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THE IMPACT OF R&D SUBSIDIES ON COMPANIES' PERFORMANCE - THE CASE OF SI I&DT QREN

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Abstract

Every seven years, the European Union decides on its future long-term budget, the so-called "Multiannual Financial Framework" (MFF). Among the various expenditure items covered, the Cohesion Policy is included, compromising the financial support programmes, such as the *Quadro de Referência Estratégica Nacional* (QREN) (2007-2014) and Portugal 2020 (2014-2020). With the culmination of the current framework programme - Portugal 2020 – and the opening of the debate on the future of Cohesion Policy and its priority areas, there is a need to assess the impacts of the programmes developed and rethink the strategies that should be adopted in the next cycle, from 2021-2027. It is in this context that the present study emerged. It aims to analyse the impact of subsidies to Research and Development (R&D) on the performance of companies - more specifically, the impact of QREN's *Sistema de Incentivos à Investigação e Desenvolvimento Tecnológico nas Empresa* (SI I&DT QREN).

There is already a relatively wide range of studies that explore the relationship between subsidies to R&D and companies' performance. Nevertheless, no consensus has been reached. Furthermore, the literature that analyses the impact of R&D subsidies in non-market-centred and moderate innovative economies, as Portugal, is quite scarce and limited.

The information used in this empirical study concerns the period between 2008-2017 and it was collected from the Operational Competitiveness Programme (COMPETE) included in QREN and complemented with economic and financial data gathered from the Annual System of Iberian Balances (SABI) database. We compared the performance of companies that in 2014 succeeded in obtaining subsidies to R&D with similar companies that did not receive subsidies. Resorting to information on a set of relevant variables in the period before obtaining the subsidy (2008-2013), we established a trustable comparison group using the Propensity Score Matching (PSM). Then, based on the Average Treatment Effect on the Treated, we compared companies that received subsidies with those that did not on the 2017 values (three years after the subsidy) of several outcome variables, most notably employment, labour productivity, operational results and exports. Our results show that companies that received a public subsidy to R&D three years after that present higher employment levels and export propensity than companies that did not receive the subsidy. Notwithstanding, no statistically significant differences were encounter in terms of labour productivity or overall financial performance (more precisely in the EBITDA).

Keywords: R&D subsidies; companies' performance; propensity score matching; Portugal

Resumo

A cada sete anos, a União Europeia decide sobre o seu futuro orçamento de longo prazo, o chamado "Quadro Financeiro Plurianual" (QFP). Entre as várias rúbricas de despesa abordadas, inclui-se a Política de Coesão que contempla os programas de apoio financeiro provenientes de fundos comunitários, como é o caso do QREN (2007-2014) e do Portugal 2020 (2014-2020). Com o culminar de mais um programa quadro – Portugal 2020 – e aberto o debate sobre o futuro da Política de Coesão e os seus domínios prioritários, urge avaliar os impactos dos programas desenvolvidos e repensar nas estratégias que deverão ser adotadas no próximo ciclo de 2021 a 2027. É neste contexto que surgiu o presente estudo que tem como objetivo analisar o impacto dos subsídios à Investigação e Desenvolvimento (I&D) na performance das empresas – mais concretamente, o impacto do Sistema de Incentivos à Investigação e Desenvolvimento Tecnológico nas Empresa (SI I&DT QREN).

Apesar da existência de uma gama relativamente ampla de estudos que exploram a relação entre os subsídios à I&D e a performance das empresas, nenhum consenso foi alcançado nesta matéria. Além disso, a literatura que analisa o impacto dos subsídios à I&D em economias inovadoras moderadas, como Portugal, é bastante escassa e limitada.

A informação que será usada neste estudo empírico diz respeito ao período 2008-2017 e foi recolhida através da base de dados "Sistema Anual de Balanços Ibéricos" (SABI) e na plataforma online do COMPETE QREN. Comparamos o desempenho das empresas que em 2014 conseguiram obter subsídios à I&D com empresas similares que não receberam subsídios. Recorrendo a um conjunto de variáveis relevantes no período anterior à obtenção do subsídio (2008-2013), estabelecemos um grupo de comparação fidedigno aplicando o *Propensity Score Matching* (PSM). Em seguida, com base no Efeito Médio de Tratamento, comparamos empresas que receberam subsídios com aquelas que não receberam relativamente aos valores de 2017 (três anos após o subsídio) de várias variáveis de resultado, nomeadamente, emprego, produtividade do trabalho, resultados operacionais e exportações.

Atendendo aos nos nossos resultados, as empresas que receberam subsídio público à I&D, três anos depois, apresentam níveis mais elevados de emprego e maior propensão à exportação do que as empresas que não receberam o subsídio. Não obstante, não foram encontradas diferenças estatisticamente significativas em termos de produtividade do trabalho ou desempenho financeiro (mais precisamente no EBITDA).

Palavras-chave: subsídios à I&D; performance das empresas; *propensity score matching*; Portugal.

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1. Introduction

Technology development and innovation are central aspects for competitiveness and long-term growth in today's economies (Romer, 1990; Vanino, Roper & Becker, 2019). Research and Development (R&D), in particular, emerges as a key factor for the sustained long-run growth of companies and to their competitive position (Vanino et al., 2019). Indeed, earlier on Schumpeter (1934) defended that growth is the consequence of strategic efforts by companies in developing R&D projects.

R&D activities are expected to increase social benefits, which may even surpass private benefits, leading to underinvestment in a free market (Arrow, 1962). In this context, governments tend to devise policies that aim to promote R&D projects and to help companies to overcome difficulties that may arise along the process (Cunningham, Gok & Laredo, 2012). The reasoning behind an R&D policy is not only to correct the market failure that Arrow (1962) mentioned, but also to enhance national companies' competitiveness (Kim, Suh & Zheng, 2016). Following this line of thought, innovation-oriented economies have been implementing national and/or regional policies which may be materialized in the form of direct involvement of governmental institutions or in the attribution of tax and financial incentives, to private business' R&D activities (Duch, Montolio & Mediavilla, 2009; Silva et al., 2017)

The discussion about the pertinence and efficacy of governmental support to R&D and technological innovation has always been a topic of controversy (Duch et al., 2009; Cunningham et al.,2012; Criscuolo, Martin, Overman & Van Reenen, 2019; Vanino et al., 2019).

Studies that analysed the impact of publicly funded R&D activities on firm performance are numerous and resort to both qualitative (e.g., Lenihan & Hart, 2004; PACEC, 2009) and quantitative (e.g., Karhunen & Huovari, 2015; Vanino et al., 2019) methodologies. Those that use quantitative micro economic analyses seek to assess the impact of subsidies on the performance of the granted companies (Duch et al., 2009; Karhunen & Huovari, 2015; De Balasio, Fantino & Pellegrini, 2015; Bellucci, Pennacchio & Zazzaro, 2016; Cin, Kim, Vonortas, 2017; Furman, Li & Wang, 2017; Vanino et al., 2019; Criscuolo et al., 2019), however, their results are somewhat contradictory. Some studies (e.g., Duch et al., 2009; Karhunen & Huovari, 2015; Vanino et al., 2019) evidence the existence of a positive relationship between R&D public-funding and companies' employment and turnover growth regardless the size and sector of the firm. While others, for example, Criscuolo et al. (2019), have found that subsidies to R&D projects impact positively on employment only in small companies. Furthermore, when performance is measured by labour productivity, Karhunen & Huovari (2015) show that in the five-year period after the subsidy is granted the effect of the subsidy on labour productivity is not significant and it is negative in the two-year period after the subsidy year, whereas Duch et al. (2009) concluded that in the year of conclusion of the publicly funded R&D project the labour productivity increased. When performance is proxied by the survival of the companies, Cin et al. (2017) evidenced that R&D subsidies positively impact on the survival of companies, whereas Wang et al. (2017) came up with results that showed no significant effects.

Another aspect that seems to be common among empirical evidence is that it focuses mainly on public R&D policies which take place on market-centered-economies that are considered relatively efficient. That is the case of the study made by Basit, Kuhn & Ahmed (2018), which assesses the impact of R&D grants on non-technological companies of the service sector in Germany. They have reached results that show public R&D funds have a positive impact on marketing and organizational innovation, which in turn affects positively the performance of companies. Furthermore, most of the studies mentioned above took place in leading innovative countries such as Finland (Karhunen & Huovari, 2015) and South Korea (Cin et al., 2017) or in emerging economies as China (Wang et al., 2017).

Even though there are plenty of studies made on this topic, less attention is paid to moderate innovative countries, such as Portugal. Although Duch et al. (2009) has studied a sample of Spanish companies, hence, have analysed a country similar to Portugal in terms of innovation, the companies considered were located only in the region of Catalunya.

The present study provides a comprehensive analysis on the effects of public R&D support on the performance of Portuguese companies. Furthermore, it analyses both the Services and Manufacturing sectors, in all the extent of Portuguese territory. In order to do so, we compare companies' performance across different sectors, regions and industries. Secondly, we use longitudinal data on company performance and subsidy receipt so that we are able to evaluate the relationship between participating in R&D funded programmes and the company's growth in the short-term.

The study's main research questions are: 1) What are the determinants for a company to receive a public subsidy to R&D?; and 2) Do R&D subsidies impact positively the performance of the recipient companies?

More specifically, in this dissertation, we concentrate our efforts on understanding the extent to which subsidies to R&D projects – in particular, the SI I&DT[1] QREN– have impacted on the performance of companies. Using a propensity score matching technique (Duch et al., 2009; Vanino et al., 2019), we assess the differences of performance between subsidized companies and a matched comparing group of companies that have not been granted a subsidy, based on their probability of being a participant in such programmes. Thus, the treatment effect of public R&D subsidies and the governance of such funds are estimated through the comparison of their performance before and after the project participation. Our study takes into account factors such as the size, age, past performance, past productivity, human and physical capital in order to consider the effect of company heterogeneity on the self-selection of companies into publicly supported R&D activities.

This dissertation is structured as follows. After this Introduction, Section 2 comprises the relevant literature on the topic of the reasoning behind a R&D public policy, on the choice of policy instruments, the mechanisms through which R&D policy impacts companies' performance: main hypothesis to be tested, as well as the effectiveness of such policies. In addition, we add to Section 2 literature on the determinants for being attributed a subsidy to R&D. Section 3 gives an overview of the methodology we have adopted and disclosures information about the dataset. Section 4 presents and discusses the empirical results. Finally, in Conclusions the main contributions of the present study are summarised, and the policy implications, limitations and paths for future research are discussed.

[1] SI I&DT – Sistema de Incentivos à Investigação e Desenvolvimento Tecnológico, henceforth "R&TD – QREN"

2. Literature review

2.1. Rationale for public R&D policy

The argument behind public intervention asserts that social returns to R&D activities are greater than private returns making market allocation of these resources sub-optimal (Arrow, 1962; Dutch et al., 2009). Such an argument is proved by empirical evidence developed by Jones & Williams (1998) and Griliches (1991).

Public R&D policies have long been used in Europe and constitute a broadly used tool at national level. Economic theory highlights the inefficiency of markets as the main supporting argument for public funding of research projects (Duch et al., 2009). The literature gives emphasis to two market failures (Silva, Silva & Carneiro, 2017): imperfect appropriability of knowledge and capital market limitations.

Before exploring the implications of these market failures, it is important to classify the primary output of R&D projects – knowledge. The use of a determined knowledge by one agent does not compromise the amount available to others neither its quality. Furthermore, no individual can be excluded of its use by others. Therefore, knowledge is considered a non-rival (at least in part) and non-excludable good. Due to these characteristics, knowledge possesses the nature of a public good, which leads private R&D spending to be lower than the socially optimal level (Arrow, 1962).

Moreover, on account of these knowledge features, positive externalities emerge (Arrow, 1962). These externalities result from the fact that the appropriateness of knowledge is not only up to whom has created it (companies which incur in costs to produce it) but also it can be appropriated by other companies, who have not invested at all. As a consequence, it is expected that companies underinvest in R&D because they cannot utterly appropriate its results and, so, fully benefit from its profits – under these circumstances, private R&D will systematically be lower than the socially optimal level (Arrow, 1962). What's more, empirical studies have demonstrated that social returns to R&D activities are higher than private ones, in the presence of positive externalities (Griliches, 1991; Jones & Williams, 1998; Elder & Fagerber, 2017).

Nonetheless, there is legal protection for companies that invest in R&D, preventing research outputs from becoming common, for example, through the emission of patents (Basit et al., 2018). This instrument guarantees that, by a given period of time, the innovative company owns the right to use exclusively the knowledge created. Indeed, patents serve as a reward to innovating companies and, obviously, encourage potential innovators to allocate resources to R&D. The trade-off between the benefit of more innovation and the cost associated with temporary monopoly power is pointed as the optimal choice for a patent length (Duch et al., 2009). Literature justifies the existence of legal protection arguing that the welfare loss of long patents is not significant compared to the social cost of choosing to short a patent (Nordhaus, 1969). However, according to Cerulli (2010), the existence of patents or secrecy inhibits the effect of positive externalities associated with research projects, thus, corrects this market failure. Some authors go even further suggesting that R&D should not even be classified as a public good. Nevertheless, Arrow (1962) defends that legal protection cannot completely convert intangible knowledge into an excludable and entirely appropriable good. In addition, preventing the diffusion of knowledge reduces the efficiency and the quantity of R&D activities, once knowledge concerns both: the output of research and the input for future studies (Arrow, 1962). This argument is also supported by Gallini & Wright (1990) and Matutes, Regibeau & Rockett (1996), whose studies have concluded that expanding the period of a patent slows down the rate of introduction of innovations and restricts the diffusion of new findings.

Equally important is to consider the implications of unprotected knowledge, which can be object of imitation by free riders. Besides being costly, Hall (2002) mentions that the cost of imitation can reach 50-75% of the cost of original inventions, the use of external knowledge implies that the free-rider has enough skills that allow him to utterly absorb the spillovers effects of R&D. Indeed, one must not confuse the implications of having access to information with having knowledge to use such information (Metcalfe, 2005). As a matter of fact, a company's "absorptive capacity" is hardly developed to its maximum. Absorptive capacity is an original term by Cohen and Levinthal (1990, p.128) which refers to the "ability to evaluate and utilise outside knowledge [which] is largely a function of the level of prior related knowledge. (…) prior related knowledge confers an ability to recognise the value of new information, assimilate it, and apply it to commercial ends. These abilities collectively constitute what we call a firm's absorptive capacity". In this sense, free riders might end up obtaining lower profits in comparison to the full potential of the externalities. Additionally, companies have a stimulus to keep doing research projects so that they develop their absorptive capacity. This implies that the net effect of externalities cannot a priori determine if the level of R&D expenditures is lower, is equivalent or is higher than the socially optimal level (Silva et al., 2017).

Regarding the second market failure that was mentioned earlier in the text, capital market limitations, it is originated by the difference between the private rate of return and the cost of external capital (Silva et al., 2017). Whenever companies do not have enough financial autonomy to perform R&D activities, they can fund them through external capital. However, asymmetric information on the predicted outcome and sunk costs in R&D investment undermine the access to external funding. Even though researchers have much more information about the potential success of the innovative process than investors, in general, they are reluctant to provide further details about it, because they fear external appropriability of their work (Hall, 2002). Furthermore, the intangible nature of knowledge - research output – makes it difficult to serve as a collateral to secure a loan (Zúniga-Vicente, Alonso-Borrego, Forcadell & Galán, 2012). This is in line with the Real Options Theory which states that investment and uncertainty are negatively related, the higher the uncertainty, the higher the risk (and the cost of capital), hence, uncertainty influences economic agents to decrease investment in fixed capital (Pindyck, 1991).

Despite the emergence of venture capital formation and other forms of early-stage capital as a solution for the absence of external funding of R&D activities, some limitations still come to light. In some cases, minimum investment is required and, if too high, it might be problematic for SME (small and medium enterprises) and start-ups (Silva et al., 2017). Moreover, the existence of a well-developed stock market constitutes a crucial requirement for the success of the venture capital sector (Black & Gilson, 1999).

To conclude, although there is not a consensus on identifying knowledge as a public good, neither on the consequences of externalities on R&D and innovations projects, the presence of market failures seems to be broadly accepted as the main reason for public policies on R&D. Most scholars argue that private initiatives alone would not meet the desirable social level of R&D expenditure.

2.2. R&D policy instruments

Public policy instruments are generally defined as "a set of techniques by which governmental authorities wield their power in attempting to ensure support and effect (or prevent) social change" (Serris, 2004, p.71).

Economic growth, environmental protection, employment, public health or military capacity are some of the most relevant ultimate objectives of innovation policy. Indeed, as stated by Borrás & Edquist (2013, p. 1515) "innovation is rarely a goal itself, but a means to achieve broader political goals". Evidently, the objectives defined for innovation process are directly dependent on national traditions and on the different types of state-market-society relations, as well as on the ideology of the government in charge (Borrás & Edquist, 2013). Since innovation policy intends to solve problems faced in the innovation process, their identification is a priority. Only after their recognition is possible to draw and implement an effective R&D policy. In this context, problem means the inexistence of a match between the objectives in terms of innovation intensity and the real innovation intensity produced by private and public organizations.

Government R&D policy instruments are often in the form of direct public funding of business R&D (e.g. subsidies or public procurement) and tax credits.

Through the use of subsidies, government can select projects with higher expected social rates of return. However, due to information asymmetries, it might be difficult for public agencies to recognize which R&D projects will impact more positively social returns and which ones of these are less likely to be developed only by private initiatives (Socorro, 2007). In this perspective, the risk that public funding will crowd-out private expenditures in R&D is considerable (David, Hall & Toole, 2000). For this reason, the allocation of public funding is of maximum importance. When badly allocated, subsidies may end up discouraging private investment in R&D activities. Indeed, the crowding out effect is probably the major concern associated to this policy instrument. Plenty of authors make an allusion on this issue, as is the case of David et al. (2000) and Dai & Cheng (2015). They all defend that a company's own R&D spending in innovation may be partially or utterly crowd out by government subsidies. In line with this argument, several empirical studies have shown that private R&D investment and public funding may have a substitutive or complementary relationship (Guellec & Van Pottelsberghe De La Potterie, 2003). Furthermore, even if used in projects likely to generate high social return, government funds may be inefficiently allocated into irrelevant activities, for instance, raising wages, acquiring unnecessary machines or hiring needless employees (David et al., 2000).

In addition, existing empirical literature suggests that a potential selection bias in the public funds allocation is a real issue (David et al., 2000). As politicians might be more concerned with maximizing their political goals than in potentialize economic efficiency, resources might be misused (Bergström, 2000). Hence, public funds may end up financing R&D activities that result in higher private returns and, so, crowding out private investment in R&D. In this perspective, subsidies can turn out to be the most inefficient and costly policy (Fischer & Newell, 2008).

Besides direct funding, tax incentives are also a means to boost private financed R&D activities. Whereas subsidies increase the private rate of return of R&D investment, tax incentives reduce the marginal cost of R&D (David et al., 2000), thus, there is not a priori a crowding out effect (Hall & Van Reenen, 2000). Furthermore, fiscal incentives have the advantage of being more impartial in terms of the nature of companies that benefit from it. Moreover, the projects and the amount of R&D expenditure is determined by private companies (David et al., 2000). Consequently, fiscal incentives are an option that minimizes the discriminatory selection of public agencies. Nonetheless, this advantage can be considered a weakness, in the sense that it is socially desirable to direct R&D towards researches with high spillover effects (Hall, 1993). This is unlikely to occur since private companies tend to use tax credits to first finance projects with the highest rate of return, which are not necessarily the ones with highest social return. Accordingly, the companies' R&D agenda might also be conditioned by focusing in short-term projects which are perceived to generate faster and higher paybacks. Another limitation of this policy instrument, which may constitute an argument against authors who believe tax credits diminishes biased selection, is that once only companies with profits can benefit from it, start-ups and small business might not have access to it (Silva et al., 2017). Therefore, tax credit does not appear to be the most effective tool for the correction of the capital market failure (Guellec & Van Pottelsberghe De La Potterie, 2003).

Another aspect that is considered by some scholars, such as Acs (2000)and Fornahl and Brenner (2003), of extreme importance for technology policies is the regional dimension. Industrial specialisation patterns and their innovation performance present differences according to each region (Paci & Usai, 2000). Additionally, knowledge spillovers are generally spatial constrained (Audretsch & Feldman, 1996). And, last but not least, policy institutions are often linked to subnational territories (Cooke, Boekholt & Tödtling, 2000), as is the case of European Union. There are studies that provide evidence that the objectives of national and regional agencies diverge significantly, and so, the allocational heterogeneity of subsidies should be considered when evaluating their effects (e.g. Blanes & Busom, 2004).

In sum, regarding tax credits, the previous concerns about attributing subsidies to R&D activities are less impactful. Although the real R&D inputs are expected to increase, crowding-out effect is unlikely to happened (David et al., 2000; Czarnitzki, Hanel & Rosa, 2011). In addition, since the decisions on how to manage and develop R&D activities are only dependant on companies' will, tax credit tends to be a more market oriented tool (David et al., 2000). Choices about fund distribution and the goals of innovations projects rely only on the management board of the companies (Czarnitzki et al., 2011).

In conclusion, operationalising the support programmes of R&D policy turns out to be tough, thus it is crucial to demonstrate their effectiveness.

2.3. The determinants of the attribution of a R&D subsidy

A central topic of investigation that arises has to do with the allocation process of public funds. The main question is whether there is a potential selection bias or whether the grants are attributed randomly. Many are the studies made on this matter which highlight some key determinants of the participation in a R&D subsidy programme, including company's size, number of qualified workers, past experience in participating in R&D programmes, companies' property structure, exports intensity and the technology intensity of the sector where the company operates.

According to the literature, one of the most significant variables is the size of the company. Frequently, larger companies tend do have a higher probability of receiving a subsidy (Herrera & Nieto, 2008). This may be explained by the fact that these companies more often have a R&D department or laboratory and develop more critical R&D activities, which in turn enables them to present a clearer and more robust R&D project that is in line with the requirements of the public agencies (Herrera & Nieto, 2008). On the other hand, smaller companies are more likely to be self-excluded from participating in such subsidy programmes since they usually have limited R&D management capacity. Though, Busom (2000) has found that smaller companies may have greater chance of being a recipient of a subsidy once public agencies may want to support them in the first place due to the credit constraints they often face.

Another factor that seems to positively influence the propensity to receive a subsidy is the companies' percentage of qualified employees (Blanes & Busom, 2004). Indeed, literature shows that the more qualified workers a company has, the more likely it is for the enterprise to see its absorptive capacity increase. Thus, it is expected that a larger share of qualified employees will contribute positively for the creation of more profitable and disruptive R&D studies (Aschhoff, 2010). Therefore, when making an application for a public R&D subsidy, presenting as critical resources for the project highly qualified workers increases the chances of the company to get the project approved.

Some authors, such as Aschhoff (2010), argue that having participated in R&D subsidy programmes in the past may impact positively the chance of being subsidized again. Moreover, evidence supports that the number of patents (applications and registered) affect positively the likelihood of becoming a recipient of a subsidy to R&D (Kaiser, 2006). In line with the thought that past experience in R&D may be determinant for receiving a subsidy, some authors use the company's age as a proxy of its experience (e.g., González, Jaumandreu & Pazó, 2005).

Property structure is another variable that has been pointed out by scholars as a feature that influences the probability of being attributed a subsidy. For instance, Duch et al. (2009) have presented empirical evidence for the fact that if a shareholder owns more than 25% of the total number of a company's shares, then the chance of it receiving a subsidy increases. Also, most studies show that foreign ownership reduces the propensity to receive a subsidy, whereas some degree of public ownership increases it (e.g. Herrera & Nieto, 2008).

Export intensity, capital and intermediate inputs of production of the companies were also found to positively affect the probability of receiving a subsidy (e.g. Duch et al., 2009; Aschhoff, 2010).

The intensity of R&D activities differs between industries for the fact that each is exposed to different technological opportunities and to different expectations of demand growth (Silva et al., 2017). In this view, many studies try to control for sector or industry differences on the awarding of a subsidy. In fact, industry characteristics influence the public agencies decision on the attribution of a grant, once they may want to enhance R&D activities in specific fields or industries (Busom, 2000). It is important to mentioned that studies' conclusions on this matter vary according to sample used. Nonetheless, there seems to be moderate evidence that low-technology industries have lower odds of receiving a subsidy when compared to high-technology ones (Busom, 2000; Herrera & Nieto, 2008).

2.4. Mechanisms through which R&D subsidies policy impacts on companies' performance

How do some companies constantly outperform others?

There are two dominant lines of thought that aim to answer this question: the external factors paradigm and the internal factors paradigm. The first emphasizes the exploitation of market power by asserting that privileged product market positions originate inflow rents (e.g. Porter, 1980). The latter emphasizes the importance of an efficient resourced-base management, which enables the company to proactively create and sustain competitive advantage by acquiring/ accumulating its strategic resources (Shafeey & Trott, 2014).

The present study intends to assess the effects of R&D public policies on the performance of companies. In order to do so, we focus our analyses on the efficient resource-based management performance theories. In this sense, the theories that serve as a basis-root for our study include (see Figure 1): Firm Growth Theory (Penrose, 1959); Resource Based View (Barney, 1991); the Dynamic Capabilities (Teece, Pisano & Shuen, 1997), and Institution-Based View (Peng, 2002).

2.4.1 Firm Growth Theory

The firm growth theory was developed by Penrose (1959). According to it, a company comprises a group of resources that can be combined in such different ways that originate creative and original products/ services for the company to sell. In their turn, such distinctive products/ services make the company unique and enhance the company to take advantage of the different productive and performance opportunities it possesses (Burvill, Jones-Evans & Rowlands, 2018). This process implies that the company continually generates new knowledge for all involved parties so that it is able to increase its activity through the creation of new resources. Often the indivisible nature of resources is pointed as one of the causes of sub allocation of resources which constitutes a barrier to the company's growth. In line with this view, a possible solution to this issue is to use the versatility that characterizes resources in the company's favor by spending the existent ones in new and more productive purposes (Nason & Wiklund, 2018).

This theoretical approach asserts that the economic value produced by companies is a consequence of both the creative combination and usage of resources and the action of human capital involved in the productive process. Indeed, the latter is the factor responsible for the promotion of a dynamic atmosphere which stimulates the formation of productive opportunities and the rise of company's innovation and growth (Coad & Guenther, 2014). Moreover, in order for a company to develop successful R&D activities, it must possess specialized human resources and, simultaneously, a highly coordinated organization capable of receiving new knowledge (Savino, Petruzzeli & Albino, 2017).

Another important aspect highlighted in the company growth theory is the continuous maintenance of company's competences and knowledge in order to protect its competitive advantages (Lockett, Wiklund, Davidson & Girma, 2011). Patent licensing is a mean through which a company may defend their intellectual property and eliminate competition. Nonetheless, intellectual property measures are only effective for a determined period of time, thus, this advantage is likely to be lost at a certain point (Burvill et al., 2018).

Therefore, as remarked by this approach, in order to protect and maximize competitive advantage a company must continuously develop activities intended to innovate and renew the economic value of its resources. In this sense, we can infer that efforts made upon R&D projects might be the first step to be taken, since there are strong evidences on the positive relationship between the generation of new knowledge and the creation of innovation in both high and low intensive R&D/technological companies (Love & Roper, 2015). Here is where R&D policies assume an important role by providing financial support or fiscal tax burden relive to companies which invest in such risky activities. In fact, the existence of R&D policies is supported by the assumption that R&D developed within companies, stimulates (directly or indirectly) innovation resulting in the production of new products, services and/or processes (Cunningham et al., 2012) – see Figure 1.

2.4.2 Resource Based View (RBV)

The *Resource Based View*, developed by Barney (1991), constitutes an extension of Penrose's theory. It considers companies to be a group of tangible and intangible resources which determine the efficiency and efficacy of the activities carried on (Burvill et al., 2018). In other words, throughout the use of tangible or intangible resources a company can set and implement a strategy which may originate strengths or weaknesses depending on the form resources are used (Schellenberg, Harker & Jafari, 2018). Moreover, according to Burvil et al. (2018), the sustained increase of company's profit and performance is deeply linked to the human capital's competences to create new knowledge, strengthening the company's competitive advantages.

In this context, this theory underlines that the company's resources are the origin of its competitive advantage and, consequently, the responsible for the increase in performance. However, this is only true if the resources are valuable, rare, inimitable and non-substitutable (Ratten & Tajeddini, 2017). Whereas the value and rarity of resources enable companies to create new economic value, inimitability and non-substitutability allow the company to retain profits related to such resources and prevent the erosion of its market power overtime. In this sense, this kind of resources along with market growth enhance the company's growth, since they enable the company to benefit from first-mover advantages (Nason & Wiklund, 2018). Furthermore, Ferreira & Fernandes (2017) defend that despite such resource characteristics are fundamental for the creation of competitive advantage, resources are only a source of it if the company is able to capitalize them.

While there is evidence that a company with value added resources is more likely to grow, there are also studies that show the opposite and even question how the combination of different resources influences the development of a company (Bromiley & Rau, 2016).

Again, considering how expensive may be developing R&D activities and the uncertainty associated to its outcome, R&D policies emerge as an enabler of engaging in such projects, most times, receiving public support is a decisive factor for a company to initiate a R&D process. Indeed, public R&D supported companies see their liquidity and the financial slack increasing, which in turn helps them to surpass innovation risk and encourages them to undertake risky R&D projects (Zona, 2012) – see Figure 1.

2.4.3 Dynamic Capabilities

A central question in the strategic management field is how companies accomplish and maintain competitive advantage (Shafeey & Trott, 2014). Strategic theory has been deeply studied at a company-level standing point where the fundamental issue being analyzed is the strategies for sustaining and safeguarding extant competitive advantage (Teece et al., 1997). Though, there is not much investigation done on understanding how and why certain companies achieve competitive advantage under systems of fast change (Teece et al., 1997).

The Dynamic Capabilities approach is a stream of research that is gaining greater importance, (Teece et al, 1997). This framework goes beyond RBV in the sense that it claims that companies develop learning processes which adapt to the market changes, emphasizing the role of innovation as a key factor for the creation of competitive advantage (Teece, 2017). The key idea underlying this view is how the efficient combination of existing company-specific capabilities (competences and resources) can be sources of advantage through their development, deployment and protection, in a fast-changing environment (Teece et al., 1997). Indeed, Dynamic Capabilities approach strengthens the view that the development of management capabilities and difficult-to-imitate combinations of organizational, functional and technological skills end up capturing entrepreneurial rents by promoting the rise of competitive advantages. Accordingly, this approach supports the importance of R&D activities since those are the basis of product and process development, intellectual property, technology transfer and human resource and organizational learning.

Many technological companies, for instance, IBM and Philips seem to have adopted an aggressive intellectual property position and have been accumulating valuable technology assets (Teece et al., 1997). Nonetheless, it has been proven not to be sufficient to ensure a significant competitive advantage. In fact, the truly global market winners tend to be the companies which show fast and timely responsiveness and have flexible product innovation (Teece et al., 1997). According to Teece (2007), a company with strong dynamic capabilities is able to profitably build and renew its resources, by reformulating them in such a way that creates innovations which address market changings. Consequently, this behaviour will not only make the company improve its performance, but also challenge the company's competitors who value more efficiency than innovation and that ignore the changes of consumers' needs (Teece et al., 1997; Buvill et al., 2018).

Following the theory developed by Teece et al. (1997), the dynamic capabilities compromise the main source of a company's competitive advantage. In line with it, R&D activities might be a competitive factor for the company in the sense that they originate knowledge which serve as a basis for innovations and differentiation (Love & Roper, 2015). Therefore, as much investment is devoted to such activities, the greater the chances of accessing and absorbing knowledge (Love & Roper, 2105). However, considering knowledge characteristics already discuss in this study (Section 2.1.), the externalities that derive from it may turn R&D activities less appealing for the companies. In such circumstances, R&D policies play a crucial role in addressing underinvestment in R&D by private business (Arrow, 1962) – see Figure 1.

2.4.4 Institution Based View

Strategic management scholars are attributing increasingly importance to the role of institutions (Peng, Sun, Pinkham & Chen, 2009). With the realization that institutions are more than just background conditions, the Institution Based View has arisen and was mostly developed by Peng (2002).

There are plenty of definitions for the term institution, for instance, Douglas North (1990, p. 3) defined it as "the humanly devised constraints that structure human interaction" and W. Richard Scott (1995, p. 33) viewed this concept as "regulative, normative, and cognitive structures and activities that provide stability and meaning to social behavior". The same author defends that the main function of institutions is to reduce uncertainty and offer significance. Once institutions establish the boundaries of what is legitimate and set the norms of behaviour, they reduce uncertainty for various players. Indeed, economic agents rationally chase their interests and make their own choices taking into account such restrictions (Lee, Peng & Barney, 2007).

This line of research treats institutions as independent variables and considers strategic choices to be an outcome of the dynamic interaction between institutions and organizations (Peng, 2002). According to Jarzabkowski (2008), managers are confronted with formal and informal constraints imposed by certain institutional frameworks. Consequently, their strategic choices are driven by such restrictions and not only by industry conditions and company capabilities. Therefore, Institution Based View argues that even when a company cannot defeat competition by cost or differentiation it can still do so by the means of nonmarket political intervention (Oliver & Holzinger, 2008).

The case of Japanese pharmaceutical industry is a good example of how impactful the institutional framework may be to managers' and industries' behaviour (Peng et a., 2009). The success of innovative Japanese electronics and automobile products have made Japanese companies to be considered innovative worldwide. However, if we focus specifically on the pharmaceutical industry, we might get surprised by realizing that there is not any Japanese pharmaceutical company among the world-class innovative pharmaceutical companies (Peng et al., 2009). The reason for that is institutional (Peng et al., 2009). According to Mahlich (2009), the Japanese health care system does not incentive the launch of innovative new medicines, since it does not reward companies for such accomplishment. Even though the government negotiates medicines' prices with companies, once fixed, it is not allowed to rise prices during the shelf life of the product. Therefore, if the prices are stable and, simultaneously, economies of scale decrease production costs, then the highest profits come from old medicines and not new ones (Peng et al., 2009). Hence, Japanese pharmaceutical companies have little benefit in investing in R&D (Peng et al., 2009). This is a good illustration of how policies to R&D may influence company's disposition to undertake R&D activities. In fact, in an institutional context where favorable conditions for the development of R&D are secured, managers feel encouraged to engage in such activities (Cunningham et al., 2012). Governments direct such policies towards specific industry sectors or regions that lack economic strength or find little reward in doing so (Cunningham et al., 2012).

Most scholars agree that enterprises' innovation performance can improve thanks to governmental incentives on R&D – see Figure 1. Along this study, we have referred the most relevant arguments that support this thesis. First, these incentives enhance the engagement in R&D and potential innovation outputs by reducing the companies' costs on the development of such activities (Fischer & Newell, 2008). Secondly, government funds (tax credits or subsidies) may promote companies' additional R&D investments (Koga, 2003; Kobayashi, 2014). Thirdly, technological opportunities and projects with high risk might not be developed by companies if they did not have access and help from the innovation policy programmes (Guellec & Van Pottelsberghe De La Potterie, 2003). Additionally, companies that benefit from this innovation policy instruments are perceived as high-quality and competitive companies and, obviously, this is reflected on its investments, its access to credit and its partnerships. Consequently, this positive signalling may end up stimulating and creating favourable conditions for even more innovations to be generated (Zhang & Guan, 2018).

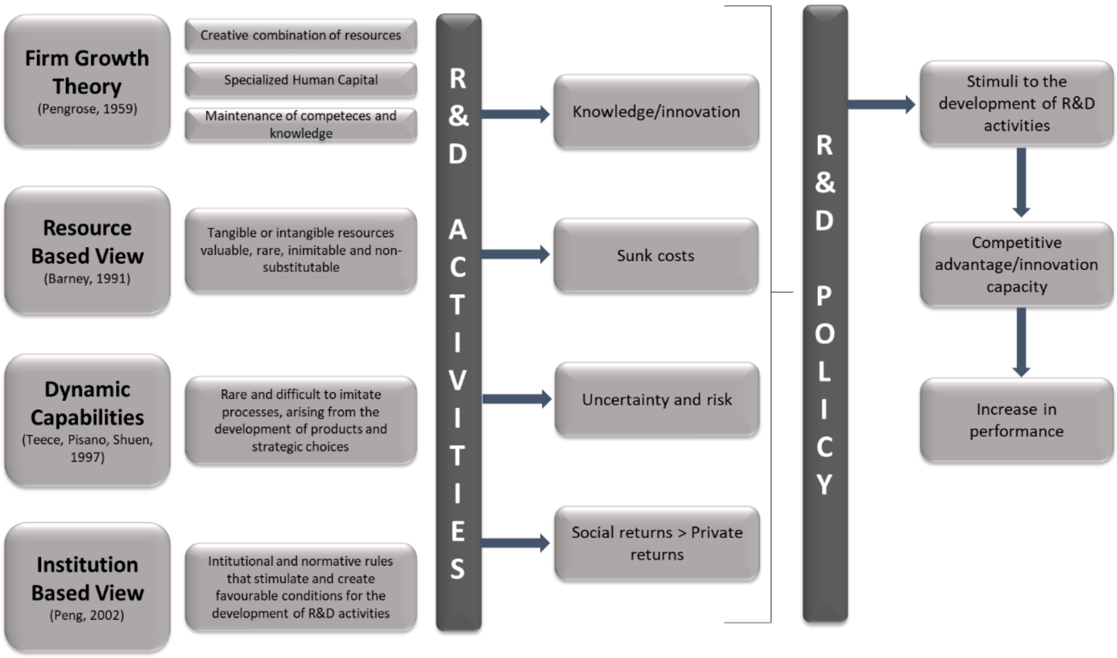

Figure 1: Theoretical Framework
Source: Own elaboration.

2.4.5 Empirical evidence of the impacts of R&D Policy on companies' performance

There is an extensive literature that points innovation as a fundamental element for the dynamic competition of markets (Love & Roper, 2015) and for the performance and survival of companies (Savino et al., 2017). As a matter of fact, innovative companies present, on average, greater levels of growth, efficiency and profits when compared to non-innovative ones (Love & Roper, 2105). This might be a result of the company's increased market value and, thus, competitive advantages (Savino et al., 2017).

In general, the range of studies on this topic (see Table 1) has identified a positive role of R&D policies on companies' employment growth (e.g., Karhunen & Huovari, 2015; Criscuolo et al., 2019; Vanino et al.,2019), value added (e.g., Duch et al., 2009), exports (e.g., Cunningham et al., 2012) and access to external capital (e.g., Meuleman & De Maeseneire, 2012).

In fact, PACEC (2009) reported 6000-9000 net additional jobs in companies which have participated in the SMART programme. Furthermore, Almus & Czarnitzki (2003) indicate that companies that received public funds may hire R&D staff, which in turn raises their levels of employment.

Literature on the additionally effect of R&D direct support (Cunningham et al., 2012) also identifies the growth of value added as a measure of the impact of R&D subsidies on the company's financial performance (Duch et.al, 2009). According to the previous author, on average, companies that receive subsidies show a faster value-added growth rate.

Additionally, according to Cunningham et al. (2012), the intensity of exports of a company is positively related with the reception of R&D funds. Indeed, as highlighted by these authors, the rationale for public R&D support is also associated with the competitive edge of companies operating in international markets which are pressured to increase exports and hence increase activities and jobs. In line with this argument, there is empirical evidence that shows R&D publicly financed companies present higher levels of exports when compared to similar companies which have not been given any grant (Duch et al., 2009).

Some scholars have also studied the effect of government subsidies on the access to external capital and have discovered that, in some cases, it transmits a positive signal to the markets. Indeed, companies that are granted with subsidies are seen as better-quality companies and this image mitigates the effect of product market uncertainty (Czarnitzki & Toole, 2007). As shown by Meuleman & De Maeseneire (2012), in Belgium R&D subsidies attribution influences positively the access of companies to long term-debt. Likewise, the work of Feldman & Kelley (2006) suggests that venture capital formation for US companies participating in the Advanced Technology Program were enhanced by R&D public grants.

Regarding the relationship between R&D grants and companies' productivity, results are not clear cut, with some studies finding no productivity increase (e.g., Karhunen & Huovari, 2015).

Although empirical evidence mainly supports that R&D policies increase the overall performance of companies, it is also important to mention that some researchers have found that there is a risk of distortion of the organizations' drive to participate in R&D projects, resulting in a misallocation of resources to activities that are not market oriented neither socially desirable (Guellec & Van Pottelsberghe De La Potterie, 2003; Kung, Zhang & Kong, 2016). Moreover, there is a time gap between the reception of subsidies and company's R&D spending (Guellec & Van Pottelsberghe De La Potterie, 2003), which might compromise the company's strategy.

Table 1: Synthesis of the studies that evaluates the impact of R&D subsidies on companies' performance

Authors	Country of Study	Type of subsidy	Sample period	Methodology	Measures of performance	Estimated Effects
Vanino, Roper & Becker (2019)	United Kingdom	Publicly-funded research Councils	2006-2016	Propensity score matching approach	Employment	+++
					Turnover	+++
Duch, Montolio & Mediavilla (2009)	Spain	R&D Subsidies in Catalunya	2000-2002	Propensity score matching approach	Value-added	+++
Karhunen & Huovari (2015)	Finland	Fund to support R&D to SMEs	2002-2012	Combined matching and difference-in differences	Labour productivity	Effect in 5 years: 0 Effect in 2 years: -
					Employment	+++
Belluci, Pennachio & Zazzaro (2016)	Italy	Regional research and innovation subsidies for collaborative research projects between SMEs and universities	2003-2012	Difference-in-differences propensity score matching	Company' sales	0
					Company's profitability (return on equity)	Short-term: - Medium-term: +
Cin, Kim, & Vonortas (2017)	Korea	Government R&D subsidy programme	2000-2007	Difference-in-differences	Survival	+++
Wang, Li & Furman (2017)	China	Innofund programme (grant applications for R&D publicly funded projects)	2005-2010	Linear probability models Regression discontinuity design	Company survival (by 2015)	0
					Equity investment received from venture capital or private equity company by 2015	0
Criscuolo, Martin & Overman (2019)	United Kingdom	Regional selective assistance programme (RSA)	1997-2004	Company level regressions (OLS, reduced form, first stage, instrumental variables)	Employment (manufacturing in logs)	+++ (small companies only)
					Capital investment (in logs)	+++
					Output (in logs)	+++
					Total factor productivity (in logs)	0
De Basilio, Fantino & Pellegrini (2015)	Italy	Fund for technological innovation, funding projects of R&D	2001-2007	Regression continuity design	Sales (in logs)	0
					Financial conditions	0
					Assets	++
					Return on assets	0
Meuleman & De Maeseneire (2012)	Belgium	Belgium, IWT - Flanders' SME Innovation Programme	1995-2004	Econometric analysis of IWT supported	External financing events	++
Almus & Czarnitzki (2003)	Germany	R&D Subsidies in East Germany	1994-1998	Econometric analysis (non parametric matching technique)	R&D spending	++
Czarnitzki & Toole (2007)	Germany	Germany, no particular programme	1994-2000	Econometric analysis	Product market uncertainty	+++
Guellec & Van Pottelsberghe De La Potterie (2003)	17 OCDE countries	No particular programme	1983-1996	Econometric analysis	Private R&D expenditure	+++
Feldman & Kelley (2006)	United States of America	U.S. Advanced Technology Program at NIST	1998	Multivariate logit regression applied to data collected through a survey	New funding	++
PACEC (2009)	United Kingdom	Grant for R&D/SMART	1998-2008	Survey and interviews	Gross value added	++
					Employment	++
Savino, Petruzzeli & Albino (2017)	Several	Various R&D Subsidies Programmes	-	Review of empirical evidence	-	-
Cunningham, Gok & Laredo (2012)	Several	Various R&D Subsidies Programmes	-	Compendium of Evidence on the Effectiveness of Innovation Policy Intervention	-	-

Legend: +, ++ and +++ indicate positive and statistical significance at 90, 95 and 99 percent levels, respectively. – indicates negative and statistical significance at 90 percent level.
Source: Own elaboration.

3. Methodology considerations

3.1. Reasoning for the methodological choice

There are two main methodological approaches commonly used to lead an investigation, the qualitative and the quantitative.

The qualitative methodology consists in the collection of information about the participants' experiences and perceptions, made through a process of observation and the conduction of a set of interviews. This kind of procedure supports the comprehension of the phenomena of interest and provides a deep description about it (Yilmaz, 2013).

The quantitative methodology tests a theory based on the causal relation between the variables measured through numerical data, which in turn is analysed by the means of mathematical and statistical methods. Indeed, quantitative methodology constitutes an attempt to validate whether the theory being tested is able to explain the studying phenomena. The expected outcome of the data analysis supported by quantitative methods is a set of generalizable conclusions (Yilmaz, 2013).

The choice of the methodology to be used must be made in accordance with the research questions (Marshall, 1996). According to Marshall (1996), questions such as "why?" and "how?" should be answered by a qualitative approach, whereas mechanistic questions, for instance, "what?" should be responded using a quantitative method.

In regard to the mentioned above, to address the two research objectives, respectively: (1) What are the determinants for a company to receive a public subsidy to R&D?, and (2) Do public subsidies to R&D impact on the performance of the recipient companies?, the most adequate methodology is the quantitative methodology. Moreover, the existent literature on the effectiveness of public subsidies (see Table 1) uses a quantitative approach as well, which gives further support to the suitability of the methodology chosen.

Similarly to the relevant studies in the area, such as Duch et al. (2009) and Vanino et al. (2019), we resort to Propensity Score Matching (PSM) technique which enable us to identify and match companies that present the same propensity to receive a public subsidy. Secondly, and after a legitim comparison group has been identified, we compare their performance using probit techniques. Based on that, we estimate the effect of R&D subsidies on the performance of the granted companies.

3.2. Describing the Propensity Score Matching (PSM) technique and the econometric specification to be estimated

According to LaLonde (1986), the best process for evaluating public programmes is to use "true" or natural experiments selected from random assignments as they provide the strongest basis to analyse cause and effect relationships. In experimental studies, units are assigned randomly to "treatment and control groups" and each group has, on average, similar units concerning all their shared characteristics. This equivalence between the groups assures that the influence of external factors which could affect the results are eliminated. Therefore, all the differences between both groups can be justified exclusively as a consequence of the public programme being studied (Duch et al., 2009).

However, as mentioned in our earlier review of literature, receiving funds for a research project is very likely to be influenced by selection bias and endogenous factors which may affect allocation decisions and self-selection of companies into such programmes (Vanino et al., 2019). In this context, the referred experimental design is generally not a reasonable approach to be adopted when aiming at evaluating public programmes.

In order to surpass the selection bias, both Duch et al. (2009) and Vanino et al. (2019) have used in their studies an alternative method, the Propensity Score Matching (PSM) technique which makes possible the comparison of two groups of companies: those that have received public subsidy (treated companies), and those which did not (non-treated companies). The PSM technique creates an appropriate control group of non-treated companies, which is as similar as possible to the treated group, based on the probability of receiving a subsidy. After, through the Average Treatment effect on the Treated (ATT) model, the authors assess the differences in performance before and after the subsidy attribution. In other words, they estimate the differences in the outcome variables between treated and non-treated companies over the period in study.

We follow a similar method as these authors. Hence, we construct a control group that shows an ex-ante equal probability of being publicly funded in such a way that both treated and non-treated companies can be considered as if they had been randomly assigned.

Following Duch et al. (2009), and assuming receiving a subsidy as being the treatment effect, we define the main impact to be analysed as the expected effect of treatment for the treated population:

$$ATT = \mathrm{E}\,(Y_1 - Y_0 \mid S=1) = \mathrm{E}\,(Y_1 \mid S=1) - \mathrm{E}\,(Y_0 \mid S=1) \qquad [1]$$

where, Y_1 is the outcome for companies which receive public subsidy and Y_0 is the outcome for companies not exposed to the treatment. And, $S_i \in \{0,1\}$ represents the participation of each company (S=1 for treated companies, S=0 for non-treated companies).

In accordance to what we have referred earlier, receiving a public subsidy cannot be considered a random event and, thus, $E\ (Y_0\ |S=1)$ is not observable and must be estimated since it represents the outcome that companies would experience whether they had not participated in the programme. In order to do so, we need to construct a control group that considers, as an alternative, the effect of no treatment on the outcome of similar companies that have not been subsidized (Vanino et al., 2019). In this sense, we apply the propensity score matching and we obtain a counterfactual sample of companies (the control group) by pairing each recipient company with a non-treated one. It is important to highlight that, as stated by Rubin (1977), conditional independence between outcomes for non-recipient and treated companies is a necessary assumption, given that some characteristics (**X**) are observable. Accordingly, the control group contemplates companies which have not participate in the public programme and whose distribution of observed characteristics is as identical as possible to the ones of participating companies. This implies:

$$0 < \Pr\ (S=1\,|\ X=\varkappa) < 1 \qquad \text{for } \varkappa \in X \qquad [2]$$

and assures that all treated companies have a counterpart in the control group.

If the vector **X** is highly dimensional, as is in this case, we may face an implementation problem. As a possible solution for this arising problem is the use of a scalar function that defines the probability of receiving treatment conditional on covariates (Rosenbaum & Rubin, 1983). This probability p(X) represents the propensity score (PS). Following this, the ATT is estimated by the matching method as:

$$ATT = E\ \{E\ [Y_1\,|\ S=1, p(X)] - E\ (Y_0\,|S=0, p(X)\,|\ S=1)\} \qquad [3]$$

In this vein, equation [3] is a derivation of equation [1] which considers the requirement of having an adequate balancing of pre-treatment variables. Fulfilling this hypothesis will provide observations with the same PS that have the same distribution of observable characteristics independently of their treatment status (Duch et al., 2009).

Given the pre-treatment characteristics, the PS is defined as the conditional probability of receiving a subsidy. Thereby we estimate a probit model with the covariates estimation:

$$\Pr\ \{S=1\,|X\} = \Phi\ \{h(X)\} \qquad [4]$$

where Φ is the normal function and h(X) is an initial specification which includes all the covariates as linear terms.

After defining PS, we procced by matching the non-treated and treated observations given their estimated propensity score using Nearest Neighbour estimator (NNM). We build the match for each treated company as a weighted average over the outcomes of non-participants, given that the weights depend on the distances between the computed PS. From this, we know that the weight is higher, as higher is the propensity similarity between companies. Then, we are finally able to estimate the average treatment of treated companies using Eq. [1].

Nonetheless, recent literature on propensity score matching technique highlights the existence of an alternative and "improved" model to estimate the average treatment effect on treated companies, the ATET. The main advantage of this alternative model is that it takes into consideration that propensity scores are estimated rather than known when calculating the standard errors.[2] In addition, while ATT model executes a simple nearest-neighbour matching with one neighbour, ATET model matches with all ties if there exist multiple observations with the same propensity score. Due to both the advantages mentioned and the addition of a Z-statistic, p-value and 95% confidence interval instead of just T-statistics on the outcome of ATET model, we will perform it as well to assess the differences in the results obtained. The equation that defines this model is similar to equation [1]:

$$ATET = \text{E}\ \{\text{E}\ [Y_1 |\ S{=}1, p(X)] - \text{E}\ (Y_0 | S{=}0, p(X) |\ S{=}1)\} \qquad [5]$$

Following the recommendation of Stuart (2010), and for the purpose of the ATT and ATET estimates, we considered the 5 nearest neighbours instead of considering only the nearest neighbour.

In respect to the dependent variable selected (performance), we consider four *proxies*: (i) labour productivity, (ii) number of employees, (iii) export activity, and (iv) company's overall financial performance as reflected by the EBITDA (Earnings Before Interest, Taxes, Depreciation, and Amortization). We then assess the evolution of each *proxy* between the years (t-5) and (t+3), that is the five-year period before receiving the subsidy and the three-year period after the subsidized project has been concluded. For that, we assume that specific

[2] SSCC – social science computing cooperative (Propensity score Matching in STATA using teffects), in https://www.ssc.wisc.edu/sscc/pubs/stata_psmatch.htm, last accessed on 15 February 2020.

effects for the company and specific effects for the sector are fixed in the growth equation, hence, we do not represent them as a change variable.

In order to regulate the specific effects at the company level, that is company size and initial levels of competitiveness and positioning in the market, we take into account, besides the variable subsidy (a binary variable which assumes the value 1 if the company received the R&D subsidy in 2014 and 0 otherwise), the average values (2008-2013) of a set of variables, most notably age, physical capital, human capital, R&D regional intensity NUTS III.

3.3. Data description

In order to estimate the impact of R&D subsidy programmes in the performance of companies, we have considered a sample of Portuguese companies which have had their projects approved under the so-called IS R&TD Individual Projects and IS R&TD Co-promotion Projects from the Operational Programme COMPETE QREN in 2014. We have chosen this year because it was the only year with projects approved after the economic crisis and TROIKA intervention in Portugal. Moreover, it permitted to have a three-year period after the subsidy and thus a reasonable time span for assessing the impact of the R&D subsidy.

The Operational Programme COMPETE is composed by three typologies of investment incentives – IS R&TD, IS SME Qualification and IS Innovation. Concerning the period between 2007 and 2014, the ratio between the total incentive granted under each IS and the total incentive granted under the IS to companies demonstrates that IS Innovation has the largest share, 73%, followed by SI R&TD, with 15%, while IS SME Qualification represents 12%.

We focus our analysis on the IS R&TD programme, in particular, the IS R&TD Individual Projects and IS R&TD Co-promotion Project. The main objective of this incentive is to increase business investment in Research and Innovation (R&I), in line with priority areas of research and innovation strategy for smart specialization, reinforcing the link between companies and entities of the R&I system and promoting the economic growth of knowledge-intensive activities and innovation-based value creation (POFC, 2015).

According to the COMPETE's Execution Report of 2014 (POFC, 2015),[3] IS R&TD Individual and Co-promotion Projects accounted 86% of the total incentive approved under this segment of COMPETE Programme.

Figure 1 depicts the framework of the Portuguese Incentive System in the period 2007-2014.

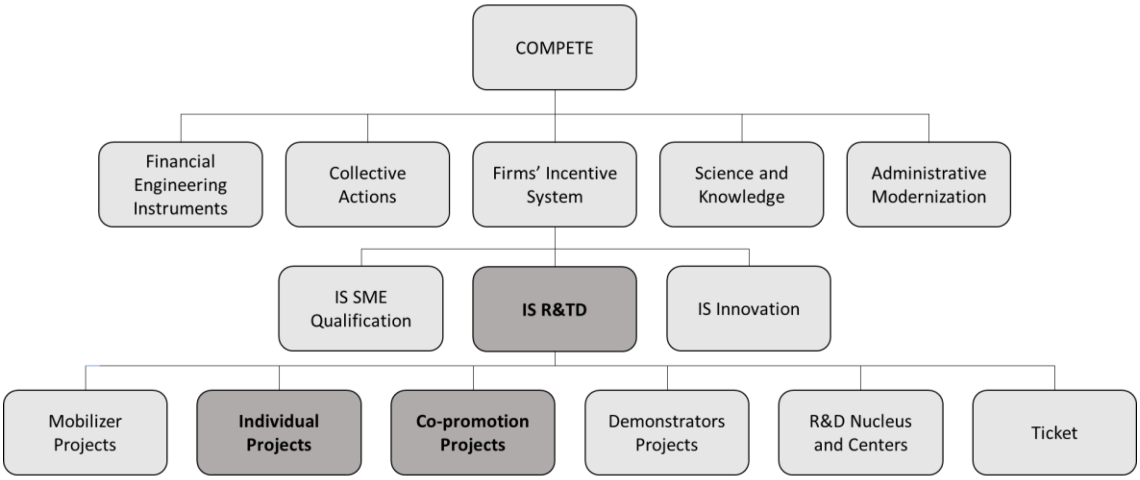

Figure 2: COMPETE QREN Programme framework

Source: Own elaboration based on information extracted from COMPETE QREN's website.

At COMPETE's website[4] we can find the list of all projects approved between 2007-2014. We selected the all the projects approved in 2014, that is, 108 projects from 104 different companies.

The activities sectors with more projects approved in 2014 were "Consulting and computer programming and related activities" (EAC 62) and "Manufacture of metal products, except machinery and equipment" (EAC 25), presenting a relative weight of, respectively 18.3% and 8.7%.

[3]http://www.pofc.qren.pt/compete/monitorizacao-e-avaliacao/relatorios-de-execucao/compete/entity/relatorio-de-execucao-compete--2014?fromlist=1, accessed in January 2020.
[4]http://www.pofc.qren.pt, accessed in September 2019.

Table 2: Sample distribution per activity sector

EAC (REV3)	Economic Activity Classification	Nº of companies	%
10	Food industries	5	4.8%
13	Textile manufacturing	7	6.7%
14	Garment industry	1	0.9%
15	Leather industry and leather products	3	2.9%
16	Wood and cork industries and their works, except furniture; manufacture of basketwork and straw	2	1.9%
20	Manufacture of chemicals and man-made fibers, except pharmaceuticals	5	4.8%
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	1	0.9%
22	Manufacture of rubber and plastic products	3	2.9%
23	Manufacture of other non-metallic mineral products	7	6.7%
24	Basic metallurgical industries	1	0.9%
25	Manufacture of metal products, except machinery and equipment	9	8.7%
26	Manufacture of computer and communication equipment and electronic and optical products	5	4.8%
27	Manufacture of electrical equipment	1	0.9%
28	Manufacture of machinery and equipment n.e.c.	5	4.8%
29	Manufacture of motor vehicles, trailers, semi-trailers and motor vehicle components	7	6.7%
30	Manufacture of other transport equipment	2	1.9%
32	Other manufacturing industries	2	1.9%
33	Repair, maintenance and installation of machinery and equipment	1	0.9%
42	Civil Engineering	2	1.9%
58	Publishing activities	2	1.9%
62	Consulting and computer programming and related activities	19	18.3%
71	Architectural, engineering and related technical activities; testing and technical analysis activities	9	8.7%
72	Scientific research and development	3	2.9%
74	Other consultancy, scientific, technical and similar activities	1	0.9%
82	Administrative and support service activities provided to companies	1	0.9%

Source: Own elaboration.

Regarding the geographical distribution of the approved projects, 55% of the projects were presented by companies located in the North Region, 29% from Central Region, 15% from Metropolitan Lisbon Region and 1% from Alentejo Region (see Figure 3). Algarve Region did not register any approved project in the reference period.

Figure 3: Control group distribution per region NUTS II
Source: Own elaboration.

Additionally, we built a control group. In order to do so, we considered the following criteria: 1) companies that have not yet received any public financial support to R&D; and 2) companies operating in the same economic activity categories as the companies included in the treatment group.

We applied a proportion of 5 non-treated companies to each treated company. We followed the procedure adopted by Duch et al. (2009), which makes our control sample more reliable and, hence, our estimation more robust. Thus, the control group includes 506 companies.

We proceeded with the construction of our database by extracting the relevant explanatory variables from the Annual System of Iberian Balances (SABI) database.[5]

For our study, we used data from two points in time: 1) before the subsidy: we considered the average of each variable five years before the subsidy was approved (i.e., the average of the variables for the period 2008 - 2013); and 2) after the subsidy: 2017, the most recent year with available data.

Table 3 presents the list of variables considered in the analysis.

Since we were not able to obtain all the relevant data for the treated companies, our treatment group is composed by 99 companies, meaning that we were able to cover 95% of all the companies that have had an approved project in 2014. The full database includes 605 observations, 16% of which are companies that received an R&D subsidy in 2014.

[5] SABI is a database website which displays financial end economic information on Iberian firms, in https://sabi.bvdinfo.com/, last accessed on November 2019.

Table 3: Descriptive statistics

Variables	Type	Definition	Unit	2008-2013				2017			
				Mean	Min	Max	Standard deviatio n	Mean	Min	Max	Standard deviation
S	Binary	1 if the company has received a subsidy to R&D in 2014, and 0 otherwise	-	0.163	0	1	0.370	-	-	-	
Prod_L	Continuous	Labour Productivity (value added/number of employees)	Thousands of euros	36.4	105.6	839.2	46.6	41.6	-623.5	905.1	63.3
L	Continuous	Number of employees	Units	144.9	0	6481	351.6	168.8	1	2660	293.5
Exp	Binary	1 if the company exports, and 0 otherwise	-	0.809	0	1	0.392	0.809	0	1	0.393
Fin	Continuous	Overall financial performance - EBITDA	Thousands of euros	1826.1	26045.1	107110.6	6285.9	3335.5	6181.9	175221.9	11768.3
VA	Continuous	Value Added	Thousands of euros	5399.8	4351.7	253200.1	14059.3	7629.1	-1941.4	179201.5	17008.1
K	Continuous	Physical Capital	Thousands of euros	5768.7	0	230783.6	18445.8	6888.2	0	181482.7	18052.5
HC	Continuous	Human capital - Average cost per employee	Thousands of euros	22.0	0	122.3	13.0	23.1	0	102.4	13.8
Age	Continuous	Company's age in 2014	Units	22.2	0	149	17.0	-	-	-	
RD_I	Continuous	R&D regional intensity NUTS III (R&D regional expenditure/GDP)	Thousands of euros	0.144	0.019	0.766	0.160	0.142	0.018	0.835	0.151
ht_manuf	Binary	1 if the company operates in a highly intensive technology manufacturing company, and 0 otherwise	-	0.076	0	1	0.265	-	-	-	
hk_serv	Binary	1 if it the company operates in an intensive knowledge services industry, and 0 otherwise	-	0.317	0	1	0.465	-	-	-	

Source: Own computations based on COMPETE and SABI.

Table 4 shows the differences in the evolution of treated and non-treated companies over the period in study. Treated companies are, on average, larger than untreated companies. The value added and overall financial performance, are, on average, lower in the case of non-treated companies. Treated companies are more likely to operate in international markets, that is, present higher export propensity. In contrast, labour productivity in 2017 was, on average, higher for companies which have not participated in the incentive programme. Moreover, this variable has, on average, increased for non-treated companies, whereas it has decreased in treated companies.

Furthermore, publicly funded companies tend to be slightly older than non-recipient ones and are, on average, located in regions with higher R&D intensity. Finally, companies receiving a R&D subsidy are more likely to belong to a highly technology intensive manufacturing sector.

Table 4: Descriptive statistics Treated companies vs Non-treated companies

Variable	2008-2013		2017		2008-2013		2017	
	Treated companies				Non-treated companies			
	Obs	Mean	Obs	Mean	Obs	Mean	Obs	Mean
S	99	1	99	1	506	0	506	0
Prod_L (average 2008-2013)	99	38.5	99	37.7	506	36.1	506	42.4
L (average 2008-2013)	99	255.9	99	251.2	506	123.2	506	152.7
Exp	99	0.9	-	-	-	-	506	0.8
Fin (average 2008-2013)	99	3909.8	99	4501.3	506	1418.4	506	3107.4
VA (average 2008-2013)	99	10632.2	99	11623.1	506	4376.1	506	6847.7
K (average 2008-2013)	99	9645.1	99	10708.6	506	5010.3	506	6140.7
HC (average 2008-2013)	99	24.2	99	26.9	506	21.5	506	22.4
Age	99	25.9	-	-	506	21.4	-	-
RD_I	99	0.160	99	0.149	506	0.100	506	0.100
ht_man	99	0.100	-	-	506	0.080	-	-
hk_serv	99	0.300	-	-	506	0.300	-	-

Source: Own computations based on COMPETE and SABI.

4. Empirical analysis

4.1. Determinants for receiving a public subsidy to R&D

In this section we estimate the Propensity Score Matching (PSM) to answer our first research question, "What are the determinants for a company to receive a public subsidy to R&D?".

Following the previous described methodological procedures, we use a bivariate probit model to estimate the PSM in order to investigate the variables that determine the propensity to be granted a public subsidy to R&D (see Table 5).

Table 5: Propensity Score Matching considering the 5 nearest neighbours, Probit regression (dependent variable: 1 if the company received the R&D subsidy and 0 otherwise)

	Outcome variables			
	Labour Productivity (2017)	**No. of employees** (2017)	**Exports** (2017)	**Financial performance** (2017)
Age	-0.0092 (0.0095)	-0.0092 (0.0095)	-0.0082 (0.0091)	-0.0092 (0.0095)
Age^2	0.0002 (0.0001)	0.0002 (0.0001)	0.0002 (0.0001)	0.0001 (0.0001)
K (average 2008-2013)	0.00003 (0.00003)	0.00003 (0.0001)	0.00003 (0.00003)	0.00003 (0.00003)
Prod_L (average 2008-2013)	-0.0005 (0.0019)	-0.0005 (0.0019)	-0.0013 (0.0018)	-0.0005 (0.0019)
HC (average 2008-2013)	0.0056 (0.0060)	0.0056 (0.0060)	0.0111** (0.0055)	0.0056 (0.0060)
RD_I	0.3457 (0.3972)	0.3457 (0.3972)	0.3910 (0.3917)	0.3457 (0.3972)
Exp	0.6297*** (0.2187)	0.6297*** (0.2187)	-	0.6297*** (0.2187)
ht_man	0.0809 (0.2423)	0.0809 (0.2423)	0.0007 (0.2406)	0.0809 (0.2423)
hk_serv	0.1877 (0.1827)	0.1877 (0.1827)	-0.0577 (0.1603)	0.1877 (0.1827)
No. of observations	605	605	605	605
LR chi2	23.47 (0.005)	23.47 (0.005)	14.55 (0.069)	23.47 (0.005)

Legend: ***, **, * indicate statistical significance at 1%, 5% and 10% levels, respectively. Grey cells identify statistically significant estimates.
Source: Own computations based on data gathered from COMPETE and SABI.

In this model we include as explanatory variables the age, square of the age, past average (2008-2013) physical capital, past average (2008-2013) labour productivity, past average (2008-2013) cost per employee as proxy for human capital, regional R&D intensity, and sector dummies (high technology manufacturing and knowledge intensive service). An export dummy was also included in the specifications for 2017 labour productivity, employment and financial performance.

Considering the explanatory variables, we use the age of the company as a proxy to organizational capacity and experience and the square of age to verify if the propensity to receive a public subsidy to R&D increases with the age of the company up to a certain point and afterwards decreases. However, their effect is found to be small and not very significant.

The same conclusion applies to other structure and market-related variables, such as the average labour productivity, cost per employee, and physical capital, as well as the regional R&D intensity (measured by the ratio of regional R&D expenditure in the total GDP). These findings are not in line with usual studies on this topic, as is the case of Herrera & Nieto (2008) which report that high-technology industries have better chances of receiving a subsidy, or the case of González et al. (2005) which point past experience (measured by the age of the company) statistically significant on the propensity to receive a subsidy to R&D in Spain.

In all the models, excluding that with the 2017 exports as the outcome, the only variable emerging as statistically significant to explain the company's propensity to receive a public subsidy to R&D is the export activity. This indicates that companies which operate in an external competition context are more likely to be publicly funded so that their internal and external competitiveness is reinforced. This is in line with the results reported by Duch et al. (2009). In the 2017 export outcome specification, human capital (proxy by the average wage cost per employee) is positive and significant. This conveys the idea that a company that is endowed with high levels of human capital is most likely to receive an R&D public subsidy.

4.2. The impact of R&D public subsidies on companies' performance

To answer the second research question, "Do R&D subsidies impact positively the performance of the recipient companies?", we apply the Average Treatment on Treated companies. Specifically, we run this model for the four *proxies* of performance (outcome variable) we have defined: (i) labour productivity, (ii) number of employees, (iii) export activity, and (iv) overall financial performance.

Table 6 presents the results of the ATT model obtained for each outcome variable, using the standard tool for propensity score matching in Stata 14, the *psmatch2* command. In view of the results presented in Table 6, we conclude that receiving a subsidy did not significantly impact on the 2017 labour productivity or overall financial performance of the recipient companies when matching them with a comparable control group of non-recipient companies. Notwithstanding, the estimations suggest that both for the unmatched and matched samples, companies that received a R&D subsidy in 2014 observed higher dynamics in terms of employment and exports.

Despite the empirical literature reports in general a positive effect of public R&D subsidy on the performance of the recipient companies, there are some studies that are in line with our results. For instance, Karhunen & Huovari (2015) measured performance by labour productivity in a sample of Finnish companies and concluded that in the five-year period after the subsidy the effect of the subsidy on companies' labour productivity was not significant, being negative in the two-year period after the subsidy was granted. Also, Criscuolo et al. (2019) found no significant effect of R&D grants in the total factor productivity. Moreover, other scholars such as Láredo, Kohler & Rammer (2016) and Mohnen, Vankan & Verspagen (2017) have highlight that the cause-effect relationship between R&D policy and its impacts in terms of productivity and employment are uncertain.

Table 6: Average Treatment Effect on the Treated (ATT)

Variable	Sample	Treated	Controls	Difference	S.E.(*)	T-stat
Prod_L	Unmatched	37.750	42.355	-4.606	6.964	-0.66
	ATT	37.750	48.256	-10.507	8.518	-1.23
L	Unmatched	251.171	152.729	98.442	32.034	3.07
	ATT	251.171	181.189	69.982	48.035	1.46
Exp	Unmatched	0.919	0.789	0.131	0.043	3.05
	ATT	0.919	0.844	0.075	0.037	2.00
Fin	Unmatched	4501.263	3107.415	1393.847	1293.123	1.08
	ATT	4501.263	3751.087	750.176	1400.187	0.54

Notes: These estimations resort to the standard tool for propensity score matching in Stata 14, the psmatch2 command (*) S.E. does not take into account that the propensity score is estimated. Grey cells identify statistically significant estimates.

Even when we estimate the average treatment on treated companies using the *teffects psmatch* command (see Table 7), the results reached are similar to the above. Indeed, the companies which received subsidies presented, three years after receiving the subsidy, a higher level of employment and a greater propensity to export; however, in terms of labour productivity and financial results no significant differences between R&D subsidy recipient and non-recipient companies emerge. Again, these results are partially in line with the literature. Several empirical studies report that R&D subsidies enhance employment and exports (see Duch et al., 2009; PACEC, 2009; Karhunen & Huovari, 2015; Criscuolo et al., 2019; Vanino et al., 2019) and have no significant impact on labour productivity (cf. Karhunen & Huovari, 2015) and financial conditions (De Basilio et al., 2015).

Table 7: Treatment-effects estimation (PSM, probit), Average Treatment on Treated (ATET)

Variable	Coef.	AI Robust Std. Error	z	P>|z|	[95% Conf. Interval]	
Prod_L	-10.507	7.560	-1.39	0.165	-25.323	4.310
L	69.981	31.964	2.19	0.029	7.332	132.631
Exp	0.075	0.362	2.06	0.039	0.004	0.146
Fin	750.176	1134.601	0.66	0.508	-1473.601	2973.954

Note: These estimations resort to the *teffects psmatch* command in Stata 14. Grey cells identify statistically significant estimates.
Source: Own computations based on data gathered from COMPETE and SABI.

5. Conclusion

In last three decades the role of R&D in economic performance has become a hot topic in policy makers' agenda and economic debates. This study aimed to contribute for this discussion by the attempting to respond to the following research questions: 1) What are the determinants for a company to receive a public subsidy to R&D?; and 2) Do R&D subsidies impact positively the performance of the recipient companies?.

Our research approach differs from existent empirical literature in the sense that even though there are plenty of studies made on this topic, less attention is paid to moderate innovative countries, such as Portugal. Indeed, developing effective R&D policies is a demanding task, which requires a deep understanding of the context, namely the national R&D system into which the companies operate.

The present study used longitudinal company-level data from Portugal to analyse the impact of public R&D subsidies on the performance of companies. In order to do so, we have compared companies' performance across different sectors, regions and industries. In concrete, we have analysed companies' performance differences between publicly funded R&D and non-subsidized companies in the period after and before the funds allocation. For that we have used PSM technique to construct a trustable comparison group which consists in a matched sample of companies that present the same propensity to receive a public subsidy to R&D. Then, we applied Average Treatment Effect model to assess the companies' performance before and after the project execution. Thus, we were able not only to identify the determinants for receiving a public subsidy to R&D, but also to estimate the casual effect of subsidies to R&D on the performance of the granted companies.

Based on data from 605 companies over the period 2008-2017, our results indicate that companies that export and have higher human capital endowments are more likely to be attributed a public subsidy to R&D. Furthermore, the results suggest that subsidies to R&D affect positively companies' performance in terms of employment and export activity which is in line with some relevant empirical literature (e.g., Duch et al., 2009; PACEC, 2009; Karhunen & Huovari, 2015; Criscuolo et al., 2019; Vanino et al., 2019). With respect to labour productivity and overall financial conditions, no significant differences emerged between treated and non-treated firms, as reported by Karhunen & Huovari (2015) and De Basilio et al. (2015).

Our results have some important implications. Policy makers should withdraw from our research that the societal effects of R&D subsidies on productivity growth and jobs creation are not granted (Larédo et al., 2016; Mohnen et al., 2017). Although they show a positive relationship between employment growth and propensity to export, financial conditions and labour productivity presented no significant improvement. Therefore, R&D policy instruments may need to be adjusted. Evidently, a correct choice of policy instruments requires a deep understanding of the systemic bottlenecks that prevent their success, ranging from lack of interaction between business and I&I institutions, inadequate skills/ capabilities or uncertainty about future demand (Elder & Fagerberg, 2017). In this sense, our results emphasise the importance of knowing deeply the national R&D context of a country when developing an effective R&D policy (Elder & Fagerberg, 2017).

Even though our results are corroborated by other empirical studies, our analysis presents limitations that should be noted. First, while it is true that Propensity Score Matching is able to solve potential common support problems, it cannot completely isolate unobservable factors that influence grant allocation and post-grant performances. Second, the estimations obtained with this methodology are, naturally, dependent on the treated and control groups. Therefore, if the sample included in the analysis is not representative of the entire population, there is a risk of a potential biased estimation of the overall economic effect. Third, the temporal horizon being studied might not be enough to assess the real effect of public R&D subsidies on the performance of companies. Due to unavailability of more recent data, we have considered a lag of three years between the attribution of subsidy and its estimated impact. However, it is possible that its turnover effect regarding labour productivity and the overall financial conditions will only take place in a future period. Fourth, we have only analysed one instrument of R&D policy, which may not be representative of the impact of R&D policy on companies' performance in Portugal.

Following the limitations of our study, there are several lines of further research that can be carried out to improve and complement our analysis. In order to control the for unobservable company specific effects, making several periodical observations in the same company (e.g., before, during and after receiving a subsidy for participants) might be a possible solution. Also, it could be advantageous to consider other type of variables, particularly those connected to company's organizational characteristics, strategy and markets. Lastly, studying another policy instrument that aims to enhance Portuguese R&D system would also be very interesting and relevant to provide a better picture of the results of the Portuguese R&D policy.

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