise of 1.33 % between 2015 and 2016, which is slightly above the overall job creation in 2016 (+1.28 %) of all other Belgian companies belonging to the same sectors of activity. However, at sector level, results are more divergent.

TABLE 1 DOMESTIC EMPLOYMENT BY SECTOR OF ACTIVITY FROM 2014 TO 2016
(in FTEs)

	Sample of R&D companies					*All other companies[21]*
Sector of activity	**2014**	**2015**	**2016**	**Share in 2016 (in %)**	**Change from 2015 to 2016 (in %)**	***Change from 2015 to 2016 (in %)***
TOTAL	**273,349**	**275,096**	**278,745**	**100.0**	**+1.33**	***+1.28***
Of which Food and beverages	15,171	15,503	15,897	5.7	+2.54	*+1.40*
Of which Textile and paper	14,866	14,974	14,996	5.4	+0.15	*-0.53*
Of which Chemicals and pharma	39,463	39,574	40,153	14.4	+1.46	*-0.04*
Of which Rubber, plastics products, non-metallic mineral products	17,334	17,596	18,248	6.5	+3.71	+2.14
Of which Basic metals and fabricated metal products	23,683	23,088	23,081	8.3	-0.03	*+0.18*
Of which Electronic and electrical equipment	15,261	14,820	14,430	5.2	-2.63	*-0.47*
Of which Machinery and equipment	14,337	14,075	13,927	5.0	-1.05	*-0.66*
Of which Other manufacturing industry	26,661	26,838	26,742	9.6	-0.36	*+0.48*
Of which Construction	9,220	9,384	9,811	3.5	+4.54	*-0.83*
Of which Wholesale and retail trade, repair of motor vehicles	20,987	21,695	22,398	8.0	+3.24	*+1.74*
Of which IT and other information services	13,319	13,997	14,660	5.3	+4.74	*+4.10*
Of which Architecture, engineering, technical testing and analysis	7,624	7,913	8,119	2.9	+2.60	*+2.29*
Of which Scientific research and development	3,877	4,166	4,194	1.5	+0.66	*-14.09*

Source: NBB (Central Balance Sheet Office, own calculations).

Compared to the population of all other companies, 2016 employment growth is higher for R&D companies in all sectors of activity except the manufacture of basic metals and fabricated metal products, the manufacture of electronic and electrical equipment, the manufacture of machinery and

[19] Employment referred to in this section is expressed in average full-time equivalents. The source used is code 9087 from the standardised financial statements.

[20] NBB.Stat.

[21] Population of 203,592 companies that filed financial statements in the three consecutive years. Only business sectors in which at least one R&D company is active have been taken into account. Therefore, the following sectors of activity have been excluded: forestry and fishing (NACE codes 02 and 03), mining of coal, lignite and metal ores, and extraction of crude petroleum and natural gas (NACE codes 05 to 07), mining support service activities (NACE code 09), air transport (NACE code 51), postal and courier activities (NACE code 53), accommodation (NACE code 55), financial and insurance activities (NACE codes 64 and 65), employment activities (NACE code 78), public administration, defence and compulsory social security (NACE code 84), education (NACE code 85), human health activities (NACE codes 860, 861 and 862), residential care and social work activities (NACE codes 87 and 88), cultural, gambling, sports and recreation activities (NACE codes 91 to 93), other personal service activities (NACE code 96), activities of households as employers and undifferentiated goods- and services-producing activities of households for own use (NACE codes 97 and 98) and activities of extra-territorial organisations and bodies (NACE code 99).

equipment and other manufacturing industry. The metal industry shows a sharp decline in average FTEs, down by approximately 600, between 2014 and 2015. To a large extent, this is attributable to the restructuring of ArcelorMittal Belgium announced in January 2013. Due to a further weakening of the European economy and the resulting low demand for its products, the Liège facility of ArcellorMittal Belgium decided to close several flexible lines, affecting approximately 1,300 people. Many people left the company during 2014, resulting in a lower average employment figure in 2015 compared to 2014. To a lesser extent, the metal industry's fall in employment in 2015 can be attributed to Umicore. In early 2015, Umicore signalled its intention to sell its Zinc Chemicals business and its Building Products activities. In order to prepare for the sale, two new legal entities were established – EverZinc Belgium[22] and VM Building Solutions Benelux[23] – to which the personnel concerned were transferred. In this case, it is therefore not a question of job losses: the jobs just moved out of the R&D sample.

The electronic and electrical equipment sector presents a comparable picture. The average number of FTEs actually shrank by approximately 400 for two years in a row. Here, the entire fall can be explained by significant business combinations, instead of just job cuts. At the beginning of 2015, Barco finalised the sale of its Defense & Aerospace division to US-based Esterline Corporation. As a result, all employees of Barco's Defense & Aerospace division joined the Esterline Group. At the end of March 2014, Alstom Belgium first moved its power and grid divisions into newly established companies that were subsequently sold to General Electric. As Alstom's financial year ends on March 31st, the impact on average employment is not apparent until the 2015 figures. The impact of the restructuring of Pioneer is only visible in 2016, again due to the atypical closing date. At the end of March 2015, the Home Audiovisual business unit of Pioneer was sold to another Japanese group Onkyo. At the same time, the DJ business unit was transferred to a new company Pioneer DJ Europe Ltd, that is not included in the R&D sample.

In the machinery and equipment sector, the fall in employment numbers was also spread over the two years under review. In 2014, CNH Industrial Belgium acquired the activities of the Antwerp division of New Holland Tractor Ltd. One year later, many fixed-term contracts were not renewed and several staff members became unemployed with a company supplement; that influences average employment not only in 2015 but also in 2016.

Other manufacturing industry recorded employment growth in 2015, followed by a small dip in 2016. Because of higher production volumes, both Daf Trucks Vlaanderen and Punch Powertrain had to hire additional staff. The 2016 dip can be explained by the bus builder Van Hool. Many jobs disappeared due to the closure of the Eos factory in Bree. Production was gradually transferred to Macedonia. Additionally, at the end of 2015, Siemens split off its medical imaging activities into Siemens Healthcare.

Despite these negative developments in some sectors of activity, which are partly due to real job losses and partly due to business combinations, employment expanded in other sectors. In 2016, the strongest growth was recorded in the IT sector. On the 1st of January 2016, Alten Belgium absorbed Quasus, so that the Quasus personnel were transferred to Alten Belgium. Delaware Consulting actually merged with three companies. In the construction sector, on the other hand, the 2016 figures are not boosted by mergers. Several companies expanded their workforce, including Thomas et Piron Home, Jan De Nul and GeoSea.

Manufacturers of rubber, plastics and non-metallic mineral products also recorded a marked rise in average employment during the period 2014-2016, particularly in 2016. Several business combinations during 2015 and 2016 resulted in transfers of employees to CBR Cementbedrijven. Eternit, on the other hand, experienced growing demand. The necessary capacity increase, by means of weekend work, was achieved by recruiting additional production staff members.

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[22] Formerly Umicore Zinc Chemicals Belgium.

[23] Formerly VM Zinc Benelux and UK.

1.9 VALUE ADDED OF R&D COMPANIES

Value added is the value which a firm adds to its inputs via the production process during the financial year. A company's value added indicates its contribution to the prosperity of the country or region (in % of GDP). In accounting terms, this is calculated as the sum of the staff costs (code 62 in the standardised annual accounts), depreciation and value adjustments (codes 630 and 631/4), provisions for liabilities and charges (code 635/7), other operating expenses (code 640/8) and the operating profit or loss from recurrent activities (code 9901 – code 76A + code 66A), less operating costs capitalised as restructuring expenses (code 649). Since value added is created only by reference to unbiased market transactions, operating subsidies (code 740) must also be eliminated. The value added figures in this section are stated at current prices.

TABLE 2 VALUE ADDED BY SECTOR OF ACTIVITY FROM 2014 TO 2016
(in € million – current prices)

	Sample of R&D companies					*All other companies*[24]
Sector of activity	**2014**	**2015**	**2016**	**Share in 2016 (in %)**	**Change from 2015 to 2016 (in %)**	***Change from 2015 to 2016 (in %)***
TOTAL	**39,324.2**	**41,450.7**	**45,025.0**	**100.0**	**+8.62**	***+4.62***
Of which Food and beverages	1,748.1	1,721.8	1,822.5	4.0	+5.85	*+4.23*
Of which Textile and paper	1,477.0	1,531.6	1,622.0	3.6	+5.90	*+0.86*
Of which Chemicals and pharma	10,553.6	11,135.8	13,805.1	30.7	+23.97	*+7.14*
Of which Rubber, plastics products, non-metallic mineral products	1,791.8	1,840.6	1,988.4	4.4	+8.03	*+5.57*
Of which Basic metals and fabricated metal products	2,638.8	2,881.9	2,905.5	6.5	+0.82	*+4.38*
Of which Electronic and electrical equipment	1,657.2	1,688.0	1,724.7	3.8	+2.18	*+9.54*
Of which Machinery and equipment	1,847.3	1,893.3	1,891.2	4.2	-0.11	*+5.36*
Of which Other manufacturing industry	4,805.4	5,648.7	5,678.9	12.6	+0.53	*-0.16*
Of which Construction	985.6	1,186.8	932.7	2.1	-21.41	*+1.71*
Of which Wholesale and retail trade, repair of motor vehicles	1,676.6	1,695.1	1,712.6	3.8	+1.03	*+7.75*
Of which IT and other information services	1,540.5	1,572.7	1,702.9	3.8	+8.28	*+5.47*
Of which Architecture, engineering, technical testing and analysis	732.7	802.3	838.8	1.9	+4.55	*+6.05*
Of which Scientific research and development	439.2	478.3	653.6	1.5	+36.66	*-22.15*

Source: NBB (Central Balance Sheet Office, own calculations).

Table 2 shows that total value added generated by the sample of 1.964 R&D companies in 2016 amounts to € 45 billion, which represents 10.6 % of Belgium's gross domestic product[25]. Compared to 2015, 8.6 % growth was recorded, whereas value added attributable to all other Belgian companies belonging to the same sectors of activity only rose by 4.6 %. The overall figures mask considerably divergent results at sector level. Despite being a relatively small sector in terms of value added, scientific R&D firms show the most impressive increase. This remarkable rise is explained by

[24] Population of 203,592 companies that filed financial statements in the three consecutive years. For further details, we refer to footnote 21.

[25] NBB.Stat.

the change in accounting treatment for research costs (see Annex 1). As from accounting periods starting in 2016, research costs must be fully amortised immediately. This change has a negative impact on the income statement. On the one hand, research costs incurred in 2016 are fully expensed in the income statement. On the other hand, research costs from previous periods are still amortised according to the old valuation rules. At the level of value added, one would expect this impact to be reflected in a lower profit. At Galapagos, however, the operating loss was actually reduced thanks to higher milestone payments received in the context of various research programmes, plus the fact that expenses relating to services and other goods reverted to normal following the one-off expenses incurred in the global share issue in 2015. At Ablynx too, the operating loss did not rise as much as the depreciation charges. Turnover more than doubled, driven by increased milestone payments from the collaboration with Boehringer Ingelheim, among other things. The contrast with the population of all other companies could not be bigger. This is due to a reorganisation. In early 2016, all activities of Janssen Infectious Diseases-Diagnostics (not in the R&D sample) were transferred to Janssen Pharmaceutica (R&D sample), resulting in higher value added generated by R&D chemical and pharmaceutical companies. However, this business reorganisation explains only approximately 4 % of Janssen Pharmaceutica's growth in value added. Owing to the new accounting rules, Janssen Pharmaceutica's depreciation ended up € 0.7 billion higher in 2016. Despite these higher operating expenses, the company succeeded in increasing its recurrent operating profit by € 1.1 billion. GlaxoSmithKline Biologicals performed very well too. The additional depreciation charge of € 1 billion was only partly neutralised by an operating loss.

Value added in the IT sector also displayed an upward trend, outperforming all other Belgian companies in 2016. The business combinations of Alten Belgium and Delaware Consulting only played a limited role. Indeed, 179 IT companies managed to increase their value added, while only 90 suffered a decline. Nokia Bell recorded the strongest rise. All components of valued added contributed to this growth.

In 2016, only one sector experienced a major negative trend in value added: the construction sector. After an extremely favourable year in 2015 – boosted by the execution of several large projects – Jan De Nul's value added in 2016 was characterised by smaller projects and smaller margins due to increasing competition, turning an operating profit into an operating loss. Dredging International faced a comparable downturn, but managed to keep the recurrent operating result out of the red. The only other sector in which the 2016 value added fell below the 2015 level was the machinery and equipment industry. Atlas Copco Airpower's turnover shrank by 2 %, resulting in a lower recurrent operating profit and thus lower value added.

In terms of value added, other manufacturing industry is the second largest sector. Given the decline in the population of all other Belgian companies, the performance of this sector is not that bad. The drop in value added of Total Petrochemicals & Refining – caused by a lower recurrent operating profit and the omission of a major impairment loss on trade receivables – was largely offset by increased value added in another Total group company and in Kuwait Petroleum, both resulting from higher excise duties.

2 MICROECONOMIC IMPACT OF R&D ACTIVITIES IN BELGIUM

As already mentioned in the introduction, numerous papers cover topics relating to the impact of R&D investment for non-financial corporations, and dealing with the impact on turnover, productivity, profitability, or employment. In what follows, we focus on the impact of R&D on employment, value added and labour productivity. All computations and calculations in this chapter were made using R[26]. R is a computer language and environment for statistical computing and graphics. R is open-source software and is widely used by data scientists across many different fields.

2.1 RESEARCH METHOD

The research question addressed in this chapter is whether employment (or value added or labour productivity) grows faster, on average, if the company invests in R&D activities. In other words, how would the outcome variable have changed over time if these R&D companies had not invested in R&D. As this situation cannot be observed, it has to be estimated using statistical techniques. A group of R&D companies can be compared with a group of firms that do not invest in R&D activities. However, these two groups might not only differ in their involvement in R&D, they may also differ in other characteristics that affect both their R&D involvement and the outcome in question (for instance, employment growth or value added growth). In other words, the difference in employment growth or value added growth between R&D companies and non-R&D companies does not necessarily identify the impact of R&D investment. Therefore, in order to assess the impact of R&D investment on a specific variable such as employment or value added growth, it is important to construct a non-R&D group that is similar to the R&D group in terms of a number of characteristics that affect both participation in R&D and employment or value added growth. Propensity score matching reduces this matching problem to a single dimension[27]. Propensity score matching is a statistical technique in which a "treatment" case (in this study, the treatment is R&D investment) is matched with one or more control cases based on each case's propensity score. The propensity score is defined as the probability that a corporation in the combined sample of R&D and non-R&D companies invests in R&D activities, given a set of observed variables. R&D firms are matched with non-R&D firms based on an estimate of the probability that the entity invests in R&D (the propensity score). Rather than attempting to match all values of the determining variables (such as size, sector of activity, solvency, etc.), companies can be compared on the basis of propensity scores alone. Rosenbaum and Rubin (1983) showed that the propensity score is a balancing score. Furthermore, they concluded that matching can be done on any balancing score, provided that strong ignorability holds. Almus and Czarnitzki (2003) used propensity score matching to evaluate the impact of R&D subsidies on innovation, but the method has been used in many other domains as well[28].

2.2 DATA

The propensity score matching methodology requires two samples to be constructed: a sample of companies that invest in R&D on a yearly basis and a sample of firms that do not invest in R&D. The biennial R&D survey by Belspo provides a list of all respondents for the period 2010-2015. The R&D sample was created by selecting those companies that incurred R&D expenses during all six years from 2010 until 2015. The non-R&D sample includes the respondents that reported zero expenditure on R&D for at least two years and did not participate in or respond to the survey for the other years. We assume that the R&D situation of corporations that declared no involvement in R&D activities over at least a two-year period did not change significantly during the period for which they did not participate in the survey. For both samples, we select only those entities that filed standardised financial statements for the accounting periods 2010, 2014, 2015, 2016 and 2017. In addition, as the impact on employment will be investigated, an additional selection criterion is that the company must

[26] R Core Team (2017).

[27] Rosenbaum and Rubin (1983), Heinrich et al (2010).

[28] For example: Jalan and Ravallion (2003) and Galiani et al (2005).

employ at least 1 FTE on average, both in 2010 and during the entire period 2014-2017. The shareholder structure of all groups was checked. Non-R&D firms that belong to a group identified as an R&D group, i.e. for which a group entity is included in the R&D sample of chapter 1, is removed from the sample as it is assumed that such companies can benefit from the R&D activities of the related entity. Since R&D only plays a minor role in some sectors of activity, and some types of entities generally do not file standardised annual accounts, the following branches are excluded from the scope of the research:

- Transportation (NACE codes 49 to 51)
- Accommodation and food service activities (NACE codes 55 and 56)
- Financial service activities, except insurance and pension funding (NACE code 64)
- Insurance, reinsurance and pension funding, except compulsory social security (NACE code 65)
- Real estate activities (NACE code 68)
- Rental and leasing activities (NACE code 77)
- Employment activities (NACE code 78)
- Office administrative, office support and other business support activities (NACE code 82)
- Public administration and defence; compulsory social security (NACE code 84)
- Education (NACE code 85)
- Residential care and social work activities (NACE codes 87 and 88)
- Arts, entertainment and recreation (NACE codes 90 to 93)

Finally, 31 companies were removed from the samples as they were involved in a group restructuring or business combination within the 7-year period, resulting in the transfer of activities from one entity to another, as a result of which the individual financial statements of these entities do not provide an accurate picture of the actual situation during the period under review.

2.3 VARIABLES

2.3.1 Outcome variables

The purpose of this chapter is to determine whether value added grows faster, on average, in companies that incur R&D expenditures. The predicted variable or the outcome variable, is the average annual growth of value added during the period 2010-2017. This measure can be calculated for all types of standardised financial statements (both full, abbreviated and micro). The definition of value added is included in section 1.9. In order not to lose observations with negative value added, the annual average is calculated by a simple geometric mean instead of a compound annual growth rate. More precisely, average annual growth of value added during the period under review is calculated as follows:

$$\frac{\left(\frac{value\ added_{2017} - value\ added_{2010}}{absolute\ value\ of\ value\ added_{2010}}\right)}{5}$$

Additionally, the impact of R&D investment on average annual employment growth is tested. This variable is calculated based on the item 'average full-time equivalents during the year' (code 9087), available in all standardised financial statements as well. In conformity with value added, the average annual employment growth is defined as follows:

$$\frac{\left(\frac{code\ 9087_{2017} - code\ 9087_{2010}}{code\ 9087_{2010}}\right)}{5}$$

Finally, the impact of R&D investment on average annual growth of labour productivity is looked at. As figures for both employment and value added are available, this outcome variable can be easily obtained as follows:

$$\frac{\left(\frac{\frac{value\ added_{2017}}{code\ 9087_{2017}} - \frac{value\ added_{2010}}{code\ 9087_{2010}}}{absolute\ value\ of\ \frac{value\ added_{2010}}{code\ 9087_{2010}}}\right)}{5}$$

As explained in section 2.1, differences in the outcome variable will be investigated by means of propensity score matching. To calculate the propensity scores for the matching, a logistic regression is calculated, in which R&D is the dependent variable. R&D only receives the values 1 or 0: 1 for R&D companies and 0 for non-R&D companies. The logistic regression estimates R&D according to several predictors or control variables.

2.3.2 Control variables

It seems intuitively obvious that involvement in R&D activities depends very much on the sector of activity. A hotel or supermarket will most likely have less incentive to invest in R&D compared to a manufacturer of engine control units or a pharmaceutical company. Section 1.3 provides evidence that R&D companies are not distributed among the sectors of activity in the same proportion as the total population of all Belgian firms. The sector of activity is also a determinant of employment, value added or labour productivity growth, as labour intensity, economic growth and margins all differ from one branch to another. Therefore, sectors of activity are defined as control variables on the basis of the two-digit NACE code for the firms. All sectors of activity with less than nine observations (R&D and non-R&D together) are removed from the sample. As such, 33 sectors of activity remain in the sample, each of them represented by one control variable with values 1 (meaning yes) or 0 (meaning no). These 33 sectors are given in Annex 3.

Back in 1942, Joseph Schumpeter developed a theory that R&D investment depends on the size of the company. Section 1.5 seems to support this theory. This section clearly demonstrates that R&D investment is more common among large groups. As small firms might not grow at the same pace as larger firms, size can also be a determining factor in employment growth. Moreover, Heuse and Rubbrecht (2018) demonstrate that value added growth of Belgian non-financial corporations varies according to company size, depending on the sector of activity to which the entity belongs. Employment[29] in 2010 relative to the two-digit NACE sectoral mean is included as a size measure in the logistic regression. Other frequently used size measures are total assets or revenue. However, the amount of revenue is not available for companies filing their standardised financial statements in the abbreviated format.

Schumpeter (1942) also believed that internal finance is an important determinant of R&D expenditures. Baghat and Welch (1995) and Lai *et al.* (2015) found evidence that there are indeed significant positive correlations between a company's R&D investment and its financial autonomy. Financial autonomy might also have an impact on a firm's employment growth and value added growth. In this study, the equity ratio is used as a measure of financial autonomy. This ratio is calculated by dividing total equity (code 10/15 of the standardised annual accounts) by total assets (code 20/58) and can similarly be obtained for financial statements in any type of format. The equity ratio throws light on a company's overall financial strength. It is also considered a test of the soundness of the capital structure, or the percentage by which the assets may be overvalued before creditors risk losing money in the event of a forced sale. A higher equity ratio or a higher contribution of shareholders to the capital reflects a better long-term solvency position and greater independence in relation to the capital markets. Moreover, companies with a higher equity ratio have a lower interest burden, and thus have more cash available for R&D investment amongst other things. Conversely, a low equity ratio implies a higher credit risk for the creditors and an increased risk of losses as a large portion of the company's earnings is spent on interest payments.

Section 1.4 demonstrated that the analysed R&D firms are in general slightly older than Belgian corporations in general. Since young firms do not necessarily grow at the same pace as more mature firms, age can also be a determining factor in employment and value added growth; it is therefore included as a control variable in the regression.

[29] Measured by means of the code 9087 from the standardised financial statements.

2.4 DESCRIPTIVE STATISTICS

The final total sample comprises 1,171 companies: 344 R&D firms and 827 non-R&D firms. The table in Annex 3 shows how the R&D and non-R&D samples are constructed according to the sector of activity to which the firms belong. Wholesale (28 %) and computer programming and consultancy (7 %) are best represented within the non-R&D sample. The R&D sample includes relatively more entities from engineering, technical testing and analysis (11 %), computer programming and consultancy (11 %), the electronics industry (10 %), chemicals industry (10 %), machinery industry (7 %) and scientific R&D (6 %).

TABLE 3 DESCRIPTIVE STATISTICS FOR R&D AND NON-R&D SAMPLES

	Sample of R&D companies					***Sample of non-R&D companies***				
Variable	**Min**	**Median**	**Max**	**Mean**	**SD**[30]	***Min***	***Median***	***Max***	***Mean***	***SD***
Employment relative to sectoral mean *(year 2010)*	0.02	1.29	87.94	3.87	8.13	*0.02*	*1.12*	*175.6*	*3.56*	*11.46*
Equity ratio in 2010 *(in %)*	-118.92	41.85	97.52	42.82	25.74	*-291.3*	*34.61*	*99.69*	*35.31*	*32.38*
Age (in years)	5	26	119	29	17	*5*	*26*	*105*	*29*	*16*
Average annual mployment growth 2010-2017 *(in %)*	-10.36	1.76	105.7	5.39	12.20	*-13.27*	*1.17*	*151.4*	*3.81*	*13.02*
Average annual value added growth 2010-2017 *(in %)*	-127.80	4.21	293.3	10.95	27.16	*-28.99*	*2.89*	*352.4*	*6.46*	*19.62*
Average annual labour producti-vity growth 2010-2017 *(in %)*	-0.003	0.0002	0.046	0.0004	0.003	*-0.07*	*0.0002*	*0.004*	*0.0002*	*0.003*

Source: NBB (Central Balance Sheet Office, own calculations).

Descriptive statistics of the two samples are presented in Table 3, for all variables used in the analysis. As expected, the R&D sample comprises on average slightly larger corporations compared to the non-R&D group. The median employment relative to the sectoral mean – used as a size criterion – within the R&D sample amounts to 1.29 and the mean 3.87. Both values are lower in the non-R&D sample: 1.12 and 3.56 respectively. The statistics indicate that the R&D group comprises fewer companies with a low equity ratio. Both the median and the mean equity ratio of the R&D sample clearly exceed the respective values of the non-R&D group. The minimum age in both sets is 5 years. This is obvious, as one of the selection criteria was that the entity must have filed financial statements for the accounting period 2010 and the reference year is 2015 (most recent year of the R&D survey). The mean age is 29 years in both groups, which means that they are both already well balanced in terms of age. Based on median and mean figures, average annual employment growth over the 7-year period generally seems higher in the R&D sample. The same situation is observed as far as average annual growth of value added is concerned, notwithstanding the fact that the R&D group comprises lower minimum and maximum values. Median and mean average annual growth of labour productivity is comparable in both samples.

2.5 RESULTS

2.5.1 Estimating the propensity scores

In order to calculate propensity scores for the 1,171 companies, a logistic regression is estimated. The dependent variable is R&D (1 = yes, 0 = no). The control variables are employment in 2010 relative to the two-digit NACE sectoral mean (as a measure of size), 14 sector variables (naceXX[31]), the equity ratio in 2010 (solvency2010) and the age. To determine the sector variables to be included in the logistic regression model, a forward model selection method is used. Starting from a baseline equation with the other control variables, in each forward step, the sector variable that gives the

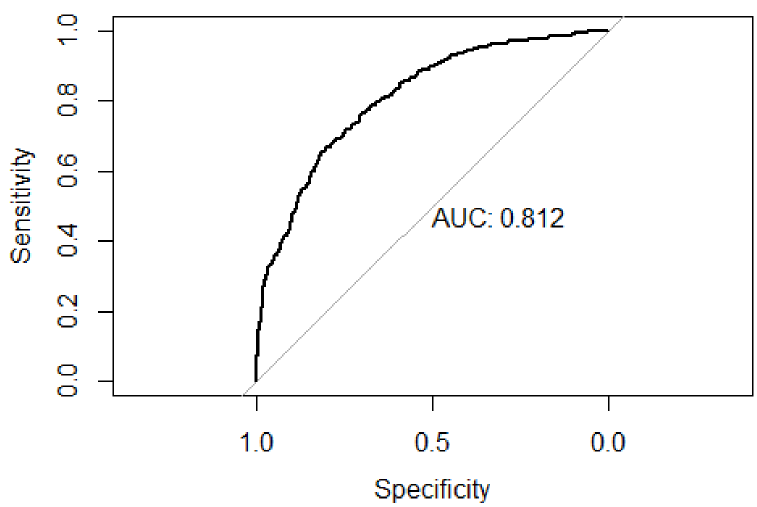
[30] Standard deviation.

[31] The definition of the different NACE codes is included in Annex 3.

single best improvement to the model is added. The process is stopped when a non-significant[32] sector variable would have to be added. The results are set out in Annex 4.

It is obvious that for the entire sample, the outcome (R&D or not) is already known. But the estimated logistic regression can calculate a predicted R&D value for each company in the sample. This predicted value is a score – the propensity score – between 0 and 1 and represents the probability that the company invests in R&D, based on the parameters size, sector of activity, solvency and age. In the next section, the two samples R&D and non-R&D will be matched by means of this propensity score. However, we first have to verify whether the chosen logistic regression performs well in distinguishing between R&D firms and non-R&D firms.

CHART 8 ROC CURVE OF THE FITTED LOGISTIC REGRESSION



Source: NBB (Central Balance Sheet Office, own calculations).

A receiver operating characteristic (ROC) curve is a commonly used way to visualise the performance of a binary classifier, and the area under the curve (AUC) summarises this performance in a single number. A ROC curve plots the true positive rate (i.e. how often does the logistic regression predict 1 for R&D companies) on the y-axis against the false positive rate (i.e. how often does the logistic regression predict 1 for non-R&D companies) on the x-axis for every possible threshold to link the propensity score to 0 or 1. A model with high discrimination ability will have an ROC curve which goes close to the top left corner of the plot. A model with no discrimination ability will have an ROC curve that coincides with the 45-degree diagonal line. The ROC curve of the fitted logistic regression is shown in Chart 8. The AUC equals 0.812 and represents the probability that the model finds the R&D company among arbitrary pairs of R&D and non-R&D firms.

2.5.2 Matching the two samples

Every company (R&D or non-R&D) received a propensity score based on the fitted logistic regression. The two samples can be matched by means of this propensity score. However, there are various algorithms for matching every R&D company with a comparable non-R&D company (in terms of sector of activity, size, age and solvency). The most straightforward algorithm is nearest neighbour matching. This means that a non-R&D firm is chosen as a match for an R&D firm in terms of the closest propensity score. Examples of other matching algorithms using propensity scores are optimal matching (focuses on minimising the average absolute distance between the propensity scores

[32] At a 90 % confidence level.

across all matched R&D and non-R&D entities) and full matching (similar to optimal matching; in addition, subclasses are created, in which each company is assigned to one or more firms of the opposite group). The algorithm used in this study is nearest neighbour matching. The other algorithms have been tested as well but did not result in better matches. The options chosen are as follows:

- Discard: this argument specifies whether to discard observations that fall outside some measure of support of the distance score before matching, so that they cannot be used at all in the matching. The argument was set to 'both', meaning that both R&D and non-R&D companies that are outside the support of the distance measure, are excluded from the matching process.
- Without replacement: this means that each non-R&D company can only be considered once. In other words, each non-R&D firm can be matched to only one R&D entity.
- Ratio: this argument specifies the maximum number of non-R&D entities to which an R&D firm may be matched. In order to take advantage of the bigger non-R&D sample, the ratio was set to 2.
- Caliper: to avoid the risk of poor matches, a maximum distance or "caliper" between the propensity scores is specified. To qualify as a match the distance between the propensity scores must not exceed the caliper. Cochran and Rubin (1973) recommend a caliper size of one-fifth of the standard deviation of the estimated propensity scores of the sample. A caliper should be tight enough to produce close matches in order to avoid selection bias, but not so tight that it becomes impossible to produce a sufficient number of matches. Different caliper sizes were tried out. 0.15 resulted in satisfactory matches without losing too many observations.

The matching results are shown in Table 4.

TABLE 4 RESULTS SHOWING THE EFFECTIVENESS OF THE PROPENSITY SCORE MATCHING

Summary of balance for all data:

	Means R&D	Means non-R&D	SD non-R&D	Mean Diff	eQQ Med	eQQ Mean	eQQ Max
distance	0.4879	0.2130	0.1733	0.2749	0.2602	0.2750	0.4641
size2010	3.8662	3.5598	11.4617	0.3064	0.1600	1.2602	87.6288
nace46	0.0407	0.2781	0.4483	-0.2374	0.0000	0.2384	1.0000
nace26	0.1017	0.0048	0.0694	0.0969	0.0000	0.0959	1.0000
nace20	0.1017	0.0133	0.1146	0.0884	0.0000	0.0872	1.0000
nace72	0.0640	0.0024	0.0491	0.0615	0.0000	0.0610	1.0000
nace52	0.0029	0.0387	0.1930	-0.0358	0.0000	0.0349	1.0000
nace43	0.0058	0.0411	0.1987	-0.0353	0.0000	0.0349	1.0000
nace24	0.0203	0.0024	0.0491	0.0179	0.0000	0.0174	1.0000
nace71	0.1134	0.0653	0.2472	0.0481	0.0000	0.0465	1.0000
nace62	0.1076	0.0701	0.2555	0.0374	0.0000	0.0378	1.0000
nace28	0.0727	0.0351	0.1841	0.0376	0.0000	0.0378	1.0000
nace27	0.0233	0.0060	0.0776	0.0172	0.0000	0.0174	1.0000
nace13	0.0407	0.0169	0.1291	0.0238	0.0000	0.0233	1.0000
nace22	0.0494	0.0290	0.1680	0.0204	0.0000	0.0203	1.0000
nace21	0.0116	0.0060	0.0776	0.0056	0.0000	0.0058	1.0000
solvency2010	0.4282	0.3531	0.3238	0.0750	0.0690	0.0797	1.7242
age	28.6163	29.0593	15.9761	-0.4430	1.0000	1.3227	14.0000

Summary of balance for matched data:

	Means R&D	Means non-R&D	SD non-R&D	Mean Diff	eQQ Med	eQQ Mean	eQQ Max
distance	0.3763	0.3675	0.1831	0.0088	0.0392	0.0495	0.1759
size2010	4.3035	4.3154	16.1348	-0.0118	0.6652	2.1622	87.6288
nace46	0.0532	0.0589	0.2358	-0.0057	0.0000	0.0228	1.0000
nace26	0.0266	0.0152	0.1225	0.0114	0.0000	0.0190	1.0000
nace20	0.0380	0.0399	0.1960	-0.0019	0.0000	0.0114	1.0000
nace72	0.0038	0.0076	0.0870	-0.0038	0.0000	0.0000	0.0000
nace52	0.0038	0.0000	0.0000	0.0038	0.0000	0.0038	1.0000
nace43	0.0076	0.0057	0.0754	0.0019	0.0000	0.0000	0.0000
nace24	0.0076	0.0076	0.0870	0.0000	0.0000	0.0038	1.0000

	Means R&D	Means non-R&D	SD non-R&D	Mean Diff	eQQ Med	eQQ Mean	eQQ Max
nace71	0.1483	0.1654	0.3720	-0.0171	0.0000	0.0152	1.0000
nace62	0.1407	0.1464	0.3539	-0.0057	0.0000	0.0038	1.0000
nace28	0.0913	0.0932	0.2910	-0.0019	0.0000	0.0190	1.0000
nace27	0.0266	0.0171	0.1298	0.0095	0.0000	0.0152	1.0000
nace13	0.0532	0.0399	0.1960	0.0133	0.0000	0.0190	1.0000
nace22	0.0646	0.0627	0.2428	0.0019	0.0000	0.0076	1.0000
nace21	0.0152	0.0133	0.1147	0.0019	0.0000	0.0038	1.0000
solvency2010	0.4137	0.4050	0.2560	0.0087	0.0220	0.0252	0.3133
age	29.4373	29.0875	16.6356	0.3498	1.0000	0.8061	14.0000

Percent Balance Improvement:

	Mean Diff	eQQ Med	eQQ Mean	eQQ Max
distance	96.7966	84.9301	81.9901	62.1076
size2010	96.1330	-315.6300	-71.5770	0.0000
nace46	97.5977	0.0000	90.4294	0.0000
nace26	88.2291	0.0000	80.1820	0.0000
nace20	97.8504	0.0000	86.9202	0.0000
nace72	93.8210	0.0000	100.0000	100.0000
nace52	89.3753	0.0000	89.1001	0.0000
nace43	94.6141	0.0000	100.0000	100.0000
nace24	100.0000	0.0000	78.2003	0.0000
nace71	64.4098	0.0000	67.3004	0.0000
nace62	84.7604	0.0000	89.9386	0.0000
nace28	94.9448	0.0000	49.6929	0.0000
nace27	44.7660	0.0000	12.8010	0.0000
nace13	44.0112	0.0000	18.2510	0.0000
nace22	90.6798	0.0000	62.6290	0.0000
nace21	65.9413	0.0000	34.6008	0.0000
solvency2010	88.4023	68.1710	68.3296	81.8281
age	21.0310	0.0000	39.0565	0.0000

Sample sizes:

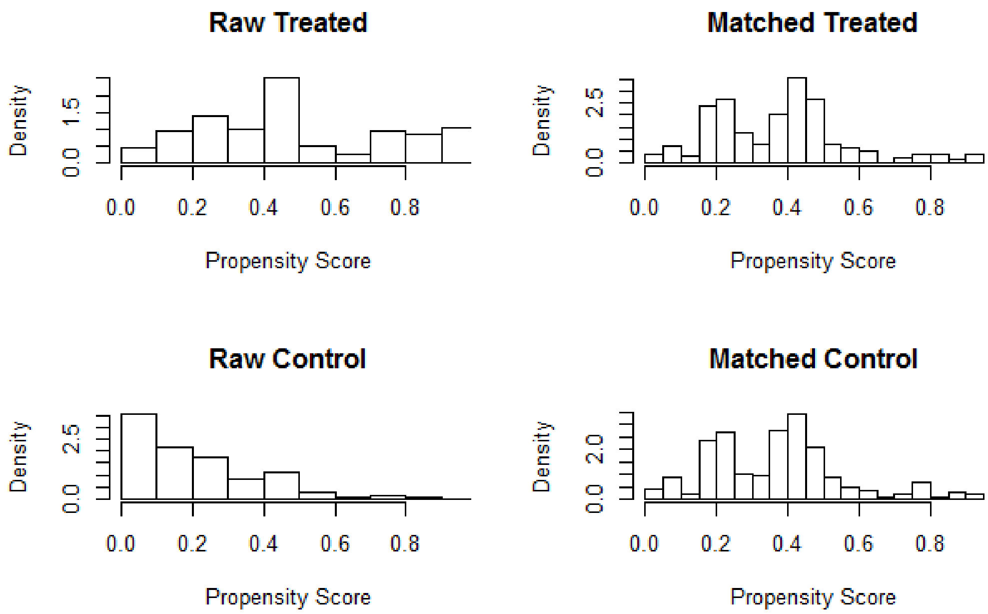
	non-R&D	R&D
All	827	344
Matched	408	263
Unmatched	371	56
Discarded	48	25

Source: NBB (Central Balance Sheet Office, own calculations).

In the summary of balance for all data section of Table 4, the mean equity ratio (solvency) in R&D companies equalled 42.82 % before matching, whereas it amounted to 35.31 % in non-R&D entities. The difference in means (7.5 percentage points) can be found in the column Mean Diff. After matching, however, this difference was reduced substantially to 0.87 percentage points as shown in the summary of balance for matched data section of Table 4. The rightmost columns in the summary data show the median, mean, and maximum quartile differences between the R&D and non-R&D firms. Smaller QQ values in the summary of balance for matched data section (compared to the first summary table) indicates better matching. The improvement section indicates that there are signs of improvement for all variables, as far as the mean difference is concerned.

Finally, the last section of Table 4 indicates that 25 R&D and 48 non-R&D companies were excluded from the matching process. 263 R&D entities were matched with 408 non-R&D entities, while 56 R&D firms and 371 non-R&D firms remain unmatched as a result of the specified caliper or maximum distance between the propensity scores. Chart 9 displays the similarity of the propensity score distributions before and after matching. Treated refers to the R&D group and control refers to the non-R&D group. The histograms before matching on the left-hand side differ to a great degree. Conversely, the histograms after matching on the right-hand side are more similar. Thus, matching achieves a remarkable improvement in similarity between the two propensity scores' distributions. This suggests that the selection bias has been reduced substantially.

CHART 9 HISTOGRAMS OF PROPENSITY SCORES BEFORE AND AFTER MATCHING



Source: NBB (Central Balance Sheet Office, own calculations).

2.5.3 Balancing tests on the control variables of the matched samples

The next step is to assess the quality of the matching process. For that we need to check whether the propensity score adequately balances characteristics between the matched R&D and the matched non-R&D groups. In other words, there should be no statistically significant differences between the covariate means of the matched R&D sample and the matched non-R&D sample. For each of the covariates age, solvency and employment in 2010 relative to the two-digits NACE sectoral mean, a two-sided t-test was performed before (unpaired) and after matching (paired). We test the hypothesis that the observed difference in means (for age, solvency and employment in 2010 relative to the two-digits NACE sectoral mean) between the R&D sample and the non-R&D sample is statistically different at a 5 % significance level. So, the null hypothesis is that the difference between the two means is equal to zero. The results of the t-tests are summarised in Figure 1. The conclusion is that – before matching – the means of solvency are statistically different at a 5 % significance level. After matching, the means of solvency are statistically indifferent at a 5 % significance level. The means of age and employment in 2010 relative to the two-digits NACE sectoral mean are statistically indifferent at a 5 % significance level, both before and after matching. In other words, in terms of solvency, age and size, the matched samples are well-balanced.

FIGURE 1 BALANCING TESTS ON THE CONTROL VARIABLES OF THE MATCHED SAMPLES

TWO-SIDED T-TEST FOR THE AGE

Before matching:

Welch Two Sample t-test
t = -0.40639, df = 595.51, **p-value = 0.6846**
95 percent confidence interval: between -2.583703 and 1.697760
sample estimates: mean of x = 28.61628 mean of y = 29.05925

After matching:

Paired t-test*
t = 0.27779, df = 262, **p-value = 0.7814**
95 percent confidence interval: between -2.129755 and 2.829375
sample estimates: mean of the differences = 0.3498099

TWO-SIDED T-TEST FOR THE EQUITY RATIO

Before matching:

Welch Two Sample t-test
t = 4.1994, df = 799.19, **p-value = 2.977e-05**
95 percent confidence interval: between 0.03996797 and 0.11012756
sample estimates: mean of x = 0.4281735 mean of y = 0.3531257

After matching:

Paired t-test*
t = 0.49119, df = 262, **p-value = 0.6237**
95 percent confidence interval: between -0.02618735 and 0.04359493
sample estimates: mean of the differences = 0.008703789

TWO-SIDED T-TEST FOR EMPLOYMENT RELATIVE TO THE SECTORAL MEAN (SIZE)

Before matching:

Welch Two Sample t-test
t = 0.51716, df = 891.35, **p-value = 0.6052**
95 percent confidence interval: between -0.8564747 and 1.4693294
sample estimates: mean of x = 3.866229 mean of y = 3.559801

After matching:

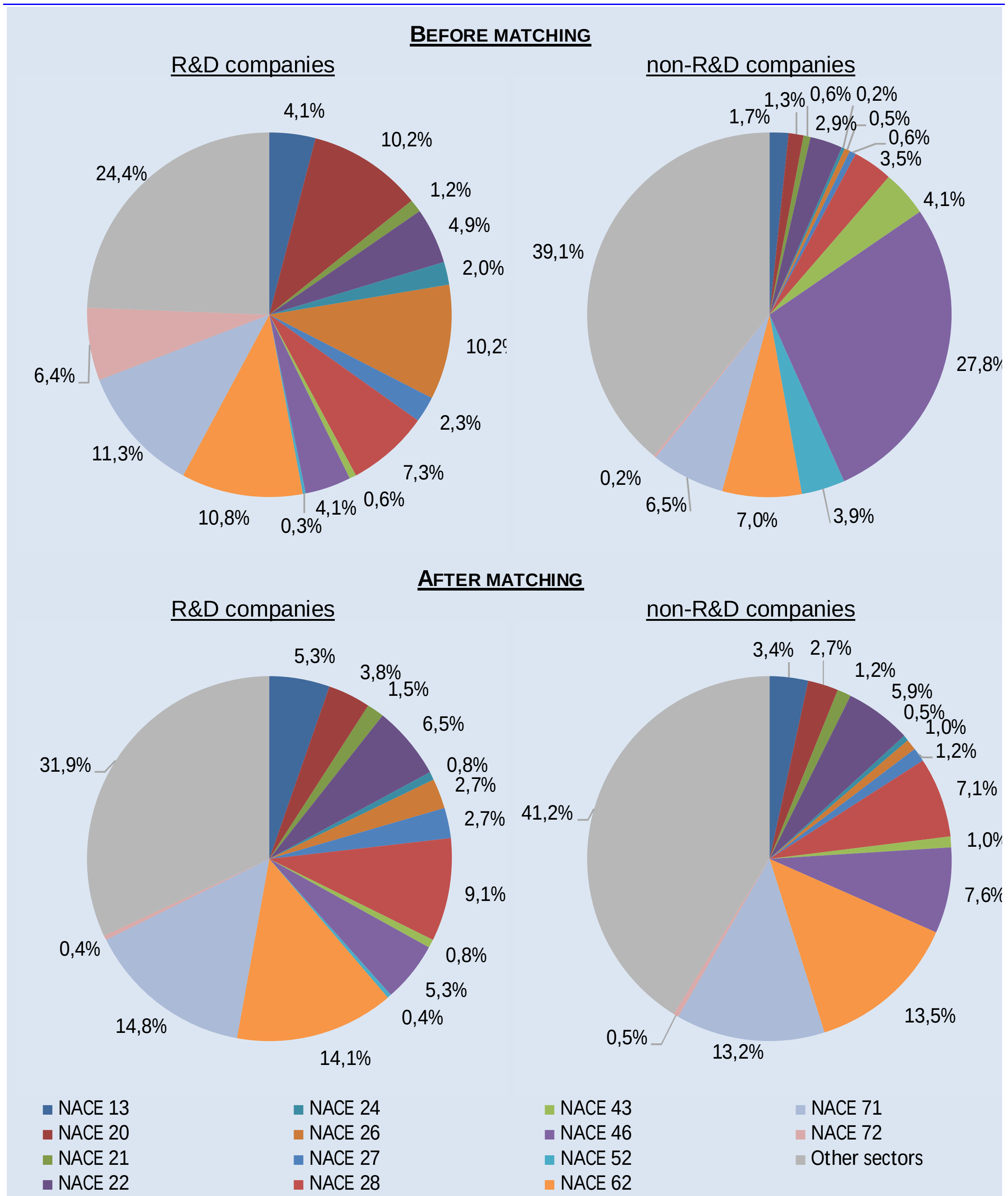
The means of the difference between the equity ratio averages of the matched R&D and the matched non-R&D sample do not exhibit a normal distribution. As a result, bootstrapping was used to perform the hypothesis test:
95% Confidence interval for population mean: between -2.27044 and 1.97465
ð Accept H0

Source: NBB (Central Balance Sheet Office, own calculations).
* For the three covariates, a bootstrap was used to test whether the means of the difference between the averages of the matched R&D and the matched non-R&D sample exhibit a normal distribution. The results were positive for age and solvency.

The distribution of the R&D and non-R&D companies among the different sectors of activity can be visually compared before and after matching. The distributions are shown in Chart 10. The graphs clearly demonstrate that the matching process has improved the balance between the different sectors of activity.

CHART 10 DISTRIBUTION OF COMPANIES AMONG SECTORS OF ACTIVITY

(two-digits NACE code*)



Source: NBB (Central Balance Sheet Office, own calculations).
* A description of the NACE codes is included in Annex 3.

2.5.4 Testing the average impact of R&D on the matched samples

Now that well-balanced matched samples have been created, tests may be performed on these samples to study the average impact of yearly R&D investment. The first hypothesis tested is that yearly R&D investment has on average a positive impact on average annual growth of value added over a 7-year period. Therefore, the null hypothesis is that there is no difference between the average annual value added growth of R&D companies and the average annual value added growth of non-R&D companies during the period 2010-2017 (H0). The alternative hypothesis is that the average annual value added growth of the R&D group exceeds the average annual value added growth of the non-R&D group (H1). The null hypothesis is tested at a 5 % significance level by means of a paired[33] one-sided t-test on the matched samples. However, in order for the test to be reliable, it must be verified that the means of the difference between the average annual value added growth of the matched R&D sample and the average annual value added growth of the matched non-R&D sample display a normal distribution. The check was performed by means of a bootstrap[34]. The result of the paired t-test is shown in Figure 2.

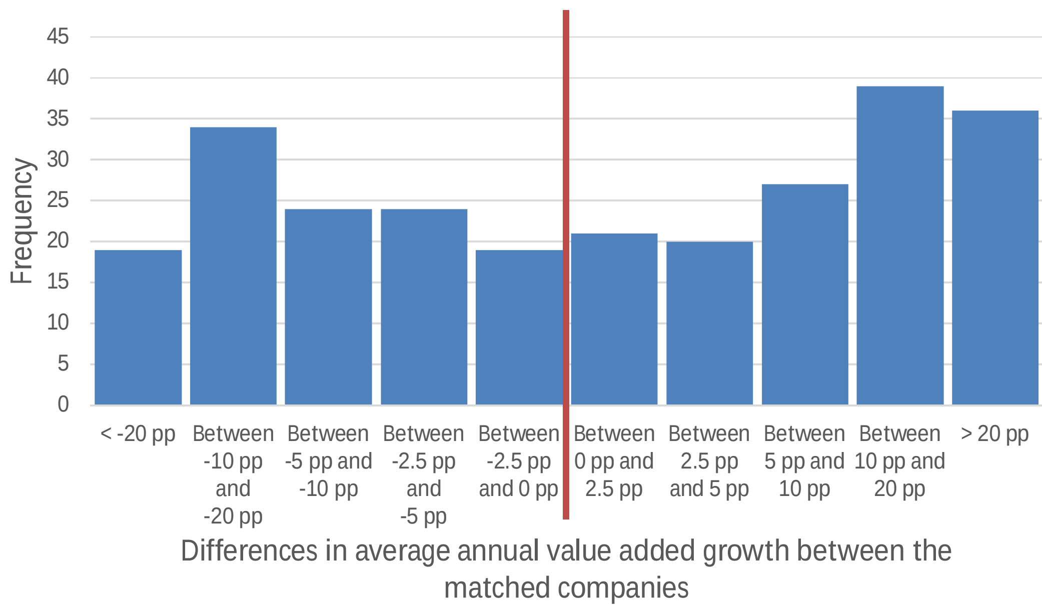
FIGURE 2 AVERAGE IMPACT OF R&D ON ANNUAL VALUE ADDED GROWTH – PAIRED T-TEST RESULT

Paired t-test
t = 2.6922, df = 262, **p-value = 0.003777**
95 percent confidence interval: between 0.01832473 and Inf
sample estimates: mean of the differences = 0.0473664

Source: NBB (Central Balance Sheet Office, own calculations).

At a 5 % significance level, we can reject the null hypothesis. This implies that the alternative hypothesis is true, meaning that – on average – yearly R&D investment had a positive impact on average annual value added growth between 2010 and 2017. This result can also be illustrated in a graph. Chart 11 displays a histogram of the differences in average annual value added growth between the matched entities (R&D minus non-R&D). The graph clearly shows that, on average, average annual value added growth is higher in the R&D group. There are significantly more observations on the right-hand side of the zero. The mean difference equals 4.7 percentage points and the median difference amounts to 1.3 percentage points.

CHART 11 HISTOGRAM OF THE DIFFERENCES IN AVERAGE ANNUAL VALUE ADDED GROWTH BETWEEN THE MATCHED COMPANIES



Source: NBB (Central Balance Sheet Office, own calculations).

[33] Austin (2011).

[34] A non-parametric bootstrap is used. 100,000 bootstrap samples are taken from the dataset of 263 differences in growth. For each of these 100,000 samples, the mean is calculated. To verify whether these means are normally distributed, each of them is standardised into a Z-score. Subsequently, these 100,000 values are visually compared with a normal distribution with mean 0 and standard deviation 1, by using a quantile-quantile plot on the one hand and a density plot on the other hand.

However, the results above might have been influenced by the introduction of changes to the Belgian patent box regime in 2016. These changes may well have influenced some firms' value added. In order to prove that the results above hold independent of the changes to the patent box regime, a test was performed for the following outcome variables as well: average annual value added growth between 2010 and 2016, average annual value added growth between 2010 and 2015, and average annual value added growth between 2010 and 2014. For all these periods, the null hypothesis (no difference in average annual value added growth between R&D and non-R&D firms) can be rejected at a 5 % significance level, which means that the alternative hypothesis (annual average value added growth in the R&D group is – on average – larger than in the non-R&D group) must hold true.

Obviously, now that the matched sample has been created, the impact of R&D on other performance measures can be tested. So, the second hypothesis tested is that yearly R&D investment has, on average, a positive impact on the average annual employment growth over a specific period. The periods tested are once again 2010-2017, 2010-2016, 2010-2015 and 2010-2014. After verification of the normal distribution, a paired one-sided t-test at a 5 % significance level was performed on the matched samples, whereby the null hypothesis is that there is no significant difference between the average annual employment growth of R&D companies and the average annual employment growth of non-R&D companies (H0), and the alternative hypothesis is that the average annual employment growth of R&D entities exceeds – on average – the average annual employment growth of non-R&D companies (H1). At a 5 % significance level, we can reject the null hypothesis for the four different outcome variables (four periods). On average, the R&D group experienced stronger average annual employment growth compared to the non-R&D group. For the period 2010-2017, the mean difference between the matched entities equals 2.3 percentage points and the median difference amounts to 1.8 percentage points. The figures indicate that a considerable number of R&D companies did worse than their non-R&D peer in terms of average annual employment growth. This could imply that, in some cases, R&D efforts lead to such productivity gains that jobs can be cut. However, this does not seem to be true for the majority of the cases. R&D investment also leads to new opportunities and/or new markets that extend the scope of the company and/or boost demand, enabling the entity to grow.

Finally, a third set of variables is tested in a similar way: average annual labour productivity growth over the periods 2010-2017, 2010-2016, 2010-2015 and 2010-2014. However, the findings suggest that R&D firms generally did not experience stronger average annual labour productivity growth compared to non-R&D firms. For the period 2010-2017, the mean difference between the matched entities is very close to zero and the median difference is even slightly negative.

Following the tests performed in this paragraph, we can conclude that R&D investment had on average a positive impact on average annual value added growth and average annual employment growth during the periods under review. But average annual labour productivity growth generally does not seem to be affected significantly by R&D expenditure at the firm level.

2.6 ROBUSTNESS CHECK

It is obviously important to evaluate the robustness of the results in order to verify whether the findings were not just obtained as a coincidence because of the chosen method or parameters. In other words, such a check provides some assurance about the reliability of the results. The robustness of the findings can be evaluated by changing the matching algorithms or by modifying the parameters of a given algorithm. Table 5 summarises the results of the robustness checks for the three outcomes analysed in Section 2.5.4: average annual growth of value added, average annual employment growth and average annual labour productivity growth.

TABLE 5 ROBUSTNESS CHECKS – RESULTS AT A 5 % SIGNIFICANCE LEVEL

Average annual growth of value added				
Matching method	2010-2017	2010-2016	2010-2015	2010-2014
Propensity score matching – nearest neighbour – ratio 2 – caliper 0.15	Reject H0	Reject H0	Reject H0	Reject H0
Propensity score matching – nearest neighbour – ratio 2 – caliper 0.05	Reject H0	Reject H0	Reject H0	Reject H0
Propensity score matching – nearest neighbour – ratio 1 – caliper 0.05	Reject H0	Reject H0	Reject H0	Reject H0
Mahalanobis metric distance matching – ratio 2	Reject H0	Reject H0	Reject H0	***Accept H0***
Mahalanobis metric distance matching – ratio 1	Reject H0	Reject H0	Reject H0	Reject H0
Average annual employment growth				
Matching method	2010-2017	2010-2016	2010-2015	2010-2014
Propensity score matching – nearest neighbour – ratio 2 – caliper 0.15	Reject H0	Reject H0	Reject H0	Reject H0
Propensity score matching – nearest neighbour – ratio 2 – caliper 0.05	Reject H0	Reject H0	Reject H0	Reject H0
Propensity score matching – nearest neighbour – ratio 1 – caliper 0.05	Reject H0	Reject H0	Reject H0	Reject H0
Mahalanobis metric distance matching – ratio 2	Reject H0	Reject H0	Reject H0	***Accept H0***
Mahalanobis metric distance matching – ratio 1	Reject H0	Reject H0	Reject H0	Reject H0
Average annual labour productivity growth				
Matching method	2010-2017	2010-2016	2010-2015	2010-2014
Propensity score matching – nearest neighbour – ratio 2 – caliper 0.15	Accept H0	Accept H0	Accept H0	Accept H0
Propensity score matching – nearest neighbour – ratio 2 – caliper 0.05	Accept H0	Accept H0	Accept H0	Accept H0
Propensity score matching – nearest neighbour – ratio 1 – caliper 0.05	Accept H0	Accept H0	Accept H0	Accept H0
Mahalanobis metric distance matching – ratio 2	Accept H0	Accept H0	Accept H0	Accept H0
Mahalanobis metric distance matching – ratio 1	Accept H0	Accept H0	Accept H0	Accept H0

Source: NBB (Central Balance Sheet Office, own calculations).

The table provides an overview of the results of the one-sided paired t-tests on the matched sample, but in each row the matching was performed by using a different method and/or parameter. The caliper was decreased to 0.05, the ratio was set to one, and instead of propensity score matching, the Mahalanobis metric distance matching was used to determine the similarity between an R&D and a non-R&D company in terms of the control variables used (sector of activity, size, solvency and age). The Mahalanobis distance is a statistical measure of the distance between an observation and a distribution of observations, introduced in 1936 by the Indian scientist Prasanta Chandra

Mahalanobis[35]. The robustness checks indicate that the conclusions in section 2.5.4 generally do not depend crucially on the methodology or the parameters chosen. Only for the period 2010-2014, the combination of the Mahalanobis distance and a ratio of 2 leads to diverging results. It must be pointed out though that, in this case, the matching process did not result in a well-balanced size variable.

2.7 ADDITIONAL R&D IMPACT TESTS

The results obtained in section 2.5.4 are based on a population of R&D companies that was defined in a relatively restrictive way, as only firms continuously – i.e. six years in a row – engaged in R&D activities are considered. To address the dynamics of the impact of R&D expenditure on entities, additional impact tests are performed by means of an alternative R&D sample. We selected all companies that incurred R&D expenses of at least € 100,000 over the years 2010 and 2011. The other selection criteria remain the same as described in section 2.2, both for the R&D and the non-R&D sample. This less restrictive sample comprises 921 R&D firms and 940 non-R&D firms. The propensity score matching process as described above is applied to this new sample. Subsequently, the impact of R&D on the same outcome variables as above is determined, being average annual growth of value added, average annual employment growth and average annual growth of labour productivity, and this for several periods (2010-2015, 2010-2014, 2010-2013 and 2010-2012).

The results of all one-sided paired t-tests are given in Table 6. The conclusions are similar to those for the more restrictive R&D sample: average annual growth of value added and average annual employment growth are generally higher in R&D entities than in non-R&D entities. As far as average annual growth of labour productivity is concerned, the null hypothesis (no difference between the R&D group and the non-R&D group) could not be rejected. However, for value added and employment, these conclusions only hold for the longer periods, 2010-2014 and 2010-2015. In fact, the null hypothesis cannot be rejected for the periods 2010-2012 and 2010-2013 (employment only). This result seems to indicate that R&D – on average – does not result in quick wins. On the contrary, a return on the investment should rather be expected in the medium or long term. This is not illogical as R&D projects (such as research to cure a specific disease, implementation of a new technology in the production process, the development of a new product, etc.) are often spread over several years. The resultant benefits will only emerge after these projects have been finalised and implemented.

[35] Mahalanobis (1936).

TABLE 6 ONE-SIDED PAIRED T-TESTS FOR A 2-YEAR R&D MATCHED SAMPLE – RESULTS AT A 5 % SIGNIFICANCE LEVEL

Average annual growth of value added				
Matching method	2010-2015	2010-2014	2010-2013	2010-2012
Propensity score matching – nearest neighbour – ratio 1 – caliper 0.15	Reject H0	Reject H0	***Accept H0***	Accept H0
Propensity score matching – nearest neighbour – ratio 1 – caliper 0.05	Reject H0	Reject H0	Reject H0	Accept H0
Propensity score matching – nearest neighbour – ratio 1 – caliper 0.10	Reject H0	Reject H0	Reject H0	Accept H0
Propensity score matching – nearest neighbour – ratio 2 – caliper 0.05	Reject H0	Reject H0	Reject H0	Accept H0
Propensity score matching – nearest neighbour – ratio 2 – caliper 0.10	Reject H0	Reject H0	Reject H0	Accept H0
Average annual employment growth				
Matching method	2010-2015	2010-2014	2010-2013	2010-2012
Propensity score matching – nearest neighbour – ratio 1 – caliper 0.15	Reject H0	Reject H0	Accept H0	Accept H0
Propensity score matching – nearest neighbour – ratio 1 – caliper 0.05	Reject H0	Reject H0	***Reject H0***	Accept H0
Propensity score matching – nearest neighbour – ratio 1 – caliper 0.10	Reject H0	Reject H0	Accept H0	Accept H0
Propensity score matching – nearest neighbour – ratio 2 – caliper 0.05	Reject H0	Reject H0	Accept H0	Accept H0
Propensity score matching – nearest neighbour – ratio 2 – caliper 0.10	Reject H0	Reject H0	Accept H0	Accept H0
Average annual labour productivity growth				
Matching method	2010-2015	2010-2014	2010-2013	2010-2012
Propensity score matching – nearest neighbour – ratio 1 – caliper 0.15	Accept H0	Accept H0	Accept H0	Accept H0
Propensity score matching – nearest neighbour – ratio 1 – caliper 0.05	Accept H0	Accept H0	Accept H0	Accept H0
Propensity score matching – nearest neighbour – ratio 1 – caliper 0.10	Accept H0	Accept H0	Accept H0	Accept H0
Propensity score matching – nearest neighbour – ratio 2 – caliper 0.05	Accept H0	Accept H0	Accept H0	Accept H0
Propensity score matching – nearest neighbour – ratio 2 – caliper 0.10	Accept H0	Accept H0	Accept H0	Accept H0

Source: NBB (Central Balance Sheet Office, own calculations).

3 SUMMARY

Numerous scientific articles confirm the link between R&D and productivity, sales growth or another performance measure. Policymakers have also recognised the importance of R&D for obtaining sustainable competitive advantage. With the help of several tax concessions, high-quality education and research facilities, Belgium performs better than the European average in terms of R&D. The business enterprise sector accounts for the largest share of this R&D expenditure.

Triggered by recent changes in the accounting legislation regarding the accounting and disclosure of R&D costs in the financial statements, and taking into account the strategic importance of Belgian R&D companies for the competitive position of the country's economy, this paper endeavours to provide a snapshot of the characteristics of Belgian R&D corporations. A comparison between the accounting R&D concept and the statistical R&D concept – as defined by the OECD in the Frascati Manual – demonstrates that the annual accounts cannot be used as a source to differentiate R&D companies from non-R&D firms. In order to identify Belgian R&D entities, we used data from the biennial survey by the Belgian Science Policy Office's (Belspo) scientific and technical information department.

Despite the fact that many companies invest in R&D projects, R&D expenditure in the Belgian business sector is highly concentrated: based on a solid sample of 1,964 R&D firms, the top 10 of companies investing the most in R&D account for more than half of all R&D costs incurred in 2015. In terms of R&D budgets, the chemicals and pharma industry is the most important sector, followed by scientific R&D and the manufacture of electronic and electrical equipment. Average R&D expenditure per company is higher for older firms, reaching its maximum in firms aged over 75. It is obvious that larger companies can afford to spend more on R&D than smaller ones. This finding is also related to the group structure of R&D entities. More than half of the R&D investment can be attributed to a big group with either a Belgian or an American parent entity. Analysis of the geographic location of R&D activities demonstrates that the majority of them are located in one of Belgium's major economic centres. The 1,964 R&D companies under review together employed nearly 279,000 people and generated € 45 billion of value added in 2016.

Based on these observations, can we conclude that R&D entities perform on average better than their non-R&D peers? To investigate such a hypothesis, two datasets were compiled. The first dataset encompasses companies that invested consistently in R&D activities during a period of six years. The second dataset includes firms that undertook practically nothing in terms of R&D during that same period. By means of statistical techniques – including propensity score matching and one-sided paired t-tests – it is demonstrated that R&D investment has generally had a positive impact on average annual growth of value added and average annual employment growth for periods of four years or longer. In a shorter timespan (less than four years) and based on a less restrictive R&D sample, such a positive impact of R&D involvement could not be demonstrated. For the average annual growth of labour productivity, no evidence of any difference between the R&D and the non-R&D group was found. The big advantage of this research, compared to the existing literature, is that it not only takes into consideration large or listed companies. Thanks to the full coverage range of the Belgian Central Balance Sheet Office, medium-sized and small entities could also be taken into account in the study.

These results, however, do not guarantee that R&D efforts will always result in net job creation and value added growth. It is obvious that many other factors (such as type of R&D investment, performance of competitors, occurrence of (natural) disasters, customer behaviour, etc.) play a crucial role in the success of R&D projects. Nevertheless, the tests support the hypothesis that, on average and in the medium to long run, R&D activities do not result in net job losses and do stimulate value added growth. From an economic perspective, this justifies a country's policy of supporting and facilitating R&D as much as possible. Deeper analysis on the topic – focused on Belgian corporations – would be necessary to determine whether the above conclusions hold, depending on the type of R&D investment. What kind of R&D expenditure generally results in job creation and more value added: investment in new products, new processes, or new production tools, for instance? These results could then be used to refine the country's R&D facilitating policy. Considering that the R&D sample under review in this paper represents 10.6 % of the country's gross domestic product and 6 % of domestic employment, there is justification for investing in a thorough and effective policy.

ANNEX 1: REPORTING OF R&D

1. RECENT CHANGES IN ACCOUNTING LEGISLATION

Following the transposition into Belgian law of Directive 2013/34/EU on the annual financial statements, consolidated financial statements and related reports of certain types of undertakings, several significant changes were made to Belgian accounting legislation, applicable as from accounting periods starting on or after the 1st of January 2016. One of the major changes was the revision of the concepts of large and small undertakings within the meaning of the Company Code and the introduction of the concept of a micro-entity. The new provisions also modify the content of the annual accounts and the accounting treatment of certain items such as research costs.

A non-listed[36] firm is now considered as small – and can therefore use the abbreviated format of the financial statements – if on the closing date of the last financial year it does not exceed more than one of the following thresholds:

- annual average number of employees: 50 FTE[37]
- turnover (excluding VAT): € 9 million (against € 7.3 million previously)
- balance sheet total: € 4.5 million (against € 3.65 million previously)

The Law also introduced the new concept of "micro-entities". Micro-entities are small (non-listed) firms that do not have any subsidiary, that are not a subsidiary of another entity and that do not – on the closing date of the last financial year – exceed more than one of the following thresholds:

- annual average number of employees: 10 FTE
- turnover (excluding VAT): € 0.7 million
- balance sheet total: € 0.35 million

Table 7 presents the changes in the type of format filed by companies, mainly following introduction of the new models at the Central Balance Sheet Office at the beginning of April 2017. 21.6 % of companies which had filed full-format accounts for 2015 filed an abbreviated format for 2017, and 1.1 % even filed a micro format. Obviously, the abbreviated format contains less information in the annexes than the full format. And the annexes of the micro format are even briefer than those of the abbreviated format. Neither the abbreviated format nor the micro format includes detailed information on the nature of intangible assets. As a result, information on R&D cannot be retrieved from financial statements filed in the abbreviated or micro format.

TABLE 7 CHANGE IN THE TYPE OF FORMAT FILED BY FIRMS

Format filed for 2015	Format filed for 2017		
	Full format	Abbreviated format	Micro format
Full format	17,797	4,964	249
Abbreviated format	1,092	138,997	208,678
No standardised accounts filed	98	1,328	2,091

Source: NBB (Central Balance Sheet Office, own calculations).

2. REPORTING OF R&D IN THE FINANCIAL STATEMENTS

The introduction of new size criteria was accompanied by new annual accounts formats and slightly modified accounting rules. Up to 2016, subject to certain conditions, Belgian law allowed businesses to capitalise R&D costs incurred during the year as intangible fixed assets, and to amortise them

[36] Listed firms are always considered as large.

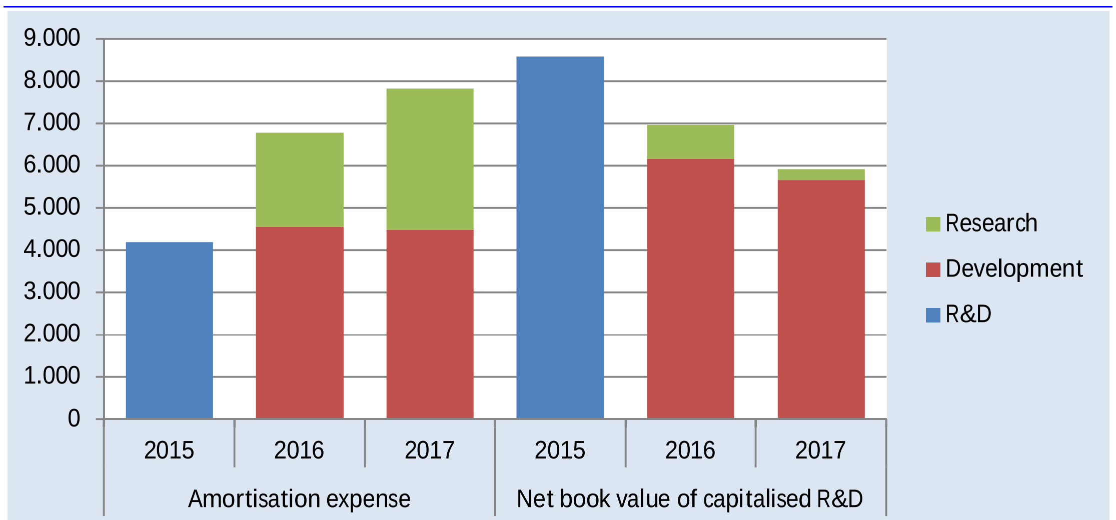
[37] The threshold of 100 FTE which automatically implied submission of full-format accounts even if the turnover criterion and balance sheet total were not exceeded has been dropped. The concept of the number of employees has also been extended to take account of company employees working abroad.

over a maximum of five years. The royal decree of 18 December 2015 transposing Directive 2013/34/EU introduced numerous changes in the balance sheet format and the breakdown of the item 'Intangible fixed assets'. More specifically, following the European Directive, research costs can no longer be capitalised. For accounting periods starting on or after the 1st of January 2016, only development costs may be capitalised. However, in order to avoid any negative impact on the tax incentives for research expenditure, this type of expenses can still be capitalised provided that they are amortised immediately and entirely during the year of capitalisation, thereby excluding any outstanding amount from the balance sheet. The amount of the research investment and the – identical – amount of the amortisation are both shown in the 'ad hoc' annex. Research costs incurred in previous years qualify for a transitional arrangement: the outstanding balance is included in the balance sheet and remains subject to the amortisation rules previously in force. Development costs, however, can still be capitalised and amortised over the life of the intangible fixed asset created. The maximum amortisation period for these assets is now ten years, compared to the previous five-year limit.

The changes in the R&D accounting are reflected in the annex of the full-format financial statements. The table concerning capitalised R&D costs has been split to show separately research costs capitalised in accounting periods starting before 2016, research costs capitalised (and fully amortised) in accounting periods starting in or after 2016, and development costs. However, based on financial statements covering 2016, Heuse and Vivet (2017) observed that the new tables in the annex have not been used uniformly by all firms. They point out that some companies did not complete the items in question, whereas these firms explicitly refer to the impact of the new rules in their management report. Furthermore, the new tables do not provide an accurate view of R&D costs incurred during the accounting period. Not only do the capitalisation criteria (cf. infra) reduce the costs taken into account, business combinations also distort the true and fair view. Indeed, the new tables do not make a distinction between R&D acquired in a business combination and other investment in R&D.

Obviously, the new R&D accounting rules do have a negative impact on the income statement during the initial years, as the profit and loss account is charged in two ways: while new research costs are fully expensed in the income statement, research costs from previous periods still affect the profit and loss by means of the amortisation charge. This does not seem to be mitigated by the positive impact of the longer amortisation period for development costs.

CHART 12 IMPACT OF CHANGES IN ACCOUNTING FOR R&D
(in € million)



Source: NBB (Central Balance Sheet Office, own calculations).

Analysis of the financial statements of 2,000 companies filing a full format for three consecutive accounting periods (2015, 2016 and 2017) reveals that aggregate amortisation charges increased by 87 % between 2015 and 2017 (Chart 12). In 2017, 1,194 of these companies disclosed amortisation on R&D in their annual accounts. Nearly 43 % of these expenses relate to research, but they are highly concentrated, as only 67 companies mention research costs in their annex, and GlaxoSmithKline Biologicals alone accounts for two-thirds of the total. In the 2017 balance sheet, the outstanding amount of capitalised R&D decreased by 31 %, compared to 2015. Here, research only represented 4 % of the total in 2017. This relates to research expenditure capitalised in previous periods and not yet fully amortised. It is hard to give an accurate estimate of the overall impact of the changes in R&D accounting on profitability measures, as not all companies apply the same amortisation period. However, Table 8 summarises the simulation of the situation under the previous accounting rules, using different assumptions. Obviously, at company level, the impact might be much greater. GlaxoSmithKline Biologicals' result before taxes, for example, plunged from a € 96 million profit in 2015 to a € 427 million loss in 2016 and a € 259 million loss in 2017. The annex to the financial statements of GlaxoSmithKline Biologicals explicitly mentions that *these losses are justified by the changes in accounting legislation regarding the capitalisation of R&D and do not reflect the economic value of the company*.

TABLE 8 SIMULATION OF THE 2017 AGGREGATE FIGURES UNDER OLD R&D ACCOUNTING RULES COMPARED TO THE ACTUAL AGGREGATE FIGURES
(companies filing a full format for accounting period 2017)

Aggregate amortisation period	Net book value of capitalised R&D	Profit (loss) before taxes	Return on sales	Return on assets
1 year (actual situation)	€ 6.2 bn	€ 52.0 bn	6.42 %	2.42 %
2 years	€ 7.6 bn	€ 53.5 bn	6.60 %	2.48 %
3 years	€ 8.1 bn	€ 54.0 bn	6.66 %	2.50 %
4 years	€ 8.3 bn	€ 54.2 bn	6.69 %	2.51 %
5 years	€ 8.5 bn	€ 54.4 bn	6.71 %	2.52 %

Source: NBB (Central Balance Sheet Office, own calculations).

To summarise, the standardised annual accounts in the full format do comprise some figures relating to a company's R&D investment during the year. Both research costs and development costs incurred during the period are disclosed, but only if they meet the criteria for capitalisation. This means that not all R&D expenditure is disclosed. What exactly is the difference?

3. DEFINITION OF R&D

According to OECD's Frascati Manual[38], research and experimental development (R&D) comprise *creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge*. To qualify as R&D, five criteria have to be jointly satisfied:

- To be aimed at new findings (novel)
- To be based on original, not obvious, concepts and hypotheses (creative)
- To be uncertain about the final outcome
- To be planned and budgeted (systematic)
- To lead to results that could be possibly reproduced (transferable and/or reproducible)

The OECD differentiates between three types of R&D activity: basic research (acquire new knowledge without any application or use in view), applied research (acquire new knowledge with a specific aim or objective), and experimental development (produce or improve products or processes, drawing on knowledge gained from research and experience). Traditionally, the private sector specialises in applied research and experimental development, while university institutions

[38] OECD (2015).

focus more on basic research. Small-sized spin-offs dedicated to R&D are an exception, but they are usually closely linked with a university. To measure the R&D efforts for policy objectives, such as the 3 % target, the OECD definition of R&D is used.

For accounting purposes, R&D costs only qualify as intangible fixed assets (this means that the related expenses may be capitalised) if several conditions are met. The assets need to be identifiable and they have to generate future economic benefits to the company. According to the advice[39] published by the Accounting Standards Commission, this means that the following criteria have to be satisfied simultaneously:

- It must be demonstrated that the product or process will generate future economic benefits for the company
- The product or process must be precisely defined and identifiable
- The costs incurred must be related to the project and separately measurable
- The technical feasibility of the product or process must be demonstrated
- The financial feasibility of the product or process must be demonstrated

As a result, expenses might satisfy the OECD definition of R&D without qualifying for capitalisation as intangible assets. Examples of such expenses are:

- Experimental work undertaken to discover possible new drugs, food elements, technologies, etc.
- Research to apply algorithms for handling large amounts of data and for handling missing data
- Search for alternative methods of computation, such as quantum computation and machine learning methods
- The study of documents, monuments or works of art in order to better understand political or cultural history
- Research to find additional applications for newly discovered technologies.

In all these cases, it is uncertain whether the project will generate future economic benefits for the company. No product or process has been discovered yet, so neither the technical nor the financial feasibility can be demonstrated. Another example of R&D that cannot be capitalised is the development of a new technology for which no business case exists as it is too expensive to implement.

Conversely, Belgian companies may capitalise costs as R&D assets even though they do not meet the OECD definition of R&D. This is illustrated by the following real-life examples:

- The development of business application software and information systems using known methods and existing software tools
- Expenditure for the creation of film productions or television programmes
- The investigation of proposed engineering projects (feasibility analysis, soil research, stability research, environmental impact research, mobility impact research, etc.), using existing techniques to provide additional information before starting the works or even deciding on implementation.

The definition involves some interpretation in the capitalisation decision. Therefore, not all companies will come to the same decision for similar expenses. Ling (2010) found that – for a small sample of high-tech starter companies from the Flemish region – advancement in the development phase and reputation are factors determining the capitalisation of R&D expenses. Furthermore, companies that have launched successful products in the past are more willing to capitalise expenditure for the development of a new product. Typically, fewer costs are activated as the project advances, because the earlier stages are usually the most cost-intensive. Ling also concluded that R&D capitalisation is used for window dressing. The more profitable the company becomes, the more likely it is that management will charge the R&D expenses to the income statement.

In order to compare the definition of R&D and the capitalisation conditions in the accounting legislation with the definition of R&D in OECD's Frascati Manual, financial statements data have been combined with Belspo's survey data. The most recent survey results available cover the period

[39] Advice 2016/16.

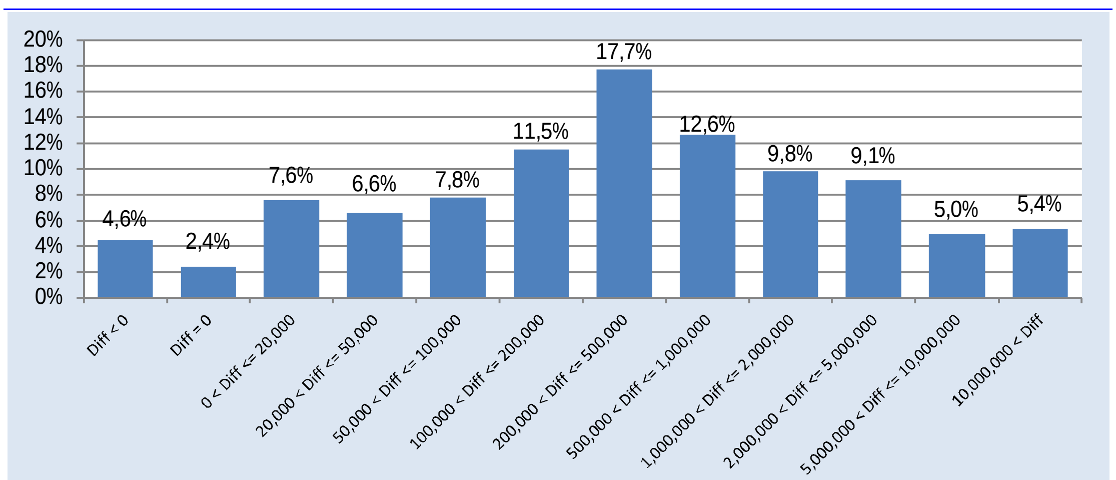
2015. For this period, 2,370 companies confirmed having spent resources on either intramural or extramural R&D. The Frascati Manual[40] distinguishes between intramural and extramural R&D expenditure as follows:

- *Expenditures on intramural R&D represent the amount of money spent on R&D that is performed within a reporting unit.* In other words, intramural R&D costs relate to R&D activities that originated within the control of the company. The related research and/or development was performed by the company's own staff.
- *Expenditures on (the funding of) extramural R&D represent the amount of money spent on R&D that is performed outside a reporting unit.* In other words, extramural R&D costs relate to R&D activities that originated outside the control of the company. The related research and/or development was outsourced to a third party.

Out of the 2,370 companies reporting R&D expenditure in the Belspo R&D survey for the period 2015, 69 entities did not file standardised financial statements ending in 2015 with the Central Balance Sheet Office (CBSO) of the NBB. Several of them are financial institutions or insurance companies as a result of which they file non-standardised financial statements that are beyond the scope of this study. Others are foreign companies that do not file standardised annual accounts either. Some companies decided to extend their accounting year beyond twelve months, which means that the financial statements covering the year 2015 end in 2016. Finally, a couple of companies did not file annual accounts closing in 2015 for other reasons (new companies established in 2015, bankruptcies, etc.). This left 2,301 R&D companies which could be linked to a 2015 financial statement.

However, the 2015 Belspo R&D survey data cover the calendar year, whereas financial statements do not necessarily end on the 31st of December and do not necessarily cover a period of 12 months. Therefore, all annual accounts not ending on the 31st of December 2015 and/or not covering a period of 12 months had to be removed in order to be able to compare accounting data with survey data. Moreover, annual accounts according to the abbreviated standard format do not contain information on R&D costs capitalised during the year. This type of expenses is aggregated with other intangible assets capitalised during the year. This means that only financial statements drawn up according to the full format can be used in this comparison exercise. 989 R&D companies could be linked to full-format financial statements covering the calendar year 2015.

CHART 13 RELATIVE DISTRIBUTION OF THE DIFFERENCE BETWEEN THE SURVEY R&D AMOUNT AND THE ACCOUNTING R&D AMOUNT FOR A SAMPLE OF 989 COMPANIES



Source: Belspo survey data, NBB (Central Balance Sheet Office).
* Diff = the survey R&D amount minus the accounting R&D amount

[40] OECD (2015).

Comparing survey data with accounting data shows that in 24 cases (2.4 %) the two figures are equal[41]. In 93 % of the cases, the Belspo R&D survey amount – which should be in line with the OECD definition of R&D – is higher than the newly capitalised R&D expenses reported in the financial statements. In three-quarters of the cases, no capitalised R&D costs are reported at all in the annual accounts. Only in 4.6 % of the cases is the survey figure lower than the accounting figure. These results clearly show that the accounting definition and conditions for capitalisation of R&D are in general much more restrictive than the OECD definition of R&D, which leads to the conclusion that the financial statements cannot be used at all to estimate the R&D intensity of a country at macro level, or even that of a company at micro level. Chart 13 gives a more detailed relative distribution of the differences between the survey data and the accounting data.

The divergent definitions, capitalisation criteria and comparison exercise clearly demonstrate that the standardised financial statements cannot be used as a single source to determine the level of an entity's R&D activity. Therefore, data obtained through the biennial Belspo R&D survey were used extensively in this study.

4. DESCRIPTION OF THE BELSPO DATA USED

The data at the NBB's disposal for the purpose of this study consist of a list of companies that are captured in the permanent inventory of the scientific potential of the country, a dataset managed by the Belgian Science Policy Office. For each of these companies, the sums invested in R&D, both intramural and extramural, reported in their response to the biennial survey is included, even if the amount is zero. If the company did not respond to the survey, it is indicated whether a figure for R&D expenditure has been estimated by Belspo. The estimated amount itself is not included in the data though. Table 9 provides an overview of the numbers of companies included in the Belspo dataset for which the actual R&D amount is available and for which the R&D amount was estimated, distinguishing between intramural and extramural expenses, for each year in the 2010-2015 period.

TABLE 9 NUMBER OF COMPANIES INCLUDED IN THE BELSPO DATASET

	2010	2011	2012	2013	2014	2015
Intramural expenditure – actual figure	2,813	3,041	3,072	3,167	3,756	3,739
Intramural expenditure – estimated figure	2,782	2,554	2,583	2,488	2,196	2,213
Extramural expenditure – actual figure	2,850	2,991	3,462	3,509	3,444	3,461
Extramural expenditure – estimated figure	2,745	2,604	2,193	2,146	2,508	2,491
Total number of companies	**5,595**	**5,595**	**5,655**	**5,655**	**5,952**	**5,952**

Source: Belspo survey data.

[41] Rounding differences – as the survey figures are expressed in thousand euros – are not considered as real differences between the two datasets.

ANNEX 2: DEFINITION OF THE SECTORS OF ACTIVITY

Name of the sector	**NACE-BEL 2008** *(2 digits)*	**NACE-BEL Definition**
Food and beverages	10 to 12	Manufacture of food products, beverages and tobacco products
Textile and paper	13 to 18	Manufacture of textiles, apparel, leather, wood, paper products and printing
Chemicals and pharma	20 + 21	Manufacture of chemicals, chemical products, pharmaceuticals, medicinal chemical and botanical products
Rubber, plastics products, non-metallic mineral products	22 + 23	Manufacture of rubber and plastics products, and other non-metallic mineral products
Basic metals and fabricated metal products	24 + 25	Manufacture of basic metals and fabricated metal products, except machinery and equipment
Electronic and electrical equipment	26 + 27	Manufacture of computer, electronic and optical products, and electrical equipment
Machinery and equipment	28	Manufacture of machinery and equipment
Other manufacturing industry	29 to 33 + 19	Manufacture of transport equipment, coke and refined petroleum products, other manufacturing, and repair and installation of machinery and equipment
Construction	41 to 43	Construction
Wholesale and retail trade, repair of motor vehicles	45 to 47	Wholesale and retail trade, repair of motor vehicles and motorcycles
Publishing and communications	58 to 61	Publishing, audiovisual and broadcasting activities, and telecommunications
IT and other information services	62 + 63	IT and other information services
Legal, accounting, management consultancy	69 + 70	Legal, accounting and management consultancy activities
Architecture, engineering, technical testing and analysis	71	Architectural and engineering activities; technical testing and analysis
Scientific research and development	72	Scientific research and development
Administrative and support service activities	77 to 82	Administrative and support service activities

ANNEX 3: BREAKDOWN OF R&D AND NON-R&D SAMPLES ACCORDING TO SECTOR OF ACTIVITY

Sector of activity *(2-digits NACE code)*	**Sample of R&D companies**	**Sample of non-R&D companies**	**TOTAL sample**
01	4	6	**10**
10	18	50	**68**
13	14	14	**28**
16	1	12	**13**
17	1	10	**11**
18	2	14	**16**
20	35	11	**46**
21	4	5	**9**
22	17	24	**41**
23	9	26	**35**
24	7	2	**9**
25	18	55	**73**
26	35	4	**39**
27	8	5	**13**
28	25	29	**54**
29	4	7	**11**
31	2	17	**19**
32	4	8	**12**
33	2	15	**17**
38	4	16	**20**
41	1	11	**12**
42	4	8	**12**
43	2	34	**36**
45	2	9	**11**
46	14	230	**244**
47	2	16	**18**
52	1	32	**33**
58	2	11	**13**
62	37	58	**95**
66	1	13	**14**
70	3	19	**22**
71	39	54	**93**
72	22	2	**24**
ALL sectors	**344**	**827**	**1,171**

01 Crop and animal production, hunting and related service activities
10 Manufacture of food products
13 Manufacture of textiles
16 Manufacture of (products of) wood (except furniture), cork, articles of straw and plaiting materials
17 Manufacture of paper and paper products
18 Printing and reproduction of recorded media
20 Manufacture of chemicals and chemical products
21 Manufacture of basic pharmaceutical products and pharmaceutical preparations
22 Manufacture of rubber and plastic products
23 Manufacture of other non-metallic mineral products

24	Manufacture of basic metals
25	Manufacture of fabricated metal products, except machinery and equipment
26	Manufacture of computer, electronic and optical products
27	Manufacture of electrical equipment
28	Manufacture of machinery and equipment
29	Manufacture of motor vehicles, trailers and semi-trailers
31	Manufacture of furniture
32	Other manufacturing
33	Repair and installation of machinery and equipment
38	Waste collection, treatment and disposal activities; materials recovery
41	Construction of buildings
42	Civil engineering
43	Specialised construction activities
45	Wholesale and retail trade and repair of motor vehicles and motorcycles
46	Wholesale trade, except of motor vehicles and motorcycles
47	Retail trade, except of motor vehicles and motorcycles
52	Warehousing and support activities for transportation
58	Publishing activities
62	Computer programming, consultancy and related activities
66	Activities auxiliary to financial services and insurance activities
70	Activities of head offices; management consultancy activities
71	Architectural and engineering activities; technical testing and analysis
72	Scientific research and development

ANNEX 4: LOGISTIC REGRESSION TO CALCULATE PROPENSITY SCORES

SUMMARY OF THE FITTED LOGISTIC REGRESSION

Model:
formula = RenD ~ size2010 + nace46 + nace26 + nace20 + nace72 + nace52 + nace43 + nace24 + nace71 + nace62 + nace28 + nace27 + nace13 + nace22 + nace21 + solvency2010 + age

Deviance Residuals:

Min	1Q	Median	3Q	Max
-2.2177	-0.7081	-0.3623	0.5138	2.5426

Coefficients:

	Estimate	Standard error	z value	p-value	Significance
Intercept	-1.918316	0.219753	-8.729	< 2e-16	***
size2010	0.016284	0.006211	2.622	0.00874	**
nace46	-1.483961	0.305362	-4.860	1.18e-06	***
nace26	3.597712	0.544820	6.603	4.02e-11	***
nace20	2.544275	0.370606	6.865	6.64e-12	***
nace72	3.844533	0.756212	5.084	3.70e-07	***
nace52	-2.038599	1.022745	-1.993	0.04623	*
nace43	-1.509458	0.740492	-2.038	0.04150	*
nace24	2.646290	0.814461	3.249	0.00116	**
nace71	1.126515	0.247988	4.543	5.56e-06	***
nace62	1.056777	0.251689	4.199	2.68e-05	***
nace28	1.222899	0.303118	4.034	5.47e-05	***
nace27	1.904897	0.585254	3.255	0.00113	**
nace13	1.316372	0.400998	3.283	0.00103	**
nace22	1.016562	0.343281	2.961	0.00306	**
nace21	1.157918	0.685154	1.690	0.09103	.
solvency2010	0.754373	0.291659	2.586	0.00970	**
age	0.006169	0.004810	1.282	0.19967	

Significance codes:
*** Significance at the 0.001 level
** Significance at the 0.01 level
* Significance at the 0.05 level
. Significance at the 0.1 level

Source: NBB (Central Balance Sheet Office, own calculations).

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