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Abstract: This paper assesses the impact of public R&D subsidies on business R&D investment in heterogeneous institutional frameworks. Public support for research and innovation activities may leverage private resources when firms are constrained by lower quality public institutions, reducing uncertainty and favouring private risky investments. We develop an institutional index based on existing indicators and group regional economies on the basis of the quality of their public institutions. We use a comprehensive sample of Spanish firms observed over more than 20 years and a larger dataset of 13 European economies drawn from the Community Innovation Survey 2014 to test the policy impact in terms of private R&D expenditure for companies operating in different institutional frameworks. Our findings reject full crowding-out and show that beneficiary firms invest more in R&D than non-beneficiaries in all regions, including those with lower institutional quality. Our results support the case of policies that promote research and innovation activities in weaker institutional contexts.

Keywords: R&D subsidies; Innovation performance; Institutions; Institutional quality; Policy evaluation

[1] The views expressed here are purely those of the authors and may not under any circumstances be regarded as stating an official position of the European Commission.

1. Introduction

Risk aversion, capital market imperfections and incompleteness in appropriating returns are among the factors explaining why private investment in R&D is typically lower than its social optimum. Economists have long argued that higher R&D investments by corporate actors are socially desirable because of the positive externalities on the society as a whole, both in terms of the technological opportunities which would benefit a wide range of users and the economic returns (Nelson, 1959; Arrow, 1962; David et al., 2000). Such a "market failure" argument justifies government support to business R&D activities, and public funding to R&D (i.e., subsidies) is one among the key policy options. From a macroeconomic perspective, while returns to R&D vary across countries and industries, calculations by the IMF (2016) suggest that increasing public subsidies to the social optimal level would lead to 40% higher business R&D investment and a corresponding long-term increase in GDP in national economies and globally by 5% and 8%, respectively.[2] Efficient and smart use of public resources has come to be viewed as a political priority in the aftermath of the economic crisis, as government funding has become a scarce resource and austerity policies have been required to several economies in the European Union (EU) (European Commission, 2010; Veugelers, 2016a).

The literature on the impact of subsidies for business R&D has for long focused on whether public support is characterised by either crowding-in – i.e., additional investment by recipient companies compared to those who do not receive public support – or crowding-out – i.e., recipient firms substitute their own resources with external funding. Theoretically, both outcomes are possible. On the one hand, companies may use public support to divert their own resources to other activities. This may be the case for R&D projects that could be successful regardless of external resources or that would otherwise be funded: the former may be an explicit choice of public agencies in view of increasing the probability of success (*cherry-picking*), the latter is often due to information asymmetries between the firm and the funding body. On the other hand, the availability of public funding may provide companies with the financial support they need to kick off their activities, in turn leveraging private resources that would not otherwise be mobilised.

Empirically, the conclusion as to whether public support leads to crowding-out or additionality varies significantly depending on the sample, period and empirical methodology. Although the literature is vast, we can safely conclude that a *small positive effect* is in place and that public subsidies are *generally not wasted*.[3] Yet, the relationship between subsidies and innovation performance is very subtle and several questions are still open. For instance, a positive impact is usually observed for financially constrained companies, where the availability of public support acts as a substitute for external finance, in particular for small and medium-size

[2] See IMF (2016) for details about the assumptions on output elasticity of private R&D, spillovers and elasticity of R&D investment to user cost. See also the discussion in Donselaar and Koopmans (2016).

[3] For instance, Becker (2015) undertakes an exhaustive survey of the empirical literature on the effects of public R&D policies and concludes that post-2000 empirical evidence reveals an overall positive effect of public subsidies in stimulating private R&D investment. A detailed review of the extant literature linking R&D subsidies and firm performance is beyond the scope of this article. Interested readers may consult surveys and meta-analyses in Garcia-Quevedo (2004), Zúñiga-Vicente et al. (2014), Becker (2015) and Dimos and Pugh (2016).

enterprises (Hyytinen and Toivanen, 2005; Zúñiga-Vicente et al., 2014). Other studies document that the impact of public subsidies is larger for radical innovation projects, that is where the probability to experience market failure and the risk associated to R&D investment are higher (Beck et al., 2015).[4] Czarnitzki and Lopes-Bento (2014) show that the effect of public subsidies might also depend on the source of funding, while Hud and Hussinger (2015) identify a crowding-out effect for the crisis year 2009.

Although a growing part of the empirical literature focuses on cross-country comparisons (Czarnitzki and Lopes-Bento, 2012; Grilli and Murtinu 2014; Aristei, 2017), the role of the institutional framework in determining the outcome of public support schemes to business R&D remains largely unexplored. This corresponds to implicitly assume that the institutions regulating economic and social exchanges have no relevant role in shaping the impact of public policy or, alternatively, that the institutional setting is homogeneous across regions and countries. However, if institutions do actually contribute to shape individual and collective choices, then we have reason to suspect that they also might have an effect on the effectiveness of public policy schemes, in particular in the realm of research and innovation.

The role that institutions play in shaping economic performance of countries has received increasing attention in both the theoretical and empirical economic literature. Institutions are typically defined as the set of rules determining the possible alternatives that individuals face when taking economic and social choices (North 1990; Williamson 2000). They determine the opportunities that economic and social agents may consider as viable to achieve their scope, as well as the constraints that society imposes to their decision-making process, setting *the effective ways to get things done* (Nelson and Nelson 2002, p.269). While this is a neutral definition, there is consensus that a higher quality of the institutional framework results in a higher performance of the economic system (see, e.g., Acemoglu et al., 2001; Rodrik et al., 2004; Acemoglu and Robinson, 2012). The definition of what makes institutions conducive to economic growth can be summarised into two main characteristics. First, institutions are social constructs that are built with the reduction of transaction costs as their main aim (Coase, 1960; Coase, 2005; North, 1991). The better they are at meeting this objective, the greater their contribution to economic performance. The efficient and effective delivery of public goods and services allows economic actors to engage in economic activities at a lower cost. Second, a clear definition and protection of property rights is fundamental to incentivize economic activities (North, 1991). Economies failing to guarantee the enforcement of contracts and constraining the discretionary power of public authorities should experience lower economic activity due to higher uncertainty in the appropriability of economic value, favouring rent seeking behaviour rather than entrepreneurship and value added creation (North, 1990; Acemoglu et al., 2004; Acemoglu and Johnson, 2005).[5] However, the protection of property rights should not

[4] Governments may have indeed a positive role in promoting highly risky innovative investment, leading the way for the most radical, path-breaking types of innovation and opening new avenues for technological advance and economic growth. This is a more complex perspective which goes beyond fixing market failures, supported by the history of innovation (Mazzucato, 2015) and consistent with smart growth and specialization policies advocated by the European Union (European Commission, 2010).

[5] It must be stressed that such theoretical framework is neutral, i.e. it does not imply that a specific regime is needed in order to achieve socio-economic prosperity. See for instance Gleaser et al. (2004).

be limited to an arbitrary subset of economic agents. On the opposite, it needs to be extended to all actors, and should encompass the ownership, the use but also the transfer of property. Adopting Ogilvie and Carus (2014) terms, property rights need to be generalised in order to boost prosperity and growth, while any particularised form is likely to generate and reinforce rents and reduce incentives to investment (Acemoglu et al., 2001). On the one hand, this definition is close to the distinction between inclusive and exclusive institutions proposed by Acemoglu and Robinson (2012) to explain historical growth and prosperity of nations. On the other hand, it allows to operationalise the concept of institutions in an empirical setting, by identifying those rules and norms which apply impartially to all individuals and, by contrast, highlighting those characteristics which lead to arbitrary (particularised) applications.

On this basis, a vast empirical literature has proposed different measures of (public) institutions and have estimated their relationship with economic outcomes. The degree of the rule of law (Charron et al., 2014, Acemoglu and Robinson, 2012), corruption (Kaufman and Kraay, 2003; Mauro, 1995), personal rights, bureaucratic and regulatory constraints (Ketterer and Rodríguez-Pose, 2018) are examples – according to the context and specific research question – of proxies measuring the quality of public institutions, and their relationship with economic growth has been tested in cross-country analysis.

The nexus between institutions and research and innovation is far less explored. Theoretically, and consistently with the above framework, the quality of the institutional setting should influence the innovative capacity of both the economic system and the individual firm (van Elk et al., 2015). There is indeed evidence that higher quality local institutions, together with high quality education and research systems, have a positive impact on innovative performance in European regions (Rodriguez-Pose and Di Cataldo, 2014).

This paper offers a complementary perspective by bridging the literature on public support for R&D with institutional theory. How does the impact of R&D subsidies vary with institutional quality? Is public support to business R&D effective where the quality of institutions is low, or is it preferable to allocate resources to the best regional (institutional) frameworks? The institutional setting in which companies are embedded may affect the way they perceive public support and their capability to make use of it. In an unsupportive institutional environment, the impact may either be null due to the reduced capacity of companies to invest and reap the benefits from their investments, or rather be positive since the policy intervention may relax a binding constraint (Hausmann et al., 2008). The implications of these two alternatives differ significantly since they call either to focus efforts only (or mostly) in the best contexts, or to support business R&D investments in the worst institutional environments, generally occurring in less developed regions. To our knowledge, this study is the first attempt to assess the relationship between institutional quality and the impact of public support to business R&D.

We build an original institutional index – consistent with the above theoretical framework and suited to our research question – drawing from existing indicators currently used in the literature. Given the heterogeneity in institutional quality across European regions, as shown by Charron et al. (2014; 2015) among others, we exploit the regional variation of the index to group regions and firms. Hence, using a sample of Spanish companies and a wider dataset of EU firms, we evaluate the impact of R&D subsidies on business R&D investment, and investigate whether the effect of R&D subsidies changes according to the quality of institutions in which firms operate.

Section 2 introduces the nexus between institutions, research and innovation, and the positioning of our study in the literature. Section 3 describes the construction of the institutional index, while data and methodology are presented in Section 4. Results for the Spanish and the European sample are reported in sections 5 and 6, respectively. Section 7 concludes with implications for policy.

2. Institutions, research and innovation

The economic literature has recently begun to explore the role of research and innovation as a channel through which institutions eventually affect economic performance (Tebaldi and Elmslie, 2012; Chadee and Roxas, 2013; Silve and Plekhanov, 2015). The theoretical argument follows closely the framework outlined above. Weak institutional settings do hinder economic growth prospects because they are associated with increased uncertainty on the possibility to reap the returns of private investment. This becomes even more relevant in the context of R&D and innovative activities, in which uncertainty of returns is higher and the disincentives deriving from an unsupportive institutional environment are likely to be larger.[6] For instance, if the rule of law affects investment propensity of private actors, the lack of protection of property rights reduces firms' innovation efforts, the likelihood to engage in R&D activities and the potential for technology transfer and diffusion (OECD, 2010; Tebaldi and Elmslie, 2013). Corruption also generates disincentives to innovate, increasing the transaction costs faced by firms and favouring rent seeking behaviour (Rodrik et al., 2004). Furthermore, in systems characterized by high degree of clientelism, public officials are likely to be influenced by the vested interests of groups attempting to promote their own particular benefits or to preserve the status quo, lowering the overall innovative capacity of the system (Anokhin and Schulze, 2009; Acemoglu and Robinson, 2012). Differently, an effective and generalised provision of public goods and services, including intangible assets such as education and training, should foster innovation activities (Blind, 2012). Tebaldi and Elmslie (2008) develop a theoretical model formalising the relationship between institutions and growth through their impact on innovation. The framework builds upon the concept that the institutional setting constitutes the root cause of growth as originally posed by North (1990; 1991), while their impact on economic performance goes through the incentives and constraints to research and innovation activities. In this perspective, innovation activities are the proximate cause of economic growth since they act as the real engine behind technological changes (North, 1990; Aghion and Howitt, 1992; Williamson, 2000). In short, the role

[6] The theoretical affinities between the so-called "new institutional economics" North (1990; 1991) and the economics of innovation have been already highlighted earlier by Nelson and Nelson (2002). They note how the process of technological advance follows behavioural routines that are coherent with the definition of institutions as rules of the game or modes of governance, as respectively defined by North (1990) and Williamson (2000).

of institutions in enabling or limiting decisions makes them a key factor favouring or hindering the creation and adoption of new productivity-enhancing technologies.[7]

Although the empirical literature on the relationship between institutional quality and innovation is undeniably scarce, the available evidence shows that good institutions, defined by effective property rights protection, a good working legal framework, control of corruption and delivery of public goods and services, are positively associated with innovation performance.[8] Tebaldi and Elmslie (2013) empirically test their model by estimating an augmented knowledge production function, using four different measures of institutional quality. They find evidence of a positive effect of institutional quality on knowledge creation and hence on economic growth. In a cross-country analysis on an OECD sample, Egert (2016) finds that institutions enhance the Total Factor Productivity effect of R&D spending, in particular when considering the rule of law and better law enforcement. In their historical analysis of the US technological change in the 19th century, Pattit et al. (2012) find that institutions have been a determining factor in shaping the technological landscape of firms.

While the theoretical and the available empirical literature show a positive relationship between institutions and innovation, we are not aware of studies assessing the impact of schemes supporting business R&D in different institutional settings. It is relevant to understand whether the impact of public subsidies is null or negligible in regions where the quality of institutions is low, especially from a policy perspective. If this were the case, it could be argued that resources should be allocated mainly where companies benefit from a supportive institutional framework, which, given the positive association between quality of institutions and economic performance, would correspond to direct public R&D funding towards the richest regions. A priori, expectations are ambiguous. On the one hand, public support should be more effective where institutions are more conducive to business and innovation investments, since firms may more easily reap the associated benefits (Rodríguez-Pose and Garcilazo, 2015). In addition, the existence of increasing returns to scale for R&D investment (Dosi, 1988; Bilbao-Osorio and Rodriguez-Pose, 2004) would suggest to focus policy efforts in those regions with the highest "stock" of knowledge which, as long as the above argument holds, should also have the soundest institutional environment. On the other hand, public support could be more effective where agents are more constrained. Indeed, if companies underinvest in R&D and innovative activities when the quality of institutions is low, implying a less business-friendly environment and inadequate provision of public goods and services, R&D support could leverage private resources into risky activities, such as those in the realm of innovation. To be noted that this argument is consistent with the theory of bottlenecks: if the main constraint is the allocation of scarce resources in an unsecure environment, the provision of public support may have a positive leverage impact. Such an argument is close to the "growth diagnostics" theory advocated

[7] The link between institutional settings and innovation performance can also be interpreted beyond the extension of the institutions-investment relationship. See, for instance, Fischer (2001) for a "systems of innovation approach" to assess the importance of the public sector and the rules shaping social and economic interactions for the creation and diffusion of knowledge.

[8] While institutions are generally characterized by path dependency and stability, there is the possibility that innovation and technological change have a feedback effect on the institutional setting, both on the formal norms and on the social rules (North, 1990).

in a different context by Hausmann et al. (2008), as well as consistent with the conjecture that the greatest gains in innovative capacity from policy should be obtained in local systems where the initial level of government quality is lower (Rodríguez-Pose and Crescenzi, 2008).

Furthermore, the focus of the literature on R&D subsidies has been mostly on cross-country samples and/or on the country-level, the latter allowing to spotlight national specificities. Hottenrott et al. (2017) find a positive impact of R&D subsidies in the Belgian Flemish region, and Cerulli and Potí (2012) reject full crowding-out in the case of Italian firms, using CIS data. Huergo et al. (2016) and Huergo and Moreno (2017) reveal that public support via subsidies or loans increases the probability of Spanish companies to engage in R&D activities, while Busom (2000) finds mixed evidence. However, the heterogeneity in sub-national institutional systems is a key factor to consider when assessing the effectiveness of policies aimed at generating knowledge and promoting its diffusion (Edquist, 2001; Rodríguez-Pose and Crescenzi, 2008; Rodríguez-Pose, 2013).[9] Strong disparities among the European regions, especially between the "core" and the "periphery", make the investigation of research and innovation drivers at the regional level of paramount importance (Tödtling and Trippl, 2005). The divide between the core and peripheral countries was on the rise already before the surge of the last economic crisis (Borsi and Metiu, 2015). Such a trend is exacerbated at the regional level for two reasons: first, regions in the periphery have not been converging to the richest core, except for Eastern economies which appear to be in a catching-up process; second, significant heterogeneity and divergence is found also within countries (Marrocu et al., 2013; Martino, 2015). This heterogeneity in economic performance is accompanied by an innovation divide, with laggard EU economies unable to reduce the gap with leaders, and with concentration of innovation activities in few regions (Moreno et al., 2005; Veugelers, 2016b). While this evidence calls for policy intervention to increase regional innovative capacity and R&D investment (Rodriguez-Pose and Di Cataldo, 2014), very little is known about the relationship between institutional frameworks and the impact of research and innovation policy. Furthermore, the regional scale has being increasingly identified as the core dimension for the process of innovation, knowledge creation and diffusion, the notion of *nation state in an increasingly borderless economic world* being less relevant, due to regional and agglomeration patterns (Fischer 2001, p.211; Moreno et al., 2005; Dosso et al., 2017). Therefore, in what follows we explore the return to public support to business R&D activities from a regional institutional perspective. The way we characterize the institutional framework of regions is the subject of the following section.

[9] In this vein, Czarnitzki and Licht (2006) assess the impact of public R&D grants on firms located in Eastern and Western Germany during the transition period. They find evidence of input and output additionality in both geographical areas, although the effect of public support on private R&D investment is more pronounced in Eastern Germany than in Western Germany.

3. The institutional index

We develop an original regional institutional index that is suitable to empirical implementation and consistent with the institutional theory as defined so far, relying on the theoretical framework set up by North (1991) and Acemoglu and Robinson (2012), among others, accounting for the remarks put forward by Ogilvie and Carus (2014). We focus on those features which make institutions supportive to research and innovation investments by companies. In particular, we use a set of indicators responding to at least one (or more) of the following criteria: (i) generalised definition and protection of property rights, (ii) delivery of public goods and services to ease business and innovation activities, and (iii) delivery of public goods and services conducive to knowledge and innovation creation, diffusion and absorption.

First, the attribution of property rights and the appropriation of the corresponding benefits need to be clearly defined, and they need to be protected together with their use and exchange. However, to ensure a productive use which is beneficial to the whole economy, all economic agents must be eligible to property rights, with no discriminatory exclusion and particularised access (Ogilvie and Carus 2014). Second, local institutions should be able to provide public goods and services easing investment and reducing transaction costs when engaging in economic activities. This corresponds to what is conventionally labelled as "quality of government" (Charron et al., 2014; Rodriguez-Pose and Di Cataldo, 2014; Charron et al., 2015). Third, we account for those public goods and services that are relevant for knowledge and innovation creation, diffusion and absorption. Specifically, we focus on access to knowledge and education, consistently with recent studies (Charron et al. 2014; Rodriguez-Pose and Di Cataldo, 2014). While this last component is not peculiar of institutional theory itself, it bridges the latter with the "systems of innovation" theory. Indeed, public institutions shape the technological and knowledge endowment of the economy by affecting the supply of high-skilled workers, the creation and diffusion of skills and the amount and quality of basic research. These factors, in turn, influence the innovation capacity of companies and the entire system in which they operate (Fischer, 2001; Lundvall, 2010).

Within this framework, we proceed to draw the indicators from a targeted subset of the EU regional Social Progress Index (SPI), developed by DG REGIO of the European Commission, which itself is based on different sources, including Eurostat, EU-SILC and the European Quality of Institutions Index (EQI), among others.[10] Overall, we selected 13 sub-indicators and aggregated them in 6 components, which in turn compose 2 dimensions. The final index is obtained by aggregating the two dimensions in a single measure (Table 1). We follow the methodology used in the construction of the original SPI. Thus, each sub-indicator is normalised to have every dimension and component on a 0-100 base, and it is transformed to have higher values representing

[10] The original index encompasses 50 social and environmental indicators and covers the 272 regions composing the European Union. In the original version, data are retrieved from different sources and then aggregated up to three social dimensions: basic human needs, wellbeing and opportunity. See Annoni et al. (2016).

a better performance.[11] The aggregation is done using an arithmetic average when moving from the sub indicators to the components, while a generalised weighted mean is applied when moving from the components to the two dimensions, and from the latter to the final index.[12] [13]

The first dimension is labelled "*Absorption Capacity"* as it encompasses the capability of an economic system to produce, adopt and diffuse knowledge and innovation. The three components include access to basic knowledge and advanced education, as well as to information and communication technologies (ICT). *Access to basic knowledge* is measured by indicators of secondary and lower education attainment, being the fundamental prerequisite for any innovation system. *Advanced education* is measured with tertiary education rates, as well as lifelong learning. Finally, *ICT access* is measured by the availability of basic access to information and communication, as internet, broadband and the possibility to digitally interact with public authorities. This dimension bridges knowledge and innovation-related indicators with institutional quality and the delivery of public services: the focus is on access, and the role of government is crucial in order to provide the needed infrastructure, as in the ICT component, and the opportunity for citizens to access to education.

The second dimension is labelled "*Generalised Property Rights"*. It is composed of 3 components and 4 indicators and encompasses both the concept of property rights in the original institutional economics framework and the quality of public goods and services delivery, the latter being the usual reference for the quality of government measures (Charron et al. 2014; 2015). In particular, corruption and impartiality of government services proxy the generalisation of security and ownership of property rights, while the remaining two indicators represent the quality of government delivery and the related opportunities.[14]

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[11] Following Annoni et al. (2016, p.10), X_t, the transformed value of X, is equal to:

$$X_t = \begin{cases} 100 * \dfrac{x - x_{min}}{x_{max} - x_{min}} & \text{if x is positively oriented} \\ -100 * \dfrac{x - x_{min}}{x_{max} - x_{min}} + 100 & \text{if x is negatively oriented} \end{cases}$$

[12] In particular, the generalised mean is equal to $\left(\frac{1}{q}\sum_{i=1}^{q} x_i^{\beta}\right)^{1/\beta}$, with $\beta = 0.5$, which ensures the mean to be inequality-adverse, attributing more weight to an increase of a value in the lower tail of the distribution than a similar increase in the upper tail. See Annoni et al. (2016) for further details and robustness tests.

[13] To note that the indicators refer to 2013 or are built as an average over the period 2011-2013. Thus, our institutional index represents accurately the institutional framework in the period 2011-2013. Since the Spanish sample we employ in a part of the analysis covers information from 1990 to 2010, we work under the standard assumption that institutions are consistent over time and that drastic changes are unlikely to occur (North, 1991; Williamson, 2000), which is likely to hold for the Spanish context. This assumption allows us to increase the size of the final sample and the power of the statistical tests. For the sake of robustness check, we also replicated the analysis considering only the last three years of our data (2008-2010). The sample size decreases drastically, but the main results are consistent with those presented along this article and are available upon request.

[14] The share of young people neither in education nor in employment is a measure of the capacity of local institutions to create opportunities for the youth, and as such it stays in this dimension, consistently with the original SPI classification.

Table 1. The Institutional Index (INSTQ)

	Dimension	Component	Indicator
Institutional Index (INSTQ)	Absorption capacity	Access to basic knowledge	Secondary enrolment rate ˘
			Lower secondary completion rate ˘
			Early school leaving ˘
		Access to information and communications	Internet at home˚
			Broadband at home˚
			Online interaction with public authorities˚
		Access to advanced education	Tertiary education attainment ˘˚
			Tertiary enrolment ˘
			Lifelong learning ˘˚
	Generalised property Rights	Opportunity and quality of government	Young people not in education, employment or training ˘
			Corruption˚*
		Quality and accountability of government services	Quality and accountability of government services˚
		Impartiality of government services	Impartiality of government services *

Notes: Following the three criteria defined above, the 13 indicators can be classified as follows: ˘ delivery of public goods and services conducive to knowledge and innovation creation, diffusion and absorption; ˚delivery of public goods and services to ease business and innovation activities; * generalised definition and protection of property rights. The classification is not necessarily cross-cutting and overlaps between different characteristics of the institutional and innovation systems, as suggested by Fischer (2001).

We choose to depart from the existing measures of government quality, for instance the European Quality of Government Index EQI, considered the state-of-the-art in measuring institutions at the regional level in Europe (Charron et al., 2014; 2015) and build our own *Institutional Index* (henceforth, INSTQ). Indeed, our measure is consistent with the institutional theory that introduced institutions in economic analysis, but it also incorporates indicators of absorption capacity and "generalised" opportunity, directly linked to the innovation performance of an economic system.[15] As outlined above, the SPI represents the parent source of our index, although we excluded some information that are functional to the measurement of the social dimensions, which are the main scope of the SPI. Furthermore, contrary to the original SPI, we did not include any measure of trust. This choice rests on two considerations and have direct implications for our research. First, we base the analysis on the so-called "formal institutions" that, in practical terms, affect activities and opportunities of

[15] Nevertheless, the indicators *Corruption* and *Impartiality of government services* we extracted from the SPI are originally drawn from the EQI. See Annoni et al. (2016) and Charron et al. (2014).

economic agents, following the original definition by North (1990; 1991). Second, while part of the literature makes use of trust as a proxy of institutional quality, the relationship between trust, formal institutions and government quality is complex and subject to the classic "chicken-egg" problem. Therefore, we stick to our definition of institutional quality that has also the advantage to operationalise the results of this study in a policy perspective: it makes more sense to tackle the quality and accountability of local governments than to tackle trust, which is likely to diffuse as a result.[16]

4. Data and methodology

We draw upon two micro-level datasets to assess the impact of public R&D subsidies for companies located in regions characterised by different degrees of institutional quality.

The Spanish context

The first source is the Spanish Survey on Business Strategies (Encuesta Sobre Estrategias Empresariales), which has been conducted yearly since 1990 by the SEPI foundation, on behalf of the Spanish Ministry of Industry. This annual survey collects on about 2,000 manufacturing companies operating in Spain. The sampling procedure ensures representativeness for each two-digit NACE manufacturing sector, following both exhaustive and random sampling criteria. More specifically, in the first year of the survey all Spanish manufacturing firms employing more than 200 workers were required to participate (715 companies in 1990) and a sample of firms employing between 10 and 200 workers were selected by stratified sampling (stratification across 20 manufacturing sectors and four size intervals) with a random start (1,473 companies in 1990). With the aim of guaranteeing a high level of representativeness, all newly created companies with more than 200 employees (rate of response around 60%) together with a random sample of firms with fewer than 200 workers and more than 10 (rate of response around 4%) have been incorporated in the survey every year. In this paper, we refer to data collected between 1990 and 2010. Our resulting sample is an unbalanced panel of 29,344 firm-year observations (4,107 firms) for which the variables used in the empirical exercises are non-missing. This dataset represents an ideal source for our study for two main reasons. From an empirical perspective, it provides exhaustive demographic information on firms and a wide set of variables to proxy their operating and innovative capabilities. By way of example, we have information such the number of employees, age, geographical location (NUTS2), sector of activity, value added, export intensity, measures of debt and

[16] The interaction between formal institutions and the so-called informal institutions is a long-lasting argument in the literature. For instance, Williamson (2000) argues that informal institutions are the fundamental drivers of economic performance. Differently, Acemoglu and Robinson (2012), as well as Ogilvie and Carus (2014) seem to suggest the opposite. We follow the second approach that, as already stated, has an operational advantage in terms of policy actions. For an alternative and stimulating perspective on the topic, see Wilson and Kelling (1982) and Tarrow (1996). Other than the theoretical framework, some problems arise when moving to the sub-national level data. Consider the Spanish regions in Table 2 as an example: when we add measures of trust (i.e. trust in the political and legal system and in the police), the Basque Community region drops from the top to the bottom of the INSTQ distribution. This is clearly due to the historical clash between the region and the national State, and it is unrelated to the quality of government, delivery of services, or the generalized definition of property rights that characterizes this region.

market shares, several proxies of the innovation process undertaken by companies, and other data about firms' labour force (i.e., share of engineers and graduates employed by the firm). Beside the richness of the data, Spain is an attractive context due to its high degree of heterogeneity across regions in terms of institutional quality, one among the highest in Europe.

Using the institutional index (INSTQ) defined in Section 3, we assign regions to 3 groups according to the value taken by the index. In particular, the cut-off points correspond to the terciles of the INSTQ distribution, that is: *Group 1*: INSTQ ≤ 33th percentile; *Group 2*: 33th < INSTQ ≤ 66th percentile; *Group 3*: INSTQ > 66th percentile.[17] Consequently, companies are allocated to groups according to the region in which they are located. Appendix A provides additional information on the composition of the sample. Table 2 reports the Spanish NUTS2 regions according to the value of INSTQ, and the resulting classification by group. The Basque Community has the highest value of INSTQ, followed by Madrid, Navarre, Cantabria and Asturias within the first group of regions. Interestingly, the region of Catalonia scores lower and belongs to the second group, despite being one of the richest regions in the country.

Table 2. Spanish regions by institutional quality and group

NUTS2	Region	INSTQ	Group
ES21	Basque Community	62,5595	3
ES30	Madrid	62,5482	3
ES22	Navarre	60,7328	3
ES13	Cantabria	58,6777	3
ES12	Principality of Asturias	57,9625	3
ES41	Castile-Leon	56,8656	2
ES23	La Rioja	56,0944	2
ES24	Aragon	55,5035	2
ES62	Region of Murcia	53,3810	2
ES51	Catalonia	50,8801	2
ES52	Valencian Community	50,2872	2
ES11	Galicia	49,0228	1
ES61	Andalusia	48,7553	1
ES43	Extremadura	48,2701	1
ES53	Balearic Islands	46,9049	1
ES42	Castile-La Mancha	45,9999	1
ES70	Canary Islands	45,9793	1

Notes: Groups are sorted in descending order of institutional quality (INSTQ)

[17] The advantage of selecting the cut-off points by splitting the distribution of INSTQ instead of choosing arbitrary values is that this criterion is completely data driven. A series of robustness checks with different clustering criteria (2 and 4 cluster, respectively) have been undertaken. The results and the corresponding implications are virtually the same as those presented here.

The European context

The second data source consists of the Community Innovation Survey 2014 (CIS), from which we can draw a sample of companies belonging to 13 European countries (Belgium, Bulgaria, Cyprus, Estonia, France, Croatia, Hungary, Italy, Lithuania, Luxembourg, Latvia, Malta, Portugal).[18] Compared to the ESEE above, we have less firm-level information and we are not able to set up a panel, given that the CIS is repeated every two years over a different sample of firms. We end up with a pool of 22,773 observations (firms) belonging to 66 NUTS1 regions. Despite the well-known limitations of CIS data, there are two main advantages justifying the use of this source in our study. First, the CIS allows us to exploit the high institutional heterogeneity at the regional level, which is a relevant dimension in the EU scenario, within and between countries. To better exploit and account for this heterogeneity across European regions, we identify four groups, with cut-off points corresponding to the quartiles of the INSTQ distribution. As shown in Table 3, in our sample this translates mainly in an East-West divide, with regions from Southern Italy and some from Portugal belonging to the groups with the lowest and highest values of INSTQ, respectively.[19]

Second, the evidence we aim at producing goes beyond one single country (i.e., Spain), but it extends to 13 different economies. In this sense, we can increase the reliability of our findings and, while the coverage of the European Union is not complete, generalise the corresponding implications for policy, at least for what concerns the European scenario.

For both samples, our main variable of interest is private spending in R&D. We consider firms' total annual R&D expenditure as the sum of in-house and extra-mural investment.[20] From this variable, we build a measure of R&D intensity, defined as R&D expenditure over turnover, and a standardised measure of R&D expenditure over the number of employees. The receipt of subsidies is identified by a dummy variable equal to one for businesses that received any form of public R&D support, and zero otherwise. Thus, no distinction has been made between various subsidy programmes that might include national, regional as well as EU financing schemes.

[18] The CIS 2014 was available to us under EUROSTAT confidentiality protocol. The selection of countries has been restricted by the need to retrieve information about the geographical location of companies (only available in the CIS 2014) and other relevant variables. Although businesses report their geographical location at NUT2 level to the National Statistical Offices, EUROSTAT disclose information at NUTS1 level only. Member states can set some restrictions on the disclosure of geographical location and other variables (such as intra-mural R&D investments). Therefore, we had to exclude from the cross-country analysis some countries such as Germany and Spain, even though they would have been suited for the analysis given their degree of regional disparities.

[19] As for the Spanish case, the results are robust to different grouping criteria (3 or 5 groups).

[20] Following the suggestion of an anonymous referee, we have replicated all the analyses presented in this document by separating internal and external R&D expenditures. The results for both R&D measures are very much in line with those presented here, confirming that our conjectures about the role of institutions on innovation activities are robust to the type of investment considered. Results are available in the online appendix of the paper.

Table 3. European regions by institutional quality and group

NUTS1 code	Country	Region name	NUTS2 subregions	INSTQ	Group
LUZ	Luxembourg	Luxembourg		74.8331	4
BE2	Belgium	Flemish Region	Antwerp, Limburg, East Flanders, Flemish Brabant, West Flanders	73.5691	4
FR5	France	Ouest	Pays de la Loire, Brittany, Poitou-Charentes	66.3649	4
FR6	France	Sud-Ouest	Aquitaine, Midi-Pirénees, Limousin	64.9011	4
FR7	France	Centre-Est	Rhône-Alpes, Auvergne	64.5972	4
PT2	Portugal	Açores	Autonomous Region of Açores	61.3389	4
FR4	France	Est	Lorraine, Alsace, Franche-Comté	61.2945	4
FR2	France	Bassin Parisien	Champagne-Ardenne, Picardy, Upper Normandy, Centre, Lower Normandy, Burgundy	60.5099	4
FR1	France	Île de France	Île de France	59.9752	3
FR8	France	Mediterranean	Languedoc-Roussillon, Provence-Alpes-Côte d'Azur, Corsica	56.1997	3
MT	Malta	Malta		55.9468	3
BE1	Belgium	Brussels Capital Region	Brussels	55.2503	3
FR3	France	Nord	Nord-Pas-de-Calais	55.2449	3
PT1	Portugal	Continente	Norte, Algarve, Centro, Metropolitan Area of Lisbon, Alentejo	54.9540	3
BE3	Belgium	Walloon Region	Walloon Brabant, Hainaut, Liege, Luxembourg (BE), Namur	54.6387	3
CY0	Cyprus	Cyprus		54.4637	3
ITH	Italy	North East	Trentino Alto Adige/Sudtirol, Veneto, Friuli Venezia Giulia, Emilia Romagna	54.2238	2
EE0	Estonia	Estonia		53.4290	2
PT3	Portugal	Madeira	Autonomous Region of Madeira	52.9558	2
FR9	France	Départements d'Outre Mer	Guadeloupe, Saint Martin, Martinique, French Guiana, La Réunion, Mayotte	47.4267	2
LT0	Lithuania	Lithuania		41.6178	2
ITC	Italy	North West	Piemonte, Valle d'Aosta, Liguria, Lombardia	41.4919	2
HU2	Hungary	Transdanubia	Central Transdanubia, Western Transdanubia, Southern Transdanubia	40.6456	2
LV0	Latvia	Latvia		39.6526	2
HU3	Hungary	Great Plain and North	Northern Hungary, Northern Great Plain, Southern Great Plain	37.1264	1
ITI	Italy	Centre	Toscana, Umbria, Marche, Lazio	34.8493	1
HU1	Hungary	Central Hungary	Central Hungary	33.8646	1
HR4	Croatia		Continental Croatia	31.8535	1
HR3	Croatia		Adriatic Croatia	29.3567	1
BG3	Bulgaria	Northern and Eastern	Northwestern, Northern Central, Northeastern, Southeastern	24.3441	1
ITG	Italy	Islands	Sicilia, Sardegna	23.5178	1
ITF	Italy	South	Campania, Abruzzo, Puglia, Basilicata, Calabria, Molise	20.5254	1
BG4	Bulgaria	South-Western and South-Central	Southwestern, Southern Central	15.3035	1

Notes: Groups are sorted in descending order of institutional quality (INSTQ). Croatia regions correspond to the NUTS2 level.

Table 4. R&D statistics by group, Spanish sample

Sample	R&D (yes)	Patents (yes)	Subsidies (yes)	All firms				R&D performers			
				R&D expend. [€]	R&D intensity	R&D / # Empl.	Patents	R&D expend. [€]	R&D intensity	R&D / # Empl.	Patents
Group 1	23.95%	3.96%	6.67%	200,094	0.0037	396.83	0.1281	835,559	0.0153	1,657.09	0.4244
				(2,187,569)	(0.0210)	(1,761.41)	(1.3392)	(4,411,555)	(0.0409)	(3,297.34)	(2.6461)
Group 2	38.99%	7.67%	10.07%	697,478	0.0067	892.32	0.3428	1,788,731	0.0171	2,288.42	0.7599
				(9,073,276)	(0.0200)	(3,248.37)	(2.1199)	(14,500,000)	(0.0291)	(4,885.56)	(3.1809)
Group 3	39.57%	7.25%	14.87%	742,744	0.0086	1,129.14	0.3353	1,831,367	0.0217	2,853.25	0.7265
				(6,731,585)	(0.0254)	(3,592.28)	(2.1256)	(10,600,000)	(0.0366)	(5,262.46)	(3.1222)
Pooled	35.89%	6.74%	10.74%	597,209	0.0066	854.15	0.2938	1,664,088	0.0183	2,380.02	0.7001
				(7,388,501)	(0.0220)	(3,112.94)	(1,9799)	(12,300,000)	(0.0337)	(4,834.39)	(3.0912)

Notes: Figures computed by pooling the working sample - 29,344 observations. Standard deviations in parenthesis. The variable "Patents" represents the number of patent applications in Spain and abroad.

Tables 4 and 5 report some basic statistics on firms' R&D for the Spanish and the European sample respectively, distinguishing between all companies and R&D performers only. Consistently with the existing empirical literature, we find that R&D expenditure, R&D intensity, and ratio of R&D over the number of employees increase with institutional quality, confirming the finding in the literature that a better institutional framework is associated with higher investments, including in R&D and innovation activities. A similar pattern is revealed when considering innovation output indicators – i.e. patents and sales due to innovative products. Note that, while the share of R&D performers (second column of each table) increases with institutional quality, it is much larger for each group when considering the European sample. A similar trend can be observed for the share of companies registering a patent or receiving public R&D subsidies. This is due to the scope of innovation surveys which, by construction, tend to be biased towards companies that a more likely to engage in R&D and innovation activities.

Table 5. R&D statistics by group, European sample

Sample	R&D (yes)	Patents (yes)	Subsidies (yes)	*All firms*				*R&D performers*			
				R&D expend. [€]	R&D intensity	R&D / # Empl.	Inno sales	R&D expend. [€]	R&D intensity	R&D / # Empl.	Inno sales
Group 1	29.03%	6.96%	28.55%	125,742	0.0166	1,154.45	0.0109	432,197	0.0571	3,966.65	0.0146
				(591,538)	(0.0759)	(4,640.78)	(0.0212)	(1,034,771)	(0.1323)	(7,930.73)	(0.0231)
Group 2	43.39%	11.15%	28.78%	296,502	0.0168	2,046.82	0.0121	683,209	0.0391	4,716.35	0.0171
				(926,910)	(0.0665)	(6,472.05)	(0.0111)	(1,309,895)	(0.0966)	(9,162.07)	(0.1643)
Group 3	46.22%	8.93%	26.13%	279,198	0.0463	2,163.23	0.0309	604,095	0.1002	4,680.54	0.0427
				(949,566)	(0.1327)	(6,824.42)	(0.1170)	(1,324,737)	(0.1808)	(9,433.93)	(0.1333)
Group 4	67.91%	20.32%	30.98%	485,218	0.0884	4,077.54	0.0612	714,458	0.1302	6,003.96	0.0680
				(1,216,328)	(0.1687)	(10,244.60)	(0.1590)	(1,419,444)	(0.1909)	(11,957.55)	(0.1652)
Pooled	45.53%	10.66%	28.31%	286,882	0.0392	2,253.58	0.0232	630,067	0.0862	4,949.44	0.0319
				(940,005)	(0.1183)	(7,156.96)	(0.0948)	(1,313,197)	(0.1634)	(9,957.83)	(0.1165)

Notes: Figures computed on 22,773 observations. Standard deviations in parenthesis. The variable "Inno sales" represents the share of sales due to new-to-the-market products.

Methodology

We apply matching estimators to evaluate the effectiveness of R&D subsidies, a standard and widely used approach to assess policy interventions. Among the alternatives, we implement the bias-corrected nearest-neighbour matching estimator proposed in Abadie and Imbens (2006).

This technique implies three main steps. First, we estimate a probability equation, known as selection equation, through a standard probit model in order to relate the probability for a firm to be subsidized while controlling for a set of firm-level characteristics. For the Spanish sample the vector of controls is exhaustive and includes: size, age, percentage of foreign shareholding, export intensity, structure of the market in which the firm operates, a measure of financial constraints, a proxy for labour productivity (valued added over number of employees), and the share of high-skilled labour force (i.e., engineers and graduates). For the CIS, the vector of covariates is less exhaustive and includes: size, export (=1 if a firm is an exporter, 0 otherwise), group (=1 if a firm belongs to an industrial group, 0 otherwise), R&D cooperation (=1 if a firm has cooperation partners on innovation activities), and a proxy for productivity obtained as the ratio between turnover and number of employees.

Once the probability equation is estimated, for each firm *i*, the nearest-neighbour (NN) matching estimator searches for the most similar firm with the opposite treatment (no R&D subsidies). Given the large sample and the similar distribution of propensity scores between treated and control units, we apply a NN search without replacement and with oversampling – i.e., we match each treated unit with three untreated observations.[21] Moreover, we require the observations on firms in the control group to belong to the same year, the same industry and the same region of treated firms. Finally, we obtain the sample average subsidies effect in the subpopulation of granted firms, denoted by ATT (Average Treatment on the Treated). After having assessed the effect of subsidies on the whole sample, we produce a set of different specifications on subsamples of regions according to our grouping, as defined above. This exercise allows us to verify if and the extent which the effect of R&D subsidies on business R&D expenditure depends on the quality of the institutions.

Some considerations on the interpretation of the results are worthwhile. Since in the above econometric setting we only consider a dummy variable that takes value equal to 1 when a company benefits from a subsidy, 0 otherwise, we cannot comment on the additionality effect of the policy – i.e., whether beneficiary firms invest in R&D above and beyond the amount corresponding to the subsidy received. What we can assess here is whether subsidised firms spend more than non-subsidised ones, and whether public support fully crowds out private R&D effort – i.e., companies replace their own resources with the amount coming from the subsidy. If our estimates showed a positive and significant difference in R&D output between the treated and the control group (the ATT value), we could attribute such a difference to the effect of the policy. Therefore, a positive and significant increase in R&D spending of the treated would reject the hypothesis of full crowding-out, for both the Spanish and the European sample. However, while this caveat is particularly relevant for the CIS data, the information on Spanish firms allows us to go a step further. Indeed, the ESEE data provides detailed information on R&D investments, distinguishing between *total* and *private* expenditure. This is particularly helpful as it implies that we can directly observe private spending *net* of the subsidy in order to assess the additionality of the policy. Put it differently, we may interpret the (positive and significant) difference as the

[21] As the results may be sensitive to implementation choices (Caliendo and Kopeinig, 2008), we have performed a series of robustness checks implementing alternative specifications and search methods (kernel and radius matching, respectively). The results are identical to those presented along this article.

additional R&D spending of treated firms compared to the untreated. Summing up, the data at hand and the implemented methodology allows us to assess: (i) crowding-out and additionality for the Spanish sample, and (ii) full crowding-out for the European sample.

Finally, it is worth noting that the Spanish data also offers the opportunity to leverage its longitudinal dimension. We propose an alternative econometric exercise, namely an Instrumental Variable regression with firm-level fixed effects, following the approach proposed by Wallsten (2000) under the assumption that the overall public budget allocated to subsidy is exogenous to firm characteristics. We compute the average amount of subsidies received by a firm per year, region, and industry defined by 2-digit NACE codes; and the number of firms supported by subsidies within these groups. These two instruments aim at capturing the temporal and spatial variation of the overall budgets, as well as the availability of subsidies across different industries. The firm-level fixed effects capture the unobserved heterogeneity in the data. The estimates following this approach are reported in Appendix C, as a robustness check. This exercise qualifies our main findings in two respects: on the one hand, it rules out unobserved characteristics as driver of our results; on the other hand, since we exploit the size of the subsidy rather than introducing a dummy, we can interpret the coefficients in terms of elasticity and better quantify the impact of subsidies.

5. Evidence from the Spanish context

Probability equation

In this section we report the results of the analysis on the Spanish ESEE sample. We estimate the probability of receiving public support for R&D activities by estimating a probit model for each group, as well as for the full sample. The dependent variable is a dummy, which takes value equal to 1 if the firm received public financing for innovation, 0 otherwise. As discussed above, the set of explanatory variables includes firm characteristics that might influence the decision to apply for public support and that are relevant in determining granting decision. All firm-level variables enter with one-year lag to reduce (potential) endogeneity. We also include a dummy variable taking value equal to 1 if the firm received a subsidy the year before, 0 otherwise. This should control for persistence in public financing, such as multiannual grants, renewals or phase-2 projects. Finally, we control for the sector of activity (2-digits NACE rev.2 classification), regional dynamics (NUTS2), and macroeconomic changes by including appropriate set of dummies. Descriptive statistics of the control variables are reported in Table 6, while Table 7 breaks them down by group. It is worth noting that figures on size, share of foreign shareholding, labour productivity and share of engineers and graduates are increasing with institutional quality, consistently with the institutional theory literature.

Table 6. Descriptive statistics of the control variables (Spanish sample)

Variable	Mean	SD	Min	Med	Max
No. of employees	230.98	723.58	1	46	25,363
Age	24.97	20.70	0	20	265
Foreign shareholding	0.1659	0.3577	0	0	1
Market share	0.1181	0.2014	0	0	1
Export intensity	0.1684	0.2498	0	0.0284	1
Debt on equity	0.0465	0.2317	0	0.0142	9.3788
Labor productivity	35,016	32,628	3.93	27,368	887,534
Engineers and graduates	0.0471	0.0728	0	0.0240	1

Table 7. Descriptive statistics for the control variables, by group (Spanish sample)

	Group 1		*Group 2*		*Group 3*	
Variable	Mean	SD	Mean	SD	Mean	SD
No. of employees	161.21	579.89	232.51	774.90	280.04	727.16
Age	21.52	20.35	25.40	20.64	26.79	20.76
Foreign shareholding	0.0874	0.2683	0.1721	0.3645	0.2138	0.3927
Market share	0.1177	0.2088	0.1081	0.1883	0.1348	0.2155
Export intensity	0.1124	0.2225	0.1872	0.2545	0.1787	0.2550
Debt on equity	0.0599	0.2847	0.0412	0.1964	0.0448	0.2416
Labor productivity	29,831	31,263	35,328	33,194	38,336	32,193
Engineers and graduates	0.0339	0.0607	0.046	0.0702	0.0584	0.0831
No. of firms	982		1,962		1,163	
No. of observations	5,178		11,909		7,189	

The estimates of the probability equation are reported in Table 8. We observe a high degree of persistence in the allocation of subsidies, as the coefficient on the lagged R&D subsidy dummy is positive and significant for all groups. Therefore, having received public support in the past is positively related to the probability of receiving funding in the next period. Size and exporter status are also significantly and positively correlated with the probability to be financed, while no role is played by neither market share, nor age (except for group 2 where the effect is barely significant). It is also worth noting that labour productivity does not affect the probability of receiving R&D subsidies, with the notable exception of group 3. Finally, the presence of high skilled workers in the company is a significant and positive factor, but only in group 2 and 3, while it is not statistically significant for companies in group 1.

In Appendix B, we report a t-test for equality of means between treated and untreated units before and after the matching. Pre-matching comparisons (unmatched) suggest that the two groups present statistically significant differences in almost all the variables considered. If the matching procedure is effective, the sample of untreated firms should not differ in statistical terms from the sample of treated firms in any dimension. In most of the cases, we find equality of means in the treated and control groups post-matching (matched), indicating that the matching procedure has generated a reliable counterfactual.

Table 8. Probability equation estimation (probit model)

Dependent variable: R&D subsidy $_t$	*Pooled*	*Group 1*	*Group 2*	*Group 3*
R&D subsidy $_{t-1}$	1.7942**	1.9432**	1.6734**	1.8735**
	(0.0439)	(0.1254)	(0.0599)	(0.0723)
ln No. of employees $_{t-1}$	0.2724**	0.3055**	0.2689**	0.2719**
	(0.0147)	(0.0334)	(0.0210)	(0.0261)
ln Age $_t$	0.0191	-0.0257	0.0768*	-0.0345
	(0.0232)	(0.0514)	(0.0338)	(0.0376)
Foreign shareholding $_{t-1}$	-0.3950**	-0.1294	-0.4978**	-0.3518**
	(0.0474)	(0.1268)	(0.0686)	(0.0777)
Market share $_{t-1}$	-0.0362	-0.1854	0.0326	-0.1309
	(0.0825)	(0.1711)	(0.1378)	(0.1271)
Export intensity $_{t-1}$	0.3289**	0.3698*	0.2624**	0.4137**
	(0.0655)	(0.1624)	(0.0894)	(0.1124)
Debt on equity $_{t-1}$	-0.1268	0.0660	-0.262	-0.0928
	(0.0782)	(0.1151)	(0.1600)	(0.1172)
ln Labor productivity $_{t-1}$	0.0584*	0.0476	0.0258	0.1274*
	(0.0292)	(0.0635)	(0.0419)	(0.0579)
Engineers and graduates $_{t-1}$	1.6366**	1.1076	1.5485**	1.9172**
	(0.2415)	(0.6312)	(0.3590)	(0.3990)
Industry, regional, and time dummies	yes	yes	yes	yes
No. of firms	4,107	982	1,962	1,163
No. of observations	24,276	5,178	11,909	7,189
Wald Chi2	4163,85**	929,10**	2,127,58**	3971,27**
Pseudo R2	0.4550	0.5142	0.3928	0.5132

Notes: Robust standard errors in parenthesis. Significant at * 5%, ** 1% level.

Estimating the impact of public support to R&D activities

Table 9 reports the results of the estimated impact of R&D subsidies on business R&D expenditure for the whole Spanish sample. The Average Treatment effect on the Treated (ATT), computed as the difference in the output variable between the firms which received the subsidy and their counterfactual (controls), is reported for the three variables of interest, namely: R&D expenditure, R&D intensity and R&D expenditure over the number of employees, all of them considering only private spending by the firm net of public support.[22] The results show that public subsidies have a significant effect on all three dimensions considered. More precisely, R&D expenditure is on average 3.3 times larger for companies receiving public support, its share over the number of employees is 2.2 larger, while R&D intensity is on average about 1.5% higher. Similar results are found when we consider R&D performers only, although the magnitude is lower (0.5, 0.6 and 1.1% respectively), given that the counterfactual includes only companies that undertake research and innovation

[22] R&D expenditure and its ratio over the number of employees are expressed in logarithms. It follows that the ATT effect must be interpreted as the ratio between the quantities for treated and non-treated companies. For instance, an ATT value of 3 implies that the value of the variable is three times (or 300%) higher for the treated than for the untreated units; similarly, a value of 0.5 implies a value 0.5 times (or 50%) higher.

activities. The evidence is also consistent with recent research on the impact of public support to R&D in the case of Spanish companies. By way of example, Huergo and Moreno (2017) reject the hypothesis of crowding-out in the case of R&D intensity, independently of the support considered, including subsidies. Overall, our results imply that public support to business R&D does not crowd-out private investments, but rather that subsidised firms invest more than their counterfactual. Furthermore, since our output measures include only private R&D spending, net of the public money received from the subsidy, we can also infer that subsidies have an additionality (crowding-in) effect, leveraging additional private resources. This finding is robust across all the three input measures.

Table 9. Impact of R&D subsidies, full sample

	Pooled				*Pooled (R&D performers)*			
Variable	Treated	Controls	ATT	t-stat	Treated	Controls	ATT	t-stat
ln R&D expenditure	12.9613	9.5962	3.3650	23.94**	12.9711	12.4475	0.5237	6.61**
R&D intensity	0.0294	0,0143	0,0151	7.78**	0.0294	0.0179	0.0115	5.84**
ln R&D exp / # employees	7.3835	5.1936	2.1899	22.06**	7.3891	6.7605	0.6286	7.52**
No. of treated units (on support)	2,625				2,623			
No. of treated units (off support)	37				39			
No. of controls	21,614				6,074			

Notes: Significant at * 5%, ** 1% level.

In what follows, we discuss the first set of key findings from this study. Tables 10 and 11 report the results of the analysis for the different groups. Table 10 shows that the impact of public subsidies for business R&D activities is positive in all groups, rejecting crowding-out and supporting additionality for all R&D output measures considered. Most importantly, the observed impact is positive also in group 1, where the quality of institutions is the lowest. It is also interesting to point out how the ATT for the two measures of R&D expenditure is larger in group 1 than in group 2 and 3, despite lower institutional quality. While the control group also includes non-R&D performers, this result is interesting as it signals the beneficial effect of public R&D support by comparing the performance of subsidised firms with respect to the average company operating in a weak institutional environment. We perform a t-test (unequal variances) to verify whether such differences in the impact (Δ ATT) between groups are statistically significant. The results are shown at the bottom of table. The test suggests that virtually all differences in the effect of subsidies across groups are statistically significant.

Table 10. Impact of R&D subsidies, by group

Variable	*Group 1*				*Group 2*				*Group 3*			
	Treated	Controls	ATT	t-stat	Treated	Controls	ATT	t-stat	Treated	Controls	ATT	t-stat
ln R&D expenditure	12.4705	8.6423	3.8282	8.58**	12.8260	9.5270	3.2990	19.79**	13.1690	10.2057	2.9633	11.87**
R&D intensity	0.0248	0.0099	0.0148	3.92**	0.0276	0.0120	0.0156	10.82**	0.0321	0.0166	0.0155	4.31**
ln R&D exp / # employees	7.0923	4.7651	2.3272	8.71**	7.3487	5.2027	2.1460	18.91**	7.4723	5.3942	2.0781	12.86**
Δ ATT	1 vs. 2	1 vs. 3	2 vs. 3									
ln R&D expenditure	0.5292**	0.8649**	0.3357**									
R&D intensity	-0.0008**	-0.0007**	0.0001									
ln R&D exp / # employees	0.1812**	0.2491**	0.0679**									
No. of treated units (on support)	325				1,223				1,040			
No. of treated units (off support)	18				11				45			
No. of controls	4,835				10,675				6,104			

Notes: Significant at * 5%, ** 1% level.

Table 11 reports the results of the same exercise when considering only the sample of R&D performers. While the value of the ATT is lower everywhere as expected, additionality is confirmed in all groups (except for R&D expenditure in group 1 for which the difference between treated and controls is not statistically significant). In terms of the magnitude of the impact, the result is the opposite of the one obtained considering all companies. Indeed, the additionality effect is larger and statistically significant in group 3 and, overall, the difference increases with institutional quality, as shown at the bottom of the table (t-test on Δ ATT). Such a result is not surprising, since we are restricting the sample to companies regularly engaging in research and innovation investments, which are therefore more likely to have higher capacity to produce and absorb knowledge, and to invest in risky innovative activities. As discussed in Section 2, these factors are positively correlated with the institutional quality, the effectiveness of the delivery of public goods and services, and the stock of knowledge and human capital in the economic system. All these dimensions are captured by our institutional index. However, the main result still holds: the impact of public subsidies on business R&D expenditure is positive and significant, supporting additionality, even in those groups where the quality of institution is the lowest, while crowding-out is rejected across the board. These findings signal that devoting public R&D support to recipients other than the best performers located in the best (and richest) institutional frameworks yields positive and significant returns.

Table 11. Impact of R&D subsidies for R&D performers, by group

Variable	*Group 1*				*Group 2*				*Group 3*			
	Treated	Controls	ATT	t-stat	Treated	Controls	ATT	t-stat	Treated	Controls	ATT	t-stat
ln R&D expenditure	12.4705	12.2412	0.2293	1.48	12.8360	12.4028	0.4336	5.40**	13.1817	12.5519	0.6298	4.82**
R&D intensity	0.0248	0.0144	0.0104	2.64**	0.0276	0.0155	0.0121	8.06**	0.0322	0.0193	0.0128	3.56**
ln R&D exp / # employees	7.0923	6.7356	0.3667	2.67**	7.3547	6.8174	0.5373	6.35**	7.4795	6.6697	0.8096	6.66**
Δ ATT	1 vs. 2	1 vs. 3	2 vs. 3									
ln R&D expenditure	-0.2043**	-0.4005**	-0.1962**									
R&D intensity	-0.0017**	-0.0024**	-0.0007**									
ln R&D exp / # employees	-0.1706**	-0.4429**	-0.2723**									
No. of treated units (on support)	325				1,222				1,039			
No. of treated units (off support)	18				12				46			
No. of controls	887				3,425				1,762			

Notes: Significant at * 5%, ** 1% level.

6. Evidence from the European context

Probability equation

We proceed here to discuss the results for the European context. As mentioned above, the analysis on the sample of European companies has the main advantage to exploit the heterogeneity of regional institutions. In addition, it allows to generalise the results of the analysis on the Spanish scenario, providing findings for a larger set of EU firms and NUTS1 regional economies. This is particularly relevant, given the paramount importance of research and innovation in the context of the EU policies (European Commission, 2010). The downsides are that we have to sacrifice the quality of the matching due to the limited number of controls in the probability equation, and that we can only assess whether public support is characterised by full crowding-out.

Descriptive statistics of the control variables in the probability equations are reported in Tables 12 and 13.

Table 12. Descriptive statistics of the control variables (European sample)

Variable	Mean	SD	Min	Med	Max
No. of employees	184.77	594.81	N.A.	N.A.	N.A.
Group	0.5042	0.4999	N.A.	N.A.	N.A.
Export	0.6777	0.4674	N.A.	N.A.	N.A.
Cooperation R&D	0.3324	0.4711	N.A.	N.A.	N.A.
Labor productivity	142,477	164,850	N.A.	N.A.	N.A.

Notes: Minima, median, and maxima have been suppressed to comply with EUROSTAT confidentiality.

Table 13. Descriptive statistics for the control variables, by group (European sample)

	Group 1		*Group 2*		*Group 3*		*Group 4*	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD
No. of employees	165.89	549.04	190.48	412.95	183.94	773.72	201.07	537.17
Group	0.4037	0.4907	0.5721	0.4948	0.4436	0.4968	0.6300	0.4829
Export	0.6179	0.4859	0.6845	0.4648	0.6766	0.4678	0.7437	0.4366
Cooperation R&D	0.2596	0.4384	0.3192	0.4662	0.3113	0.4631	0.4782	0.4996
Labor productivity	123,013	151,640	203,837	178,396	119,606	146,313	113,932	165,676
No. of observations (firms)	5,197		6,256		7,125		4,195	

Table 14 reports the estimates of the probability equation. The larger number of NUTS1 regions allows us to create four groups, using the same cut-off criterion as above. While the overall quality of the models is lower than in the previous analysis due to the limited number of covariates, we still find that size and export are positively correlated with the probability to receive R&D subsidies, as well as a negative effect of belonging to an industrial group.

Table 14. Probability equation estimation (probit model)

Dependent variable: R&D subsidy	*Pooled*	*Group 1*	*Group 2*	*Group 3*	*Group 4*
ln No. of employees	0.0682**	0.0443*	0.0205	0.1423**	0.0658**
	(0.0084)	(0.0179)	(0.0155)	(0.0162)	(0.0193)
Group	-0.1604**	-0.1612**	-0.1017*	-0.1176**	-0.2638**
	(0.0229)	(0.0476)	(0.0434)	(0.0429)	(0.0529)
Export	0.2571**	0.1929**	0.2211**	0.2889**	0.3915**
	(0.0239)	(0.0462)	(0.0473)	(0.0444)	(0.0596)
Cooperation R&D	0.5728**	0.4444**	0.5573**	0.6191**	0.6292**
	(0.5728)	(0.0437)	(0.0434)	(0.0392)	(0.0462)
ln Labor productivity	0.0069	0.0147	-0.0894**	0.0790**	0.0226
	(0.0125)	(0.0233)	(0.0248)	(0.0220)	(0.0343)
Industry and regional dummies	yes	yes	yes	yes	yes
No. of observations (firms)	22,773	5,197	6,256	7,125	4,195
Wald Chi2	2,237.03**	368.89**	494.60**	946.19**	458**
Pseudo R2	0.0984	0.0731	0.0744	0.1569	0.1028

Notes: Robust standard errors in parenthesis. Significant at * 5%, ** 1% level.

Estimating the impact of public support to R&D activities

Tables 15 and 16 report the estimates of the impact of R&D subsidies on subsidised firms compared to the control group across the four groups. Also in this case, we find that beneficiaries firms spend more in R&D than non-recipient companies in all groups, independently of the R&D measure considered. Hence, subsidies do have a positive effect for the average company also in the regional contexts where the quality of institutions is lower, as shown by the results for group 1 and 2. The main difference with respect to the Spanish sample is that the impact of public subsidies is higher in the best institutional frameworks, as reported by the *t*-test on ΔATT at the bottom of the table. One interpretation is linked to the scope of the CIS data, as the survey focuses on companies that are more likely to engage in research and innovative investment. Therefore, the same explanation provided for Table 11 (i.e. R&D performers in the Spanish context) applies here, consistently with the positive correlation between innovative capacity and institutional quality. Another possible explanation could be given by the European sample including a wider distribution of institutional quality across regions, with group 1 and 2 having lower values of the institutional index compared to the Spanish sample. This may suggest more stringent bottlenecks in taking up public subsidies, resulting in a lower impact compared to the Spanish sample. Nevertheless, this does not hinder the relevant conclusion of the analysis: supporting R&D activities of companies located in regions with weaker public institutions yields a positive effect, while full crowding-out is rejected. The impact is positive even though the framework conditions for knowledge absorption and R&D investment are worse than those for good institutional frameworks.

Table 15. Impact of R&D subsidies, by group

	Group 1				Group 2				Group 3				Group 4			
Variable	Treated	Controls	ATT	t-stat	Treated	Controls	ATT	t-st	Treated	Controls	ATT	t-stat	Treated	Controls	ATT	t-stat
ln R&D expenditure	4.5928	3.5544	1.0384	5.25**	6.9099	5.0463	1.8636	9.4	8.7354	6.1868	2.5486	13.33**	10.8736	8.4349	2.4387	12.31**
R&D intensity	0.0268	0.0149	0.0119	3.87**	0.0306	0.0146	0.0160	5.7	0.0708	0.0347	0.0361	6.97**	0.1249	0.0674	0.0575	7.72**
ln R&D exp / # employees	2.8741	2.1588	0.7153	5.64**	4.2932	3.0709	1.2223	9.7	5.5066	3.7561	1.7505	13.94**	7.0451	5.2467	1.7984	13.52**
ATT difference:	1 vs. 2	1 vs. 3	1 vs. 4	2 vs. 3	2 vs. 4	3 vs. 4										
ln R&D expenditure	-0.8252**	-1.5102**	-1.4003**	-0.6850**	-0.5751**	0.1099**										
R&D intensity	-0.0041**	-0.0242**	-0.0456**	-0.0201**	-0.0415**	-0.0214**										
ln R&D exp / # employees	-0.5070**	-1.0352**	-1.0831**	-0.5282**	-0.5761**	-0.0479**										
No. of treated units (on support)	1,484				1,801				1,862				1,253			
No. of treated units (off support)	0				0				0				47			
No. of controls	3,713				4,455				5,263				2,895			

Notes: Significant at * 5%, ** 1% level.

Table 16. Impact of R&D subsidies for R&D performers, by group

	Group 1				Group 2				Group 3				Group 4			
Variable	Treated	Controls	ATT	t-stat	Treated	Controls	ATT	t-st	Treated	Controls	ATT	t-stat	Treated	Controls	ATT	t-stat
ln R&D expenditure	11.7919	11.3061	0.4858	3.94**	12.0941	11.8009	0.2932	2.8	12.1474	11.3515	0.7959	8.45**	12.7578	11.8951	0.8627	10.71**
R&D intensity	0.0680	0.0670	0.0010	1.10	0.0536	0.0370	0.0166	3.2	0.0985	0.0527	0.0458	5.93**	0.1466	0.0839	0.0627	6.87**
ln R&D exp / # employees	7.3793	6.8713	0.5080	4.40**	7.5141	7.2347	0.2794	3.1	7.6574	6.8383	0.8191	9.96**	8.2659	7.4413	0.8246	11.51**
ATT difference:	1 vs. 2	1 vs. 3	1 vs. 4	2 vs. 3	2 vs. 4	3 vs. 4										
ln R&D expenditure	0.1926**	-0.3101**	-0.3769**	-0.5027**	-0.5695**	-0.0668**										
R&D intensity	-0.0156**	-0.0448**	-0.0617**	-0.0292**	-0.0461**	-0.0169**										
ln R&D exp / # employees	0.2286**	-0.3111**	-0.3166**	-0.5397**	-0.5452**	-0.0055										
No. of treated units (on support)	578				1,029				1,336				1,060			
No. of treated units (off support)	0				0				3				46			
No. of controls	934				1,686				1,954				1,695			

Notes: Significant at * 5%, ** 1% level.

The results for the sample of R&D performers are reported in Table 16. The magnitude of the impact decreases compared to the full sample, but the overall findings and related implications are confirmed. Consistently with the theory of bottlenecks à la Hausmann et al. (2008), the policy instrument is relaxing a constraint on companies, supporting R&D investment in adverse institutional settings. Once more, full crowding-out is rejected.

7. Conclusions

In this paper we have assessed the impact of R&D subsidies on business R&D expenditure across different regions, in Spain and Europe. Filling a vacuum in the existing literature, we have introduced the quality of public institutions as a key factor affecting the impact of R&D subsidies – i.e., how the efficiency of a policy instrument can be mediated by the framework in which firms operate. Indeed, while the interaction between the institutional quality and R&D activities has recently received increasing attention, to our knowledge this study represents the first concrete attempt to assess how the impact of subsidies, as an R&D policy tool, varies across different institutional frameworks. The main research interest lies in understanding whether public support to business R&D activities yield positive returns, or whether is characterised by crowding-out. While the known and undisputed positive relationship between research and innovative investments and institutional quality may suggest to focus public resources on the best contexts to maximise returns, public funding and R&D policy in general is justified in the worst institutional settings, as long as a positive effect is in place, crowding-out is rejected and, more generally, binding constraints to economic actors are relaxed. Our finding are relevant for policy considerations, especially in times when the allocation of scarce (public) resources needs to be justified by high returns. Not only our results reject crowding-out, showing cross-cutting evidence of positive impact on private R&D investment, but they also reveal a positive impact of public support for companies located in those regions where the quality of public institutions is lower and, hence, less supportive to economic investments, particularly in innovative activities characterised by higher uncertainty. Our results hold when we consider both a sample of Spanish companies and a wider group of firms located in different regions of the EU, with greater heterogeneity in terms of institutional quality. The analysis on the Spanish context provides particularly interesting results, as it allows to confirm additionality across regions, including and particularly in those with the weakest institutions. While limited to the assessment of full crowding-out, the results for the EU sample allow to generalise our findings and conclusions to a wider set of regions, strengthening the main economic rationale of the analysis and its policy implications. These findings imply that public R&D policy can be an important tool to stimulate knowledge creation in the business sector in disadvantaged areas, playing a key role in supporting growth and innovation beyond the core of richest regions with the best public institutions. Indeed, while focusing on the best performers may provide relatively higher returns, investing public resources to support business R&D activities in worse institutional scenarios is going to produce positive effects and is an important lever to support and diffuse knowledge and technology creation and diffusion. While the results are robust across different estimations, there are still some limitations due to the nature of the data, especially in the EU sample. Indeed, while the CIS are an established database used to investigate research and innovation dynamics at the firm level, the sample is less rich in information and would benefit from a wider range of available company information, as in the Spanish case. Furthermore, the confidentiality restrictions in accessing geographical information limited the application of our Institutional Index at the NUTS1 level only, which, while still valuable and more informative than a country level analysis, implies a loss of granularity with respect to a finer level of a disaggregation. Such an issue is more relevant the larger the regional disparities, as for instance the case in countries like Italy or Spain. Nevertheless, our findings allow to draw implications for innovation and regional development policy. The differences in the impacts of subsidies across different institutional frameworks reveal potential gains by fine-tuning the policy design by differentiating the targets of the subsidies according to regional characteristics – i.e. low or high institutional quality – and to firms' innovative behaviour – whether a company is an R&D performer or regularly engages in innovation activities. Differentiation may become an instrument to target different policy objectives, as for instance increasing the overall level of R&D expenditure, innovation performance or to tackle innovation gaps between regions with different institutional quality. Needless to say, R&D subsidies are not the only tool to achieve the above targets, but our evidence suggests that public support to business R&D activities is a valid instrument to complement other regional development policies to create a powerful policy mix aiming to leverage the innovation and productivity potential of regions, and eventually reduce regional disparities. Along these lines, future avenues of research may investigate the impact of public R&D support on different outcome measures beyond business expenditure, e.g. innovation output and economic outcomes, as well as their interaction with complementary development and industrial policies.

APPENDIX A – Composition of the European (left) and Spanish (right) sample

NUTS1	Country	No. Firms	%
BE1	Belgium	188	0.83
BE2	Belgium	1,314	5.77
BE3	Belgium	454	1.99
BG3	Bulgaria	1,050	4.61
BG4	Bulgaria	1,355	5.95
CY0	Cyprus	443	1.95
EE0	Estonia	162	0.71
FR1	France	1,261	5.54
FR2	France	674	2.96
FR3	France	232	1.02
FR4	France	358	1.57
FR5	France	657	2.88
FR6	France	409	1.80
FR7	France	689	3.03
FR8	France	300	1.32
FR9	France	48	0.21
HR3	Croatia	224	0.98
HR4	Croatia	679	2.98
HU1	Hungary	43	0.19
HU2	Hungary	23	0.10
HU3	Hungary	17	0.07
ITC	Italy	2,130	9.35
ITF	Italy	601	2.64
ITG	Italy	211	0.93
ITH	Italy	2,387	10.48
ITI	Italy	1,017	4.47
LT0	Lithuania	1,088	4.78
LUZ	Luxembourg	47	0.21
LV0	Latvia	375	1.65
MT	Malta	908	3.99
PT1	Portugal	3,339	14.66
PT2	Portugal	47	0.21
PT3	Portugal	43	0.19
Total		22,773	100

NUTS2	Region	No. Obs	%	No. Firms	%
ES11	Galicia	1,515	5.16	237	5.77
ES12	Principality of Asturias	707	2.41	84	2.05
ES13	Cantabria	382	1.30	47	1.14
ES21	Basque Community	2,158	7.73	313	7.62
ES22	Navarre	704	2.40	100	2.43
ES23	La Rioja	313	1.07	41	1.00
ES24	Aragon	1,113	3.79	163	3.97
ES30	Madrid	4,686	15.97	621	15.12
ES41	Castile-Leon	1,455	4.96	186	4.53
ES42	Castile-La Mancha	1,401	4.77	201	4.89
ES43	Extremadura	329	1.12	44	1.07
ES51	Catalonia	6,482	22.09	877	21.35
ES52	Valencian Community	4,208	14.34	589	14.34
ES53	Balearic Islands	410	1.40	60	1.46
ES62	Region of Murcia	747	2.55	99	2.41
ES61	Andalusia	2,270	7.44	388	9.45
ES70	Canary Islands	464	1.58	57	1.39
Total		29,344	100	4,107	100

APPENDIX B – Matching quality

Table B1: Balance checking for the Spanish sample

Panel a. Full sample

Variable	Matched	*Pooled* Treated	*Pooled* Controls	*Pooled* t-stat	*Pooled (R&D performers)* Treated	*Pooled (R&D performers)* Controls	*Pooled (R&D performers)* t-stat
R&D subsidy $_{t-1}$	no	0.6788	0.0374	131.96**	0.6790	0.1083	67.15**
	yes	0.6743	0.6726	0.13	0.6744	0.6679	0.50
ln No. of employees $_{t-1}$	no	5.6193	4.0150	55.95**	5.6204	5.1171	16.27**
	yes	5.5897	5.5964	-0.19	5.5908	5.7089	-3.34**
ln Age $_{t}$	no	3.3275	2.9637	22.70**	3.3277	3.2096	6.40**
	yes	3.3238	3.3104	0.62	3.3241	3.3131	0.50
Foreign shareholding $_{t-1}$	no	0.2638	0.1516	15.42**	0.2636	0.3235	-5.86**
	yes	0.2662	0.2801	-1.19	0.2660	0.3136	-3.99**
Market share $_{t-1}$	no	0.1650	0.1133	12.53**	0.1651	0.1778	-2.47*
	yes	0.1665	0.1765	-1.61	0.1665	0.1944	-4.43**
Export intensity $_{t-1}$	no	0.3268	0.1473	36.15**	0.3267	0.2648	9.68**
	yes	0.3243	0.3322	-0.99	0.3242	0.3369	-1.60
Debt on equity $_{t-1}$	no	0.0325	0.0431	-2.46*	0.0325	0.0301	0.56
	yes	0.0327	0.0303	0.59	0.0326	0.0263	1.65
ln Labor productivity $_{t-1}$	no	3.6700	3.2194	28.89**	3.6705	3.5271	8.94**
	yes	3.6631	3.6774	-0.76	3.6637	3.7157	-2.81**
Engineers and graduates $_{t-1}$	no	0.0915	0.0403	36.19**	0.0885	0.0943	-2.09*
	yes	0.0885	0.0939	-1.91	0.0885	0.0939	-1.91

Notes: Significant at * 5%, ** 1% level.

Panel b. By group

Variable	Matched	*Group 1* Treated	*Group 1* Controls	*Group 1* t-stat	*Group 2* Treated	*Group 2* Controls	*Group 2* t-stat	*Group 3* Treated	*Group 3* Controls	*Group 3* t-stat
R&D subsidy $_{t-1}$	no	0.6822	0.0225	63.15**	0.6183	0.0399	79.33**	0.7465	0.0449	83.55**
	yes	0.6646	0.6769	-0.33	0.6149	0.6037	0.57	0.7356	0.7301	0.28
ln No. of employees $_{t-1}$	no	5.5597	3.7923	24.50**	5.5052	4.0334	34.35**	5.7678	4.1589	34.87**
	yes	5.3978	5.3333	0.71	5.4874	5.5102	-0.42	5.7094	5.7654	-1.07
ln Age $_{t}$	no	3.2099	2.8373	8.63**	3.3996	2.9753	18.04**	3.2827	3.0436	9.41**
	yes	3.1701	3.2136	-0.67	3.3922	3.4003	-0.27	3.2868	3.2589	0.77
Foreign shareholding $_{t-1}$	no	0.2666	0.0754	12.91**	0.2266	0.1619	5.96**	0.3051	0.1940	8.69**
	yes	0.2538	0.2872	-1.00	0.2286	0.2383	-0.58	0.3140	0.3350	-1.07
Market share $_{t-1}$	no	0.1697	0.1149	4.69**	0.1428	0.1043	6.84**	0.1889	0.1277	8.60**
	yes	0.1706	0.1667	0.21	0.1437	0.1589	-1.84	0.1917	0.2134	-2.06*
Export intensity $_{t-1}$	no	0.3424	0.0964	20.48**	0.3014	0.1718	17.33**	0.3507	0.1449	25.79**
	yes	0.3188	0.3216	-0.11	0.3024	0.3172	-1.32	0.3426	0.3294	1.05
Debt on equity $_{t-1}$	no	0.0541	0.0529	0.10	0.0232	0.0403	-2.83**	0.0362	0.0478	-0.55
	yes	0.0556	0.0340	1.79	0.0234	0.0269	-0.77	0.0389	0.0478	-1.11
ln Labor productivity $_{t-1}$	no	3.4667	3.0057	9.53**	3.6548	3.2419	18.65**	3.7516	3.3492	18.00**
	yes	3.4538	3.6086	-2.49*	3.6467	3.6546	-0.30	3.3771	3.8087	-2.53*
Engineers and graduates $_{t-1}$	no	0.0626	0.0313	9.44**	0.0859	0.0405	22.50**	0.1071	0.0471	23.76**
	yes	0.0612	0.0704	-1.77	0.0833	0.0885	-1.24	0.0998	0.1006	-0.19

Notes: Significant at * 5%, ** 1% level.

Panel c. By group, R&D performers

		Group 1			Group 2			Group 3		
Variable	Matched	Treated	Controls	t-stat	Treated	Controls	t-stat	Treated	Controls	t-stat
R&D subsidy $_{t-1}$	no	0.6822	0.0913	26.77**	0.6180	0.1007	43.34**	0.7472	0.1317	42.20**
	yes	0.6646	0.6749	-0.28	0.6146	0.5993	0.77	0.7363	0.7257	0.54
ln No. of employees $_{t-1}$	no	5.5597	4.9702	7.30**	5.5076	5.0549	9.86**	5.7679	5.3119	9.46**
	yes	5.3978	5.5436	-1.67	5.4897	5.6062	-2.18*	5.7094	5.8771	-3.26**
ln Age $_{t}$	no	3.2099	3.0523	3.12**	3.3997	3.2192	7.02**	3.2831	3.2700	0.42
	yes	3.1701	3.2601	-1.40	3.3923	3.4301	-1.29	3.2873	3.2535	0.91
Foreign shareholding $_{t-1}$	no	0.2666	0.2409	0.98	0.2268	0.3075	-5.61**	0.3045	0.3962	-5.23**
	yes	0.2538	0.3499	-2.81**	0.2288	0.2804	-3.04**	0.3133	0.3659	-2.66**
Market share $_{t-1}$	no	0.1697	0.1880	-1.17	0.1429	0.1595	-2.44**	0.1888	0.2084	-2.14*
	yes	0.1706	0.1661	0.24	0.1438	0.1692	-3.06**	0.1916	0.2318	-3.81**
Export intensity $_{t-1}$	no	0.3424	0.2143	7.06**	0.3016	0.2797	2.42*	0.3502	0.2613	8.48**
	yes	0.3188	0.3338	-0.60	0.3027	0.3331	-2.73**	0.3421	0.3309	0.90
Debt on equity $_{t-1}$	no	0.0541	0.0347	2.21*	0.0232	0.0319	-1.25	0.0362	0.0241	1.99*
	yes	0.0556	0.0371	1.45	0.0234	0.0233	0.03	0.0389	0.0429	-0.65
ln Labor productivity $_{t-1}$	no	3.4667	3.4390	0.51	3.6553	3.5096	6.48**	3.7524	3.6053	6.15**
	yes	3.4538	3.6484	-3.23*	3.6473	3.6738	-1.03	3.7380	3.7315	-1.28
Engineers and graduates $_{t-1}$	no	0.0626	0.0561	1.75	0.0859	0.0593	10.81**	0.1072	0.0678	12.04**
	yes	0.0612	0.0671	-1.35	0.0834	0.0889	-1.35	0.0998	0.1004	-0.14

Notes: Significant at * 5%, ** 1% level.

Table B2: Balance checking for the European sample

Panel a. Full sample

		Pooled			Pooled (R&D performers)		
Variable	Matched	Treated	Controls	t-stat	Treated	Controls	t-stat
ln No. of employees	no	4.3005	4.0623	12.17**	4.5295	4.4087	4.33**
	yes	4.2986	4.2482	1.98*	4.5284	4.4944	1.92
Group	no	0.5178	0.4988	2.58**	0.6258	0.6277	0.19
	yes	0.5160	0.5136	0.96	0.6242	0.6130	0.56
Export	no	0.7828	0.6362	21.54**	0.8621	0.7705	11.59**
	yes	0.7813	0.7779	0.12	0.8611	0.8605	0.09
Cooperation R&D	no	0.4965	0.2676	33.85**	0.6309	0.3873	24.94**
	yes	0.4996	0.5066	-0.34	0.6299	0.6317	-0.07
ln Labor productivity	no	11.3322	11.2067	7.08**	11.4653	11.2166	10.43**
	yes	11.3452	11.3418	1.01	11.4613	11.4478	1.12

Notes: Significant at * 5%, ** 1% level.

Panel b. By group

		Group 1			Group 2			Group 3			Group 4		
Variable	Matched	Treated	Controls	t-stat	Treated	Controls	t-stat	Treated	Controls	t-stat	Treated	Controls	t-stat
ln No. of employees	no	4.1545	3.9984	4.02**	4.3261	4.2201	2.78**	4.3073	3.8959	11.58**	4.4224	4.2038	4.83**
	yes	4.1545	4.1777	-1.32	4.3261	4.3285	-0.05	4.3073	4.2923	0.87	4.4288	4.4625	-1.88
Group	no	0.4023	0.4043	-0.13	0.5630	0.5757	-0.92	0.4748	0.4326	3.15**	0.6485	0.6218	1.66
	yes	0.4023	0.4162	-1.02	0.5630	0.5918	-1.98*	0.4748	0.4791	-0.32	0.6490	0.6688	-1.01
Export	no	0.7109	0.5807	8.79**	0.7445	0.6601	6.52**	0.8281	0.6230	16.57**	0.8531	0.6946	11.02**
	yes	0.7109	0.7252	-0.88	0.7445	0.7455	-0.03	0.8281	0.8256	0.08	0.8596	0.8837	-1.52
Cooperation R&D	no	0.3605	0.2192	10.60**	0.4608	0.2619	15.57**	0.5161	0.2388	23.02**	0.6731	0.3907	17.54**
	yes	0.3605	0.3643	-0.11	0.4608	0.4573	0.69	0.5161	0.5401	-1.92	0.6822	0.7191	-1.60
ln Labor productivity	no	11.0228	11.1187	-2.63**	11.7233	11.8797	-5.74**	11.3616	11.0371	10.89**	11.1012	10.5921	11.54**
	yes	11.0228	11.0315	-0.28	11.7233	11.7419	-0.66	11.3616	11.3995	-1.85	11.1303	11.2134	-2.07*

Notes: Significant at * 5%, ** 1% level.

Panel c. By group, R&D performers

		Group 1			Group 2			Group 3			Group 4		
Variable	Matched	Treated	Controls	t-stat	Treated	Controls	t-stat	Treated	Controls	t-stat	Treated	Controls	t-stat
ln No. of employees	no	4.4422	4.2859	2.15*	4.6132	4.5531	1.11	4.5450	4.3325	3.63**	4.5149	4.4203	1.82
	yes	4.4422	4.4666	-1.63	4.6132	4.5965	0.47	4.5449	4.5408	0.11	4.5128	4.4625	1.11
Group	no	0.5779	0.5375	1.53	0.6851	0.6868	0.09	0.5467	0.5661	-1.09	0.6913	0.6881	0.18
	yes	0.5779	0.5732	0.13	0.6851	0.6767	0.88	0.5465	0.5429	0.31	0.6888	0.6689	0.66
Export	no	0.8010	0.7409	2.69**	0.8484	0.7900	3.79**	0.8745	0.7559	8.52**	0.8917	0.7840	7.46**
	yes	0.8010	0.8137	-0.99	0.8484	0.8413	0.06	0.8739	0.8729	0.09	0.8900	0.8838	0.93
Cooperation R&D	no	0.5433	0.3073	9.37**	0.5617	0.2977	14.12**	0.6355	0.4161	12.67**	0.7356	0.4848	13.65**
	yes	0.5433	0.5542	-0.68	0.5617	0.5688	-0.62	0.6358	0.6552	-0.98	0.7311	0.7191	0.24
ln Labor productivity	no	11.3570	11.4149	1.02	11.8592	12.0247	-4.72**	11.4119	10.9698	11.43**	11.2206	10.6049	12.58**
	yes	11.3570	11.3508	0.92	11.8592	11.8532	0.33	11.4117	11.4310	-0.61	11.2197	11.2134	0.51

Notes: Significant at * 5%, ** 1% level.

APPENDIX C – Instrumental variables approach (Spanish sample only)

Panel a. Full sample

	Pooled			Pooled (R&D performers)		
Variable	ln R&D expend.	R&D intensity	ln R&D exp / # empl	ln R&D expend.	R&D intensity	ln R&D exp / # empl
R&D subsidy $_{t-1}$	0.6554**	0.2642**	0.4025**	0.1014**	0.1971**	0.0990**
	(0.0253)	(0.0211)	(0.0161)	(0.0076)	(0.0208)	(0.0075)
ln No. of employees $_{t-1}$	1.3998**	-0.0042	0.5560**	0.8628**	-0.2952**	-0.1181**
	(0.0637)	(0.0243)	(0.0364)	(0.0291)	(0.0650)	(0.0288)
ln Age $_{t}$	0.0376	0.0009	0.0229	-0.0248	-0.0499	-0.0181
	(0.0875)	(0.0357)	(0.0521)	(0.0391)	(0.0786)	(0.0387)
Foreign shareholding $_{t-1}$	0.3032	-0.1530	0.0802	0.0474	-0.2034	0.0387
	(0.2499)	(0.0993)	(0.1453)	(0.0756)	(0.1637)	(0.0747)
Market share $_{t-1}$	1.2280**	0.0036	0.7382**	0.1242	-0.2771	0.1115
	(0.3097)	(0.1413)	(0.1799)	(0.1148)	(0.2683)	(0.1142)
Export intensity $_{t-1}$	2.0649**	0.0659	1.3812**	0.1985	-0.5525*	0.2009
	(0.3126)	(0.1227)	(0.1884)	(0.1061)	(0.2275)	(0.1051)
Debt on equity $_{t-1}$	-0.3065	-0.1020	-0.1866*	-0.0718	-0.2240	-0.0685
	(0.1619)	(0.0548)	(0.0891)	(0.0552)	(0.1554)	(0.0559)
ln Labor productivity $_{t-1}$	0.6920**	-0.0487	0.4419**	0.3161**	-0.3767**	0.2776**
	(0.0942)	(0.0436)	(0.0586)	(0.0456)	(0.1206)	(0.0451)
Engineers and graduates $_{t-1}$	2.5005**	3.2772**	2.4092*	3.1588**	6.8859**	3.1332**
	(0.9639)	(0.6393)	(0.6108)	(0.4445)	(1.5427)	(0.4375)
Time dummies	yes	yes	yes	yes	yes	yes
No. of firms	3,433	3,433	3,433	1,571	1,571	1,571
No. of observations	20,838	20,838	20,838	7,416	7,416	7,416
Hensen J statistic	3.4000	4.1920	1.0570	1.6060	1.9110	1.4140
R2	0.5059	0.1909	0.4546	0.6212	0.1844	0.3877

Panel b. By group

	Group 1			Group 2			Group 3		
Variable	ln R&D expend.	R&D intensity	ln R&D exp / # empl	ln R&D expend.	R&D intensity	ln R&D exp / # empl	ln R&D expend.	R&D intensity	ln R&D exp / # empl
R&D subsidy $_{t-1}$	0.8019**	0.2156**	0.4745**	0.6297**	0.2513**	0.3957**	0.4410**	0.1874**	0.2712**
	(0.0623)	(0.0573)	(0.0377)	(0.0389)	(0.0314)	(0.0249)	(0.0243)	(0.0197)	(0.0156)
ln No. of employees $_{t-1}$	1.0897**	0.0152	0.4634**	1.5391**	0.0442	0.6141**	1.5352**	-0.0006	0.6225**
	(0.1204)	(0.0367)	(0.0655)	(0.0936)	(0.0319)	(0.0543)	(0.1091)	(0.0485)	(0.0619)
ln Age $_{t}$	-0.1225	-0.0455	-0.0859	-0.0184	0.0188	-0.0119	0.0697	-0.0190	0.0565
	(0.1576)	(0.0430)	(0.0902)	(0.1329)	(0.0425)	(0.0796)	(0.1466)	(0.0809)	(0.0886)
Foreign shareholding $_{t-1}$	1.4292*	-0.1759	0.5833	-0.3845	-0.2893*	-0.3135	0.4714	-0.0979	0.2306
	(0.6318)	(0.1526)	(0.3573)	(0.3642)	(0.1382)	(0.2106)	(0.3689)	(0.1634)	(0.2189)
Market share $_{t-1}$	0.8106	0.1049	0.5028	1.6292**	-0.0925	0.9554**	0.9861	0.0398	0.6149*
	(0.6166)	(0.2037)	(0.3458)	(0.4780)	(0.1974)	(0.2830)	(0.5203)	(0.2787)	(0.3008)
Export intensity $_{t-1}$	1.2609	0.0159	0.7938*	2.4676**	0.0733	1.6667**	1.8162**	0.4068	1.2693**
	(0.6848)	(0.1936)	(0.3936)	(0.4310)	(0.1523)	(0.2606)	(0.5966)	(0.2578)	(0.3656)
Debt on equity $_{t-1}$	-0.1671	-0.0435	-0.0921	-0.1145	-0.0116	-0.0861	-0.5698**	-0.1947**	-0.3269**
	(0.2086)	(0.1252)	(0.1292)	(0.2742)	(0.0748)	(0.1504)	(0.2023)	(0.0560)	(0.1088)
ln Labor productivity $_{t-1}$	0.6477**	0.0851	0.3994**	0.6434**	-0.1545*	0.4129**	0.8205**	0.0284	0.5292**
	(0.1767)	(0.0988)	(0.1060)	(0.1406)	(0.0602)	(0.0904)	(0.1795)	(0.0799)	(0.1084)
Engineers and graduates $_{t-1}$	4.8375*	0.6628	3.6780*	2.0796	4.7455**	2.1666*	3.4486*	3.3113**	3.0003**
	(2.4616)	(0.5220)	(1.5932)	(1.4283)	(1.0807)	(0.8846)	(1.5518)	(1.0143)	(1.0146)
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes
No. of firms	838	838	838	1,654	1,654	1,654	1,057	1,057	1,057
No. of observations	4,380	4,380	4,380	10,247	10,247	10,247	6,791	6,791	6,791
Hensen J statistic	1.5210	2.1130	1.8710	1.1790	2.6130	0.6050	3.8000	8.6600*	3.7710
R2	0.4587	0.0805	0.4209	0.4842	0.1946	0.4242	0.5619	0.2833	0.5144

Panel c. By group, R&D performers

	Group 1			*Group 2*			*Group 3*		
Variable	ln R&D expend.	R&D intensity	ln R&D exp / # empl	ln R&D expend.	R&D intensity	ln R&D exp / # empl	ln R&D expend.	R&D intensity	ln R&D exp / # empl
R&D subsidy $_{t-1}$	0.0937**	0.1345*	0.0904**	0.1075**	0.1836**	0.1047**	0.0951**	0.2381**	0.0931**
	(0.0731)	(0.0684)	(0.0213)	(0.0108)	(0.0295)	(0.0107)	(0.0089)	(0.0227)	(0.0088)
ln No. of employees $_{t-1}$	0.9605**	-0.3375*	-0.0154	0.9044**	-0.1441	-0.0779*	0.7877**	-0.5351**	-0.1898**
	(0.0731)	(0.1311)	(0.0722)	(0.0388)	(0.0776)	(0.0386)	(0.0280)	(0.0723)	(0.0276)
ln Age $_{t}$	-0.1155	-0.1516	-0.1034	-0.0423	0.0195	-0.0353	0.0154	-0.0594	0.0179
	(0.1014)	(0.1685)	(0.0995)	(0.0485)	(0.0887)	(0.0479)	(0.0389)	(0.0806)	(0.0380)
Foreign shareholding $_{t-1}$	-0.0305	-0.1011	-0.0524	-0.0806	-0.4448*	-0.0872	0.1984**	0.2159	0.1872**
	(0.1993)	(0.2993)	(0.1966)	(0.0969)	(0.2244)	(0.0957)	(0.0684)	(0.1561)	(0.0674)
Market share $_{t-1}$	0.5167	0.0661	0.5059	-0.1116	-0.5700	-0.1016	0.1965	-0.0694	0.1453
	(0.3094)	(0.5680)	(0.3098)	(0.1506)	(0.3590)	(0.1491)	(0.1172)	(0.3107)	(0.1165)
Export intensity $_{t-1}$	0.3673	-0.0785	0.3763	0.2112	-0.6599**	0.2092	0.1583	-0.0599	0.1567
	(0.2386)	(0.4640)	(0.2359)	(0.1289)	(0.2497)	(0.1269)	(0.1122)	(0.2841)	(0.1104)
Debt on equity $_{t-1}$	0.0907	-0.4645	0.1070	-0.0045	0.0539	-0.0145	-0.1635	-0.7413*	-0.1426
	(0.3433)	(1.0267)	(0.3570)	(0.0557)	(0.1279)	(0.0545)	(0.1487)	(0.2891)	(0.1495)
ln Labor productivity $_{t-1}$	0.1547*	-0.0095	0.1253	0.3379**	-0.5642**	0.2927**	0.4116**	-0.2158	0.3725**
	(0.0784)	(0.3220)	(0.0759)	(0.0675)	(0.1491)	(0.0671)	(0.0584)	(0.1549)	(0.0580)
Engineers and graduates $_{t-1}$	4.2821**	-1.144	4.5033**	3.2720**	10.1201**	3.1862**	2.6146**	3.3645**	2.6152**
	(1.2377)	(2.7860)	(1.2183)	(0.5681)	(2.3234)	(0.5505)	0.4098	1.0827	(0.4046)
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes
No. of firms	278	278	278	842	842	842	491	491	491
No. of observations	1,040	1,040	1,040	3,961	3,961	3,961	2,415	2,415	2,415
Hensen J statistic	2.6650	4.7890	2.4190	1.1390	2.2340	1.4540	3.5090	1.4510	3.1640
R2	0.6521	0.1142	0.3827	0.6438	0.2066	0.3915	0.5936	0.2605	0.4251

Panel d. First-stage regression

	Full sample				*R&D performers*			
Variable	*Pooled*	*Group 1*	*Group 2*	*Group 3*	*Pooled*	*Group 1*	*Group 2*	*Group 3*
ln Avg subsidy $_{t-1}$	0.0409**	0.0293*	0.0474**	0.0422*	0.2217**	0.1844**	0.2159**	0.2589**
	(0.0091)	(0.0145)	(0.0135)	(0.0166)	(0.0347)	(0.0688)	(0.0459)	(0.0625)
No. subsidy users $_{t-1}$	0.0412**	0.0446**	0.0504**	0.0230	0.0708**	0.1111**	0.0788**	0.0291
	(0.0063)	(0.0113)	(0.0084)	(0.0131)	(0.0136)	(0.0336)	(0.0169)	(0.0273)
ln No. of employees $_{t-1}$	0.3122**	0.1615**	0.3639**	0.3430**	0.4667**	0.3260**	0.4792**	0.4886**
	(0.0255)	(0.0359)	(0.0385)	(0.0517)	(0.0541)	(0.1235)	(0.0771)	(0.0840)
ln Age $_{t}$	-0.0028	0.0663	0.0437	-0.0999	0.0296	0.2184	0.1395	-0.1239
	(0.0339)	(0.0617)	(0.0490)	(0.0670)	(0.0773)	(0.2007)	(0.1101)	(0.1247)
Foreign shareholding $_{t-1}$	-0.4578**	0.2356	-0.6189**	-0.5404**	-0.8655**	-0.1295	-0.9459**	-1.0877**
	(0.1036)	(0.2729)	(0.1441)	(0.1714)	(0.1566)	(0.4110)	(0.2194)	(0.2203)
Market share $_{t-1}$	-0.2754*	-0.0162	-0.3529	-0.4079	-0.5247*	0.1584	-0.7012	-0.6978
	(0.1336)	(0.1942)	(0.2059)	(0.2576)	(0.2598)	(0.5184)	(0.3957)	(0.3937)
Export intensity $_{t-1}$	0.4978**	1.0133**	0.2644	0.5897*	0.3983	1.6370**	0.0264	0.5039
	(0.1344)	(0.2924)	(0.1647)	(0.2877)	(0.2329)	(0.5917)	(0.3031)	(0.3733)
Debt on equity $_{t-1}$	0.0362	0.1669	-0.0478	0.0359	0.2139	0.9340	-0.0775	0.6176
	(0.0871)	(0.1705)	(0.0549)	(0.2249)	(0.1996)	(1.0612)	(0.1241)	(0.4411)
ln Labor productivity $_{t-1}$	-0.0244	-0.1201	-0.0478	0.1405	-0.1514	-0.3334	-0.1941	0.0952
	(0.0352)	(0.0628)	(0.0503)	(0.0832)	(0.0977)	(0.2252)	(0.1341)	(0.2107)
Engineers and graduates $_{t-1}$	3.3757**	0.9197	3.4063**	3.8064**	7.0189**	3.3414	6.8934**	7.3065**
	(0.5416)	(0.5736)	(0.8311)	(0.9174)	(1.2377)	(2.7279)	(1.6733)	(1.3771)
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes
No. of firms	3,433	838	1,654	1,011	1,571	278	842	491
No. of observations	20,838	4,380	10,203	6,255	7,416	1,040	3,961	2,415

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