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THE IMPACT OF DISTINCT TYPES OF PUBLIC FUNDING FOR INNOVATION ON THE INNOVATION PERFORMANCE OF FIRMS LOCATED IN A MODERATE INNOVATOR COUNTRY

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Dissertation

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Bio

Maria Félix was born in Viseu, on May 14th of 1999. She currently lives in Porto.

In 2017 she enrolled in the University of Aveiro, obtaining the Management bachelor in 2020. During the third year of her studies in the bachelor's degree, she went abroad to participate in the Erasmus Programme, at Comenius University in Bratislava. In 2020, she applied to the Faculty of Economics of the University of Porto and enrolled in the master's degree of Economics and Management of Innovation.

After finishing the first year of the master degree, she started her professional activity at KPMG, where she works full-time as staff in the Audit and Assurance department.

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Resumo

A literatura sobre financiamento público para inovação é vasta, no entanto, os estudos que analisam o impacto do financiamento público para inovação no desempenho inovador das empresas são escassos. A maioria desses poucos estudos concentra-se no impacto do financiamento público no desempenho económico global das empresas, incluindo investimento em I&D, exportações totais, nível de emprego, sobrevivência do negócio. Os que estudam o impacto do financiamento público para a inovação no desempenho inovador centram-se em realidades muito específicas, nomeadamente os países inovadores fortes, e tipos particulares de empresas, designadamente as *start-ups*. A presente dissertação pretende colmatar esta lacuna através de um estudo aprofundado do impacto do financiamento público no desempenho inovador das empresas num contexto, Portugal, caracterizado por um relativo atraso tecnológico e classificado como inovador moderado.

Para realizar tal tarefa, recorremos à análise contrafactual por meio do *Propensity Score Matching* (PSM), que envolve a comparação do desempenho inovador das empresas receptoras e não receptoras de financiamento público. Baseamos a nossa análise nas 13701 empresas localizadas em Portugal que responderam ao Inquérito Comunitário à Inovação de 2018 (CIS2018), que se refere às atividades de inovação desenvolvidas no período 2016-2018.

Os principais resultados do nosso estudo mostram que uma proporção bastante pequena de empresas recebeu apoio/subsídios financeiros públicos para inovação (8% do total) ou outras atividades (9,9% do total). As empresas que receberam subsídios para outras atividades (além da inovação) superam as empresas que receberam subsídios à inovação em termos de intensidade de novos produtos e intensidade de inovação incremental de novos produtos. O mesmo não aconteceu com a intensidade da inovação radical, onde as empresas que receberam financiamento público para inovação superaram aquelas que receberam financiamento público para outros tipos de atividade.

Palavras-chave: Apoio público; Desempenho inovador; Inovadores moderados; Portugal; Propensity Score Matching.

Abstract

The literature on public funding for innovation is vast, however studies scrutinizing the impact of public funding for innovation on firm's innovation performance are scanty. Most of these few studies focus on the impact of public funding on the general performance of firms, including R&D investment, total exports, employment level, business survival. Those studying the impact of public funding for innovation on the innovation performance focus on very specific realities, namely strong innovators, and particular types of firms, as the start-ups. The present dissertation aims to fill this gap by undertaking a in depth study of the impact of public funding on firms' innovation performance in a technology laggard context, Portugal, a moderate innovator context.

To undertake such endeavor, we resort to counterfactual analysis using Propensity Score Matching (PSM), which involve the comparison of the innovative performance of public funding recipient and non-recipient firms. We based our analysis on the 13701 firms located in Portugal that responded to 2018 Community Innovation Survey (CIS2018), that refer to the innovation activities developed in the period 2016-2018.

The main results of our study show that a rather small proportion of firms have received public financial support / subsidies for innovation (8% of the total) or other (9.9% of the total) activities. Firms that received subsidies for other activities (beside innovation) outperform firms that received innovation subsidies in terms of intensity of new products and intensity of incremental new product innovation. The same was not true for the intensity of radical innovation, where firms that received public funding for innovation outperformed those that received public funding for other types of activities.

Keywords: Public Funding; Innovation Performance; Moderate innovators; Portugal; Propensity Score Matching.

1. Introduction

Increasingly, innovation and technological development have been associated with more advanced performances of firms, regions, and countries (Edler, Cunnighan, Gök & Shapira, 2013), leading public authorities to implement policies aimed at fostering nations' innovation capabilities (Santos, Cincera, Neto & Serrano, 2019). Public funding for innovation is a common tool of national innovation policies, consisting, in general, of direct subsidies and grants or tax incentives (Basto, Martins & Nogueira, 2021).

There is generally a positive appreciation of the role of public support for innovation activities. Indeed, studies about the impact of public financial support for innovation show that it has a positive effect on various variables, such as, R&D investment (Hottenrott & Richstein, 2020), total exports (Basto et al., 2021), employment level (Hottenrott & Richstein, 2020; Biancalani, Czarnitzki & Riccaboni, 2021), and business survival (Zhao & Ziedonis, 2020). However, this type of studies has overlooked the impact of public funding for innovation on the innovative performance of firms, often considered as the ability of firms succeed in obtaining new products (goods and services) and new processes (Rajapathirana & Hui, 2018).

The scarce empirical evidence on the impact of public funding for innovation on innovative performance of firms have focused on very specific realities, namely strong innovators like Germany, and particular types of firms, the start-ups (Caliendo, Künn & Weissenberger, 2020; Hottenrott & Richstein, 2020), and has not reached coincident outcomes. For instance, Caliendo et al. (2020) concluded that initially subsidized start-ups for filling patents persistently perform worse than their non-subsidized counterparts. In contrast, Hottenrott & Richstein (2020) concluded that subsidized loans, combined with grants, facilitate startups turning research results into marketable products. In the same line of results, Smith (2020) scrutinized the number of new product announcements related to the technology of firms that participated between 1998 and 2000 in Advanced Technology Program (ATP) competitions and found that receiving an ATP subsidy provided positive and significantly fostered firms' commercialization behavior.

Given the scarcity of studies on the impact of public funding for innovation on the innovation capabilities of firms (beside startups), and the non-clear-cut results of this policy measure, it would be scientific pertinent to analyze the extent to which distinct public funding

for innovation (direct subsidies, grants, and tax incentives) significantly impact on firms' (beyond startups) innovation performance.

Additionally, although several studies have assessed the impact of public funding policies in technology laggard contexts, such as moderate innovator countries, little evidence was collected on the impact of such policies on firms' innovation performance. One exception is the study by Catozzella & Viveralli (2016), which focused on Italian firms. These authors uncover that public funding impacted negatively on the innovative productivity (the ratio of total innovative sales in total innovative expenditure) of firms. This result accentuates the above-mentioned debate on the impact of public funding on firms' innovation performance. Such controversy demands further empirical research on the topic, namely focusing technology laggard contexts.

Moderate innovator countries (see EC, 2021) show relatively weak or modest levels of innovative performance (Cannavacciuolo, Capaldo, & Rippa, 2015) and low levels of human capital and absorptive capacity (Hollanders, 2020); this is likely to influence the impact of public funding on firms' innovation performance. Thus, studying the case of a distinct moderate innovator, Portugal, can be in scientific and policy perspectives useful as it would bring potentially fresh evidence on an unsettled debate.

The present dissertation has two main research questions: 1) Does public funding for innovation matter for the innovation performance of firms located in Portugal?; 2) To what extent distinct public funding policies produce disparate impacts on firms' innovation performance?

To answer these questions, and in line with extant literature on the subject (e.g., Hottenrott & Richstein, 2020), we use quantitative methodologies. Specifically, we resort to counterfactual analysis using Propensity Score Matching (PSM), which involve the comparison of the innovative performance of recipient and non-recipient firms. In terms of data, we based our analysis on the 13701 firms located in Portugal that responded to 2018 Community Innovation Survey (CIS2018), that refer to the innovation activities developed in the period 2016-2018.

The present dissertation is structured as follows. In Section 2 we review the relevant literature. Section 3 describes the data, research context and how we are going to employ the methodology. In Section 4 the empirical results are discussed. In Conclusion we highlight the main contributions and limitations of our study.

2. Literature review

2.1. Main concepts

2.1.1. Public policies for innovation: The case of public funding for innovation

Public intervention in the economy occurs because of market failures, path dependency and systemic innovation (Edler & Fargerberg, 2017). The uncertainty, risk and profit maximization criteria are common impediments for firms to invest in activities related to innovation, so public support is sometimes needed to incentivize and stimulate firms' expenditure innovation, achieve higher performance, growth, and competitiveness (Santos et al., 2019).

According to Edler & Fargerberg (2017), there are three types of innovation policy: mission-oriented policies; invention-oriented policies; and system-oriented policies. Mission-oriented policies are intended to provide innovative solutions for challenges on the political agenda and have been used for many years for various purposes such as defense, agriculture, war, pharmaceuticals, and maritime exploration. Invention-oriented policies are more restricted in focus, focusing on the invention phase and leave the eventual exploration and diffusion to the market. Lastly, system-oriented policies are more recent and focus on system-level resources: the level of interaction among the various parts of the system; to what components of the system needs to be improved; or the capabilities of the actors participating in the system.

Public funding for innovation, by carrying part of the risk, encourages firms to innovate, make them more attractive to investors (Hottenrott & Richstein, 2020), and help them achieve the optimal level of innovation investment (Basto et al., 2021). Thus, since it does not have a specific purpose, and due to its nature, we can consider that it fits into the systemic vision of innovation public policies.

The public funding for innovation can be direct or indirect. Direct public funding is linked to subsidies and grants, while indirect public funding refers to tax incentives (Edler & Fargerberg, 2017). By facilitating additional investments, public funding may increase the probability of innovation success so reducing the risk of failure subject (Hottenrott & Richstein, 2020).

2.1.2. Firms' innovation performance

Innovative performance of firm is often considered as the ability of firms succeed in obtaining new products (goods and services) and new processes (Rajapathirana & Hui, 2018). Thus, innovative firms are described as having grown potential to create significant and newly upgraded products, processes, marketing methods and organizational changes. (Odei, Stejskal & Prokop, 2021).

Within the literature, the degree of innovation and the firms' innovation performance can be measured by several variables. Caliendo et al. (2020) used patents and subjective perceptions of entrepreneurs on innovational activities to measure the firms' innovation performance. New product announcements are also a valuable metric for evaluate the innovation performance, indicating that firms look at new product introductions as being tied to their capacity to successfully innovate (Smith, 2020). Hottenrott & Richstein (2020) evaluate the innovation performance by the number of new products or process innovation implemented in the first three years after the subsidy receipt. Investment expenditure for R&D is other commonly used indicator for evaluating the innovation performance of firms (Odei, Stejskal & Prokop, 2021).

2.1.3. Moderate innovators

According to the European Innovation Scoreboard (EIS) (EC, 2021), countries and regions are categorized into four innovation performance categories: innovation leaders, strong innovators, moderate innovators, and emerging innovators.

This EIS is based on a set of indicators grouped into four categories: structural conditions (such as the availability of talent), investment made, namely in R&D, innovation activities, such as patent registrations, and the impact of innovation, namely in terms of exports. Countries classified as moderate innovators have weak or moderate levels of innovative performance and modest levels of development that do not allow them to keep up with the leaders and strong innovators (Cannavacciuolo et al., 2015). They share certain weaknesses such as (FCT, 2013; EC, 2021): low labor productivity rate; low educational level of the working population; weak attractiveness for foreign direct investment; reduced hiring of R&D services by firms from other institutional sectors; costs, financing, access to markets barriers faced by firms, and a limited presence of high-technology industries.

2.2. Theoretical framework: Main mechanisms through which public funding for innovation impacts on innovation performance of firms

Public funding for innovation can be needed due to market failures derived from capital market imperfections and the fact that knowledge is a non-rival good (Catozzella & Viveralli, 2016).

According to the capital market imperfections argument, firms without internal funds do not invest in valuable projects (Mazzucato & Semieniuk, 2017). Regarding the non-rival nature of knowledge, the argument goes that it makes impossible to appropriate all the advantages from innovation, which makes social marginal returns on new knowledge superior than the privates (Stojčić, Srhoj & Coad, 2020).

In the context of these market failures, and in the absence of governmental intervention, it is expected an under provision of R&D investment (Ebersberger, 2005), which is likely to convey a level of innovative activities below that considered as the social optimum (Zúñiga-Vicente, Alonso-Borrego, Forcadell & Galán, 2014).

Public funding for innovation should just be used if it actually increases private and social R&D spending and should require that the possibly increased innovation activity eventually turns into higher innovation output (Ebersberger, 2005). Although public funding for innovation has as its primary objective the increase of innovative activities in a firm (Santos et al., 2019), this positive effect is not always observable (Rehman, Hysa & Mao, 2020).

The most important public policy instruments to improve R&D are direct subsidies (grants, loans, and procurements), fiscal incentives, R&D consortia and public research performed in public institutions (Zúñiga-Vicente et al., 2014). Through these public policies, some mechanisms stimulate firms to increase private investment, making public intervention complementary by decreasing the cost of private R&D (Rehman et al., 2020) – see Figure 1.

There are four mechanisms through which public intervention could stimulate "complementary" private R&D (David, Hall & Toole, 2000): public R&D rise the efficiency of the firm's R&D by decreasing common cost or increasing "absorptive capacity"; public R&D signal upcoming demand; public R&D may expand the odds for success on the other projects of firms; and finally, public R&D let firms to overcome fixed R&D startup expenses - "pump-priming".

The first three mechanisms would increase the estimated revenues or decrease the expected expenses of the available projects of firms. The last mechanism, by reducing the firm's fixed costs, decreases the opportunity cost of capital.

When public support has a positive effect on a firm, it generally occurs the so-called 'additionality principle' (Orlic, Radicic & Balavac, 2019). In this case, the public R&D spending is complementary and so "additional" to private R&D spending (David et al., 2000). This principle occurs when public funding does not replace the firm's investment. In these cases, firms invest more in innovation than if they did not have access to the public support, which means that exist a complementary relationship (Rehman et al., 2020). This is also called 'crowding-in' effect (Barbieri et al., 2020), which tends to be clearer in firms that are regular receivers of public support than in first-time receivers, in financially constrained firms, and in smaller and younger firms (Zúñiga-Vicente et al., 2014).

The crowd-in effect or additionality principle consists in a 3-parts logic model (BEIS, 2017): input additionality, output additionality and outcome additionality. The input additionality occurs when public funding leads to more private-sector R&D activity, or as a minimum is not fully crowded out by decreases in private-sector activity, leading firms to invest more than they would without the public support. Rising inputs into technological development and research will improve capabilities to innovate (Ebersberger, 2005) and knowledge, such as higher quality research, more qualified workers, and more sophisticated assets (Shinkle & Suchard, 2019). These increased capabilities will lead to higher levels of innovative activities, for example a higher number of new products, processes and services will eventually generate boosts in variables such growth, productivity, and employment. When innovation leads to improved outcomes for firms and a better performance overall, it occurs the outcome additionality (BEIS, 2017).

The negative effect of public funding occurs when it substitutes or crowds out private R&D expenditure (Xu et al., 2021), which is often called the substitution effect (Santos, 2019). It establishes that increasing public sector R&D expenditure drives down or even eliminates private sector R&D expenditure (Carlson & Spencer, 1975). If the public support replaces and eliminates the R&D private investment that a firm was already willing to make in the case of not receiving the public support, it means that there will have a negative effect on innovation performance in firms and have no influence on the development of new products or on the number of registered patents (Santos, 2020). If the substitution of public for private

investment is one-for-one, it would mean that occurred a total crowding out (Ebersberger, 2005).

There is also the possibility that the public funding has a non-significant or mixed effects (Barbieri et al., 2020). There are some cases where the effect of the public intervention has both additionality and substitution effects. In a firm, the effect of public support can change over time, being recognized additionality for one-year lag and substitution for the next, or it can be complementary in one firm in a country and substitute in another (Zúñiga-Vicente et al., 2014).

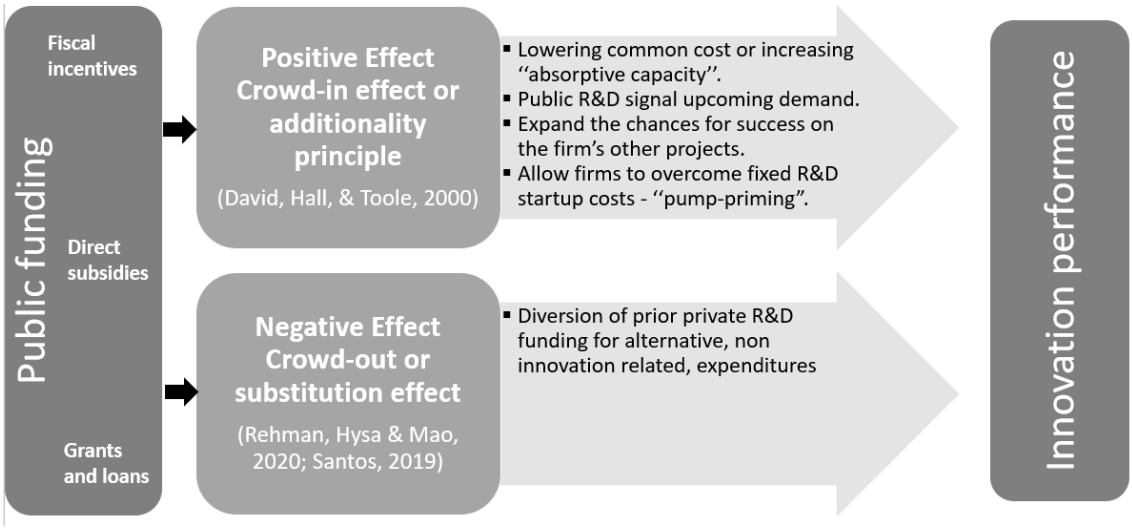


Figure 1: Theoretical framework

Source: Own elaboration.

2.3. Synthesis of the empirical evidence on the impact public funding for innovation impacts on performance of firms

Over the years, many authors studied the impact of the different types of public funding for innovation on the performance of firms (see Table 1), being the most frequently studied public policy instruments the fiscal incentives, direct subsidies, and grants and loans (Basto et al., 2021).

Some recent empirical literature on the impact of R&D tax incentives on firms' performance has analyzed countries such as Australia (Holt, Skali and Thomson, 2021), Portugal (Basto et al., 021), Italy (Biancalani et al., 2021), and Norway (Nilsen, Raknerud & Iancu, 2018). Using matching and differences-in-differences methods the studies concluded that of R&D

tax incentives promoted firms' performance as reflected by R&D investment (Basto et al., 2021; Holt et al., 2021), exports (Basto et al., 2021), obtaining equity and debt capital (Biancalani et al., 2021), hiring of more employees (Biancalani et al., 2021; Nilsen et al., 2018), value added, sales revenue (Nilsen et al., 2018). Notwithstanding, Nilsen et al. (2018) did not found positive effects on return to total assets or productivity for firms who received support.

In terms of direct subsidies, there are studies focusing on different realities: China (Gao, Hu, Liu & Zhang, 2021), USA (Smith, 2020), Portugal (Santos, 2019), Italy (Catozzella & Vivarelli, 2016; Colombo, Croce & Guerini, 2013); Spain (Busom, 2000; González, Jaumandreu & Pazó, 2005), Germany (Cantner & Kösters, 2015); Israel (Conti, 2018); Austria (Garcia & Mohnen, 2010), Sweden (Söderblom, Samuelsson, Wiklund & Sandberg, 2015), and a mix of European countries (Bondonio, Biagi & Stancik, 2016). Gao et al., (2021), Smith (2020), Catozzella & Vivarelli (2016), Cantner & Kösters (2015) and Garcia & Mohnen (2010) used matching and regression methods to evaluate the impact of the direct subsidy on the innovation performance of firms. They concluded that R&D subsidies in overall stimulate firms' exploratory innovation, which is quantified by the proportion of novel patents (Gao et al., 2021; Cantner & Kösters, 2015), increases the the amount of new product announcements related to technology (Smith, 2020), and the output side of innovation, determined by the share of total sales due to new or substantially altered products (Garcia & Mohnen, 2010). In contrast, the Italian study concluded that the impact of the public funding turns out to be negative when referred to the ratio of total innovative sales in total innovative expenditure (i.e., to innovative productivity) (Catozzella & Vivarelli, 2016). In terms of general performance, the Portuguese and European studies, using the same methods of analysis, concluded that direct subsidies foster firms' performance as reflected by sales (Santos, 2019; Bondonio et al., 2016), employment (Santos, 2019; Bondonio et al., 2016; Cantner & Kösters, 2015; Söderblom et al., 2015), value added (Bondonio et al., 2016), investment (Colombo, Croce & Guerin, 2013; Santos, 2019; Conti, 2018), technological progress (Santos, 2019), survival rates (Conti, 2018), and R&D expenditure (Busom, 2020; Garcia & Mohnen, 2010; González et al., 2005). Regarding firms' labor productivity, Santos (2019) concluded that the subsidy seems to have a negative impact, whereas Bondonio et al. (2016) established that no statistically significant impact emerged.

Regarding grants and loans, empirical studies has analyzed their impact on firms' performance in countries such as the USA (Zhao & Ziedonis, 2020; Howell, 2017; Wallsten, 2000), U.K. (BEIS, 2017), Germany (Hottenrott & Richstein, 2020), Spain (Bertoni, Martí & Reverte, 2019; Huergo & Moreno, 2017) and Canada (Bérubé & Mohnen, 2009). Using regression and matching methods, they found that grants and loans have a positive impact on business survival (Zhao & Ziedonis, 2020; BEIS, 2017; Howell, 2017), employment (BEIS, 2017; Hottenrott & Richstein, 2020; Bertoni et al., 2019), R&D investment, (Hottenrott & Richstein, 2020; Huergo & Moreno, 2017), revenues (Hottenrott & Richstein, 2020; Howel, 2017), sales growth (Bertoni et al., 2019), and innovation performance evaluated by the number of new products or process innovation implemented (Hottenrott & Richstein, 2020; Bérubé & Mohnen, 2009), number of patents (Howell, 2017), world first product innovations and commercialization of their innovations (Bérubé & Mohnen, 2009). In contrast, Wallsten (2000) found that public support has no impact on employment.

Table 1: Synthesis of recent studies that analyze the impact of public funding on firm performance

Public policy instrument	Authors (year)	Country	Period	Number of firms	Methodology	Proxy for the public policy instrument	Outcome Variables	Proxies for the outcome variables	Results
Tax incentives	Holt, Skali &Thomson (2021)	Australia	2005–2012	2 500	Difference in Difference and Ordinary Least Squares	R&D Tax Concession	Investment	Amount of additional R&D invested for every dollar of tax revenue forgone	+
	Basto, Martins & Nogueira (2021)	Portugal	2006-2015	2 274	Propensity Score Matching and Difference in Difference	Portuguese system of tax incentives - SIFIDE	Intangible investment	Percentage of total assets in the period of matching	+
							R&D staff	Hiring of staff in R&D activities	+
							Total Export	Export volumes in % of total sales	+
	Biancalani, Czarnitzki & Riccaboni (2021)	Italy	2008-2015	89 834	Propensity Score Matching and Difference in Difference	Italian Startup Act	Equity	Equity in thousands of Euros	+
							Debt	Bank loans in thousands of Euros	+
							Employment	Number of employees	+
	Nilsen, Raknerud & Iancu (2018)	Norway	2002-2013	21755	Stratification and Propensity Score Matching	R&D tax credit scheme Skattefunn (SKF)	Value added	Percentage points growth in value added	+
							Sales Revenue	Sales growth	+
							Employment	Number of employees	+
							Return to total assets	Percentage points growth in return to total assets	/
							Labour productivity	Value added per employee	/
Direct Subsidy	Gao, Hu, Liu & Zhang (2021)	China	2010-2014	1 503	Propensity Score Matching	Local and Central R&D subsidy	Exploratory innovation	Proportion of novel patents	+
	Smith (2020)	USA	2001-2014	442	Heckman's method	Advanced Technology Program (ATP)	New product announcements related to technology	Number of new products a firm announced between 2001 and 2014	+

Public policy instrument	Authors (year)	Country	Period	Number of firms	Methodology	Proxy for the public policy instrument	Outcome Variables	Proxies for the outcome variables	Results
	Santos (2019)	Portugal	2007-2013	320	Propensity Score Matching and Difference in Difference	Portuguese innovation subsidy (SI Innovation)	Fixed Assets	Net and accumulated value of the investment made over in fixed assets	+
							Value Ceation	Ratio between the gross value added and sales	/
							Productivity	Ratio between the gross value added (GVA) and the number of employees	-
							Sales	Value of exports	+
							Total Factor Productivity	Technological progress	+
							Employment	Number of employees	+
							EBITDA	Firms' cash-flow and profitability	+
	Catozzella & Vivarelli (2016)	Italy	1998 - 2000	2855	Heckman's metghod and Bivariate switching model	Financial support to innovation during the 3 years preceding the survey	Innovative productivity	Ratio of total innovative sales in total innovative expenditure	-
	Bondonio, Biagi & Stancik (2016)	European Coutries	2007 - 2009	14 759	Difference in difference and Propensity Score Matching	ICT Innovation	Employment	Number of employees	+
							Sales	Increased sales measured in euros	+
							Added Value	Increased added value measured in euros	+
							Labour productivity	Value added per employee	/
	Busom (2000)	Spain	1988	154	Regression models	R&D subsidy program in Spain	R&D effort	R&D expenditure or R&D personnel	+
	Cantner & Kösters (2015)	Germany	1994 - 2006	450	Propensity Score Matching	R&D subsidy	Employment	Working time of founders, active partners, conventional employees, hired labor and trainees	+
							Patente Output	Patent applications that can be attributed to the start-up's R&D activity within the first three years	+

Public policy instrument	Authors (year)	Country	Period	Number of firms	Methodology	Proxy for the public policy instrument	Outcome Variables	Proxies for the outcome variables	Results
	Colombo, Croce & Guerini (2013)	Italy	1994-2008	288	Error correction model specification and system generalised method of moment	R&D subsidy	Investment	Cash flow sensitivity and firm size	+
	Conti (2018)	Israel	1990-2014	2 304	Linear probability model	Government R&D subsidies	Survival rates	If the firm went through an IPO or acquisition or if it increased funds in the five years after the first subsidy application	+
							Attract External investment	Raise private funds at inception	+
							Patent Production	The number of granted patents applied for by a startup	+
	Garcia & Mohnen (2010)	Austria	1998-2000	1287	Structural Modeling	Government support for innovation in Austria	R&D expenditures	R&D/sales ratio	+
							output side of innovation	Share of total sales due to new or substantially modified products	+
	González, Jaumandreu & Pazó (2005)	Spain	1990-1999	2214	Estimation model; Tobit Model	Government R&D subsidies	R&D effort	Ratio of total R&D expenditures to sales	+
	Söderblom, Samuelsson, Wiklund & Sandberg (2015)	Sweden	2002 - 2008	130	Propensity Score Matching and Novel Matching Aproach	VINN NU subsidy	Sales	Average annual sales from the year following the filing of the subsidy application until year 2011	+
							Access to financial capital	External equity	+
							Attract Human	Attracting qualified employees and financier	+
Grants and loans	Zhao & Ziedonis (2020)	USA	2002-2008	241	Regression models	Michigan R&D loan program	Business survival	If a startup is still active and in good standing 2 (4) years after the competition	+
	BEIS (2017)	UK	2008-2012	-	Propensity Score Matching and Difference in Difference	Public support for innovation in the UK	Business survival	Average of percentage points more likely to survive	+
							Employment	Additional employed	+
							Turnover	Average turnover	/

Public policy instrument	Authors (year)	Country	Period	Number of firms	Methodology	Proxy for the public policy instrument	Outcome Variables	Proxies for the outcome variables	Results
	Hottenrott & Richstein (2020)	Germany	2005-2012	5 267	Propensity Score Matching and Exact Matching	Start-up received a grant, a subsidized loan, or both	R&D expenditures	Expenditure in R&D	+
							Market Success	Total revenue	+
							Firm Size	Number of employees	+
							Tangible Investment	Acquisition of tangible assets	+
							Innovation output	New products or implementation of a process innovation	+
	Bertoni, Martí & Reverte (2019)	Spain	2005 - 2011	512	Propensity Score Matching and Instrumental variable Analysys	EBT program and PYME program	Employment	Number of a firm's employees	+
							Sales growth	Firm's sales in Euro	+
	Bérubé & Mohnen (2009)	Canada	2002-2004	2 785	Propensity Score	R&D grants for Canadian firms	New products	Number of new or significantly improved products	+
							World first product innovations	If products can be a first-to-market product or an already-on-the-market-product	+
	Howell (2017)	USA	1983 - 2013	7,436	Regression discontinuity design and Ordinary Least Squares	Small Business Innovation Research (SBIR) program	Innovation	Number of patents	+
							Finance	Probabilbity of subsequent Venture Capital	+
							Revenue	Revenue in $ Million	+
							Successful Exit and Survival	Successful investments through an IPO or acquisition	+
	Huergo & Moreno (2017)	Spain	2002-2005	4407	Heckman's method and Propensity Score Matching	CDTI programme, programme of R&D subsidies and the Framework Programme of the European Commission	R&D activities.	Probability of conducting R&D activities	+
	Wallsten (2000)	USA	1990-1992	479	Ordinary Least Squares and Structural analysis	Small Business Innovation Research (SBIR) program	Employment	Number of a firm's employees	/
							Sales	Firm's sales in dollaes	+
							Patents	number of patents the firm applied	+

3. Methodology

3.1. Research question and estimation method

To analyze the impact of public support on performance of firms, the main methodologies adopted by the authors in their studies are quantitative, more specifically econometric methods (see Table 1).

The authors use different methodologies such as regression models (Busom, 2000; Zhao & Ziedonis, 2020), namely ordinary least squares (Holt et al., 2021; Wallsten, 2000; Howell, 2017), linear probability models (Conti, 2018), bivariate switching models (Catozzella & Vivarelli, 2016), stratification (Nilsen et al., 2018), structural model (Garcia & Mohnen, 2010; Wallsten, 2000); Tobit Model (González et al., 2005) and Heckman's model (Huergo & Moreno, 2017; Smith, 2020).

The two most adopted methodologies are propensity score matching (Gao et al., 2021; Cantner & Kösters, 2015; Söderblom et al., 2015; Nilsen et al., 2018; Hottenrott & Rxichstein, 2020; Bérubé & Mohnen, 2009; Huergo & Moreno, 2017; Bertoni et al., 2019), and a combination of difference-in difference and propensity score matching (Basto et al., 2021; Biancalani et al., 2021; Santos, 2019; BEIS, 2017). The reason authors using difference-in-difference also use propensity score matching is that difference-in-difference methods are used for evaluating the impacts of policies that are introduced at a specific point in time and compares changes over time in a non-treated group to the changes over time in a in a treated group, attributing the "difference-in-differences" to the policy effect. However, using this methodology, the program or public policy and treated groups may be different in ways that would impact their compositions or trends over time. To address this problem, authors usually complement the difference-in-differences method with the Propensity Score Matching or use it as the main methodology of analysis (Biancalani et al., 2021).

The Propensity Score Matching (PSM) consists of two steps which estimates the treatment effect of applying matching estimators (Santos, 2019). First, it is identified a control group consisting of firms with a similar probability of receiving treatment. The similarity between firms is found using probabilities of treatment, which are called the propensity score. After estimating the propensity score, the aim is to rectify the bias between groups and to make them the most similar before the intervention period. With this methodology, matching will

just be between firms with the same attributes in the period prior to begin of the project (Basto et al., 2021).

Given that in public policy applications it is not possible to observe all criteria of eligibility comprehensively, the PSM make it possible to estimate eligibility and the probability of participation to the largest amount possible (Biancalani et al., 2021). Although expanding the number of observable covariates represents a practical limitation since probabilities of finding a control unit reduce with the number of characteristics used in the match (Cantner & Kösters, 2015), PSM decreases differences in observable characteristics between groups as well as decreasing differences in characteristics that are unobservable by removing highly disparate firms from the corresponding control group (Hottenrott & Richstein, 2020). Moreover, the PSM condenses into an only variable – the propensity score – all the relevant information to the determination of a control group (Basto et al., 2021). The fact that this approach permits controlling for the variables that can affect the likelihood of treatment and the program results, permits to remove the endogeneity resulting from the selection bias (Gao et al., 2021).

Despite the numerous advantages mentioned, this method has some limitations comparing to traditional regression analysis. Matching based on the propensity scores drops out several observations because of the condition that observations from different treatment groups are matched just if they are near to each other in all aspects of propensity scores (Gao et al., 2021). More precisely, observations are only considered if their propensity score values have a positive density within the treated group of as well as non-treated firm (Cantner & Kösters, 2015). The main deficiency of the propensity-score matching methodology is that the control and treated group firms should differ only in characteristics that are observable and that no unobservable characteristics affecting the outcome diverge among the two groups. This assumption is usually infringed when selection is based on non-observable information. This violation may bias the estimation (Bertoni et al., 2019). So, the major limitation of using PSM is that this approach only considers and can control observable characteristics (Santos, 2019; Söderblom et al., 2015).

The purpose of the present dissertations is to understand if public funding for innovation matter for the innovation performance of firms located in Portugal and whether distinct public funding policies produce disparate impacts on firms' innovation performance. To answer these research questions, and in line with extant literature on the subject (see Table

1), we resort to counterfactual analysis using Propensity Score Matching (PSM). With this method, we are going to construct a control group by matching each firm that received public funding with the firms that did not receive but have similar characteristics. Using these matches, we can estimate the impact of the public funding and conclude if distinct public funding policies produce disparate impacts on firms' innovation performance. In terms of data, we based our analysis on the 13701 firms located in Portugal that responded to 2018 Community Innovation Survey (CIS2018), that refer to the innovation activities developed in the period 2016-2018.

3.2. Variable proxies

To analyze if public funding for innovation matter for the innovation performance of firms located in Portugal, and in line with the literature (Basto et al., 2021; Biancalani et al., 2021; Gao et al., 2021; Santos, 2019; Bondonio et al., 2016; Cantner & Kösters, 2015; Söderblom et al., 2015; Hottenrott & Richstein, 2020; Bertoni et al., 2019), we use dummies as treatment variables:

- 'innovation subsidy', which assumes the value 1 when the firm received between 2016-2018 an innovation subsidy and 0 otherwise, and
- 'other subsidies', which assumes the value 1 when the firm received between 2016-2018 other type (beside innovation) of subsidies.

Few authors have studied the impact of financial public support on innovative performance. These scarce amount of studies has used different proxies for the outcome variables, including the ratio of total R&D expenditures to sales (Catozzella & Vivarelli, 2016; González et al., 2005; Garcia & Mohnen, 2010); the expenditure on R&D activities (Busom, 2000; Hottenrott & Richstein, 2020); the number of patent applications (Cantner & Kösters, 2015; Conti; 2018; Wallsten, 2000; Howell, 2017); the number of new or significantly improved products (Bérubé & Mohnen, 2009; Hottenrott & Richstein, 2020).

In the present study, innovative performance (the outcome variable) is analyzed from different perspectives. In line with the literature, and using the data available on the 2018 Community Innovation Survey, we use as proxies for the outcome variable the following indicators which embrace distinct dimensions of innovation performance of firms:

- **product innovation**, a dummy variable which assumes the value 1 when the firm made product innovation (i.e., introduced new or improved goods or services) in 2016-2018 and 0 otherwise;
- **process innovation** a dummy variable which assumes the value 1 when the firm made process innovation (i.e., introduced any new or improved processes that significantly differ from its previous processes) in 2016-2018 and 0 otherwise;
- **technological innovation**, a dummy variable which assumes the value 1 when the firm made product or process innovation in 2016-2018 and 0 otherwise;
- **radical innovation**, a dummy variable which assumes the value 1 when the firm made radical product innovation (i.e., introduced new or improved product, good or service, that was new to the market, not previously marketed by any of its competitors) in 2016-2018 and 0 otherwise;
- **incremental innovation**, a dummy variable which assumes the value 1 when the firm made incremental product innovation (i.e., introduced new or improved product, good or service, that was identical or very similar to the products already offered by its competitors) in 2016-2018 and 0 otherwise;
- **intensity of new products**, which is computed as the percentage of firm's turnover that corresponds to the sales of new product;
- **intensity of radical innovation**, which is computed as the percentage of firm's turnover that corresponds to the sales of new radical product.
- **intensity of incremental innovation**, which is computed as the percentage of firm's turnover that corresponds to the sales of new incremental product.

To build the control group for matching each firm in each group (that which received and that not receiving the subsidies), we considered several variables that reflect firm's absorption capability and some of its main characteristics.

For representing the **absorption capability** of the firm, we consider the **efforts devoted to innovation**, proxied by R&D activities (dummy assuming value 1 if the firm developed intramural research and development activities between 2016 and 2018, and 0 otherwise), human **capital endowments**, proxied by the percentage of employees with tertiary

education, and **external collaborations**, proxied by the number of collaborations established with other firms and organizations between 2016 and 2018.

The **main traits** of the firms that we considered include:

- the **size** of the firm (Bondonio et al., 2016) in terms of the number of employees (Gao et al., 2021; Söderblom et al., 2015) separated in three main categories, small (10-49 workers), medium (50-249 workers), and large (250 and more workers);
- the **sector of activity** according to sectors' technological and knowledge intensity (Peneder, 2007):
  - **Low and medium low:** agriculture; forestry: fishing; food drink and tobacco; textiles, clothing; leather and footwear; wood and products of wood, and cork; rubber and plastics; non-metallic mineral products; basic metals; fabricated metal products; furniture: miscellaneous manufacturing; recycling; construction; sale, maintenance and repair of motor vehicles and motorcycles, retail sale of automotive fuel; retail trade, except of motor vehicles and motorcycles; repair of personal and household goods; hotels and catering; inland transport; water transport; private households with employed persons.
  - **Medium:** mining and quarrying; pulp, paper and paper products; mineral oil refining, coke and nuclear fuel; mechanical engineering; motor vehicles; electricity, gas and water supply; wholesale trade and commission trade, except of motor vehicles and motorcycles; ccommunications; real estate activities; renting of machinery and equipment.
  - **Medium high, high, and very high:** chemicals; office machinery, insulated wire, other electrical machinery; electronic valves and tubes: telecommunication equipment; radio and television receivers; scientific instruments, other instruments, building and repairing ships and boats; aircraft and spacecraft; railroad equipment and transport equipment nec; air transport; supporting and auxiliary transport activities; activities of travel agencies; financial intermediation, except insurance and pension funding: insurance and pension funding, except compulsory social security; activities auxiliary to financial intermediation; computer and related activities; research and development; legal, technical, and advertising; other business activities; public administration and defense; compulsory social security; education; health and social work; other community, social and personal services; extra-territorial organizations and bodies.

4. Empirical results

4.1. Descriptive analysis

Public financial support over the period 2016-2018 was granted to a rather small set of firms. Indeed, out of the 13701 firms, 1095 (8.0% of the total) received subsidies for innovation, while 1335 (9.9% of the total) received other types of subsidies.

In terms of innovation performance, about 36% of the firms introduced, during 2016-2018, new or improved products or processes, that is, are technological innovators. Those that introduced new or improved products correspond to 27%, whereas those that introduced new or improved processes comprise 32% of the total. Although a reasonable number of firms claimed to innovate, the average percentage of firm's turnover that corresponds to the sales of new product is only 11%, with 5% of the turnover corresponding to incremental product innovations and 2.5% to radical product innovation.

Regarding firms that received subsidies for innovation, the impact that this subsidy has on the firms' innovative performance seems to be noticeable (Table 2). The treated firms had more technological, product and process innovation and are also more intense in terms of radical and incremental innovation. Although this subsidy is beneficial in all variables studied to measure the firm's innovative performance, in percentage terms, the variables that had the most impact is the radical product innovation and its intensity, since firms that do not receive the subsidy have only 2% of the turnover corresponding to radical product innovations and the ones that receive have 9%. Of those that received the subsidy, 46% innovated in terms of radical product innovation and those that did not receive only 10% innovated.

In firms that received other types of support, the impact on innovative performance seems also positive, although less marked. In terms of radical innovation, the impact was not so high, however, in terms of incremental innovation almost doubled: firms that do not receive the subsidy have only 5% of the turnover corresponding to incremental product innovations and the ones that receive have 10%.

Comparing firms that received subsidies for innovation and firms that received other types of subsidies, at a first glance, the ones that received innovation subsidies managed to perform better in terms of innovation than those that received other types of subsidies: about 82 % of the firms that received an innovation subsidy innovated technologically, which compares favorably to the 61% of those that received other type of subsidies.

Table 2: The descriptive statistics of the relevant variables by subsidies group

	Variables		All firms (#13701)	Subsidies for innovation		Other types of subsidies	
				Treated firms (#1095)	Non-treated firms (#12606)	Treated firms (#1355)	Non-treated firms (#12346)
Treatment variables	**Subsidy to innovation** (dummy assuming value 1 when the firm received the subsidy and 0 otherwise)		8.0%	100.0%	0.0%	27.2%	5.9%
	Other subsidies (dummy assuming value 1 when the firm received the subsidy and 0 otherwise)		9.9%	33.6%	7.8%	100.0%	0.0%
Innovation performance	**Technological innovation** (dummy assuming value 1 when the firm introduced product or process innovations and 0 otherwise)		35.7%	81.6%	31.7%	60.7%	32.9%
	Product innovation (dummy assuming value 1 when the firm introduced product innovations and 0 otherwise)		27.0%	71.8%	23.1%	49.2%	24.5%
	Process innovation (dummy assuming value 1 the firm introduced process innovations and 0 otherwise)		32.4%	75.9%	28.6%	57.9%	29.6%
	Radical product innovation (dummy assuming value 1 the firm introduced radical product innovations and 0 otherwise)		13.1%	46.3%	10.2%	24.3%	11.8%
	Intensity of new products (% of firm's turnover that corresponds to new product)		11.1%	22.6%	10.1%	17.3%	10.4%
	Intensity of radical innovation (% of firm's turnover that corresponds to new radical product)		2.5%	8.8%	1.9%	4.4%	2.3%
	Intensity of incremental innovation (% of firm's turnover that corresponds to new incremental product)		5.0%	11.1%	4.5%	9.5%	4.6%
Absorption capability	**R&D activities** (dummy assuming value 1 if the firm developed intramural research and development activities and 0 otherwise)		11.4%	68.9%	6.5%	27.5%	9.7%
	Human capital endowments (% firms in each category)	0% of employees with tertiary education	14,7%	1,9%	15,8%	5,0%	15,8%
		]0%; 50%]	68,2%	72,2%	67,9%	79,2%	67,0%
		]50%; 100%]	17,1%	25,8%	16,3%	15,8%	17,2%
	External collaborations (number of collaborations with other firms or organizations)		1.1	2.2	1.1	1.5	1.1
Firms' characteristics	**Technological and knowledge intensity**	**Low and medium low**	42.1%	33.9%	42.8%	43.1%	42.0%
		Medium	37.1%	45.4%	36.3%	39.5%	36.8%
		Medium high, high, very high	20.9%	20.7%	20.9%	17.4%	21.2%
	Size	**Low**	67,9%	34,1%	70,9%	46,6%	70,3%
		Medium	19.4%	28.7%	18.6%	29.6%	18.3%
		Large	12.7%	37.3%	10.5%	23.8%	11.5%

This finding is also valid for other types of innovation: 71.8% of those that received innovation subsidies innovated in terms of product and 75.9% in terms of process, compared to firms that received other types of innovation and innovated on average 49.2% and 57.9%, respectively. The only variable where this difference is less noticeable is in the percentage of new incremental products, where both groups innovated in a similar way: 11.1% (firms that received innovation subsidies) and 9.5% (firms that received other subsidies). However, the same does not happen in radical innovation, where the difference is substantially greater: of the firms that receive subsidies for innovation, on average, they have 8.8% of radical products, while those that receive other types of subsidies, have only half (4.4%).

In general terms, firms that collaborate with other firms or entities can more easily access subsidies, both for innovation and other types of subsidies (Figure 2). Furthermore, those who do not collaborate receive on average more subsidies that are not for innovation.

The same is true about R&D effort, those that do intramural R&D, on average receive much more subsidies. It is important to highlight the importance of developing intramural ID in a firm's ability to receive subsidies for innovation (and other types of subsidies), since those that don't only receive an average of 2.8% (8.1%) and those that do receive 48.1% (23.7%).

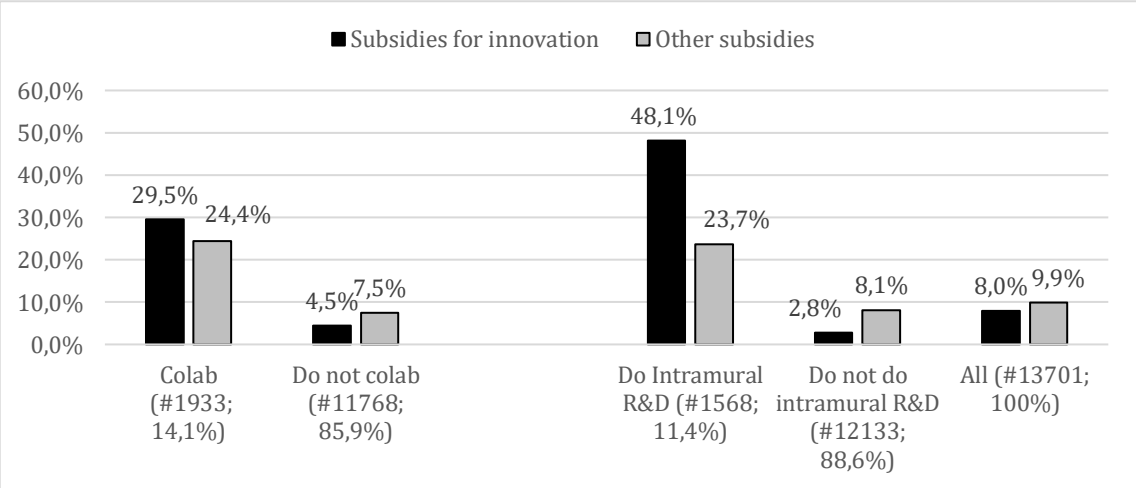


Figure 2: Impact of External collaborations and R&D activities on different types of subsidies

In terms of human capital of our population, firms that receive public financial support for innovation activities are proportionately more represented in groups with high human capital intensity (Figure 3). While in the group of firms that do not have any employee with higher education, only 1% (3.4%) of the firms received public support for innovation activities

(other activities), in the group of firms with 75% or more of workers with education higher, this percentage is almost 15% (9%).

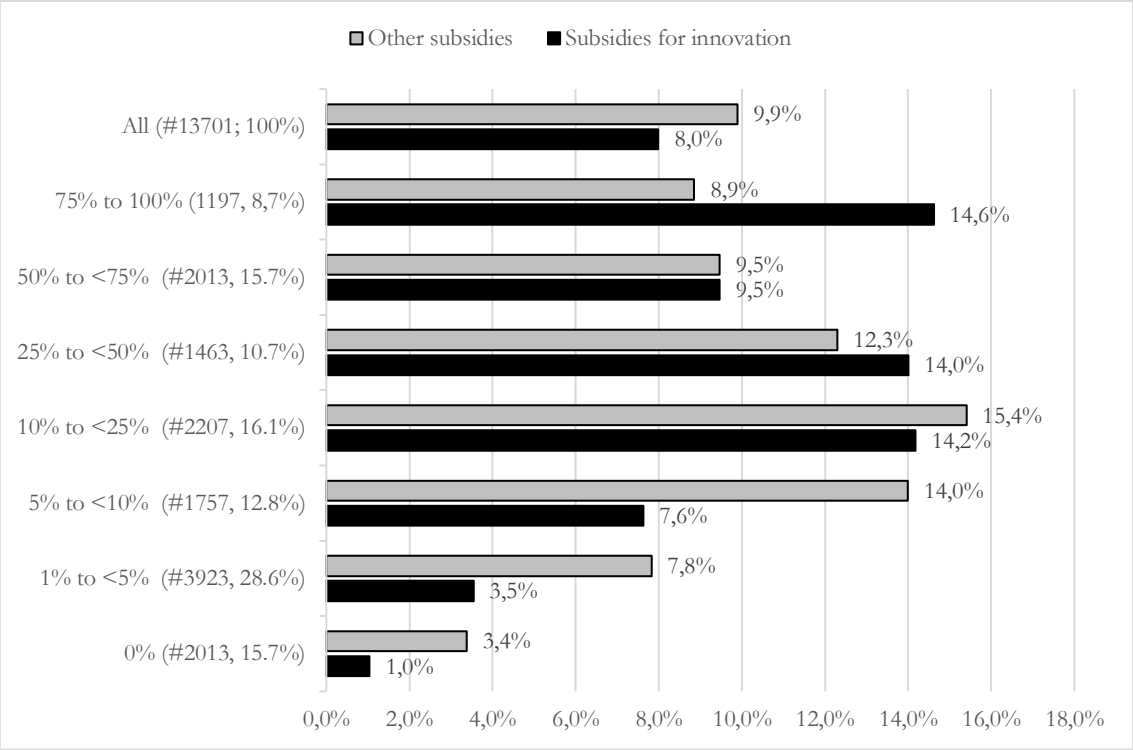


Figure 3: Impact of Human capital endowments on different types of subsidies

Regarding technological and knowledge intensity, the difference between firms receiving subsidies for innovation and other subsidies is not very pronounced (Figure 4), however, within the group of high, very high and medium we have a group of 323 who are considered very high who receive more subsidies to innovation compared to the others (14.6% of subsidies to innovation and 8.7% of other subsidies).

Those with a more pronounced difference are those considered low and medium low, receiving 10.1% from other subsidies and 6.4% from subsidies for innovation.

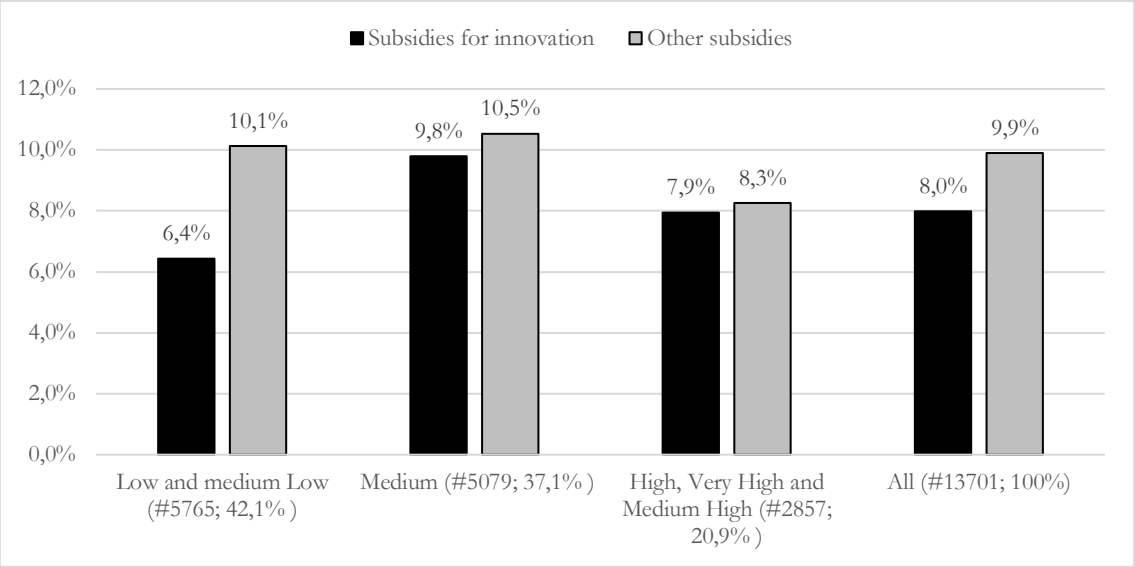


Figure 4: Impact of Technological and knowledge intensity on different types of subsidies

The proportion of large firms that receive support is much higher than the rest (Figure 5). In relative terms, for those that are large, the proportion that receives subsidies for innovation or for other purposes is much higher than the proportion in the other groups. While in the small group, only 4% receive subsidies for innovation, in the large group it is 23.5%, the differences between dimensions are much more accentuated for subsidies for innovation than for other purposes. That is, those who receive subsidies are the largest, in relative terms, but the difference between the proportion of those who receive for innovation is much greater than the proportion of those who receive other subsidies.

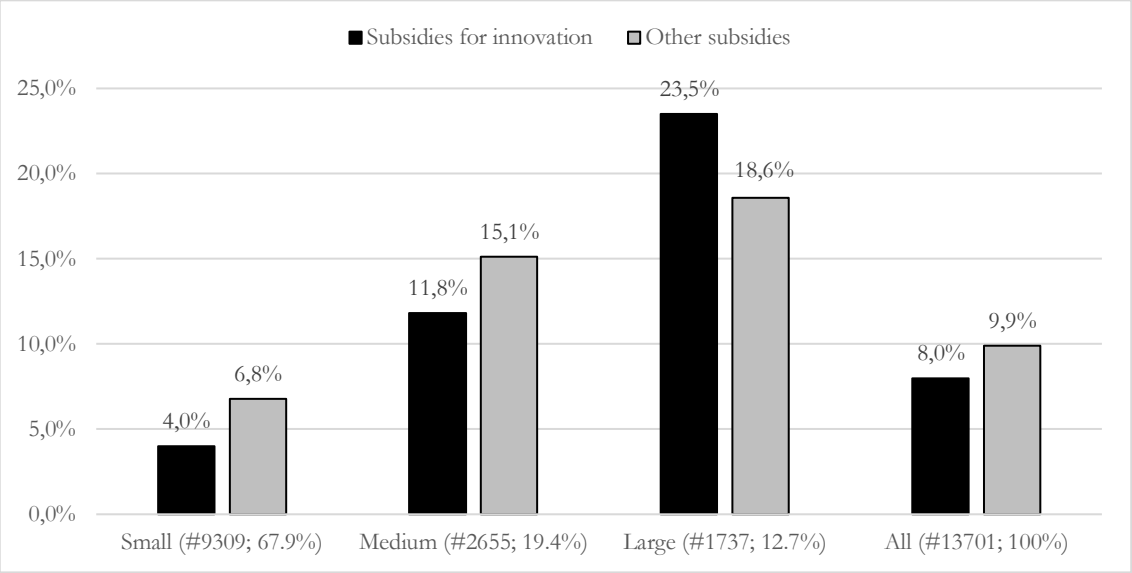


Figure 5: Impact of firm's size on different types of subsidies

Table 3: Correlation matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	**Subsidy to innovation** (dummy assuming value 1 when the firm received the subsidy and 0 otherwise)	1.0000																
2	**Other subsidies** (dummy assuming value 1 when the firm received the subsidy and 0 otherwise)	0.2342*	1.0000															
3	**Technological innovation** (dummy assuming value 1 when the firm introduced product or process innovations and 0 otherwise)	0.2821*	0.1727*	1.0000														
4	**Product innovation** (dummy assuming value 1 when the firm introduced product innovations and 0 otherwise)	0.2977*	0.1657*	0.8154*	1.0000													
5	**Process innovation** (dummy assuming value 1 the firm introduced process innovations and 0 otherwise)	0.2741*	0.1804*	0.9288*	0.7183*	1.0000												
6	**Radical product innovation** (dummy assuming value 1 the firm introduced radical product innovations and 0 otherwise)	0.2907*	0.1103*	0.5204*	0.6382*	0.4839*	1.0000											
7	**Intensity of new products,** (% of firm's turnover that corresponds to new product)	0.1288*	0.0772*	0.2660*	0.2846*	0.2526*	0.2322*	1.0000										
8	**Intensity of radical innovation (**% of firm's turnover that corresponds to new radical product)	0.1770*	0.0624*	0.3128*	0.3836*	0.2917*	0.6011*	0.2474*	1.0000									
9	**Intensity of incremental innovation** (% of firm's turnover that corresponds to new incremental product)	0.1229*	0.1005*	0.4637*	0.5687*	0.4237*	0.2032*	0.2368*	0.1126*	1.0000								
10	**R&D activities** (dummy assuming value 1 if the firm developed intramural research and development activities and 0 otherwise)	0.5315*	0.1666*	0.4151*	0.4368*	0.4049*	0.4008*	0.2183*	0.2373*	0.2116*	1.0000							
11	**Human capital**	0.1724*	0.0873*	0.2296*	0.2179*	0.2218*	0.1774*	0.1242*	0.1188*	0.1052*	0.2311*	1.0000						
12	**External collaborations** (number of collaborations with other firms or organizations)	0.3986*	0.1668*	0.3198*	0.3375*	0.3259*	0.3333*	0.1819*	0.2133*	0.1579*	0.5131*	0.2113*	1.0000					
13	**Medium**	0.0693*	0.0856*	0.0568*	0.0463*	0.0601*	0.0357*	-0.0110	0.0097	0.0127	0.0633*	0.0917*	0.0223*	1.0000				
14	**Large**	0.2177*	0.1111*	0.1575*	0.1566*	0.1536*	0.1387*	0.0373*	0.0529*	0.0582*	0.2372*	0.1932*	0.2269*	-0.1868*	1.0000			
15	**Low and medium low**	-0.0489*	0.0069	-0.0347*	-0.0366*	-0.0375*	-0.0339*	-0.0959*	-0.0398*	-0.0301*	-0.0840*	-0.1727*	-0.0621*	0.0426*	-0.0866*	1.0000		
16	**Medium**	0.0508*	0.0166	0.0029	0.0078	0.0047	0.0119	0.0554*	0.0056	0.0192*	0.0540*	-0.0539*	0.0180*	-0.0108	-0.0363*	-0.6542*	1.0000	
17	**Medium high, high, and very high**	-0.0009	-0.0280*	0.0387*	0.0352*	0.0399*	0.0270*	0.0507*	0.0416*	0.0138	0.0378*	0.2739*	0.0541*	-0.0389*	0.1484*	-0.4375*	-0.3940*	1.0000

Note:* statistically significant at 5%.

The correlation matrix (Table 3) allows us to establish the correlation between each pair of variables studied and corroborate the descriptive analysis.

It is possible to notice that, on average, those firms that receive innovation subsidies also tend to receive other types of subsidies. Furthermore, firms that receive innovation subsidies tend to develop various types of innovation, especially product innovation and radical product innovation. R&D effort and external collaborations are positively related to the probability of firms receiving innovation subsidies.

The correlations are significantly lower between the variables and the probability of receiving other types of subsidies than innovation subsidies. Even so, those that receive subsidies for other purposes tend to develop different types of innovation, especially process innovation.

4.2. Results of the estimations

4.2.1. Determinants for receiving public subsidies for innovation and other types of subsidies

In this section we estimate the Propensity Score Matching (PSM). The first part of the estimation resorts to bivariate probit model to investigate the variables that determine the propensity to be granted a public subsidy to innovation and other activities (see Table 4). In this model, we include as independent / explanatory variables the R&D activities, human capital endowments, external collaborations, size, and sector technological and knowledge intensity.

The probability that firms receive subsidies for innovation and other types of subsidies depends a lot on the characteristics of those firms. Indeed, firms that perform intramural R&D activities are significantly more likely to have received in the period of 2016-2018 subsidies for innovation and other activities, although the impact of intramural R&D on the former is much higher. Moreover, firms that have higher levels of human capital and collaborates with a higher number and distinct types of external organizations are much likely to have received subsidies for innovation and other activities.

Compared to medium size firms, smaller firms tend to be less likely to have received subsidies for innovation or other activities. In contrast, larger firms are statistically more prone than medium firms to have received subsidies for innovation, but not subsides for other activities.

Firms operating in high and very high technology and knowledge intensity sectors are significantly less likely than those operating in medium (and very low and low) intensity sectors to have received subsidies for innovation or other activities.

Table 4: Probit regression (dependent variable: 1 if the firm received subsidies for innovation/ subsidies for other activities and 0 otherwise)

		Subsidies for innovation	Subsidies for other activities
Intramural R&D (dummy variable=1 if the firm performs intramural R&D activities; 0 otherwise)		1.459***	0.361***
		(0.049)	(0.053)
Human capital (ln)		0.213***	0.129***
		(0.042)	(0.022)
Number of external collaborations (ln)		0.321***	0.223***
		(0.030)	(0.031)
Size of the firm (default: medium size)	Small	-0.370***	-0.375***
		(0.051)	(0.031)
	Large	0.132**	0.012
		(0.058)	(0.053)
Sector technological and knowledge intensity (default: medium intensity)	Very low and low intensity	0.023	0.098***
		(0.047)	(0.031)
	High and very high intensity	-0.250**	-0.298***
		(0.121)	(0.115)
Average Variance Inflation Factor (VIF) [maximum VIF]		1.29 [1.50]	1.29 [1.50]
No. of observations		13701	13701
Wald chi2		2017.95 (0.000)	901.71 (0.000)
Pseudo R2		35.1%	6.5%

Legend: ***, **, * indicate statistical significance at 1%, 5% and 10% levels, respectively. Bootstrap standard errors in brackets. Grey cells identify statistically significant estimates.
Source: Own computations based on data gathered from CIS18.

4.2.2. The impact of receiving public subsidies for innovation and other types of subsidies on firms' innovation performance

To answer the research question, "Does public funding for innovation matter for the innovation performance of firms located in Portugal?", we apply the Average Treatment on Treated firms. Concretely, we run the model for the seven proxies of innovative performance we have defined: (i) technological innovation, (ii) product innovation, (iii) process innovation, (iv) radical product innovation, (v) intensity of new products, (vi) intensity of radical innovation and (vii) intensity of incremental innovation.

The results of the ATT model for assessing the impact of subsidies for innovation activities on innovation performance (measured by the 7 outcome variables), using the standard tool for propensity score matching in Stata 17, the psmatch2 command, are presented in Table 5.

Table 5: The impact of subsidies for innovation - Average Treatment Effect on the Treated (ATT)

Variable	Sample	Treated	Controls	Difference	S.E.(*)	T-stat
Technological innovation	Unmatched	0.816	0.317	0.498	0.014	34.42
	ATT	0.816	0.886	-0.070	0.020	-3.49
Product innovation	Unmatched	0.718	0.231	0.487	0.013	36.50
	ATT	0.718	0.818	-0.099	0.024	-4.22
Percentage of new product innovations in total turnover	Unmatched	22.64	10.08	12.55	0.826	15.20
	ATT	22.64	25.14	-2.505	1.816	-1.38
Process innovation	Unmatched	0.759	0.286	0.473	0.014	33.36
	ATT	0.759	0.829	-0.070	0.022	-3.16
Radical product innovation	Unmatched	0.463	0.101	0.361	0.010	35.55
	ATT	0.463	0.540	-0.077	0.026	-2.91
Percentage of radical new product innovations in total turnover	Unmatched	8.793	1.943	6.849	0.329	20.79
	ATT	8.793	10.09	-1.299	1.009	-1.29
Percentage of incremental new product innovations in total turnover	Unmatched	11.129	4.514	6.615	0.456	14.49
	ATT	11.129	14.31	-3.181	1.074	-2.96

Notes: These estimations resort to the standard tool for propensity score matching in Stata 17, the psmatch2 command (*) S.E. does not take into account that the propensity score is estimated. Grey cells identify statistically significant estimates. Untreated: 12606; Treated: 1095. Total: 13701. LR chi2(7)= 2681.10, Prob > chi2 = 0.0000.

Based on the estimation results, we conclude that receiving subsidies for innovation activities significantly enhances technological innovation, including product and process innovation, and radical new product innovation of the recipient firms when matching them with a comparable control group of non-recipient firms. Notwithstanding, for the matched samples, firms that received subsidies for innovation activities between 2016 and 2018 failed to observe higher performances in terms of the share of new (radical) product innovations in total turnover.

Results of the impact of subsidies for other activities on innovation performance (Table 6) are similar of those regarding the subsidies for innovation. For the matched samples, subsidies for other activities enhances innovation activities in general, except for the percentage of new product innovations in total turnover, where the subsidy does not help to achieve a better performance.

Table 6: The impact of subsidies for other activities - Average Treatment Effect on the Treated (ATT)

Variable	Sample	Treated	Controls	Difference	S.E.(*)	T-stat
Technological innovation	Unmatched	0.606	0.329	0.277	0.013	20.52
	ATT	0.606	0.894	-0.288	0.026	-11.06
Product innovation	Unmatched	0.491	0.245	0.246	0.012	19.67
	ATT	0.491	0.838	-0.347	0.029	-11.63
Percentage of new product innovations in total turnover	Unmatched	17.25	10.41	6.839	0.754	9.07
	ATT	17.25	21.17	-3.922	2.238	-1.75
Process innovation	Unmatched	0.578	0.295	0.282	0.013	21.47
	ATT	0.578	0.829	-0.251	0.028	-8.72
Radical product innovation	Unmatched	0.242	0.118	0.124	0.009	12.98
	ATT	0.242	0.623	-0.380	0.032	-11.58
Percentage of radical new product innovations in total turnover	Unmatched	4.394	2.282	2.111	0.303	6.96
	ATT	4.394	13.43	-9.041	1.234	-7.32
Percentage of incremental new product innovations in total turnover	Unmatched	9.471	4.556	4.914	0.415	11.82
	ATT	9.471	13.70	-4.236	1.266	-3.35

Notes: These estimations resort to the standard tool for propensity score matching in Stata 17, the psmatch2 command (*) S.E. does not take into account that the propensity score is estimated. Grey cells identify statistically significant estimates. Untreated: 12346; Treated: 1355. Total: 13701. LR chi2(7)= 575.11, Prob > chi2 = 0.0000.

In addition to *psmatch2*, we also estimated the Propensity Score Matching using *teffects psmatch*. Using *teffects psmatch* the similarity between firms is based on estimated treatment probabilities, the propensity scores. The average treatment effect is calculated by taking the average of the difference between the potential outcomes and observed outcomes for each firm. Thus, it becomes advantageous to use *teffects psmatch* instead of *psmatch2*, since the *teffects* considers the fact that propensity scores are estimated instead of known when calculating standard errors. Although *psmatch2* gives us several possible matching algorithms, it needs to use bootstrap to correctly estimate standard errors.

The results of the ATET model of the impact of subsidies for innovation activities and subsidies for other activities on innovation performance, using the *teffects psmatch* command in Stata 17, are presented in Table 7. We can conclude that the firms which share the same

characteristics and received subsidies for innovation activities, tend to innovate more than those which have not received such subsidies at technological, product, and process levels. Moreover, they are much more likely to outperform the others in radical innovation.

In terms of intensity of new products (% of firm's turnover that corresponds to new product), there is no evidence that firms that receive and do not receive subsidies for innovation are different. However, the subsidies for innovation have a significant and positive impact on the intensity of radical innovation, that is, the percentage of firm's turnover that corresponds to new radical product. Nonetheless, in terms of intensity of incremental innovation (percentage of firm's turnover that corresponds to new incremental product) the subsidy has no impact. Subsidies for innovation activities causes firms' radical product innovation to be increased by an average of 0.1% and the radical innovation intensity (in % of the turnover) to be increased by an average of 2.5 percentage points. Subsidies for innovation activities do not seem to significantly impact on the intensity of product innovation nor the intensity of incremental new product innovation. This contrast with results of the impact of subsidies for other activities which enhance both the intensity of product and incremental new product innovation.

It is interesting to note that excluding the radical innovation performance and intensity (in % of the turnover), the impact on innovation performance of subsides for other activities is higher than that of subsidies for innovation activities. Thus, if the public authorities' goal is to increase firms' innovation performance and innovation capabilities in general, they should focus their policy instrument on subsidies for other activities instead of subsidies for innovation activities. However, if their objective is to promote new to the world products, they should rely on subsidies for innovation activities.

Our results suggest that subsidies for innovation affect positively firms' innovation performance in terms of technological, product, and process levels, which is in line with some relevant empirical literature. Indeed, several studies that used the same methodology have evaluated innovation performance through the number of patents (taken as a proxy for technological, product, and process innovation) and concluded that public subsidies to innovation foster patent activity (Gao et al., 2021; Cantner & Kösters, 2015). Furthermore, Hottenrott & Richstein (2020) and Huergo & Moreno (2017) found that public subsidies to innovation promotes innovation performance, the latter being measured by the ratio of total R&D expenditures to sales.

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

Impact of	Variable	Coefficient	AI robust std. err.	z	P>|z|	[95% conf. interval]	
Subsidies for innovation activities	Technological innovation	0.080	0.015	5.500	0.000	0.051	0.108
	Product innovation	0.086	0.018	4.830	0.000	0.051	0.121
	Percentage of new product innovations in total turnover	0.215	1.524	0.140	0.888	-2.772	3.202
	Process innovation	0.072	0.017	4.140	0.000	0.038	0.106
	Radical product innovation	0.088	0.021	4.180	0.000	0.047	0.129
	Percentage of radical new product innovations in total turnover	2.480	0.947	2.620	0.009	0.623	4.336
	Percentage of incremental new product innovations in total turnover	0.072	0.893	0.080	0.936	-1.680	1.824
Subsidies for other activities	Technological innovation	0.129	0.012	10.18	0.000	0.105	0.154
	Product innovation	0.106	0.013	8.210	0.000	0.081	0.131
	Percentage of new product innovations in total turnover	3.818	0.929	4.110	0.000	1.996	5.639
	Process innovation	0.141	0.013	10.90	0.000	0.116	0.167
	Radical product innovation	0.028	0.012	2.360	0.018	0.005	0.051
	Percentage of radical new product innovations in total turnover	0.432	0.453	0.950	0.341	-0.456	1.320
	Percentage of incremental new product innovations in total turnover	3.323	0.562	5.910	0.000	2.221	4.425

In terms of intensity of new products, our results suggest that no difference in innovation performance arise between firms that receive and those that do not receive subsidies for innovation. This is not in line with the literature that estimate the Propensity Score Matching, since authors found a positive correlation between subsidies for innovation and the number of new products a firm announced, a proxy for intensity of new products (Hottenrott & Richstein, 2020; Bérubé & Mohnen, 2009).

5. Conclusion

Even though in the literature we can find numerous studies using Propensity Score Matching that focus on the topic of public funding for innovation (Basto et al., 2021; Biancalani et al, 2021; Nilsen et al., 2018; Santos, 2019; Bondonio et al., 2016; Söderblom et al., 2015; Bertoni et al., 2019), studies that analyze the impact of public funding for innovation on firms' innovation performance are rare. This scarce empirical literature has focused on very specific realities, namely firms located in countries classified as strong innovators like Germany, and particular types of firms, the start-ups (Cantner & Kösters, 2015; Hottenrott & Richstein, 2020). Given the scarcity of studies on the impact of public funding for innovation on the innovation capabilities of firms, it would be scientific pertinent to analyze the impact on firms' innovation performance in technology laggard contexts, such as moderate innovator countries, since these countries show relatively weak or modest levels of innovative performance and low levels of human capital and absorptive capacity and this is likely to influence the impact of public funding on firms' innovation performance.

The present dissertation contributes to fill in this gap by analyzing the impact of the public funding on Portuguese firms' innovation performance, a moderate innovator context.

Based on a set of 13701 firms that responded to 2018 Community Innovation Survey (CIS2018), we found that although a reasonable number of firms claimed to innovate (36% of the firms introduced, during 2016-2018, new or improved products or processes), the average percentage of firm's turnover that corresponds to new (radical) products is only 11% (2.5%). Additionally, we uncovered that a rather small proportion of firms have received public financial support / subsidies for innovation (8% of the total) or other (9.9% of the total) activities. Resorting to Propensity Score Matching techniques, namely the average treatment effect on the treated (ATET) models, we gathered enough evidence that suggests that comparable firms that received subsidies for innovation activities tend to innovate more at technological, product, and process levels than those which have not received such subsidies. Moreover, the former firms are much more likely to outperform the latter in radical innovation performance.

Firms that received subsidies for other activities (beside innovation) outperform firms that received innovation subsidies in terms of intensity of new products and intensity of incremental new product innovation.

Our results have important implications. First, at the scientific level, we bring additional empirical evidence for the impact of public funding on the innovation performance of firms, since the results that already exist focus mainly on the general performance of firms, including R&D investment (Hottenrott & Richstein, 2020), total exports (Basto et al., 2021), employment level (Hottenrott & Richstein, 2020; Biancalani, Czarnitzki & Riccaboni, 2021), and business survival (Zhao & Ziedonis, 2020). Secondly, in terms of policy implications, even though we were not able to distinguish between the type of innovation policy instruments (e.g., grants/ subsides vs. tax incentives), the results indicate that subsidies for activities other than innovation have a greater impact on the firms' innovation performance, except in case of radical innovation. Thus, it is important for policy authorities to know that, depending on their purpose, the instrument to be used should be different.

Since our study proved that public funding (either to innovation activities or to other types of activities) is important for the innovative performance of firms, it is worrying that less than 10% of the 13701 studied firms, in the triennium of 2016 -2018, received these types of support. Increasing this type of support could in a moderate context, such as Portugal, foster firms' innovation capabilities and performance and in this way to help the country climb the ladder of innovation rankings.

Even though this dissertation has some contributions to the innovation literature, it presents several limitations. First, due to database constraints we were not able to distinguish between the impact of different types of policy instrument (direct subsidies, grants, and tax incentives). This would be an important avenue for further research but requires that CIS to include a question discriminating these policy instruments. In addition, our study has a specific context of a moderate innovator, in a specific period (2016-2018), so it would be interesting to analyse other periods and other contexts to check the robustness of the results.

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