Chapter 1 Introduction

1.1 Overview

Implementing effective innovation policies is not an easy task, even though theoretical arguments and empirical evidence support public intervention in this regard. Policy makers have imperfect information about which innovation projects are deterred, and to what extent, as a consequence of knowledge spillovers, of firms' financial constraints or of failures in complementary markets. Ex-ante evaluation of whether the social benefits of supporting a particular project would exceed social costs is difficult, as is anticipating the timing of outcomes and whether the policy impact will be permanent or temporary. Ex-post policy evaluation becomes then an important tool help check the effects of a policy given the institutional and business environment. It can also provide useful information to revise it.

These three essays contribute fresh empirical evidence on the allocation of public support to firms and on its impact on innovation investment, outcomes and/or productivity. Chapter 2 analyzes the case of an emerging country, Colombia, in a cross-sectional setting. It expands the well-known Crepon-Duguet-Mairesse framework by integrating the allocation of public subsidies to innovation as an additional equation into the model. It also allows for variation in the association between innovation and productivity, and for variation across industries, given the large heterogeneity observed in these dimensions. Chapters 3 and 4 focus on dynamic aspects of the allocation of direct support to R&D and innovation in a high-income country, Spain. In this case, because longitudinal data are available, the focus is, respectively, on the impact of public subsidies on firms' innovation activities across the business cycle, and on the impact of the length of participation on innovation outcomes.

All three chapters use firm-level data from firm-level innovation surveys conducted by the respective statistical offices. Inspired in the European Community Innovation Survey, which in turn is based on the OECD Oslo Manual, these surveys provide quantitative and qualitative information on innovation activities, types and outcomes in firms in all industries. Access by researchers to firm-level data has promoted extensive empirical research on innovation at the firm level. Because questionnaires contain share some common questions, they also have enabled to some extent comparative, cross-country studies.

Current innovation surveys, however, suffer from some limitations. Mairesse and Mohnen (2010) point out some of them. Ease of access to microdata by researchers is not uniform across countries; survey periodicity varies, so that longitudinal data sets are not always available to researchers; relevant information about the firm (human capital, management practices, capital intensity, performance indicators) or its context (firm's position in the market, degree of competition, strength of regulatory constraints, labor market factors) is not collected; sampling procedures are not uniform; merging innovation survey data with other firm-level surveys is often not possible. These limitations add to the measurement issues regarding the definition of innovation, innovation types, inputs and outcomes. In these surveys, for example, answers to many questions reflect subjective perceptions of the respondents, which may lead to over-reporting innovations, especially of organizational or marketing types. Limitations are identified, among others, in Cirera and Muzi (2016) concerning innovation in developing countries; in a report published by the National Academies of Sciences, Medicine, et al. (2017), Advancing Concepts and Models for Measuring Innovation: Proceedings of a Workshop, and at the Blue Sky Forum organized by the OECD every ten years.

Particularly relevant for policy evaluation is the lack of information on the ease of imitation as a deterrent of potential innovation projects; on objective indicators of financial constraints to complement subjective perceptions, and on some specifics of public support, such as distinguishing between applying and obtaining, and duration of support when obtained. All three essays are affected by some of these limitations, conditioning the questions that can be addressed, the type of empirical analysis that can be performed, the interpretation of the results, and thus the discussion of their policy implications. The content of each chapter is summarized next.

1.2 Chapter 2. Innovation, Public Support, and Productivity: A Cross-Industry Comparison

Innovation is an extremely important concern in Latin American countries. As a recent World Bank report by Cirera and Maloney (2017) highlights, innovation –in its wider sense, which includes from frontier R&D to generate new-to-the-world products to adoption of technologies, managerial and organizational practices– is critical for productivity growth and hence for accelerating development and reducing poverty. Even though potential returns to innovation are very large in developing countries, they invest much less in innovation than advanced countries (Goñi and

Maloney 2017). Cirera and Maloney (2017) refer to this as the *Innovation Paradox*. They identify three determinants of innovation performance, one of them being the government capability to implement effective innovation policies. Market and government failures may be more widespread in these countries, so that implementing an effective policy mix may be harder when the scope of these failures is high, complementary factors are missing and institutions are weak. Identifying the barriers for an effective innovation policy is therefore of paramount importance, especially given that these barriers often arise from several parts of the economic system. Consequently, an exclusive focus on R&D may not be appropriate, as Cirera and Maloney (2017) point out. Among others, managerial capabilities need to be developed as well (Bruhn, Karlan, and Schoar 2018).

Colombia even lags behind other Latin-American economies regarding innovation and productivity. Over the last decade, R&D investment has reached about 0.2%of the GDP, which compared to the average of the region (0.7%), is relatively low (see Figure 1.1).



Figure 1.1: Research and Development Expenditure (as % of GDP)

Note: Data extracted from the World Bank. Last update 14-Nov-2018.

Colombia has implemented specific policies to foster innovation in the business sector. Direct support through subsidies and loans, and tax deductions for R&D and technological development projects are available to firms. There is nonetheless little empirical evidence on the profile of beneficiaries from this support, on the correlation between the allocation of support and actual or perceived barriers to innovation, and on the final impact on productivity. These are important matters to consider in order to evaluate the effectiveness and potential shortcomings of policies intended to foster innovation.

Several issues have to be taken explicitly into account when analyzing direct support –loans or grants- to firms in particular: i) allocation of support is not random, but a result of a firm's decision to apply for it and the public agency to award it; perceived barriers to innovation may affect the resulting allocation; ii) returns to innovation may differ significantly across the firms' productivity distribution, and iii) allocation of support and returns to innovation might differ across manufacturing and service industries.

This chapter addresses these three issues extending earlier work. Although public support has been used as an explanatory variable in the CDM framework, as in Griffith, Huergo, Mairesse, and Peters (2006), to the best of our knowledge only Czarnitzki and Delanote (2017), who use Belgian data, account for its endogeneity by instrumenting it. They do not analyze the allocation process, however. Regarding returns to innovation, some previous studies find that the returns to innovation vary with firms' productivity (Bartelsman, Dobbelaere, and Peters 2014; Segarra and Teruel 2011) although in opposite directions in different countries. If private returns to innovation -as measured by their contribution to labor productivity- are higher for more productive firms, then direct public support for innovation should focus on the subset of productive firms that underinvest in innovation. If returns to innovation are the same on average for all firms at any productivity level, then there would be no need for a targeted support policy.

A cross-industry comparison is emphasized in this essay because services account for about 60% of GDP in Colombia. Services have some differential traits with respect to manufacturing industries, and these traits may shape incentives to innovate. Service industries often produce intangible products (e.g., information, consulting services); the quality and value to the user are not revealed until consumption; consequently, uncertainty may be higher. Service and manufacturing industries differ as well in terms of market features such as the degree of competition and regulation. Restrictions to FDI, barriers to entry and conduct regulation could significantly affect some activities within the service industry (think of telecommunications, financial services or education) compared to manufacturing. Third, the ability to generate innovations through R&D is very heterogeneous across different industries, with adoption of technologies (ICTs) being more important in some (Paunov and Rollo 2016; Segarra-Blasco 2010).

To address these issues the basic Crèpon-Duguet-Mairesse model, designed to test the links between R&D, innovation and productivity at the firm level, is extended in two ways: first, an equation describing the allocation of direct support is added as the first step of the model; second, the productivity equation in the last step is estimated using quantile regression methods to allow for potentially heterogeneous returns to innovation. Figure 1.2 represents the four stages of the extended model.



Figure 1.2: An Extended version of the CDM (1998)

The data set for this chapter is drawn on two firm-level datasets gathered by the Colombian National Statistics Department (DANE): the Survey of Innovation and Technological Development in Services, EDITS-III (2010-2011) and the Survey of Innovation and Technological Development in Manufacturing, EDIT (2009-2010).¹ The sample consists of 905 manufacturing firms, 954 firms in knowledge-intensive business services (KIS), and 1,419 firms in remaining service activities. The sampling procedure differs across manufacturing and services, so the sample is not equally representative in both cases. In manufacturing firms with 10 or more employees are sampled; in KIS, firms with 20 or more employees, except for banking activities, where all the census is sampled. In traditional services firms with at least 20 employees in utilities, education and health and entertainment, film and TV are sampled, while in the wholesale and retail trade only firms with at least 50 employees, and in hospitality at least 40, are sampled. This has to be taken into account in all cross-industry comparisons, as the sample for traditional services will be biased towards larger firms.

Because these are basically cross-sectional data, the aim is to uncover regularities and correlations that may be informative from a policy perspective, without claiming to establish causal relations. Simultaneity issues cannot be properly addressed. A case in point is the potential endogeneity of perceived barriers to innovate, in particular of financial constraints. Innovation surveys do not provide factual or

¹DANE is the acronym for Departamento Administrativo Nacional de Estadística. See the website: www.dane.gov.co. EDIT is the acronym for Encuesta de Desarrollo e Innovación Tecnológica.

objective information (i.e., a firm's credit rating). In our case, we test for exogeneity using as instruments the log of firm size and lagged sales per worker and do not reject the null.

Significant differences across manufacturing and certain service industries are found. The first concerns the allocation of public support for innovation. Firms that face financing constraints are more likely to benefit from public support in manufacturing and in traditional services. In knowledge-intensive services (KIS), however, firms that perceive regulations to be a hurdle for innovation are more likely to have public support. Controlling for previous innovation effort, engaging in innovation activities is positively correlated with public support, especially in manufacturing and KIS.

Regarding the link between innovation and productivity, in all service industries, including KIS, introducing all types of innovations increases productivity of firms below the median of the productivity distribution, but not of those above it. Within manufacturing innovation results in higher productivity in all quantiles of the distribution, but again slightly more in lower quantiles. At the same time, returns to human capital are significant and increasing with productivity in all industries, suggesting that investing in human capital is private and socially profitable across the board.²

With respect to policy implications, this empirical analysis suggests that improving the financial system to make it easier for innovators to obtain private funding could help promote innovation in manufacturing or traditional services. This might not be sufficient for KIS, where access to public funding for innovation is correlated with the perception that regulations are an obstacle to innovate. Some regulations may dampen the returns to innovation in this sector, and innovation support might be a way to offset this effect. The World Bank's Enterprise Survey for Colombia reports some indicators of potential bottlenecks for 2017/18. Out of 993 surveyed firms, 24% identify customs and trade regulations as a major constraint; the number of days to clear import from customs or to obtain an import license is high (almost 18 and 30 days respectively); as are the number of days to obtain a constructionrelated permit or an operating license.³ Further analysis to identify the type of regulations that might hinder innovation activities in KIS in Colombia is needed. This suggests that there may be complementarities between innovation policy and other policies (Goñi and Maloney 2017; Mohnen and Röller 2005). Recent work by Arque-Castells (2018) also provides empirical insights on these complementarities across 28 EU countries.

² This chapter, started in 2014 and finished in 2016, has been published with the title "Innovation, Public Support, and Productivity in Colombia. A Cross-industry Comparison" in *World Development*, 99 (2017), pp.75-94.

³See The World Bank Group, Enterprise Surveys: https://bit.ly/2ZKpJkf

As stated above, the data used in this chapter are basically cross-sectional. Although the availability and use of some lagged variables may help somewhat in reducing simultaneity and endogeneity issues, this does not eliminate them necessarily. To better control for unobserved factors, longitudinal data would be preferred. Since the Colombian Statistical Office (DANE) is running these surveys periodically, this opens the door to a replication exercise (for other years) as well as to using a more appropriate econometric framework to unveil the causal relationship between public support for innovation and its dynamic effects on productivity, in line with Raymond, Mairesse, Mohnen, and Palm (2015). Besides, a longitudinal perspective should be looking at what barriers affect the different components of R&D, distinguishing between exploratory (i.e. research) and exploitative (i.e., development) activities. A second avenue for further research would focus on the relationship between innovating and exporting, as in Peters, Roberts, and Vuong (2018), who show that trade related regulations, such as export or import tariffs, may affect returns to innovation and R&D. A deeper understanding of both the self-selection into exporting and innovating in Colombia could be an issue of policy interest as well.

Finally, in many emerging and developing countries, including Colombia, a dualeconomy system exists, that is, formal and informal economic activities. A line of work is exploring how innovation and the allocation of public support are affected by informality or by corruption. This is an important issue for future research.⁴

1.3 Chapter 3: Subsidizing Innovation over the Business Cycle

This chapter investigates the impact of public support to business investment in R&D over the different phases of the business cycle. It addresses the following questions: (i) Does firms' access to support vary over the business cycle? (ii) Does the impact of support remain constant over the cycle? (iii) How does support affect monetary (R&D investment) and non-monetary (R&D employment) decisions? The first question intends to determine whether firms that benefit from public support in recessions differ from firms that benefit from it during expansions, as both firms and the public agency could change their behavior over the cycle. For instance, financially constrained firms might apply for support during expansions, but abstain from doing so during recessions. The second question intends to determine whether the impact of public support is smaller in recessions than in expansions or otherwise.

 $^{^{4}}$ Fu, Mohnen, and Zanello (2018) is one of the few papers that analyzes the relationship between innovation and productivity using a CDM framework and capturing the effects for formal and informal firms.

The third question intends to inquire beyond the standard monetary effect of public support and look into the time allocation of employees to R&D activities. Firm-level panel data from Spain covering the period 2006 to 2014 are used to investigate these questions.

This research is related to studies on firms' R&D and innovation investment choices during the recent crisis and to studies evaluating the impact of public support on these decisions. Earlier studies have shown that business R&D investment is pro-cyclical on average, both at the aggregate and firm level (Aghion, Angeletos, Banerjee, and Manova 2010; Aghion, Askenazy, Berman, Cette, and Eymard 2012; Beneito, Rochina-Barrachina, and Sanchis-Llopis 2015; Cincera, Cozza, Tübke, and Voigt 2012; Fabrizio and Tsolmon 2014). Figure 1.3 unveils a significant positive correlation between GDP growth and business R&D investment (BERD) in the EU-28 area dropped by 2.5% while GDP decreased by 3.5. Spain followed a similar but more severe path.





Note: Data extracted from the OECD Main Science and Technology Indicators for BERD, GDP growth rates.

Empirical research suggests that procyclicality is mainly driven by the joint or separate action of market imperfections and knowledge spillovers, generating not only a static market failure but also inducing a dynamic misallocation of R&D investment over the cycle. A question then arises: would a countercyclical policy providing public support to R&D be able to mitigate the dynamic failure predicted by previous models? The answer hinges on the sign and size of the multiplier or additionality effect during recessions.

Only two firm-level studies focus on the effect of public support to R&D during the financial crisis years: Hud and Hussinger (2015) and Aristei, Sterlacchini, and Venturini (2017). Hud and Hussinger (2015) use German SMEs firm-level data from the period 2006 to 2010. They find that public subsidies have an overall positive effect on firms' private R&D investment, but they also find some evidence of a small and temporary crowding out effect in 2009. By 2010 the estimated additionality effect becomes positive again, but is smaller than during the pre-crisis years. A closer analysis of firms that received R&D subsidies before, during and after the crisis indicates that SMEs firms changed their investment behavior during the crisis year, allocating funds that would have been spent on R&D to other business areas. These findings suggest a negative or pro-cyclical multiplier of R&D subsidies. Aristei et al. (2017) compare the effect of public support in five EU countries during the crisis period and do not find evidence of additionality in any. It would then seem that public support would be less effective during recessions. The data used in both studies face some limitations though, as they do not use a long enough firm-level panel.

This chapter extends previous work by the cited authors in several directions owing to the availability of firm-level panel data, in particular data from the Spanish Innovation Panel (PITEC) for the period 2005 and 2014. The empirical strategy consists of both analyzing the allocation of public support and its determinants over time as well as estimating the impact or the degree of additionality of R&D subsidies on investment in innovation per employee and also on the employee time allocation to R&D activities. Estimates are obtained for several participation spells within three distinct periods: before the crisis (2005-2008), during the crisis (2009-2012), and after the crisis (2013-2014). A spell is defined here as the number of years a firm reports receiving a subsidy within a given period. A semi-parametric local linear matching approach (the propensity score) combined with difference-indifferences (conditional difference-in-differences, CDID, Heckman, Ichimura, Smith, and Todd 1998) allows addressing selection on both observables (through matching) and unobservables (by differencing) associated with subsidization of R&D. This approach intends to mimic an experimental setting as closely as possible. That is, subsidy recipients (treated firms) are matched to a sample of non-recipients (control firms) that are closely similar to the treated in observed dimensions before treatment. The treatment effect is then estimated by differences in differences. This may lead to relatively small sample sizes and associated problems, such as low statistical power, so there is a trade-off. Finally, the richness of the data allows to take into account that the effects of support take some time to unfold, that firms receive direct support at different points in time and that its effects may last more than one period.

Findings are the following. First, the allocation of R&D subsidies in Spain did not change significantly during the crisis. Second, the multiplier varies depending on the firms' participation spell and with the type of outcome –monetary or nonmonetary- considered. Third, timing and length of participation matter, with longer spells leading to a higher multiplier. While the impact of public support during the recession years is found to be pro-cyclical for investment in innovation in monetary terms, when looking at the time allocation to R&D activities the multiplier is higher and longer during the recession. These results are robust for SMEs. Overall, they suggest that direct support to business R&D may mitigate the negative effect that recessions have on highly cyclical R&D investments through the reallocation of more human capital to R&D activities, even if monetary investment does not increase. That is, public support allows firms to assign employee time to innovation activities that would not be performed without support. Public support may have prevented the reduction of knowledge capital during the big recession by subsidy recipients.

Several mechanisms could explain why firms may hoard their skilled workers in times of crisis. First, according to Bloom, Romer, Terry, and Van Reenen (2013), the presence of "trapped factors" or fixed inputs may lead to a higher innovation activity when a firm faces a negative shock. The opportunity cost of inputs used to design and produce new goods would fall, and skilled employees might be trapped because they have human capital that is specific to the firm. Second, the type of labor contracts may also play a role in the decision to keep skilled employees in order to preserve the absorptive capacity of the firm. This would be consistent with Lopez-Garcia and Montero (2012), who find that for the case of Spain, the share of temporary employees within the firm is negatively associated with the firm's probability of innovating.

A natural extension of this line of research would consist in including more postcrisis years as data from the PITEC surveys become available. This would allow analyzing whether innovation investment, allocation of employees and innovation outcomes have changed relative to the pre-crisis period.

Some areas of further research could look further into the effects of the subsidy multiplier over the business cycle. For instance, research questions that could be asked include analyzing separately the subsidy multiplier on the exploratory (i.e., research) and exploitative (i.e., development) components of R&D. Moreover, there is room for further progress in determining the changes in the firm's R&D personnel structure that could also happen in the face of a crisis.

1.4 Chapter 4: Duration Dependence in R&D Subsidization and Firm's Innovative Behavior

The main aim of Chapter 4 is to investigate the degree of persistence in the use of R&D subsidies and its potential impact on firms' innovation outcomes. Three questions are addressed: (i) what are the drivers of a firm's persistent use of R&D subsidies?; (ii) what is the effect of continuous use of R&D subsidies on firm's introduction of product and process innovations ?; (iii) to what extent continuous engagement in R&D subsidization prevents a firm from stopping innovation projects? This chapter examines the relationship between firm-specific characteristics, and the continued use of public support measured by R&D subsidies leads to better innovation outcomes. A spell is defined here as a period of uninterrupted use of R&D subsidies by the firm.

Examining the role of firms' subsidy history is an aspect that has received some attention over the last years. Hussinger (2008) and Aschhoff (2009) provide evidence that subsidy history matters for both the allocation of support and its potential effects on innovation. Most recent work on this regard has found true state dependence of participation in both R&D subsidization and R&D tax incentives, meaning that successful applicants in past applications would be more likely to get funding in subsequent years (Busom, Corchuelo, and Martínez-Ros 2017). However, much less attention has been paid to examine the drivers of persistence in subsidy use and its potential effect on firms' innovation results. Aschhoff (2009), has addressed this issue to a certain extent, finding that frequent recipients of R&D grants have higher chances of increasing their R&D inputs and outputs. However, in her case data is cross-sectional, limiting her methodological approach.

The study of the effectiveness of different policy instruments used by governments and public agencies -subsidies, loans, tax deductions, and so forth- to provide incentives to increase private R&D and innovation investment has been the focus of evaluation research for some time (see Zúñiga-Vicente, Alonso-Borrego, Forcadell, and Galán 2014 for a survey). The most recent evidence is provided by Czarnitzki and Hussinger (2018), who analyze the link between public funding and R&D input and output in Germany. In general, empirical studies show that R&D subsidies have the potential for encouraging firms to engage in R&D and to invest more intensely (in the case of Spain, see Arqué-Castells 2013; Arqué-Castells and Mohnen 2015).

Most studies use a static, treatment-effects approach because panel data are seldom available. They thus offer only limited insights into the extent of continuity of participation in R&D subsidy programs, on its drivers and on its potential effects on the innovation behavior at the firm level. There is a lack, however, of empirical evidence focusing on the analysis of the effect of persistence in the use of R&D subsidies on innovation results. Absent crowding out effects, we might reasonably expect that persistence in benefiting from R&D subsidies will induce firms to achieve higher innovation results as well as providing them with higher chances to continue performing their innovation projects. This means that a higher number of consecutive years using the policy would also be an input for increasing the rate of innovation success.

This chapter contributes to previous literature in several ways. First, persistent use of R&D subsidies is modeled as the number of successive years in which a firm gets R&D funding (R&D subsidy spells) instead of analyzing whether firms that receive support in period t they get funding in time t+1. For this purpose, discretetime duration models are used to measure the degree of persistence in the use of R&D subsidies. Second, the effect of continuous use of R&D subsidies on innovation outcomes is analyzed by modeling a standard innovation production function which relates innovation outcomes to innovation inputs such as R&D, skills and other firm-level characteristics and introducing the degree of persistence into the model. Appropriate non-linear dynamic probit and panel data models are estimated to uncover these relationships.

The third aspect this chapter investigates is the interruption of innovation effort. Some evidence has shown that when firms receive public support for innovation, economic outcomes beyond productivity, such as firm survival and employment improve (BEIS 2014; Cerulli and Potì 2012; Czarnitzki and Delanote 2017; Hottenrott and Lopes-Bento 2014). In recent years, there has also been an increasing amount of literature on understanding the mechanisms underlying the decision of quitting innovation projects (Mohnen, Palm, Van Der Loeff, and Tiwari 2008 for the Netherlands; Radas and Bozic 2012 for the case of Croatian firms; Garcia-Vega and Lopez 2010 and García-Quevedo, Segarra-Blasco, and Teruel 2018 for the Spanish case). All these studies however overlook the fact that public funding can reduce the potential risk of stopping innovation projects.

Our results suggest the following: (i) firms receiving public funding for R&D activities accumulate knowledge and experience that increase the chances of getting support in future applications; (ii) continuous R&D performers have a positive likelihood of reducing the hazard of ending an R&D subsidy spell. This holds across both manufacturing and services industries, of different technological intensity; (iii) new-to-market product innovation is triggered by SMEs participating continuously into the R&D subsidization program, in all industries as a whole but especially in knowledge-intensive services and medium-low-tech manufacturing and (iv) survival in R&D subsidization also reduces the likelihood of abandoning R&D projects at either the concept stage or mature stages, especially in high-tech manufacturing.

The findings in this study are subject to some limitations. First, the lack of information on the duration of a subsidy award from a single application could lead to an overestimation of persistence in project subsidization. Second, it is not possible to identify subsidy application costs and how they might change over time because of lack of information on all applications, including those that have been rejected. Third, when analyzing the decision to stop innovation projects we could not control for the number of projects a firm is conducting, information that could help identify the firm's capacity to deal with different project portfolios.

With these considerations in mind, these findings may provide some insights into innovation policies. When designing programs policymakers could take into account that firm participation is to a good extent a self-sustained process, in part maybe because application costs fall, in part because once a firm engages in R&D the cost of producing new ideas and further innovations falls or a combination of both. Identifying the factors that determine application costs could be useful, especially if the policy aims at encouraging the spread of socially beneficial innovation activities across firms. The finding that new-to-market product innovation is triggered by SMEs participating continuously into the R&D subsidization program suggests that the agency's selection of projects is successful in identifying truly innovation projects. The social benefits of occasional participation would not be obvious.

A number of issues would deserve further research. One is investigating how persistence in R&D subsidization is reinforced by persistence in performing R&D activities, that is, what mechanisms are driving the reinforcement process. The second would involve estimating the social returns of innovation subsidies in Spain, in line with work by Takalo, Tanayama, and Toivanen (2013) for Finland and Koehler (2018) for Germany.

References

- Aghion, P., Angeletos, G.-M., Banerjee, A., and Manova, K. (2010). Volatility and growth: Credit constraints and the composition of investment. *Journal of Monetary Economics*, 57(3), 246–265. Retrieved from http:// www.sciencedirect.com/science/article/pii/S0304393210000176 doi: https://doi.org/10.1016/j.jmoneco.2010.02.005
- Aghion, P., Askenazy, P., Berman, N., Cette, G., and Eymard, L. (2012). Credit constraints and the cyclicality of R&D investment: Evidence from France. *Journal of the European Economic Association*, 10(5), 1001–1024.
- Aristei, D., Sterlacchini, A., and Venturini, F. (2017). Effectiveness of R&D subsidies during the crisis: firm-level evidence across EU countries. *Economics of Innovation and new Technology*, 26(6), 554–573. Retrieved from https:// doi.org/10.1080/10438599.2016.1249543 doi: 10.1080/10438599.2016 .1249543
- Arqué-Castells, P. (2013). Persistence in R&D Performance and its Implications for the Granting of Subsidies. *Review of Industrial Organization*, 43(3), 193-220. Retrieved from https://EconPapers.repec.org/RePEc:kap:revind:v:43: y:2013:i:3:p:193-220
- Arque-Castells, P. (2018). What Drives Differences in R&D Across Countries? Insights from the Intensive and Extensive Margins. Retrieved from https://papers.ssrn.com/abstract=3202894
- Arqué-Castells, P., and Mohnen, P. (2015). Sunk costs, extensive R&D subsidies and permanent inducement effects. *The Journal of Industrial Economics*, 63(3), 458–494.
- Aschhoff, B. (2009). The effect of subsidies on R&D investment and success– Do subsidy history and size matter? ZEW-Centre for European Economic Research Discussion Paper(09-032).
- Bartelsman, E., Dobbelaere, S., and Peters, B. (2014). Allocation of human capital and innovation at the frontier: firm-level evidence on Germany and the Netherlands. *Industrial and Corporate Change*, 24(5), 875–949.
- BEIS. (2014). Estimating The Effect of UK Direct Public Support For Innovation. , 04. Retrieved from http://www.gov.uk/government/uploads/system/ uploads/attachment_data/file/369650/bis-14-1168-estimating-the -effect-of-uk-direct-public-support-for-innovation-bis-analysis -paper-number-04.pdf
- Beneito, P., Rochina-Barrachina, M. E., and Sanchis-Llopis, A. (2015, Jun 01). Ownership and the cyclicality of firms' R&D investment. International Entrepreneurship and Management Journal, 11(2), 343–359. Retrieved from https://doi.org/10.1007/s11365-014-0320-9 doi: 10.1007/s11365-014 -0320-9

- Bloom, N., Romer, P. M., Terry, S. J., and Van Reenen, J. (2013, May). A Trapped-Factors Model of Innovation. American Economic Review, 103(3), 208-13. Retrieved from http://www.aeaweb.org/articles?id=10.1257/aer.103.3 .208 doi: 10.1257/aer.103.3.208
- Bruhn, M., Karlan, D., and Schoar, A. (2018). The Impact of Consulting Services on Small and Medium Enterprises: Evidence from a Randomized Trial in Mexico. *Journal of Political Economy*, 126(2), 635-687. Retrieved from https:// doi.org/10.1086/696154 doi: 10.1086/696154
- Busom, I., Corchuelo, B., and Martínez-Ros, E. (2017). Participation inertia in R&D tax incentive and subsidy programs. *Small Business Economics*, 48(1), 153–177.
- Cerulli, G., and Potì, B. (2012). Evaluating the robustness of the effect of public subsidies on firms' R&D: an application to Italy. Journal of Applied Economics, 15(2), 287 - 320. Retrieved from http://www.sciencedirect.com/ science/article/pii/S1514032612600130 doi: https://doi.org/10.1016/ S1514-0326(12)60013-0
- Cincera, M., Cozza, C., Tübke, A., and Voigt, P. (2012). Doing R&D or not (in a crisis), that is the question.... European planning studies, 20(9), 1525–1547.
- Cirera, X., and Maloney, W. (2017). The innovation paradox: Developing-country capabilities and the unrealized promise of technological catch-up. Washington, DC: World Bank.
- Cirera, X., and Muzi, S. (2016). *Measuring firm-level innovation using short questionnaires: Evidence from an experiment.* The World Bank.
- Czarnitzki, D., and Delanote, J. (2017). Incorporating innovation subsidies in the CDM framework: Empirical evidence from Belgium. *Economics of Innovation* and New Technology, 26(1-2), 78–92.
- Czarnitzki, D., and Hussinger, K. (2018). Input and output additionality of R&D subsidies. Applied Economics, 50(12), 1324–1341.
- Fabrizio, K. R., and Tsolmon, U. (2014). An empirical examination of the procyclicality of R&D investment and innovation. *Review of Economics and Statistics*, 96(4), 662–675.
- Fu, X., Mohnen, P., and Zanello, G. (2018). Innovation and productivity in formal and informal firms in Ghana. *Technological Forecasting and Social Change*, 131, 315 - 325. Retrieved from http://www.sciencedirect.com/science/ article/pii/S0040162517310971 doi: https://doi.org/10.1016/j.techfore .2017.08.009
- García-Quevedo, J., Segarra-Blasco, A., and Teruel, M. (2018). Financial constraints and the failure of innovation projects. *Technological Forecasting and Social Change*, 127, 127 - 140. Retrieved from http://www.sciencedirect.com/ science/article/pii/S0040162517307291 doi: https://doi.org/10.1016/ j.techfore.2017.05.029
- Garcia-Vega, M., and Lopez, A. (2010). Determinants of Abandoning Innovative Activities: Evidence from Spanish Firms. *Cuadernos de Economía y Dirección de la Empresa*, 13(45), 69 - 91. Retrieved from http://www.sciencedirect .com/science/article/pii/S1138575810700244 doi: https://doi.org/10 .1016/S1138-5758(10)70024-4
- Goñi, E., and Maloney, W. F. (2017). Why don't poor countries do R&D? Varying rates of factor returns across the development process

(Vol. 94). Retrieved from http://www.sciencedirect.com/science/ article/pii/S0014292117300247 doi: https://doi.org/10.1016/j.euroecorev .2017.01.008

- Griffith, R., Huergo, E., Mairesse, J., and Peters, B. (2006). Innovation and productivity across four European countries. Oxford review of economic policy, 22(4), 483–498.
- Heckman, J., Ichimura, H., Smith, J., and Todd, P. (1998). Characterizing Selection Bias Using Experimental Data. *Econometrica*, 66(5), 1017–1098. Retrieved from http://www.jstor.org/stable/2999630
- Hottenrott, H., and Lopes-Bento, C. (2014). (International) R&D collaboration and SMEs: The effectiveness of targeted public R&D support schemes. *Research Policy*, 43(6), 1055–1066.
- Hud, M., and Hussinger, K. (2015). The impact of R&D subsidies during the crisis. Research policy, 44(10), 1844–1855. Retrieved from http:// www.sciencedirect.com/science/article/pii/S0048733315001006 doi: https://doi.org/10.1016/j.respol.2015.06.003
- Hussinger, K. (2008). R&D and subsidies at the firm level: an application of parametric and semiparametric two-step selection models. Journal of Applied Econometrics, 23(6), 729-747. Retrieved from https://onlinelibrary .wiley.com/doi/abs/10.1002/jae.1016 doi: 10.1002/jae.1016
- Koehler, M. (2018). Estimating the benefits of R&D subsidies for Germany. ZEW-Centre for European Economic Research Discussion Paper (18-002).
- Lopez-Garcia, P., and Montero, J. M. (2012). Spillovers and absorptive capacity in the decision to innovate of Spanish firms: the role of human capital. *Economics of Innovation and New Technology*, 21(7), 589-612. Retrieved from https://doi.org/10.1080/10438599.2011.606170 doi: 10.1080/ 10438599.2011.606170
- Mairesse, J., and Mohnen, P. (2010). Using innovation surveys for econometric analysis. *Handbook of the Economics of Innovation*, 2, 1129–1155.
- Mohnen, P., Palm, F. C., Van Der Loeff, S. S., and Tiwari, A. (2008). Financial constraints and other obstacles: are they a threat to innovation activity? *De Economist*, 156(2), 201–214.
- Mohnen, P., and Röller, L.-H. (2005). Complementarities in innovation policy. European economic review, 49(6), 1431–1450.
- National Academies of Sciences, E., Medicine, et al. (2017). Advancing concepts and models for measuring innovation: Proceedings of a workshop. National Academies Press.
- Paunov, C., and Rollo, V. (2016). Has the internet fostered inclusive innovation in the developing world? World Development, 78, 587–609.
- Peters, B., Roberts, M., and Vuong, V. A. (2018). Firm R&D Investment and Export Market Exposure. ZEW - Centre for European Economic Research-Discussion Paper, 18. Retrieved from https://dx.doi.org/10.2139/ssrn.3289091
- Radas, S., and Bozic, L. (2012). Overcoming failure: Abandonments and delays of innovation projects in SMEs. *Industry and Innovation*, 19(8), 649–669.
- Raymond, W., Mairesse, J., Mohnen, P., and Palm, F. (2015). Dynamic models of R&D, innovation and productivity: Panel data evidence for Dutch and French manufacturing. *European Economic Review*, 78, 285-306. Retrieved from https://www.scopus.com/inward/

record.uri?eid=2-s2.0-84937827176&doi=10.1016%2fj.euroecorev .2015.06.002&partnerID=40&md5=8c614817460dae449c556f124ea24767 (cited By 14) doi: 10.1016/j.euroecorev.2015.06.002

- Segarra, A., and Teruel, M. (2011). Productivity and R&D sources: evidence for Catalan firms. *Economics of Innovation and New Technology*, 20(8), 727–748.
- Segarra-Blasco, A. (2010). Innovation and productivity in manufacturing and service firms in Catalonia: a regional approach. *Economics of Innovation and New Technology*, 19(3), 233–258.
- Takalo, T., Tanayama, T., and Toivanen, O. (2013). Estimating the Benefits of Targeted R&D Subsidies. *The Review of Economics and Statistics*, 95(1), 255-272. Retrieved from https://doi.org/10.1162/REST_a_00280 doi: 10.1162/ REST_a_00280
- Zúñiga-Vicente, J. Á., Alonso-Borrego, C., Forcadell, F. J., and Galán, J. I. (2014). Assessing the effect of public subsidies on firm R&D investment: a survey. *Journal of Economic Surveys*, 28(1), 36–67.