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Do financial constraints moderate the relationship between innovation subsidies and firms' R&D investment?

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Received 20 July 2020
Revised 2 October 2020
Accepted 9 December 2020

Abstract

Purpose – The purpose of this paper is to analyse whether the effect of innovation subsidies on firms' R&D investment varies depending on whether the firm is suffering from financial constraints.

Design/methodology/approach – To address this analysis, the authors provide a theoretical model and test their hypothesis using an econometric analysis of an unbalanced panel of 3,865 innovative Spanish firms during 2010–2017. They employ the SABI database to obtain firms' financial and economic data and incorporate firms' MORE financial rating. Specifically, the authors use the GMM-SYS technique to regress and measure the marginal effects of innovation subsidies size on firms' R&D investment and the influence of firms' financial constraints.

Findings – The results of this work indicate that financial constraints negatively moderate the effect of subsidies on R&D investment; that is, those firms that receive a subsidy and suffer financial constraints invest less in R&D projects than those which also receive the subsidy and do not suffer financial constraints. Besides, this work found that innovation subsidies alone do not significantly increase firms' R&D investment.

Originality/value – From a neoclassical point of view, the existence of financial constraints is the justification of public innovation policies. However, due to the difficulty of measuring financial constraints, innovation literature has abandoned the analysis of this crucial variable. This work reintroduces this vital variable and analyses how it interacts with innovation subsidies on firms' R&D investment.

Keywords Innovation subsidies, R&D investment, Financial constraints, GMM-SYS, Firm innovation

Paper type Research paper

1. Introduction

Ever since Nelson (1959) and Arrow (1962), economic theory has been studied in depth how innovation results in the creation and exploitation of knowledge. From this perspective, firm innovation is defined as a private investment in assets capable of improving the exploitation of knowledge and increasing firm's productivity (Cohen, 2010). Much of the literature on innovation has focussed on analysing how public intervention can encourage this type of private investment (Mowery and Rosenberg, 1989; Nelson and Winter, 1977). One of the public policies that has generated most interest from the outset is the granting of public subsidies to firms (Link, 1982; Scott, 1984).

Since then, many authors have analysed the effect of subsidies on firm innovation, both their individual impact (Dimos and Pugh, 2016) and their interaction with various characteristics of the firm (Jugend *et al.*, 2020). Researchers have focussed on analysing the interaction with firm size (Belitz and Lejpras, 2016; Herrera and Sánchez-González, 2013; Songling *et al.*, 2018), sector of activity (Carboni, 2017; Nylund *et al.*, 2019; Urban *et al.*, 2018; Yin *et al.*, 2019) and age (Arvanitis and Stucki, 2012; García-Quevedo *et al.*, 2014; Protogerou *et al.*, 2017). However, few studies have analysed the effects produced by the firm's financial situation (Cecere *et al.*, 2020; Cincera and Ravet, 2010; Hall *et al.*, 2016).

From a neoclassical point of view, this is not very understandable as it is a fact that firms suffer financial constraints which justify the granting of subsidies (Becker, 2015;

Funding: This work is supported by the Spanish Ministry of Science, Innovation and Universities under grants FPU18/00343 and PID2019-105140RB-I00.

European Journal of Innovation Management

1460-1060
DOI 10.1108/EJIM-07-2020-0286

Myers and Majluf, 1984). Yet, in addition to being few, the results of the studies that have analysed this situation are contradictory in themselves. Some of them state that having a correct distribution of internal funds is more important for R&D investment than for ordinary investment (Czarnitzki and Hottenrott, 2011a; Himmelberg and Petersen, 1994), while others find that R&D investment is as sensitive to financial constraints as ordinary investment (Mulkay *et al.*, 2001) and yet others consider R&D investment to be insensitive to financial constraints (Bond *et al.*, 2005).

In order to try to shed light on this issue, this paper analyses the existence of the interactive effect between the size of the subsidy received and the financial constraints on firms' R&D investment. In general, research that has taken into account financial constraints and subsidies for innovation has done so by considering both as independent variables (Becker, 2015). However, as recent studies have pointed out, the effect of subsidies for firm innovation can be influenced by the existence of financial constraints on the firm (Hain and Christensen, 2019; Montresor and Vezzani, 2016, 2019).

To check whether this is possible, an unbalanced panel of 3,865 Spanish innovative firms was analysed over the period 2010–2017. The results showed that, during this period, innovation subsidies did not manage to increase firms' R&D investment. It was also found that this effect is different for firms that suffer financial constraints from those that do not. As the size of the subsidy increased, firms that were financially constrained and which received a subsidy invested significantly less in R&D than those that were not financially constrained while receiving a subsidy of the same size.

This article is structured as follows: Section 2 establishes the theoretical framework; Section 3 delves into the data and methodology; Section 4 shows and analyses the results and Section 5 presents the conclusions and main implications of this work.

2. Theorical framework

2.1 Innovation subsidies and R&D investment

The literature on firm innovation tends to consider only the generation of patents or the introduction of new products as innovation. However, as Aschhoff and Sofka (2009) point out firms' R&D investment is a fundamental part of the innovation process. R&D investment can be oriented towards the acquisition of new assets capable of improving the productivity of a process (Bontempi, 2016). Thus, in a broad sense, innovations are the result of R&D investment projects that generate a set of positive knowledge spillovers for the firm (Ugur *et al.*, 2020).

R&D investments are not similar to other firm investments such as advertising or other assets (Himmelberg and Petersen, 1994). This is because the capital market is not able to properly model the risk of such investment and consequently does not lend its funds or does so at a high cost to the innovating firm (Hall, 1992; Mazzucato and Semieniuk, 2017). The limited rationality of the agents operating in that market generates the information asymmetries that create the imbalance (Stiglitz and Weiss, 1981).

From this point of view, institutional aid is justified as the only way to correct these capital market failures and enable positive spillovers to be generated (Kamien and Schwartz, 1978). Within the variety of existing public policies, innovation subsidies are the main tool for correcting this situation. For example, Herrera and Bravo Ibarra (2010) analysed a sample of 1,718 Spanish firms in 2000–2001 and found that the propensity to patent increased by 28.7% with those receiving innovation subsidies compared to those that did not receive them. Alecke *et al.* (2012) analysed a set of 1,484 German firms from Thuringia German region in 2003 and concluded that those that received an innovation subsidy increased their probability of patenting by 20% compared to those that did not receive it. However, Burhan *et al.* (2017) analysed the determinants of patent generation in India from 2005 to 2010 and concluded that public subsidies, while increasing the propensity to generate individual patents, did not have a significant effect on combined patent generation.

Following the credit crunch caused by the 2008 crisis, analysis of the financial situation of firms has regained some relevance in the study of subsidies in firm innovation (Cerulli, 2010; Haapanen *et al.*, 2014; Hall and Lerner, 2010). Various works, such as Silva and Carreira (2012), took up this line and analysed whether or not the financial situation is a determining factor when receiving a subsidy. These authors studied the determinants of receiving this type of aid in a sample of 7,079 Portuguese firms during the 1996–2004 boom period and concluded that the financial situation was not a determinant for receiving an innovation subsidy. Others, such as Czarnitzki and Hottenrott (2011b), analysed a sample of German firms during the period of economic expansion following German reunification (1993–2002) and found that high-tech firms (those with the greatest financial constraints), having received an innovation subsidy, innovated more than those in other sectors having also received public aid.

According to Haapanen *et al.* (2014), if public programmes to promote firm innovation are correctly designed and implemented, firms that receive an innovation subsidy should expand their investment in innovative projects. This is the first hypothesis of this work, which seeks to analyse whether such firms innovate more than those that do not receive subsidies (see Figure 1).

H1. Firms that receive a subsidy increase their R&D investment

2.2 Financial constraints and R&D investment

Fazzari *et al.* (1988) developed the first model that introduced financial constraints into firms' investment analysis. They proposed a classification of financially "constrained" and "unconstrained" firms based on the investment's elasticity in response to changes in firms' cash flow (investment– cash flow sensitive, ICFS). They also suggested that financially constrained firms should have greater difficulty in accessing outside financial resources. As a result, firms in this situation direct positive operating cash flows towards financing investments, rather than, for example, paying dividends.

To test this hypothesis, Fazzari *et al.* (1988) analysed 422 US firms between 1970 and 1984 and confirmed their theory. Constrained firms had a higher ICFS than unconstrained firms. Thus, the ICFS was used by many as the main measure of financial constraints. In the literature on firm innovation, the model by Fazzari *et al.* (1988) was used in the first stage of research on innovation subsidies (Hall, 2002; Mulkay *et al.*, 2001).

Over time, however, ICFS became subject to some serious criticism. Kaplan and Zingales (1997) blamed it for not reflecting the changes in Tobin's Q, and others, such as Cleary *et al.* (2007), pointed out its inconsistency in the representation of the slope of elasticity described, arguing that it is not monotonous, but U-shaped. Due to these criticisms, the ICFS lost relevance Silva and Carreira (2017), and although it is still used (Guariglia, 2008; Pindado *et al.*, 2011), other indirect and direct methods have been chosen to calculate this measure.

Currently, some authors obtain this information from questionnaires returned by managers based on a self-assessment of firms' financial problems (Beck *et al.*, 2008). Examples of this are Eurostat's "Access to Finance", "Survey on the access to finance of SMEs in the EuroArea" and "Community Innovation Survey". Such direct methods succeed

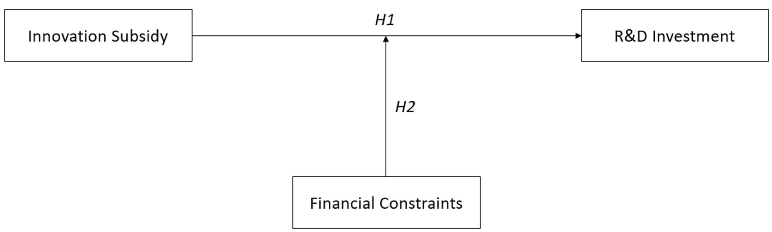

Figure 1.
Conceptual model

in eliminating the biases introduced by indirect financial methods but introduce other biases concerning the implicit subjectivity of the respondent.

Therefore, as a solution to the problems posed by both indirect and direct measures, some authors writing about firm innovation have decided to use information from independent external sources as a proxy for the financial situation of firms (Czarnitzki and Fier, 2002; Czarnitzki and Hottenrott, 2011b; Hoffman *et al.*, 1998; Toivanen and Niininen, 2000). These works have used different external financial ratings as proxies for firms' image in the capital market.

Recently, Hud and Hussinger (2015) analysed a panel of German innovative firms during the period before and after the Great Recession, and their results showed that the firms which suffered the greatest financial constraints and which received innovation subsidies during the worst years of the crisis (2008–2009) managed to increase and maintain R&D investment to a greater extent than those which did not receive public support. Mateut (2018) also studied the comparative effects of state innovation support programmes in different European countries and noted that subsidies were able to reduce financial constraints and increase firm innovation in all of them. Both works point out the importance of deepening the analysis of financial constraints as a key factor in the advancement of literature.

However, the most recent review works that analyse the effect of subsidies on firm innovation have pointed out the need to analyse the existence of interaction relationships between different characteristics of a firm, including financial constraints (Becker, 2015; Dimos and Pugh, 2016; Zúñiga-Vicente *et al.*, 2014). This new line of research makes a great deal of sense since certain characteristics of the firm can condition the effect of the subsidy. This was pointed out by Hyytinen and Toivanen (2005) in their seminal work on how the amount of innovation subsidy received interacts with a firm's sector of activity on R&D investment. Similarly, Altomonte *et al.* (2016) noted the existence of an interaction effect between a firm's financial constraints and exports, on the likelihood of patenting.

According to Farre-Mensa and Ljungqvist (2016), regardless of the method used to measure the financial situation, it can be argued that innovation subsidies will affect R&D investment differently in firms that suffer from financial constraints compared to those that do not, as the need for funds is different in each case.

H2. Financial constraints moderate the effect of innovation subsidies on firms' R&D investment

3. Data and methodology

3.1 Dataset

The economic and financial data of the firms were obtained from the SABI database created by INFORMA D&B in collaboration with the firm Bureau Van Dijk. This database provides access to more than 1.25m firms in Spain. The data extracted from SABI included accounting information on the firms and information on the subsidies received as reflected in their reports. The MORE rating provided by ModeFinance (also available from SABI) was used to measure the financial situation.

To study the effects of subsidies and the influence of financial constraints during the period following the hardest years of the Great Recession, a panel of Spanish innovative firms was selected for the period 2010–2017. To choose the sample of selected firms, a search protocol was applied that included firms that, during that period, reflected "Research" and/or "Development" items on their balance sheets. This search protocol yielded a total of 3,865 firms. Specifically, 1,687 firms reported research activities in their balance sheets, 2,665 firms reported development activities and only 487 firms reported both activities in the same period. Table 1 shows the descriptive analysis of the variables selected and Table 2 an analysis of their correlations.

Variable	Scale	Base	Mean	S. E.	Min.	Max.
$\Delta(R\&D/TA)_{it}$	Continuous	Logarithmic	−1.473	1.422	−14.686	12.786
Sub_{it}	Continuous	Logarithmic	0.366	1.822	0	17.666
$Financial\_Cons_{it}$	Binary		0.593	0.491	0	1.00
CF/TA_{it}	Continuous	Logarithmic	−1.862	1.635	−11.287	5.934
FE/TA_{it}	Continuous	Logarithmic	−3.590	2.490	−20.403	4.007
$ROTA_{it}$	Continuous	Logarithmic	−1.957	2.088	−12.840	5.934
$Imp/Sales_{it}$	Continuous	Percentage	34.522	30.18	1.00	100
$Exp/Sales_{it}$	Continuous	Percentage	35.746	29.118	1.00	100
$Size_{it}$	Continuous	Logarithmic	3.731	1.22	0	10.451
Age_{it}	Continuous	Logarithmic	3.133	0.63	0	4.762
Inno_Reg	Binary		0.515	0.5	0	1.00
HighTech_Manuf	Binary		0.178	0.382	0	1.00
MedHighTech_Manuf	Binary		0.022	0.148	0	1.00
HighTech_Service	Binary		0.028	0.166	0	1.00

Table 1.
Descriptive statistics

3.2 Variables

3.2.1 Dependent variable. The dependent variable with which investment in firm innovation is measured is the annual increase in R&D investment and is relativised as a function of the firm's total assets ($\Delta(R\&D/TA)_{it}$). This measure has been used by Barajas and Huergo (2010) as a proxy for innovation investment in environments where investment in knowledge plays an important role (Czarnitzki and Hottenrott, 2011a). In accordance with Spanish accounting regulations, intangible assets are an accounting item that includes both firm innovations and innovative projects that have not yet been completed but can prudently be considered to be successful (Cañibano and Gisbert, 2007).

3.2.2 Moderating variable. The existence of financial constraints ($Financial\_Cons_{it}$) is analysed in this work as the variable that moderates the effect produced by innovation subsidies. As Czarnitzki and Hottenrott (2011b) did, the credit rating of a prestigious firm was used to determine their existence. In this case, the MORE rating provided by the firm ModeFinance (2012) was used. This rating is a multidimensional algorithm that analyses various aspects of the economic and financial behaviour of firms, such as profitability, liquidity, solvency and efficiency, among others. It is used by various Spanish governmental agencies such as the ICO, "Official Institute of Credit" (Bermejo, 2016). Since the rating is on a scale (AAA-D), a rating lower than BB has been set to determine the existence of financial constraints by establishing a dichotomous variable (1, if the firm has financial constraints, 0 otherwise).

3.2.3 Independent variable. The variable chosen to reflect the innovation subsidies was the amount received (Sub_{it}). The estimation of the coefficient of this parameter by means of the econometric methodology used allows for the analysis of the variation of the effect according to the size of the amount received. This is a point that the literature on innovation has omitted due to the use of probit estimation models that consider this fact as a dichotomous state (Dimos and Pugh, 2016).

3.2.4 Control variables. The variables selected to monitor the observable heterogeneity produced by the difference between the firms were of an economic-financial nature and dichotomous variables on the specific characteristics of the firms. Among the variables of an economic-financial nature relating to the situation of the firm (studied by the previous literature), it can be observed both determining variables and factors that influence the innovation of firms (Becker, 2015).

The financial effort of the firm (FE/TA_{it}) has been identified by the Oslo manual (OECD, 2018), previously by Cantner and Pyka (2001) and more recently by Montresor and Vezzani

Table 2.
Correlation matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
$\Delta(R\&D/TA)_{it}$	1.00													
Sub_{it}	−0.031	1.00												
$Financial\_Cons_{it}$	−0.059	0.053	1.00											
CF/TA_{it}	−0.037	0.067	0.074	1.00										
FE/TA_{it}	−0.044	0.007	0.321	0.011	1.00									
$ROTA_{it}$	−0.058	0.031	0.229	0.472	−0.015	1.000								
$Imp/Sales_{it}$	−0.026	0.032	−0.024	0.058	0.075	0.043	1.00							
$Exp/Sales_{it}$	0.029	0.082	0.012	0.060	0.091	0.093	0.107	1.00						
$Size_{it}$	−0.120	0.238	0.211	0.081	0.054	0.108	0.005	0.111	1.00					
Age_{it}	−0.061	0.037	−0.100	−0.091	−0.102	−0.064	0.015	−0.028	0.273	1.00				
Inno_Reg	−0.016	−0.026	−0.029	0.036	−0.014	0.009	0.075	0.054	−0.007	0.001	1.00			
HighTech_Manuf	−0.009	0.014	−0.040	0.075	0.027	0.028	0.055	−0.031	−0.011	−0.028	0.093	1.00		
MedHigTec_Manuf	0.033	0.042	−0.033	−0.007	−0.036	−0.019	−0.075	0.201	0.076	0.064	0.082	−0.159	1.00	
HighTech_Service	−0.091	−0.053	0.041	0.051	0.005	0.095	−0.037	−0.010	−0.066	−0.191	−0.039	−0.045	−0.136	1.00

(2016) as a proxy variable for the decision to innovate or not. If firms are already experiencing a high financial effort, it will be more difficult for them to embark on an innovation project that requires a high investment during an uncertain period of time.

The return on total assets ratio ($ROTA_{it}$) measures the relationship between the operating profit (EBIT) and total assets. This ratio has been used in investment studies; Bermejo (2016) also presented it as a determining factor affecting the decision to invest.

The ratio between the volume of imports ($Imp/Sales_{it}$) and exports ($Exp/Sales_{it}$) on the turnover is a proxy for the external competitiveness of the firm. Those that compete in other markets demonstrate a greater adaptability to change and a capacity to deal with firms worldwide that continuously implement improvements in their processes and products, whether incremental or radical (Altomonte *et al.*, 2016).

The size of the firm ($Size_{it}$) in this paper has been set as a continuous variable that reflects the number of employees that the firm had in each period. This variable has been identified as a key factor in firm innovation from the beginning of the research (Mansfield, 1964) to the present (Belitz and Lejpras, 2016; Songling *et al.*, 2018). Large firms have greater capacity to access financial resources and human resource specialisation, which makes them more innovative. On the other hand, small firms are more dynamic and flexible, notable for their easy adaptability to changes in the technological environment as they have flexible structures capable of quickly developing and implementing innovations.

The location of a firm (*Inno_Region*) has been established as a dichotomous variable which reflects whether the firm is located in the most innovative regions of Spain: Madrid, Basque Country or Catalonia (1 if they met this condition, 0 if not). As indicated by Barajas and Huergo (2010), this variable captures the territorial effects of those regions with an R&D effort above the Spanish average.

The age of the firm (Age_{it}), a continuous variable, has been used as an indicator of the firm's experience and ability to obtain resources. As Nelson (1959) pointed out, mature and established firms tend to have advantages related to innovation management and their relationship with stakeholders. However, young firms, as is the case with small firms, may have a greater capacity to adapt to change and innovation since they do not suffer from rigidities resulting from longstanding routines (Cincera *et al.*, 2016).

Finally, the variable assigned to monitor the heterogeneity among the different industries is the technological intensity of the firm's industry (Protogerou *et al.*, 2017). To define this, three dichotomous variables were established (1 if it belongs to this industry, 0 if not) using the classification established by Eurostat (2018) according to the international NACE code. High technology intensity manufacturing (*HighTech_Manuf*): pharmaceuticals; computing (hardware), optics and electronics and aeronautics. Medium-high technology intensity manufacturing (*MedHighTech_Manuf*): chemicals, metallurgy; electrical material and equipment; other machinery; motor vehicles; other transport and other manufacturing assets. High technology intensive services (*HighTech_Service*): IT (Software) and R&D Services.

3.3 Methodology

The high degree of uncertainty and the long period of maturity associated with R&D investment means that firms must have a sustained commitment over time in order for projects to be successfully completed (Bontempi, 2016). Due to these exceptional conditions, an analysis of firm innovation requires the application of an analytic methodology that takes into account the time perspective. Therefore, the most appropriate methodology is that of panel data, something that the literature on firm innovation has revived in recent years (Hall *et al.*, 2016). The model proposed is as follows:

$$\Delta(R\&D/TA)_{it} = \beta_0 + \beta_1 Sub_{it} + \beta_2 Finan\_Const_{it-1} + \gamma_1(Sub_{it} * Finan\_Const_{it-1}) + \beta_3 Z_{it-1} + \beta_4 X_{it} + \varepsilon_{it}$$

The parameters of these variables were estimated using a method of instrumental variables capable of monitoring the endogeneity of the explanatory variables and the unobservable heterogeneity of the firms. The best option to achieve this was to use the generalised method of moments (GMM). This is a generic econometric technique for estimating parameters of a regression equation, developed as an extension of the method of moments. The GMM incorporates delayed endogenous variables as instrumental variables of the estimators (Ogaki, 1993). This method is particularly appropriate in this study since it requires taking into account the time dimension in both empirical models, given the dynamic and cumulative nature of firm innovation.

The estimation method used during the first years of this line of research (Diamond, 1999; Toivanen and Niininen, 2000; Callejón and García-Quevedo, 2005; Zhu *et al.*, 2006) was the model developed by Anderson and Hsiao (1981) and Arellano and Bond (1991), known as GMM difference. However, after criticism by Bloom *et al.* (2002), the parametric method that prevailed was the one known as GMM System (GMM-SYS) developed by Blundell and Bond (1998) and Roodman (2006); this model has recently been used by Cincera *et al.* (2016) and Lööf and Nabavi (2016), among others.

The GMM-SYS method is specifically designed for dynamic data panels over a short period of time and with a large sample of individuals (Blundell and Bond, 1998). This sample may suffer from conditional fixed effects and idiosyncratic errors, which are heteroscedastic in each firm but not heteroscedastic among the rest of firms. The two-step GMM method allows these effects to be eliminated through an estimator formed from the weighted matrix of the residue vector. In this way, it is possible to obtain an estimator that is as consistent as that of the homoscedastic case, but more efficient. In this case, the estimation technique was applied with a two-step specification using the STATA xtabond2 econometric package developed by Roodman (2006). To prevent the standard errors of the two-step specification from being biased downwards (Blundell and Bond, 1998) the option "Orthogonal" was added (available in xtabond2) as indicated by Roodman (2009).

The choice of the instruments used to estimate the effects on the GMM-SYS model depended on the assumption of endogeneity or exogeneity of the variables. In this study, in order to eliminate the problem of endogeneity, the terms used for the equation of first differences of the variables on the right side of the model were their delays from *t-1* to *t-3* for those referring to moment *t* and from *t-2* to *t-4* for those defined in the specification for the period *t-1*.

In addition, the application-specific robustness tests of the GMM-SYS were carried out. The first was a Wald (z) test on the joint significance of the coefficients obtained in each of the specifications. This test was applied through an χ^2 distribution under the null hypothesis of no joint significance (the degrees of freedom are shown in brackets). Second, the test developed by Arellano and Bond (1991) was used to analyse the existence of serial correlation between the second order residues of the first difference equation (AR (2)). This was applied by means of a normal distribution under the null hypothesis of no correlation. Finally, the validity of the instruments was analysed by means of Hansen's (1982) over-identification restriction test. This test was applied by means of an χ^2 distribution under the null hypothesis of no correlation between the instruments and the error term (the degrees of freedom of each specification are shown in brackets). Hansen's J statistic was chosen over Sargan's (1958) because the latter is only appropriate for the GMM difference estimator under the assumption of homoscedasticity and absence of serial correlation Roodman (2006).

The analysis of the interaction was carried out according to the steps and classification established by Sharma *et al.* (1981). Starting from a base equation, the variables analysed (specification 1–3) were introduced until arrival at the complete model (specification 4). To further analyse interaction, the marginal effects were analysed according to Mitchell (2012).

4. Results

4.1 Financial constraints, innovation subsidies and R&D investment

Table 3 shows the results of the estimation of the variables that influenced the variation of R&D investment of the analysed firms. Columns 1 and 2 show the individual model specifications on innovation subsidies and financial constraints separately, while column 3 shows both variables in the model without taking into account their interaction. Finally, column 4 reflects the final model by introducing both variables and their interaction.

As can be seen in columns 1–3, the firm's being awarded a subsidy in the previous period had a negative effect on the fact that investment in the firm's intangible assets increased, without taking into consideration the effect of the interaction. However, introducing all the variables into the full model (column 4) does reveal a small but significant positive effect (0.020). This means that an increase in the amount of the subsidy by 1% would increase investment in intangible assets by 0.02%. Because this effect is small and contradicts that of specifications 1–3, hypothesis 1 cannot be accepted. This result is in line with those obtained by other research applying the GMM methodology, which also found a non-significant effect. For example, Koski (2008) found no significant effect in his analysis of 1,122 fine manufacturing firms over the period 1999–2003.

The interaction between financial constraints and subsidy size shows a significant negative effect (−0.079) on the firm's R&D investment. Thus, it could be said that financial constraints do moderate the effect produced by innovation subsidies significantly so that

Estimat. Method: SYS-GMM Dep. Var.: $\Delta(R\&D/TA)_{it}$	(1) Coef. (S.E.)	(2) Coef. (S.E.)	(3) Coef. (S.E.)	(4) Coef. (S.E.)
$\Delta(R\&D/TA)_{it-1}$	0.167*** (0.012)	0.150*** (0.006)	0.142*** (0.003)	0.151*** (0.004)
Sub_{it}		−0.032*** (0.002)	−0.108*** (0.007)	0.020*** (0.002)
$Financial\_Cons_{it-1}$	−0.127*** (0.014)		−0.035*** (0.001)	−0.053*** (0.013)
$Sub_{it}*Financial\_Cons_{it-1}$				−0.079*** (0.002)
CF/TA_{it-1}	−0.008 (0.005)	−0.053*** (0.009)	−0.028*** (0.005)	−0.020*** (0.004)
FE/TA_{it-1}	−0.044*** (0.010)	−0.063*** (0.010)	−0.068*** (0.005)	−0.058*** (0.008)
$ROTA_{it-1}$	0.031*** (0.010)	0.038*** (0.009)	0.044*** (0.003)	0.044*** (0.004)
$Imp/Sales_{it-1}$	0.007*** (0.001)	0.006*** (0.001)	0.006*** (0.001)	0.006*** (0.001)
$Exp/Sales_{it-1}$	−0.002** (0.001)	−0.005*** (0.001)	−0.003*** (0.001)	−0.004*** (0.001)
$Size_{it}$	0.071*** (0.015)	0.006*** (0.014)	0.041*** (0.009)	0.070*** (0.008)
Age_{it}	−0.150*** (0.018)	−0.127*** (0.016)	−0.149*** (0.012)	−0.146*** (0.012)
$Inno\_Reg$	−0.012 (0.032)	−0.054 (0.042)	0.001 (0.027)	0.008 (0.026)
$HighTech\_Manuf$	−0.052 (0.073)	0.030 (0.100)	−0.064 (0.076)	−0.094 (0.070)
$MHigTec\_Manuf$	0.134*** (0.025)	0.152*** (0.027)	0.137*** (0.015)	0.162*** (0.013)
$HighTech\_Service$	−0.153*** (0.025)	−0.224*** (0.024)	−0.209*** (0.014)	−0.173*** (0.012)
$Year$	−0.001*** (0.000)	−0.001 (0.000)	−0.001*** (0.000)	−0.001*** (0.000)
Z	7.64e + 06 (22)	1.63e + 06(22)	2.59e + 08 (23)	4.82e + 08 (26)
AR (1)	−1.94	−1.92	−1.93	−1.94
AR (2)	0.48	0.45	0.48	0.45
AR (3)	0.38	0.50	0.48	0.52
Hansen	(207.00) 191	195.00 (186)	219.64 (212)	217.09 (228)
No. observations	655	655	655	655
No. groups	313	313	313	313
No. instruments	214	209	236	255

Note(s): *** and ** denote statistical significance at the level of 1% and 5%, respectively

Table 3. R&D investment. Unbalanced panel. Time-period 2010–2017

firms with financial constraints show a smaller negative effect than those that do not suffer from this circumstance; hypothesis 2 is thus accepted. This result is in line with the analysis carried out by Ughetto (2008), who analysed Italian innovative firms and found a relationship between being a medium-sized, high-tech firm without financial problems and R&D investment. According to the theoretical discussion, financial constraints interact differently in each type of firm with the impact of receiving a subsidy.

Figure 2 clearly shows that there is a significant difference between firms that are financially constrained and those that are not. However much the amount of financial subsidy received by firms with financial constraints increases, it does not increase their final R&D investment but rather decreases it. Conversely, firms without financial constraints increase their R&D investment as the amount of subsidy increases. This analysis is in line with the analyses made by Himmelberg and Petersen (1994) and Czarnitzki and Hottenrott (2011a). Similarly, this paper points out that internal funds are more important for R&D investment than for ordinary investment. Regarding the classification of interaction effects, according to Sharma *et al.* (1981), financial constraints are a quasi-moderate variable. This means that although they interact with the independent variable they also have their own effect on the dependent variable. This type of effect is typical in economic analyses since variables are never completely independent of each other (Sekaran and Bougie, 2016). In this case, as the literature on financial constraints has analysed, suffering financial constraints have a negative impact on investment. In the sample analysed, going from a condition without financial constraints to one with restrictions significantly reduces firms' R&D investment by 0.053%.

The contrast of the hypotheses of this work is far from the mainstream of the literature on innovation subsidies, but it resembles the results found in the literature on corporate finance that used the same methodology to analyse the effect on corporate innovative process. As Dimos and Pugh (2016) point out, most of the literature on innovation subsidies uses semi-parametric methods such as propensity score matching (PSM) in its analyses, thereby finding significant positive effects. However, those works that have used the GMM methodology find negative or non-significant effects.

The explanation for this difference can be found in the observation that semi-parametric techniques introduce certain strict assumptions that are very often violated. The PSM is based on the assumption of strong ignorance, which means that the firms in the treated and control groups only differ in observable characteristics and that unobservable characteristics

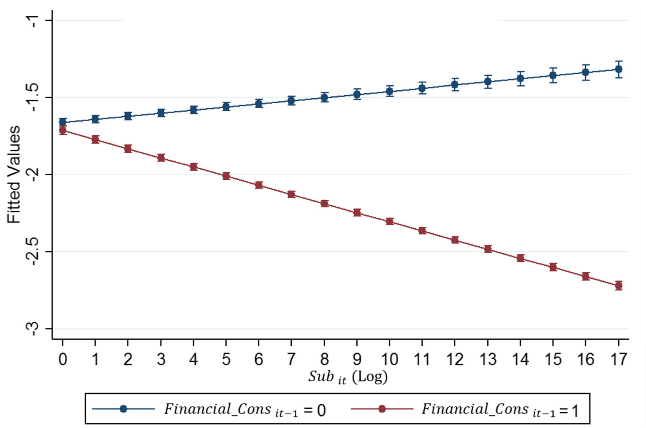

Figure 2.
Marginal effects of the interaction between subsidy size and financial constraints on R&D investment

do not affect the outcome differently in the two groups. This assumption is usually violated when there is unobservable information (e.g. regarding leadership, firm strategies or how receiving a subsidy affects employee motivation psychologically versus not receiving it). The violation of this assumption distorts the estimate of the equation in a way that is equivalent to the omission of a variable in an OLS estimate (Li and Prabhala, 2007).

An empirical example of this difference between effects obtained according to the methodology is the work of Bertoni *et al.* (2019). These authors analysed the impact of equity loans on the growth in firm size and sales for a sample of young innovative Spanish firms. The PSM estimate set the size of the effect for each variable at 12.148 and 1.087 respectively, while the GMM-SYS estimate reduced it to 0.105 and 0.180, respectively.

Therefore, according to the literature, the PSM estimation method is efficient for cross-sectional samples; however, it introduces large upward biases into time series. In contrast, the GMM method is designed specifically for panel data and, in particular, the GMM-SYS specification is more efficient than any other in this respect. Furthermore, this estimation method is able to efficiently deal with unobservable heterogeneity by eliminating it, after calculating first differences.

The results confirm the analysis of the previous literature. The estimator of the coefficient of financial expenses (−0.058), cash flow (−0.020) and return on total assets ratio (0.044) is consistent with the conclusions obtained by Cincera *et al.* (2016), who set the effect of cash flow at −0.078 in their analysis of innovation by leading young technology firms in the United States between 2004 and 2008. In Spain, the most innovative firms did not finance their innovations with their own resources. With regard to the estimators of the other control variables, no significant effect was found related to either the location of the firm or the technological intensity of the industry.

All these coefficients are in line with the interpretation that firms which had a greater capacity to generate internal cash flows did not reinvest them in expanding investment in the firm's intangible assets. This is because firms that have a product cycle in the maturity phase allocate resources they have generated internally to marketing, sales and/or dividend policies to compensate agents that financed the initial stages of the product. In addition, it should be pointed out that young firms were those that invested the most in intangible assets, demonstrating that in developing stages, the creation and exploitation of knowledge is fundamental to this type of investment. If a firm's age is 1% lower, investment in this type of innovation project increases by 0.146%.

The geographical location of a firm did not significantly influence R&D investment. In this case, the coefficient of the estimator of this variable was not significant; the firms that were in the Spanish regions of Madrid, Catalonia and the Basque Country did not increase their investment in intangible assets to a greater extent than those in other regions. According to the analysis carried out by Buesa *et al.* (2010), this is due to the fact that in all Spanish regions there is currently an institutional framework for supporting innovation in a place which is more advanced than in the past.

Finally, the coefficients of the estimators of the variables related to the technological intensity of the firm's industry also showed significantly positive results for the firm's belonging to a medium-high technology sector (0.162). These results are consistent with the work that has analysed the influence of the technological intensity of industry in other European countries (Alecke *et al.*, 2012; Aschhoff and Sofka, 2009; Czarnitzki and Hottenrott, 2011b). It should be noted that the coefficient of the estimator of high-tech industry did not yield a significant result and that of high-tech services is negative (−0.173). This is due to the fact that innovative Spanish firms have focussed on the chemical, metallurgical, electrical equipment and motor vehicle industries: industries that are considered to fall under medium-high technology intensity and where R&D investment projects are greater since they are competitive at world level (Peraza and Aleixandre, 2016).

4.2 Robustness analysis

In the panel data robustness tests, the full model specification (col. 4), all tests gave positive results. Firstly, the Wald test (z) rejected the null hypothesis of joint non-significance of the estimated parameters in a significant way (χ^2 (44) = 4.82e + 08). Secondly, the AR test rejected the null hypothesis of the existence of serial correlation between the second-order residues in the first difference equation ($N(0; 1) = 0.45$). Finally, Hansen's J-test also rejected the null hypothesis of the non-validity of the instruments significantly (χ^2 (228) = 217.09).

As shown in Table 4, the robustness tests of the interaction analysis (t-Student) were shown to be positive, and it can be seen that, as the size of the subsidy increased, the negative effect is significantly reduced in firms without financial constraints and increased in those with restrictions.

5. Conclusions and main implications

This analysis, regarding the moderation of financial constraints on the effect of innovation subsidies on firms' R&D investment, yielded important conclusions and implications for firms, public administrations and academia alike.

Firstly, it was shown that innovation subsidies are not a sufficient driver for firms to innovate. The main driver is the firm's skill set, which determines the efficient use of innovation subsidies or their lack of usefulness. This means that researchers must focus their analyses within firms themselves, analysing best practices and success stories in order to be able to ascertain why some firms manage to increase their R&D investment more than others. What stood out furthermore was the importance of being in sectors that are favourable to innovation with regard to the country in which a set of positive externalities are generated (trained labour, non-appropriable knowledge, relations with suppliers and customers) and which promote innovation and become determining factors in a firm's activity. The analysis of the control variables also showed that internal funds were not key to increasing R&D investment. This result ties in with the literature that has pointed out that R&D investment is not sensitive to cash flows (Bond *et al.*, 2005). Secondly, the main implication of this work for public administrations is that, contrary to general opinion, it was shown that supporting firms suffering from financial constraints does not succeed in significantly increasing innovation. The current public plans for supporting innovation are generic programmes that can be attended by all firms which meet the requirements and follow appropriate bureaucratic procedures. Innovation subsidy plans should be oriented such that projects are evaluated individually, addressing real problems and assessed by expert committees, as is the case with projects from Spanish agencies such as ENISA or CDTI. From this work, the need arises for public administrations to introduce long-term evaluation systems to measure

Table 4.
Marginal effects of the interaction between subsidy size and financial constraints on R&D investment

Sub_{it} (Log)	Coef. (S.E.)
$Sub_{it} = 0 \mid Financial\_Cons_{it-1} = 0$	−1.660*** (0.012)
$Sub_{it} = 0 \mid Financial\_Cons_{it-1} = 1$	−1.712*** (0.014)
$Sub_{it} = 6 \mid Financial\_Cons_{it-1} = 0$	−1.540*** (0.014)
$Sub_{it} = 6 \mid Financial\_Cons_{it-1} = 1$	−2.069*** (0.011)
$Sub_{it} = 12 \mid Financial\_Cons_{it-1} = 0$	−1.418*** (0.020)
$Sub_{it} = 12 \mid Financial\_Cons_{it-1} = 1$	−2.424*** (0.011)
$Sub_{it} = 18 \mid Financial\_Cons_{it-1} = 0$	−1.297*** (0.029)
$Sub_{it} = 18 \mid Financial\_Cons_{it-1} = 1$	−2.780*** (0.014)

Note(s): *** denotes statistical significance at the level of 1%

the efficiency of their policies and correct them if the expected results are not achieved (Stefani *et al.*, 2019).

Thirdly, the findings of this paper are of profound interest to the academic community because they go against the current. Following the 2008 crisis, there has been a pendulum effect aimed at justifying the need for public intervention. However, the use of an efficient and robust econometric technique for panel data such as the GMM-SYS calls into question the conclusions reached by work that applied other parametric or semi-parametric techniques. Thus, this paper reopens the debate on which methodology should be used to analyse the effects of subsidies on innovation.

In addition, this work has faced certain limitations among which the database stands out. SABI is a database of mainly economic and financial data, oriented towards the field of accounting and finance. This has been very useful when capturing variables on the financial characteristics of a firm but a disadvantage when capturing the variables on firm innovation. Therefore, the main line of research that is emerging as a result of this work is the analysis, along the same lines, of specific innovation databases such as the European Innovation Survey (CIS) or the Survey on Business Strategies.

Finally, this research has opened a window to apply advanced financial techniques to innovation topics. Future works should follow this multidisciplinary approach combining techniques and data from different sources. For example, researchers could combine questionnaires based on a self-assessment of firm's financial problems and innovation activities with firms' external credit ratings. By this way, researchers would be able to avoid the subjectivism problem about firms' financial status and to analyse a broad scope of innovation variables. Moreover, using information from primary and secondary sources provide an opportunity to combine theories from other areas of management studies which take into account the internal behaviour of firms, their relationship with extern institutions and industry and regional effects. This approach will enrich the literature, and the implications for companies, researchers and public institutions will be much more relevant.

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