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Does R&D tax credit impact firm behaviour? Micro evidence for Portugal Get access Arrow

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Does R&D tax credit impact firm behaviour?

Micro Evidence for Portugal

Alexandre Paredes[1], Joana Mendonça[2], Bruno Damásio[3], Fernando Bação[4]

Abstract

In this study, we use panel data to analyse the impact of an R&D tax credit on R&D personnel, particularly the impact on Ph.D. holders allocation, comparing low R&D intensity firms with medium-high and high R&D intensity firms. The results show that, in medium-high and high R&D intensity firms, the R&D tax credit had a significant impact on allocating Ph.D. holders in firms after three years of participation in the tax incentive scheme. We use a database covering 7710 firms that performed R&D at least once in Portugal over the twenty-three-year period 1995 to 2017, provided by the official business R&D survey data and a database of firms that applied for tax credit incentives at least once in the same period. Based on the estimation of impulse-response functions by local projections, we assess the impact of introducing the tax incentive scheme for corporate R&D in firms from different R&D intensity sectors.

Keywords: Firms, Ph.D. holders, R&D, Tax credit

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1. Introduction

As noted in recent studies, there is so far very little theoretical guidance or definite empirical evidence on the stimulating effect of public funding on private R&D (Dimos and Pugh, 2016, Wang *et al*., 2017, Vanino *et al*., 2019). Incentivising and providing the conditions for R&D investment by businesses ranks high on the innovation policy agenda of countries. In addition to providing direct funding for R&D through instruments such as grants and public procurement, many countries also provide indirect support through the tax system (OECD, 2019). Literature has shown the impact of a tax credit on firms' R&D activities (Billings, B. *et al.*, 2001), mainly at the aggregate or sectoral level (Bogliacino and Vivarelli, 2012; Antonucci and Pianta, 2002; Evangelista and Savona, 2002). Some relevant research has also started exploring increased technological collaborations or access to external financial and human resources as a result of subsidies (Ahn *et al*., 2020; Söderblom *et al*., 2015; Meuleman and De Maeseneire, 2012; Bianchi *et al*., 2019). There is relevant research comparing direct funding to perform R&D activities versus tax incentives as political instruments (Mansfield and Switzer, 1985). There is also work that assesses and compares the impact of public support, whether in the form of grants or tax credits, between SMEs and large firms (Wang and Tsai, 1998), and other authors focus on the impact of tax credits for business R&D on productivity (Ortega-Argilés *et al*., 2010; Parisi *et al*., 2006; Conte and Vivarelli, 2005; Mairesse and Sassenou, 1991). Finally, some research evaluate the impact of adoption of fiscal incentives instruments for R&D due to the conviction that R&D contributes to economic growth or assures competitiveness, to assist exporting companies in gaining market power in international markets (Ho *et al*., 2021). However, little is known about the impact of an R&D tax credit on R&D personnel, particularly the impact on highly qualified human resources who hold a Ph.D. Thus, an important novelty of this study is that its focus of interest shifted from the detection of possible effects of an R&D tax credit on R&D expenditure and consequently on productivity and economic growth for the detection of possible effects of an R&D tax credit on R&D personnel and in particular the effect on Ph.D. holders allocation.

Countries have used different policy instruments to promote and increase engagement in R&D activities, including R&D tax incentives. In the EU and OECD, several countries use this type of instrument (Appelt *et al*., 2016). This paper aims at evaluating the impact of R&D tax credits on the R&D activities of firms in Portugal. We make use of two databases containing R&D firm-level microdata from a twenty-three-year period 1995 to 2017, based on an R&D survey and administrative R&D tax relief microdata. We use a database covering 7710 firms that performed R&D at least once in Portugal, provided by the official business R&D survey data and a database of firms that applied for tax credit incentives at least once in the same period.

Our research gives a valuable contribution to the literature as it uses extensive data for a considerable period, allowing the evaluation of the effects of a concrete political instrument aimed at firms that performed R&D activities, not at an aggregate or sectoral level, but the firm level. A key advantage of studying the impact of R&D tax credits at a firm level is that it allows capturing much more variation in R&D tax subsidy rates than is possible at a more aggregate level of data (Bogliacino and Vivarelli, 2012), like evaluating and comparing the impact of R&D tax credits in different sectors of R&D intensity (Ortega *et al*., 2011).

In this context, we address the following research questions: Does a tax credit impact the allocation of Ph.D. holders at the firm level? Will this impact be identical both in firms that have performed R&D activities in low R&D intensity and medium-high and high R&D intensity sectors?

In this study, having access to a multitude of variables for the characterization of firms that performed R&D activities, namely types of expenditure, nature of human resources, whether they used internal funds or had access to public funds, and economic activity sector, we intend, considering the local projection approach (Jorda, 2005) to estimate the impulse-response functions (IRF) of SIFIDE[5] on the number of Ph.D. holders allocated at firm level from different R&D intensity sectors.

We find that R&D tax credits have significant implications after three years in the allocation of Ph.D. holders in medium-high and high R&D intensity sectors, those that by their nature necessarily require more highly qualified R&D personnel.

The remaining sections of this paper are organized as follows: we present a literature review on the R&D tax incentives and their impacts in section 2. In section 3, we present the data source and methodology used to assess the impact of R&D tax incentives on R&D personnel. We present and discuss the main findings in section 4 and conclude in section 5, suggesting the relevance of the findings for policies and potential avenues for future research in this area.

2. Background

2.1. The policy perspective and the effectiveness of R&D tax credits

R&D expenditures have long been an important concern for innovation analysts, who have used them as proxies for innovation inputs and have considered them a determinant of growth,

[5] Tax incentive scheme for corporate R&D

productivity, and competitiveness (Mowery and Rosenberg, 1989; Coccia, 2008). For this reason, R&D intensity targets are one of the main objectives of the European Union's research and innovation policy agenda, namely the Lisbon Strategy, devised in 2000, and the related Barcelona Target, set in 2003, which targets EU R&D expenditure to 3% of gross domestic product (GDP) on R&D, of which two-thirds should come from the private sector.

More recently, the importance of the Barcelona Target has been reiterated and reinforced in the Europe 2020 strategy, part of the EU flagship initiative (European Commission, 2010), which supports an increase in private research and innovation investment and places emphasis on the importance of policies positively affecting the demographics (creation and growth) of firms operating in new/knowledge-intensive industries.

The growing knowledge orientation of the economy and society, together with changes in the labour market, makes investment in skills and their lifelong upgrading increasingly important. Skilled human capital for research, innovation, and economic development is crucial in sustaining the needs of a knowledge economy (European Commission, 2020).

Economic theory indicates that knowledge development (Schumpeter, 1949) and technical change (Solow, 1957) are the major sources of productivity growth in the long term. R&D is a major source of technical change (Romer, 1990; Guellec and van Pottelsberghe de la Potterie, 2001), and this is recognized as a key element for increasing the knowledge base and, with it, the growth, productivity, and competitiveness of an economy (Mowery and Rosenberg, 1989; Coccia, 2008). In fact, most of the arguments in favour of policies targeted at raising the level and efficiency of R&D rely on the assumption that there are close links between R&D investment and micro-and macro-economic performance (Mitchell, 1999; Bilbao-Osorio and

Rodríguez-Pose, 2004; Griffith *et al.*, 2004; Kafouros, 2008). The effects of 'micro-macro convergence' of private and public drivers in the implementation and promotion of business R&D are not only visible in the potential returns in productivity but also in employment growth (Morbey and Reithner, 1990; Cincera *et al*., 2009; Hall *et al.*, 2010).

An increase number of countries adopted goals-based R&D policies to stimulate innovation and R&D based on two principles: business R&D is the main driver of innovation and economic growth; and, current R&D expenditures are insufficient to reach the desired levels of innovativeness and competitiveness (Carvalho, 2011). Governments can stimulate private R&D in different way, namely through direct funding, which include grants, loans, subsidies and incentives, such as tax credits. Many countries whether adopted fiscal incentive instruments for R&D, due to the conviction that R&D contributes to economic growth or assures competitiveness, or alternatively granting of subsidies, to assist exporting companies in gaining market power in international markets (Ho *et al*., 2021). However, direct government funding for private research has several disadvantages vis-à-vis R&D tax incentives. First, it results in substantially larger administrative costs. Furthermore, government do not have an information advantage as to which projects will succeed or potentially bring highest social returns (CPB *et al*., 2014). Governments increasingly rely on R&D tax incentives to promote business R&D investment, expecting this to result in at least additional R&D performance - often described as input additionality (Appelt *et al*., 2016). Both theoretical and empirical evidence shows that tax incentives effectively help firms reduce R&D costs and achieve market efficiency (Hall and van Reenen, 2000). Between tax incentives and direct funding, literature shows that tax incentives have a lower administrative burden and mitigate the risk of "picking losers" more than direct funding (Dechezleprêtre *et al*., 2016). Therefore, tax incentives are more market-friendly and have become more prevalent in facilitating R&D activities (OECD, 2014).

Firms' R&D efforts in response to policy changes may vary depending on whether policy changes are perceived to be permanent or transitory. Thus, the magnitude of public support may vary over time and be affected by firms' R&D investment behaviour and its persistency. The additionality of R&D tax incentives may also vary with their design and with the use of direct funding or other forms of government support (Appelt *et al.*, 2016). Different tax treatments of different expenditure categories imply that tax policies vary in their relative generosity across industries, being crucial to find exogenous measures and tax policy instruments that exhibit sufficient variation to identify their impact robustly (Thomson, 2017).

2.2. The different dimensions of analysis of an R&D tax credit

The reasons behind the growing preference for the tax incentives go beyond any possible advantage of any tax incentive scheme over direct support measures (Carvalho, 2011). Despite many scholars believe that the production and dissemination of knowledge exhibit a range or market failures and these failures are likely to undermine incentives to invest in R&D and introduce new innovations (Geroski 1995), the market failure is no longer the sole economic rationale for the public support of private R&D. Others factors reveals being more important, namely the *absorptive capacity* and in particular the competition for R&D investment and human resources highly qualified, namely researchers to perform R&D activities. R&D is essential to a firm's *absorptive capacity* – "the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends is critical to its innovative capabilities" (Cohen and Levinthal, 1990).

Studies carried out to date assessed and compared the impact of public support for R&D activities, whether in direct funding (grants) or tax credits, but little is known about the impact that these instruments have on R&D personnel, in particular. Those studies were developed at the sectoral level where (micro)data of firms arises aggregated by economic activity sector. However, at the sectoral level, the impact of public support for R&D activities can be affected by biases and negative (Antonucci and Pianta, 2002) or positive effects (Evangelista and Savona, 2002) on employment, depending on the activity sector. Bogliacino and Vivarelli (2012) took a sectoral approach and showed the positive and highly significant impact that R&D expenditure has on employment. This study suggests, however, that further investigation at the firm level is needed.

Aggregate micro-level statistics can be particularly useful for understanding industry and macro-level dynamics and are thus extremely valuable for policy design, monitoring, and evaluation. Moreover, micro-level statistics allow the evaluation of an economic system's characteristics at the most accurate scale (unitary/firm) and industry and macro-level when such data can be aggregated. The majority of studies at a macroeconomic level show a positive effect of public funding and tax incentives on private R&D expenditure (David *et al*., 2000). The problem of a study at the macroeconomic level is that both types of funding (public and private) may be influenced by common factors (Guellec and van Pottelsberghe, 2003), with consequent bias in the estimated relationships.

The existing literature allows identifying the positive impact that R&D expenditure has on productivity (Mairesse and Sassenou, 1991; Ortega-Argilés *et al*., 2010), however little is known about the impact that R&D expenditure has on employment. The French *Jeune Entreprise Innovante* (JEI) scheme supports firms who have been in business for less than eight years and whose R&D expenditure represents at least 15% of tax-deductible expenditure. Small technology firms are the primary beneficiaries of this scheme (fewer than 20 employees). Firms that benefited from the JEI scheme in 2004 or 2005 experienced higher annual employment growth, with an estimated growth differential of 8.4 percentage points compared with similar firms that did not receive the JEI scheme support (Mitchell, J. *et al*., 2020).

The majority of studies focused on the impact of innovation activities on productivity, competitiveness, economic growth, and employment dynamics (Conte and Vivarelli, 2005; Parisi *et al*., 2006). However, innovation is a much broader concept than R&D, and not all firms that are successful at developing or implementing innovation are necessarily R&D performers, as noted by the OECD Innovation Strategy (OECD, 2010) and its update (OECD, 2015a).

As economies become more knowledge-based and dependent on intangible assets, economies and firms achieve large returns on R&D investments, creating new and better jobs (European Commission, 2020). Incorporating and performing R&D activities, require personnel with high levels of knowledge and specialization together with scientific and technical expertise. The terms of incorporating R&D are different from sector to sector, particularly when comparing high-tech and low-tech sectors (Pavitt, 1984). The larger the weight of knowledge-intensive sectors, the higher the capacity to invest in R&D. Among knowledge-intensive activities, high and medium-high-tech manufacturing are key engines for R&D investments in the business sector (Coad and Vezzani, 2017; Hernández *et al*., 2018).

In studies carried out to date, firms in the high-tech sector, requiring more highly skilled human resources, not only have higher R&D expenditure but also the efficiencies and higher productivity compared with companies in the low-tech sector (Ortega *et al*., 2011). In recent studies (Piva and Vivarelli, 2018; Barbieri *et al*., 2019), a positive effect of R&D expenditures totally due to firms operating in high-tech industries and large companies was found while no job creation due to technical change was detectable in traditional sectors. For these reasons, the present research focuses on the impact of an R&D tax credit and its implications on the educational composition of R&D personnel in firms, particularly in the allocation of Ph.D. holders, whether in low R&D intensity firms or medium-high and high R&D intensity firms.

2.3. The design of R&D tax relief provisions in Portugal

Government support for business R&D seeks to encourage firms to invest in knowledge that can result in innovations that transform markets and industries and result in benefits to society. For this purpose, beyond providing grants and buying R&D services ("direct" support), many governments provide fiscal incentives. These fiscal incentives can take the form of advantageous tax treatment of innovation inputs (R&D expenditures), as well as preferential treatment of R&D outputs (incomes from licensing or asset disposal attributable to R&D or patents).

The will to foster a knowledge-based economy has led several countries, including Portugal, to a greater compromise with public policies to stimulate business R&D. Since the introduction of SIFIDE in 1997, with a temporary suspension of the R&D tax credit in 2004-05, there has been a sustained growth of total government support to business R&D as a percentage of GDP, considering ‘the police mix’: direct government funding of business R&D and tax incentives for R&D (Carvalho, 2013; OECD, 2021).

Public support is provided to firms with the intention of correcting or alleviating difficulties to appropriate the returns to their investment in new knowledge and shortcomings in the market for the financing of risky projects, especially for small start-up firms without collateral. Public support for business R&D is typically justified as a means of overcoming these market failures. In addition, countries may use tax incentives to attract the R&D activities of multinational corporations (MNEs) which typically account for a substantial share of R&D expenditure (Appelt *et al*., 2016).

In its scientific and technological system, Portugal provides a tax relief through a hybrid R&D tax credit. Start-ups enjoy an enhanced credit rate on R&D volumes as long as they have not yet made use of the incremental tax offset. The mains features of the R&D tax incentives in Portugal are: in the case of insufficient tax liability, unused credits can be carried-forward for 8 years; the base amount above which R&D expenditures qualify for the incremental tax credit is defined as average amount of qualifying R&D expenditures in the two previous fiscal years; there is no ceiling and incremental R&D expenses are capped at EUR 1.5 million (OECD, 2021).

3. Data and methodology

3.1. Data source

To develop this analysis, we used data from the official business R&D survey[6] data over the twenty-three-year period 1995 to 2017. The R&D Survey is a compulsory survey delivered to all firms that potentially performed R&D activities in Portugal. The information collected focuses on resources related to R&D activities, financing, and performing R&D activities. In Portugal, the landscape of R&D expenditure structure changed significantly in this period, with the Business Sector representing 21% of the total weight in 1995 while in 2017 representing more than 50% (DGEEC 2021 and DGEEC 2014. available at: (https://www.dgeec.mec.pt/np4/206/).

The R&D survey is a census survey of all firms that potentially performed R&D activities between 1995 and 2017. The survey was only conducted in the odd years (every two years) between 1995 and 2007 and became annual after 2008. In this period, 7710 firms carried out R&D at least once but not in all the years. Therefore, we faced an unbalanced panel of firms.

Data on R&D tax incentives were gathered through administrative data. The R&D tax incentive database is also an unbalanced panel of firms since 1997 to 2015, the tax incentive system was disrupted in 2004 and 2005, and the fact that 2875 firms resorted to tax incentives in at least one year, but not in all the years.

For this analysis, we merged both databases using firms' fiscal numbers as the primary key. Although the periods of the two databases are not precisely coincident - the database created from the surveys has data for 1995 to 2017, while the database created from tax incentives has data for 1997 to 2015 - it was decided to maintain these two periods with the following objectives: (i) having data on R&D activities from 1995 onwards, assess the impact of the

[6] Follows the Eurostat and OECD methodological guidelines and the definitions of the Frascati Manual

introduction of the tax incentive system (1997); and ii) with available data on the tax credit granted up to 2015, assess the impact of this measure on expenditure on R&D activities up to two years (2017) after the tax credit was granted.

After merging the two databases, some outliers were identified. For instance, in the twenty-three-year period, some firms could be in the database in a single year with high R&D expenditure. Since it is unlikely that a firm would invest a massive amount in R&D in a single year, we investigated this situation and realized that, in fact, this could happen as a result of a change in the status of the firm or as a result of mergers, acquisitions and the reorganization of a group of firms. In these cases, there was a change in the fiscal number and, as a consequence, a change in the ID number in the database.

Outliers were removed from the database when a firm invested a large amount in R&D in only a single year. For the sake of data quality in the time series, in cases of mergers, acquisitions, and reorganizations of a group of firms, firms within the group were grouped according to the same area of economic activity (NACE at 2-digit level). The primary purpose of this aggregation was to create subgroups of firms performing R&D in the same NACE allowing to treat them coherently in the time series and avoid treating them as outliers and simply to delete those records.

For this analysis and from the official business R&D survey database, we used the following set of variables at the firm level: at the human resources level, the number of R&D personnel, the total full-time equivalent (FTE) staff, and the number of doctorates. In terms of R&D expenditure, the following variables were used: current R&D expenditure (labour costs of R&D personnel and other current R&D costs), capital R&D expenditure (land and buildings;

machinery and equipment), internal funds, expenditure according to the sector of activity (NACE Rev. 2). Despite the existence of other sources of funds data, their share in the whole were negligible. In fact, firms have limited access to external finance and to rely on their internal funds to undertake R&D projects (Sterlacchini and Venturini, 2019). A dummy variable was created for firms that resorted to tax credits (1 if a firm resorted to tax incentives and 0 if not).

We used the OECD taxonomy of economic activities based on R&D intensity based on International Standard Industrial Classification, ISIC Revision 4 (OECD, 2016) since this taxonomy focuses solely and explicitly on a measure of R&D intensity[7]. This taxonomy is an alternative to the taxonomy proposed by Eurostat and OECD to classify the manufacturing industry according to technological intensity and knowledge-intensive services based on NACE Rev. 2.

In the present study, we adopt the concept of R&D from the Frascati Manual, where R&D comprises creative and systematic work undertaken in order to increase the stock of knowledge - including knowledge of humankind, culture, and society - and to devise new applications of available knowledge (OECD, 2015b).

Table 1 presents the summary statistics of the data used. It is worth mentioning that 7710 firms performed R&D at least once but not in all the years and the fact that 2875 firms resorted to tax incentives in at least one year, but not in all the years.

[7] R&D intensity is calculated as the industry's business R&D expenditure divided by gross value added

Table 1. Summary statistics and description of the variables

Variable	Mean	SD	Min	Max	Description
Employee	121.59	785.85	0	37,437	Number of employees
R&D employee	6.99	27.52	0	1,172.80	Employees in R&D activities
PhD	0.39	1.69	0	83	PhD holders
Current expenditure	386.41	1,959.46	0	71,535.37	Current R&D expenditure (€ 000's)
Labor costs	236.2	1,133.55	0	49,794.78	Labor costs of R&D personnel (€ 000's)
Other current costs	150.20	1,143.54	0	51,326.75	Other current R&D costs (€ 000's)
Capital expenditure	123.13	2,209.11	0	176,491.85	Capital R&D expenditure (€ 000's)
Internal funds	442.82	3,169.75	0	191,719.01	Internal funds for R&D (€ 000's)
SIFIDE	0.23	0.42	0	1	Dummy, 1 if a firm resorted to tax incentive and 0 if not

Firms have limited access to external finance and have to rely on their internal resources to undertake R&D projects. Credit constraints to R&D are mainly due to information asymmetries between firms and lenders, which make monitoring costs very high, as well as to the intangible nature of R&D that makes these investments hard to collateralised (Brown *et al*. 2012). This might also explain the fact that the weight of public funds in total of funds for R&D in the set of 7710 firms that performed R&D at least once our database is negligible, and for this reason in our research we used only the internal funds variable.

3.2. Methodology

As regards the firm size class, the theoretical framework of determinants of corporate R&D intensity of a given country depends on both the sector (structural) composition effect and intrinsic effect (Pakes and Schankerman, 1984; Erken, 2008; Mathieu and van Pottelsberghe de la Potterie, 2010; Becker and Hall, 2013; Sterlacchini and Venturini, 2019). The structural factors affecting an economy can be exogenous or endogenous. Endogenous factors are characteristics typical of a given industry sector(s), while exogenous factors are usually external to the sector(s) and the country's macroeconomic system. Intrinsic factors determine the characteristics of the firm(s) and its behaviour, for example, the firm's knowledge, financial capacity or strategy, and its R&D investment (Moncada-Paternò-Castello and Smith, 2009).

Firm location is also an important factor as a firm's R&D investment increases with its proximity to universities and a skilled labour force (Vivarelli, 2013; Capello, 2014; Amoroso *et al.*, 2015), namely, Ph.D. holders.

The variation of R&D tax incentives support can be used to compare the R&D performance of firms that receive support and those that do not. The fundamental estimation challenge is that it is not possible to observe the "counterfactual" – how much R&D the firms receiving R&D tax relief would have performed if they had not received this support. Given the inability to observe the "counterfactual" directly, the best alternative is to compare the firms that receive tax relief with those that do not receive it but are as similar as possible.

In the present study, we consider the local projection approach (Jorda, 2005) to estimate the impulse-response functions (IRF) of SIFIDE on R&D personnel. Considering the IRF, we assessed the impact of – introduction of SIFIDE – on the different R&D personnel categories: persons employed, R&D personnel in FTE, and Ph.D. holders. First, this assessment was made considering all firms regardless of the economic activity sector, and then by organizing firms by economic activity sector using the NACE Rev.2 classification, particularly according to R&D intensity criteria, from low to high R&D intensity.

Furthermore, we track the h-period ahead impact of SIFIDE event (participation in the tax incentive scheme) occurring in firm i and year t on the cumulative growth of the number of R&D personnel, by way of the estimation of the following successive equations:

$$y_{i,t+h} - y_{i,t-1} = \boldsymbol{x}'_{it}\boldsymbol{\beta}^{h} + \delta^{h} D_{it} + \varepsilon_{i,t+h}, \text{where } \varepsilon_{i,t+h} = \lambda_{t+h} + \mu_{i} + v_{i,t+h}$$

Where: $y_{i,t}$ denotes the number of R&D personnel in the i-th firm and period t (therefore $y_{i,t+h} - y_{i,t-1}$ is the growth from $t-1$ to $t+h$); $\boldsymbol{x}'_{it}$ is a vector of covariates (in our case labour costs of R&D personnel and capital R&D expenditures); D_{it} is a binary variable that takes value one if the i-th firm participated in the SIFIDE program in period t and zero otherwise. It is worth noting that our main interest comprises the coefficients δ^h as these quantities underpin the structure of the IRF, as we shall see later on. It should also be pointed out that, to ensure the appropriate identification of the causal effect of R&D expenditure on R&D employment, that is, to avoid endogeneity issues, both time and firm fixed effects were considered and denoted by, respectively, λ_{t+h} and μ_i. $v_{i,t+h}$ is an idiosyncratic random disturbance i.i.d. robust clustered standard errors are considered.

The advantages of local projections are numerous: i) they can be estimated by simple regression techniques with standard regression packages; ii) they are more robust to misspecification; iii) joint or point-wise analytic inference is simple; and iv) they easily accommodate experimentation with highly nonlinear and flexible specifications (Jorda, 2005). Since local projections can be estimated by univariate equation methods, they can be easily calculated with available standard regression packages. Moreover, local projections are easy to implement, the shocks are estimated in a robust way, the inference is simple and more important allow to capture the dynamic effect of shock and not only the static effect of shock like in a propensity score matching design.

4. Results and discussion

The results from the model adopted show that the fiscal shock – the introduction of SIFIDE, had no significant impact in the two first categories of R&D personnel (persons employed and R&D personnel in FTE), but a positive impact in the case of Ph.D. holders. Fig. 1 shows the positive impact of introducing the tax incentive scheme for R&D (SIFIDE), regardless of the R&D intensity sector, in Ph.D. holders allocation.

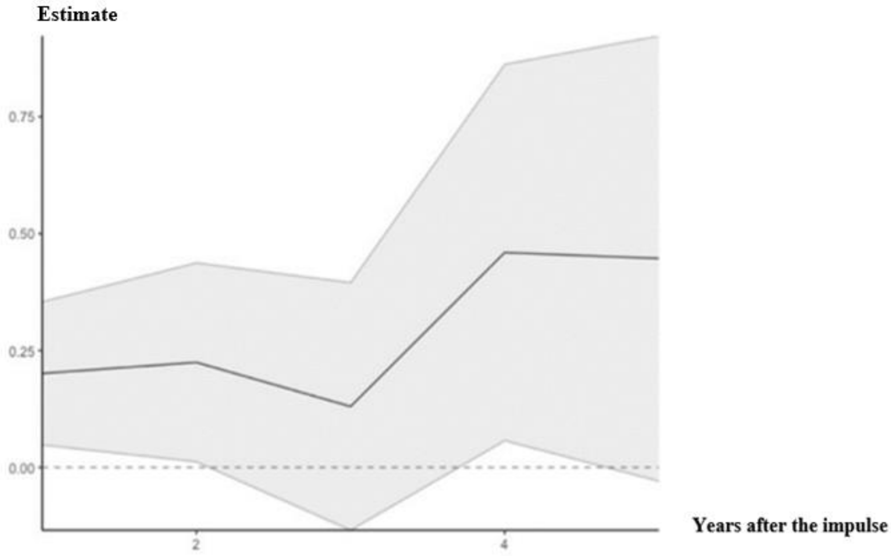

Figure 1. Impulse responses to a shock in the introduction of tax incentive scheme (SIFIDE): all firms, regardless of the technological intensity

Notes: The solid central dark line is the response corresponding to estimates based on the model adopted for the set of firms that performed R&D; the shaded grey area is the conventional 95-percent confidence level error of the linear projection response.

In Fig. 1, we can observe the impact of the introduction of SIFIDE in a defined period, where the solid central dark line represents the IRF, whereas the shaded grey area is the 95% confidence interval. Based on the model adopted, the solid central dark line show predicted values h-period after the impact of SIFIDE event. Considering the whole set of firms, regardless the R&D intensity sector, in the short-run (one year after the impulse) there is a positive impact in the cumulative addition of Ph.D. holders (0.20) and three years later the cumulative addition of Ph.D. holders is much more significant – more than double: in the beginning of the period was 0.20 and in the end 0.45 (see table 2). These findings are in line with the results from Martinez-Ros (2019), where the results showed a positive impact of

R&D&I tax credit and environmental investment on employment for Spanish MSMEs (micro firms), and SMEs. In the same fashion, these findings are in line with the results observed in France in 2004 and 2005, where firms that benefited from the *Jeune Entreprise Innovante* scheme experienced higher annual employment growth, with an estimated growth differential of 8.4 percentage points compared with similar firms that did not receive the JEI scheme support (Mitchell, J. *et al*., 2020).

The multitude of variables for the characterization of firms that performed R&D activities in Portugal, as already described, namely the nature of human resources, led us to evaluate the impact of SIFIDE in the Ph.D. holders allocation and not only the R&D personnel overall.

Table 2 shows the impact of introducing the tax incentive scheme for R&D (SIFIDE), where all firms were included regardless of the R&D intensity sector. We can observe that the tax credit had a slight impact in Ph.D. holders' allocation, whether in the short-run (0.20) or three years ahead (0.46), but remaining stable in the subsequent years (0.45).

Table 2 - Impulse responses to a shock in the introduction of a tax incentive scheme in all firms

Years after the impulse	h=1	h=2	h=3	h=4	h=5
Estimate	0.20	0.23	0.13	0.46	0.45
Std. Error	0.09	0.13	0.16	0.25	0.29
t-statistic	2.16	1.74	0.81	1.88	1.54
p-value	0.031	0.082	0.418	0.060	0.123
Number of observations included	5829	5476	5078	4020	3133
Number of events included	3042	2890	2694	2163	1686

Notes: The table reports the Estimates of the impulse response function, where dependent variable $y_{i,t}$ denotes the number of PhD holders and Estimates the predicted values h-period after the impact of SIFIDE event.

Considering the set of firms, regardless the R&D intensity sector, a firm that having performed R&D and resorted to tax incentives had a positive impact of 0.20 in the cumulative addition of Ph.D. holders one year later and 0.45 five years later.

To better understand the impulse responses to a shock in the introduction of SIFIDE, we assessed this impact in firms classified in different R&D intensity sectors, namely comparing low R&D intensity with high R&D intensity.

All firms were classified according to the NACE rev.2, which allows us to classify them according to the R&D intensity. After assessing the impact of the introduction of the tax incentive scheme in overall firms, we assessed the same impact by one hand in the firms classified as low R&D intensity and by the other hand the firms classified as medium-high and high R&D intensity[8].

When compare low R&D intensity firms with medium-high and high R&D intensity firms, we can observe (Fig. 2) that in the low R&D intensity firms, the impulse responses to a shock (introduction of SIFIDE) remain stable after a second year, and the grey area of the confidence region falls into a negative area (under zero).

[8] Since the number of firms classified as high R&D intensity was relatively low we considered both categories together: medium-high and high R&D intensity

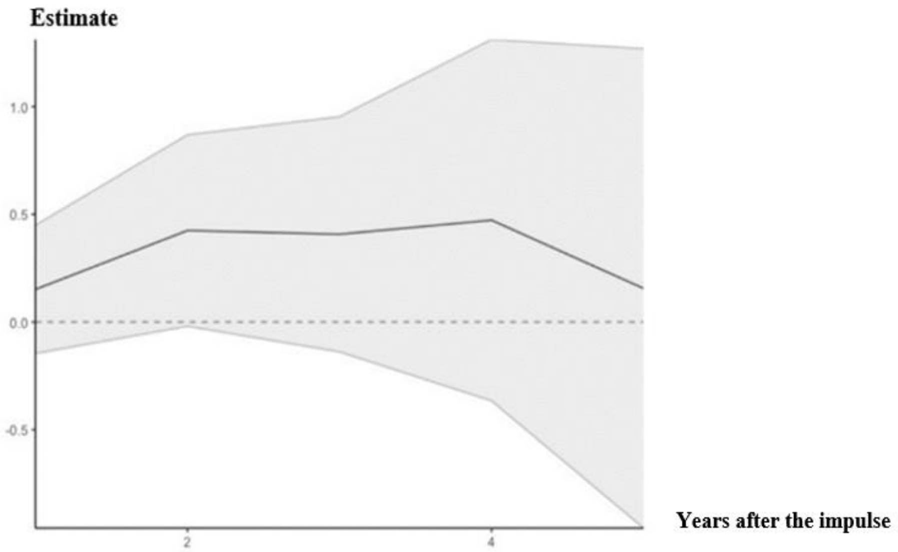

Figure 2: Impulse responses to a shock in the introduction of tax incentive scheme in the Low R&D intensity firms

Notes: The solid central dark line is the response corresponding to estimates based on the model adopted for the set of firms that performed R&D; the shaded grey area is the conventional 95-percent confidence level error of the linear projection response.

We can observe a very different situation in the medium-high and high R&D intensity firms (Fig. 3), sectors that by their nature require highly qualified human resources (Ph.D. holders). Here the effect is very clear and permanent, where a significant impact in the Ph.D. holders allocation exists after three years, and the grey area (95% confidence interval) is clearly above zero. Regardless the type of R&D performed, basic research, applied research or experimental development, PhD holders play a determinant role within firms as researchers. R&D contributes to a firm's *absorptive capacity*, where Ph.D. holders are determinant in influencing the *absorptive capacity* within firms. Firms need to develop *absorptive capacity* by interacting with academia (Rafols, I. *et al*., 2013).

In Fig. 3, we can observe that in the short-run (one year after the impulse) there is a positive impact in the cumulative addition of Ph.D. holders (0.46) and four years later this cumulative addition of Ph.D. holders is much more significant (1.18). The estimates gathering from the model adopted shows that in the case of the medium-high and high R&D intensity firms, beyond the significant increase of the cumulative addition of Ph.D. holders these firms turned to be more prone to increase their *absorptive capacity* with natural implications in their innovative capabilities.

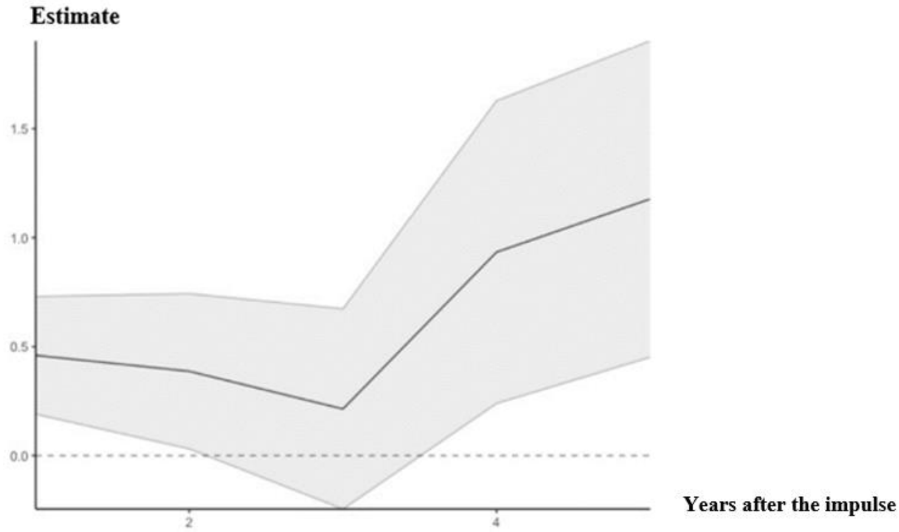

Figure 3: Impulse responses to a shock in the introduction of a tax incentive scheme in the Medium-high and High R&D intensity firms

Notes: The solid central dark line is the response corresponding to estimates based on the model adopted for the set of firms that performed R&D; the shaded grey area is the conventional 95-percent confidence level error of the linear projection response.

These findings are in line with the results from Evangelista and Savona (2002), where the results show that public support for R&D activities can positively affect employment, depending on the activity sector. In the same fashion, these findings are in line with the results from Bogliacino and Vivarelli (2012). Despite taking a sectoral approach (having suggested further investigation at the firm level), it shows a positive and highly significant impact that R&D expenditure has on employment.

Finally, Table 3 shows the difference observed when comparing the estimations of the impact of the tax incentive scheme in low R&D intensity firms with medium-high and high R&D intensity firms. Here we can observe distinct estimates when comparing the impact in the Ph.D. holders allocation after three years and subsequent years in low R&D intensity (0.41 and 0.16) with the medium-high and high R&D intensity firms (0.93 and 1.18). Comparing the two R&D intensity sectors, we can observe that in the short-run (one year after the impulse) the cumulative addition of Ph.D. holders in the medium-high and high R&D intensity firms (0.46) is more than three times higher than in low R&D intensity firms (0.15). Four years later there was a stagnation in the addition of Ph.D. holders in low R&D intensity firms (0.16), while in the medium-high and high R&D intensity firms there was a significant increase (1.18).

Table 3 - Impulse responses to a shock in the introduction of tax incentive scheme: Low R&D intensity firms versus Medium-high and High R&D intensity firms

	Low R&D intensity firms					Medium-high and High R&D intensity firms				
Years after the impulse	h=1	h=2	h=3	h=4	h=5	h=1	h=2	h=3	h=4	h=5
Estimate	0.15	0.43	0.41	0.41	0.16	0.46	0.39	0.21	0.93	1.18
Std. Error	0.18	0.27	0.33	0.33	0.68	0.16	0.22	0.28	0.42	0.44
tstat	0.84	1.57	1.23	1.23	0.23	2.80	1.79	0.77	2.21	2.67
p-value	0.403	0.116	0.219	0.219	0.818	0.005	0.074	0.444	0.027	0.008
Number of observations included	5829	5476	5078	4020	3133	5829	5476	5078	4020	3133
Number of events included	813	750	679	521	388	2229	2140	2015	1642	1298

Notes: The table reports the Estimates of the impulse response function, where dependent variable $y_{i,t}$ denotes the number of Ph.D. holders and Estimates the predicted values h-period after the impact of SIFIDE event. Estimates were calculated separately for the low R&D intensity firms and medium-high and high R&D intensity firms.

This means that, while for the low R&D intensity firms, at the end of the period, there is no cumulative addition of Ph.D. holders (the addition of Ph.D. holders is residual in the last year: 0.16), the other way around, in the medium-high and high R&D intensity firms there is a significant incremental number of Ph.D. holders (cumulative addition of 1.18 on average per firm in the last year).

5. Conclusions

The limited number of studies on the impact of fiscal schemes makes it difficult to draw any major policy conclusions or distinguish between the merits of these policy instruments' various designs. Nevertheless, despite the noted limitations, we can conclude that R&D tax credit is important since it positively impacts Ph.D. holders' allocation. We conclude that there is sufficient evidence to suggest that the tax credit implemented in Portugal offers an attractive source of support for firms in the allocation of Ph.D. holders, in particular in the medium-high and high R&D intensity sectors.

The paper analyses the impact of tax incentive scheme for corporate R&D on R&D personnel on an unbalanced panel of 7710 firms that performed R&D at least once in Portugal over the twenty-three-year period 1995 to 2017. The results from the model adopted suggest that the tax credit impacts the allocation of Ph.D. holders at firm level and this impact is different depending on the R&D intensity sector. The results suggest that the tax credit impact, on the cumulative addition of Ph.D. holders on average per firm, is much more significant in firms from medium-high and high R&D intensity sectors than in firms from low R&D intensity, after three years, in particular in the last year.

A tax credit scheme must be designed and implemented to induce a positive socio-economic impact, whether temporary or more permanent. The reported results contribute to the literature since they suggest that, from the science and technology policy perspective, firms from medium-high and high R&D intensity sectors that applied for tax credit incentives at least once are more prone to allocating Ph.D. holders, in particular after three years.

Policymakers need to consider the context firms face and many characteristics of firms, namely the economic activity sector and, in particular, the R&D intensity sector. The design of policy incentives should also be specific, rather than generic, focusing on targeting and identifying firms that are more proactive in performing R&D activities. We contribute to the literature by analysing the impacts of a public instrument on R&D personnel for firms of different R&D intensity sectors. Additionally, policymakers must invest in human capital to face potential skill shortages. More importantly, such policies must be designed and implemented in a way such that they produce assets and net positive social returns.

The findings of this paper are essential for both top managers and policymakers. From the management point of view, our research points to the possibility that top managers in firms can adjust their R&D activities, namely the composition of R&D personnel. Knowing the impact in the allocation of Ph.D. holders, year after year, would help in the development of the program of work and budget of R&D projects. Regardless the type of R&D performed, basic research, applied research or experimental development, PhD holders play a determinant role within firms as researchers. R&D contributes to a firm's *absorptive capacity*, where Ph.D. holders are determinant in influencing the *absorptive capacity* within firms. Firms need to develop their *absorptive capacity* by interacting with academia (Rafols, I. et al., 2013). From the policy perspective, our research highlights the impact of a policy instrument in the composition of R&D personnel from the business enterprise sector. Therefore, policy instruments can be improved and better designed to boost R&D activities and particularly the allocation of Ph.D. holders.

A further promising avenue for future evaluation research could be to explain the choice of the type of instrument (e.g., grants versus tax credits) based on the characteristics of firms (e.g., size, year of registration), since for instance, SME are the dominant structure of the Portuguese economy. Future research should explore the impact of a tax incentive scheme for corporate R&D in productivity, at the firm level, particularly in medium-high and high R&D intensity sectors, where the reported results in this study suggest that firms in these sectors of R&D intensity are more prone to allocating Ph.D. holders. Future research should also explore the impact of a tax incentive scheme for corporate R&D in the allocation of R&D personnel, namely researchers, regarding the academic background and, in particular, the allocation of Ph.D. holders regarding their research area.

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[9] Tax incentive scheme for corporate R&D – Law No. 52-C/1996, December 27
[10] Tax incentive scheme for corporate R&D – Law No. 55-A/2010, December 31

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