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An Endogenous Approach to the Cyclicity of R&D Investment under Credit Constraints: Firms' Cash Flow Matters!

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Abstract

This paper examines the sensitivity of firms' R&D expenditures to being externally financial constrained to undertake innovation projects, considering that being constrained is endogenous. It focuses on devising a model that enable us to explore the combined impact of liquidity constraints, demand shocks, and credit cycle on the cyclicity of R&D, controlling by the firms characteristics. The methodology proposed consists of jointly estimating three interrelated equations with mixed distributions of dependent variables. The results obtained complete and improve those of the previous research. It is found that the effect of the business cycle on the perception of external financial constraints is subject to the availability of internal funds in each firm. On the other hand, constrained firms expend in R&D halve of the unconstrained ones, and the sensitivity of firms' R&D expending to GDP is countercyclical in firms with low cash flows and procyclical in firms with high cash flows. The R&D expending of firms is negatively associated with the aggregate leverage ratio of the non-financial sector. These results mean that business decisions, in particular R&D expending decisions, and macroeconomic variables are strongly related. A better understanding of these interrelations should help in designing macroeconomic policies aimed at stabilizing the economy and reduce growth volatility.

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Keywords: R&D expending (</search?q=R%26D+expending>); financial constraints (</search?q=financial+constraints>); business cycle (</search?q=business+cycle>); credit cycle (</search?q=credit+cycle>)

1. Introduction

Public authorities are interested in understanding innovation related decisions, for example expending on research and development (R&D) or not, the amount of investment, patenting, introduction of new products or processes, etc., because of the important spillover effects on knowledge dissemination resulting from such decisions with positive effects on overall economic

growth. Innovation activities are costly and firms that want to innovate will need financial resource to fund investment in knowledge related assets. When internally supplied funds, mainly retained earnings, are insufficient to finance investment the additional funds will have to be externally supplied. Adverse selection and moral hazard problems from information asymmetries, between insiders (managers) and outsiders (financial investors), result in market imperfections in the form of finance rationing and / or high cost of capital [1,2]. Firms are said financially constrained when market imperfections lead them to turn down investment projects with positive net present value (NPV) at the competitive cost of capital.

Since [3], many papers have empirically researched the interdependency between investment and financing conditions of firms, when firms are financially constrained. This research measures the extent to which a firm may be financially constraint or not, by looking at the sensitivity of firms' level of investment in tangible assets to the level of internally generated cash flows, controlling from investment opportunities (Tobin's q for example). The paper is also about financial constraints and how such constraints affect investment decisions. [\(https://www.cookiebot.com/en/what-is-behind-powered-by-cookiebot/\)](https://www.cookiebot.com/en/what-is-behind-powered-by-cookiebot/) using for empirical analysis, a representative sample of Spanish manufacturing firms during the period 1998–2016, but with important differences with respect to previous research. First, the variable that identifies if a firm is financially constrained or not is obtained, in this paper, from the response to a questionnaire in which firms in the sample are explicitly asked to answer yes or no to having difficulties in obtaining external finance. This way of identifying whether a firm is financially constrained or not, instead of using financial ratios, overcomes the difficulty of separating between the effects of being financially constrained from the effects of higher or lower profitability, in investment decisions [4]. However, at the same time, the firm that responds to the questionnaire will have its reasons and circumstances to answer yes or no to the posed question and, for this reason, being financially constrained or not will itself be endogenously determined. This means, from a methodological point of view, that the effect of being financially constrained in investment decisions cannot be evaluated in isolation from the factors, that **Show details** > endogenously explain why a firm is financially constrained.

Second, it is examined the effect of being subject to external financial constraints in firms that invest in intangible assets, in particular firms that invest in R&D. Although practically all firms invest in machinery or equipment at some time or another, doing R&D is restricted to a sub sample of firms that self-select into such activities. Since the sample of firms that expend positive amounts of funds in R&D is not a random sample of the population of all firms, the examination of the effect of financial constraints in R&D investment must be done, controlling for the possible sample selection bias resulting from the endogenous decision of firms of doing R&D or not. Additionally, the low outside value of intangible assets and of knowledge related ones, in particular, limits the substitution among external and internal sources of funds to finance investment, increasing the interdependence between investment and finance decision beyond those observed in tangible assets.

Third, this paper focuses mainly on the effect of macroeconomic variables related with the business and credit cycles and with the monetary policy, on the likelihood that a firm will be financially constrained, as well as on the direct effect of these variables in R&D investment decisions by firms. These effects will be assessed in the paper using firm level data along a relatively long period of time and including the constraint of being financially constrained or not as one of the explanatory variables of R&D expending. The use of firm level data has the advantage, over using R&D expenditures on aggregate, that the effect of macroeconomic variables on the endogenous variables can be estimated

controlling for differences in the characteristics of firms, for example, size, age, and financial situation. Second, including the situation on being financially constrained or not as one of the explanatory variable of the R&D expenditures, together with the macroeconomic variables, allows us to separate the effect of these macroeconomic variables in R&D expending into a direct and an indirect effect (this one through the influence of macroeconomic variables in the situation of being constrained or not).

This paper aims at new field of the economic literature. Other papers have examined the effect of financial constraints, as measured in this paper, in R&D expending and innovation decisions by firms [5,6,7,8,9,10,11,12]. However, they do not endogenously determine why a firm is financially constrained as it is done here. Other papers have also examined the R&D decisions by firms, including that of doing it or not [13,14] and those on the volume of R&D expending [13,14,15,16,17,18,19,20,21,22,23,24,25,26] but they do not consider financial constraints and macroeconomic variables on the dependent variables. Finally, there are papers on the influence of macroeconomic variables in R&D expending [27,28,29,30,31,32] but these papers do not consider the firm being externally constrained or not as explanatory variable. Therefore, this paper is the first one that examines the determinants of being externally financially constrained and the joint effect of the constraint on R&D expending, with a particular focus on macroeconomic conditions that affect both, being constrained and R&D expending, controlling by firm level characteristics.

The rest of the paper is organized as follows. **Section 2** provides the theoretical framework and the model proposed. **Section 3** details the description of the sample data, the variables used in the empirical results obtained. Finally, **Section 4** presents the conclusions and the implications of the findings in terms of the designing of macroeconomic policies.

2. Methods and Materials

In this section, the main theoretical arguments on the determinants of a firm being externally financial constrained are detailed, as well as those determinants of a firm which, first, are used to make decisions on R&D and, therefore, to establish the amount of investment necessary in this activity. The endogenous variables, being financially constrained, doing R&D and R&D expending, are finally integrated into an econometric model that takes into account the joint determination of the three of them.

2.1. The Determinants of Being Financially Constrained

2.1.1. Characteristics of Firms

A firm is financially constrained when, because of financial market imperfections, it must forgo investment projects with positive NPV in the absence of such imperfections. Most of the market imperfections are caused by information asymmetries, affecting borrowers and lenders, resulting in situations of moral hazard and adverse selection [1,2,33,34,35]. Determining when a firm is financially constrained is not an easy task because the forgone NPV investment projects are not observable by the researchers. In practice, financial constraints are identified in two ways, using accounting ratios to assess the influence of the internal financial situation of the firm in the volume of investment [3,12,31,32,36], and asking directly to the firms how difficult it is for them to obtain internal and/or external funds to undertake particular projects [37,38]. The financial constraints variable used in this paper is obtained through a survey where firms answer to a direct question about the difficulties to get

external finance for their innovation projects. In this section, the factors that may determine that a firm answers either yes or no to this question are examined.

At the firm level, the observable characteristics most often related with the information asymmetries, that may turn into moral hazards and adverse selection problems, are age and size of the firm. Repeated bank–firm relations and repeated interactions of firms with external financiers, in general produces valuable information and builds ties between borrowers and lenders, thus either reducing information asymmetries or generating the mutual trust that makes them irrelevant for a successful transaction [39]. Through this argument, it is concluded that the likelihood of being financially constrained will decrease with the age of the firm, for a given level of demand of investment. Since older firms are also more likely to rely less on external finance than young ones, given that these ones grow at much faster rates than the older ones, for given information asymmetries; external financial constraints are also more likely on young than in old firms as the difference between new investment and internally generated cash flows is higher in young rather than in old firms. As for the effect of size of the firm on information asymmetries, the theory and empirical analysis [11,40,41] claims that larger firms are more transparent and have more diversified sources of finance than the small ones. Therefore, the likelihood of being financially constrained and the size of the firm will be inversely related.

A firm belonging to a business group or holding structure will have access to external funds from the internal financial market from pooling the cash flow of all group members at the parent company level. A foreign subsidiary or a firm participated by foreign shareholders may operate as being part of a business group. Research has found that, controlling for the size of the firms, belonging to a business group in general [10,37], and having foreign firms as shareholders in particular [42,43,44], lowers the likelihood that a firm will be financially constrained in terms of access to external finance.

External suppliers of funds, for example banks, rely on information extracted from accounting statements as a way to assess the soundness of the borrowing firm. Two proxy variables for the financial soundness of a firm are the leverage ratio and the cost of issued debt [45,46]. The same leverage ratio will imply a higher probability of default in firms with low internally generated cash flows than in firms with high internal cash flows. Therefore, to assess the effect of leverage and cost of debt in the likelihood of being financially constrained, it will be necessary to control for the cash flows of the firm too.

2.1.2. Particularities of R&D Investment

Investment decisions on R&D are modeled. The assets resulting from R&D activities of firms are intangible, with uncertain economic value and, in many cases, specific to the firm that invests on them (low realization value). At the same time, R&D activities by one firm generate knowledge spill over and positive externalities on other firms [47]. The low realization value of intangible assets limits their use as collateral in bank loans and other debt like instruments. This, together with the so-called “lemon” premium [48], will determine that R&D investments are mainly financed with own funds, i.e. equity issues and retained earnings. The empirical analysis confirms this hypothesis [6,45,49,50,51,52].

The “pecking order” theory of financial structure [2] will strongly apply to finance of R&D investment with an important premium when going from internal funding to external funding. Therefore, the availability of internally generated cash flows is an important control variable when

explaining the likelihood of a firm being externally financial constrained. Other explanatory variables of the likelihood of being financially constrained, justified by the particular features of R&D investment, are either, whether the firm has patents or whether the firm receives external subsidies for their innovation activities or not. Patents are the tools used by firms to protect the economic value of their innovations, while the public subsidies to R&D activities are justified by the knowledge spill over.

Firms that patent their innovations from R&D activities will have a higher stock of knowledge-related assets in their portfolio than firms with no patents, as firms will limit the patents to those of expected high economic value. If intangible knowledge related assets have less value as collateral than tangible assets, and firms with patents have higher endowment of these intangible assets than firms without patents, then the patents variable can be expected to be positively associated with the likelihood of being financially constrained. The prediction would be different if patents could serve as collateral in external finance operations, in which case firms with patents could face softer external financial constraints than firms with no patents.

Firms that receive public subsidies for innovation related activities will, in general, face lower external financial constraints since subsidies will increase internal cash flows. But, probably more important, receiving government subsidies contributes to soften external constraints in an indirect way, as prospective lenders may view the subsidies like an external endorsement of the financial viability of the business by the public agency. Therefore, a negative association is expected between receiving a public subsidy and being financially constrained.

R&D expenditures compete with investment in other assets for the funds available for financing total investment. Higher investment in tangible assets may indicate that funds left for R&D expending are relatively small and the likelihood that a firm has difficulties in finding external finance for innovation activities will be relatively high [32]. The amount of money a firm invests in tangible assets in a given period of time should be relevant information in the assessment of the likelihood that a firm is externally financially constraint to undertake innovation activities.

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2.1.3. Macroeconomic Conditions

In a given moment in time all firms in the economy share the same macroeconomic conditions so in cross section analysis the macroeconomic variables can be ignored. With time series data the macroeconomic conditions will vary over time and it is possible to investigate how changes in macroeconomic conditions affect the situation and decisions of individual firms, particularly the likelihood of being externally financial constrained. The macroeconomic variables considered here are those having to do with the business cycle, the credit cycle and the expectation of changes in monetary policy.

The business and the credit cycle, as well as the expectations on monetary policy and changes in interest rates, can affect the likelihood of a firm being financially constrained through the demand and the supply sides. In periods of economic expansion, individual firms anticipate permanent growth of aggregate demand; each firm expects a similar pace of increase in its own sales, production capacity and therefore capital investment. There is evidence showing business investment, including R&D investment, is pro cyclical [27,28,29,30], i.e., it is positively correlated with GDP growth. If firms' demand of investment increases in periods of expansion and decreases in periods of contraction, then, for given supply conditions of funding, the firm's likelihood of being financially constrained will be positively associated with the GDP growth of the economy (business cycle).

But the aggregate supply of funds to finance investment may also depend on the business cycle, as stated by the credit cycle hypothesis mainly attributed to [53] on what is known as financial instability hypothesis (FIH). Minsky's FIH implies some herd behavior of banks, and external financiers in general, when deciding on financing investment projects or not. In periods of economic expansion, banks are over optimistic on the future prospects of borrowers, then credit supply increases causing further upward trends in the prices of assets, higher credit growth, and so on. When expectations change and asset prices stop growing, or decline, then the priority of borrowers is to deleverage and use all cash flows to cancel pre-existing debt. For those who want to continue investing, the possibility of getting external finance, given internal financial and economic conditions based on expectations of accelerated loss of assets value, are related to the selling decisions of those who overinvested in the past. The credit cycle is captured by a variable aggregate debt of the business sector of the economy. The Minskyan FIH predicts a negative association between the likelihood of a firm being financially constrained, for any internal financial and economic conditions, and the time evolution of whole economy wide leverage variable [\(https://www.cookiebot.com/en/what-is-behind-powered-by-cookiebot/\)](https://www.cookiebot.com/en/what-is-behind-powered-by-cookiebot/).

The time evolution of interest rates from monetary policy decisions will also affect the behavior of asset prices as well as the lending by banks and other financiers. Higher (lower) interest rates are expected to affect negatively (positively) the values of asset prices and the willingness to lend. Central banks will make monetary policy decisions—changes in official interest rates—based upon inflation expectations, increasing them when inflation is expected to increase, and lowering them when inflation expectations are also low. In this paper, perfect forward looking by economic agents is assumed and future observed inflation rate is used as an indicator of expectations on the future evolution of interest rates. The hypothesis is that inflation in $t + 1$ will affect current borrowing and lending decisions in period t and, therefore, the likelihood of being financially constrained also in period t . Taking into account the sign of the association between inflation expectations and interest rates (cost of funds), inflation in $t + 1$ is positively associated with a higher probability of perceiving financial constraints by firms in time period t . Show details >

So far, it is assumed that macroeconomic conditions affect all firms equally in their likelihood of being externally financially constrained. There is a literature that claims that the sensibility of R&D and other investment to macroeconomic environment should differ among firms depending on their internal financial and economic conditions [4,12,21,31,54,55,56]. However, much less is known on how the influence of macroeconomic conditions, on the likelihood of a firm being financially constrained, varies across firms. For example, firms with high internally generated cash flows can be isolated from external financial markets conditions because they rely on internal funding for their investment decisions. One way to account for the possible interaction of macroeconomic conditions and the internal cash flows of the firms, in determining that a firm is externally financial constraint, consists in writing the coefficient of the GDP growth variable as a function of the cash flows of the firms.

2.2. Decisions on Doing R&D and on R&D Expenditures

If financial constraints are binding, constrained firms are expected to invest less in R&D than unconstrained ones. Since R&D decisions depend on other variables, rather than being financially constrained, the average R&D expenditures of unconstrained firms must be compared with the average expending of the constrained ones, controlling for the rest of the variables that may

determine the decision to do R&D and the level of expending. The other variables that may affect R&D-related decisions, in addition to being financially constrained, are reviewed below.

The decision of a firm of being active in performing R&D activities implies incurring in fixed sunk costs [57]. Since the returns from the R&D activities, in terms of increasing revenues and profits, are uncertain, and in many cases it will take time before reaching a certain threshold, implementing the decision to be active in R&D will demand a substantial investment with uncertain returns, and assets with low realization value. Debt like financial instruments will not be suitable to finance the sunk costs incurred in the investment to build an infrastructure for R&D activities, so firms will have to rely on equity similar instruments, such as internally generated cash flows. Firms with large size are more likely to have the internal resources needed to develop the desired infrastructure than small ones, so the likelihood that a firm is active in R&D activities is expected to increase with the size of the firm.

Once a firm has decided to do R&D, the volume of this may increase less, equal, or more than proportionally with the volume of sales. The prediction is then of a positive association between the volume of R&D spending and the size of the firm, for example sales or number of employees, but if the elasticity of expenditures to size of the firms is lower, equal, or larger than one is an empirical question since results vary among previous studies [13,15,20,24,46,58].

On the revenue side of making R&D decision, it can be expected that firms that produce and sell differentiated products, with higher price-cost margins, in large product markets, for example exporting firms, will be those anticipating higher increase in revenues and profits from the decision of being active in R&D [59]. Being an exporter is also evidence that a firm has developed capabilities in terms of knowledge about buyers' preferences, production technologies and organizational systems that will complement those acquired through the R&D activities. The positive effects on profits from selling more differentiated products, and being an exporter, are likely to favor the decision to be active in R&D, as well as the volume of resources dedicated to these activities in a firm of a given size. From these arguments, and taking into account the results from previous research [22,23,36,60,61,62], the hypothesis is that product differentiation and being an exporter are positively associated with both, the likelihood of doing R&D and the expending on R&D.

Public subsidies that firms receive for doing R&D is a source of income additional to that obtained from selling the innovated products. Public authorities justify the subsidies in terms of the knowledge externalities generated by innovation activities so the objective of the subsidies is to increase R&D expending above the volumes that would be decided with only private benefits and costs. However there is a controversy in the literature on whether public subsidies increase R&D expending or leave it equal to the expending the firm would decide without the subsidy, i.e. the subsidy substitutes the own expending [17,18,21,57,63]. Whether receiving public subsidies influences R&D related decisions or not will be an empirical question.

The variables that inform about the financial and economic conditions of firms, such as leverage, cost of debt, ratio of cash flows, and so on can influence the amount of R&D investment beyond their effects on the likelihood of being externally financial constrained, as long as they affect the cost of capital and the availability of other sources of funds, mainly the internal ones [64,65,66]. Therefore they must be part of the explanatory variables of R&D expending together with the variable on whether the firm is externally financial constrained or not.

The macroeconomic conditions of the economy are expected to have an influence on the R&D expending decision beyond the effect they have on the likelihood that a firm will be externally financial

constrained. Therefore should also be part of the model on the determinants of R&D related decisions. Previous research has documented the behavior of R&D expending parallel to the business cycle, i.e., procyclical R&D expending [27,28,29,30], but [31] argue that such procyclical behavior is only observed in financial constrained firms. This suggests a different sensitivity of firms' decisions on R&D to the business cycle depending on their financial and economic situation. [12] obtained similar results for Spanish manufacturing firms.

Much less has been investigated about the sensitivity of R&D expending to the credit cycle. If the time evolution of the credit cycle is evidence of oversupply of funds in expansion periods and of under supply of funds in periods of contraction, and firms respond to the availability of funds with more or less investment, then the evolution of the credit cycle should be positively associated with R&D expending.

2.3. Model Formulation

The econometric model that summarizes the theoretical analysis presented so far includes two main dependent variables: (i) If a firm is externally financial constrained or not, (ii) the R&D expenditure of firms that do R&D. Since the decision of doing R&D or not is taken by firms under rational grounds, the sample of firms that do R&D is not a random sample of the population of firms. This circumstance is taking into account by introducing a third equation that must be jointly estimated with the other two, being the decision of doing R&D or not the dependent variable. The estimation approach is based on the generalized structural equation model (GSEM) of [67,68] provides a detailed discussion of these aspects of the GSEM framework. The full-information maximum likelihood estimates produced by GSEM are capable of handling this form of simultaneity. In this context, GSEM is similar to Roodman's cmp procedure, which models recursive systems of equations with mixed distributions of dependent variables (continuous, binary, censored, etc.). The econometric procedure used to jointly estimate the three interrelated equations is formulated as follows:

$$C_i = \mathbf{1}[Y'Z_i + \varepsilon_{1i} > 0] \quad \text{Show details} \quad (1)$$

$$Y_i = \mathbf{1}[\beta'X_i + \varepsilon_{2i} > 0] C_i, \forall C_i = 1 \quad (2)$$

$$S_i = [\delta'W_i + \eta Y_i + \varepsilon_{3i}] C_i, \forall C_i = 1 \quad (3)$$

where $i = 1, \dots, n$ are firms, $\mathbf{1}[\cdot]$ is the indicator function that shows if firm i performed R&D (C_i) for Equation (1) and if firm i unsuccessfully sought financing for its innovation activities (Y_i) for Equation (2); S_i is the R&D intensity, Equation (3); Y_i and S_i are not observable $\forall C_i = 0$. X_i , Z_i and W_i are vectors of variables that collect individual characteristics which may be common or not in the specifications of Equations (1)–(3). ε_{1i} , ε_{2i} and ε_{3i} are distributed as:

(4)

with the variances of ε_{1i} , and ε_{2i} equal to one and the variance of ε_{3i} equal to σ^2 . The model allows for correlation between unobservable information from Equations (1)–(3).

3. Results

3.1. Sample Data and Variables

The econometric model summarized in Equations (1) to (3) will be estimated with data from a representative sample of Spanish manufacturing firms in the period 1998–2016. The data are collected as part of the Survey on Business Strategies (*Encuesta sobre Estrategias Empresariales*, ESEE) conducted annually by the SEPI Foundation. The population of firms surveyed by the ESEE includes manufacturing firms operating in Spain with 10 or more employees. All manufacturing firms with 200 or more employees are included in the survey, while the firms with between 10 and 199 employees are represented by a sample selected to be statistically representative across manufacturing sectors. Although the ESEE started in 1991 the question of whether a firm is externally financial constrained to undertake innovation projects was first included in the 1998 survey, so the data used in this research comprise panel data on individual firms from 1998 to the latest year available when this research was started, 2016. The sample data contain a total of 23,398 firm year observations and no fewer than 887 firms per year.

The empirical model is the result of selecting the dependent and explanatory variables in the Equations (1)–(3). The selection is made according to data availability and to the theoretical arguments on the determinants of each endogenous variable presented in the previous section.

The main Equation (3) on the determinants of R&D expending is formulated as follows:

$$\begin{aligned} \text{Log}(R\&D)_{it} = & a_0 + a_1 \text{Don't Find Funding}_{it} + a_2 \text{Log}(\text{Sales})_{it} + a_3 \text{Log}(\text{Age})_{it} + a_4 \text{Group} \\ & \text{Membership}_{it} + a_5 \text{Owned Foreign Capital}_{it} + a_6 (\text{Debt with Cost Liabilities})_{i(t-1)} + a_7 (\text{Cash} \\ & \text{Flow/Assets})_{i(t-1)} + a_8 \text{Debt Average Cost}_{i(t-1)} + a_9 \text{Log}(\text{Investment in Equipment})_{i(t-1)} + a_{10} \text{Export} \\ & \text{Activities}_{it} + a_{11} \text{Standardized Product}_{it} + a_{12} \text{GDP Deflator}_{(t+1)} + a_{13} \text{GDP Growth}_t + a_{14} (\text{Debt Non-} \\ & \text{Financial Companies/GDP})_t + a_{15} [\text{GDP Growth} \cdot (\text{Cash Flow Liabilities})]_t + \text{Sectorial Dummies}_{it} + \\ & \text{ErrorTerm}_{it} \end{aligned} \quad (5)$$

The sub index i refers to a firm and t indicates the year. The dependent variable is the log of the amount of money that firm i expends in R&D in year t , as reported in the survey. The explanatory variable on being financially constrained or not is *Don't Find Funding*, a dummy variable that takes the value of 1 if the firm responds it is externally financial constrained to obtain funds for innovation activities and 0 otherwise. A negative and statistically significant estimated coefficient for this variable will indicate that firms being financially constrained expend in R&D less than the unconstrained ones, controlling for the rest of explanatory variables.

The size of the firm is measured by the volume of sales in logs $\text{Log}(\text{Sales})_{it}$. Including the log of sales as explanatory variable Equation (5) is equivalent to an equation that explains the log of the intensity of R&D expending, i.e., the log of R&D expenditures per euro of sales. A value of the estimated coefficient of the log of sales variable equal (lower/higher) to (than) 1 indicates that the intensity of R&D expending is constant (decreases/increases) with the size of firms. Related variables that can capture the effects of size in R&D expending decision are *Group Membership_{it}* (a binary variable that takes the value of 1 if the firm belongs to a business group and zero otherwise), and *Foreign Ownership_{it}* (a binary variable that takes the value of 1 if more than 50% of the shares of the firm are held by non-residents in Spain). R&D expending tends to be concentrated around the parent company; if the firm i that belongs to a group is the parent company of the group, then it is likely to have a positive effect on R&D expending, while if it is a subsidiary the opposite sign is expected. Foreign ownership of firm i implies that the firm is a subsidiary of a foreign company and most likely

will be the foreign parent company who will supply the R&D output to the subsidiary (negative coefficient is expected).

The internal financial and economic situation of the firm are captured by the explanatory variables, lagged one period: leverage ratio ($Debt/Liabilities$) $_{i(t-1)}$, average cost of debt ($Interest/Debt$) $_{i(t-1)}$, and ratio of cash flows (net profit plus depreciation) over total assets ($Cash\ flow/Assets$) $_{i(t-1)}$. The economic and financial situation of the firm are expected to condition the likelihood of the firm being externally financial constrained and, since the variable on being constrained is modelled as endogenous variable (see below), then these variables measure the influence of the financial and economic conditions of the firm on R&D investing, beyond the indirect effect from their influence on being constrained or not. High debt dependent and high cost of debt are likely to influence negatively the decision to invest and particularly the investment in R&D as an intangible asset. Firms with high cash flow have more internally generated funds to finance investment in R&D but they may proportionally invest less than those with low cash flows if the latter view R&D investment as a way of increasing future profitability.

The explanatory variables $Export_{it}$ (binary variable that takes the value of 1 if the firm is an exporter and 0 otherwise), $Standardized\ Product_{it}$ (binary variable that takes the value of 1 if the firm produces and sells standardized products and 0 otherwise), $Log(Investment\ in\ Equipment)$ $_{i(t-1)}$ (the amount the firm expends in machinery and equipment in year t expressed in logs) and $Log(Age)$ $_{it}$ (number of years since the firm was created in logs) capture the endowment of complementary resources and activities that may increase the economic value of investing in R&D and therefore increase the volume of investment. To be an exporter increases the knowledge of markets and probably technologies that complement the internally generated one by the firm, as well as a larger market for the innovations that result from R&D investment; a positive effect of exporting in R&D expending is then expected. The investment in tangible assets may compete for funds with investment in R&D so higher investment in the former reduces the amount invested in the latter, or tangible and intangible assets can be complementary and firms that invest more in tangible assets also invest more in R&D. Age and product standardization will have a positive effect on R&D expending when complement to the knowledge created (for example experience in existing technologies contributes to lower production costs and R&D expending is mainly for process innovations), and a negative when interfere with the new knowledge (for example experience increases the costs of change to new technologies and the innovation is mainly in new products).

The time-varying macroeconomic conditions of the Spanish economy, common to all firms, include the expectations on monetary policy, the business, and the credit cycles. The influence of future monetary conditions on current R&D expending is captured with the rate of change in the Spanish GDP deflator in year $t + 1$, $GDP\ Deflator$ $_{t+1}$. The business cycle variable is the rate of growth in the real GDP of the Spanish economy in year t , $GDP\ Growth_t$. Finally, the credit cycle is measured by the time evolution of the ratio of debt of non-financial corporations over the GDP, ($Debt\ Non-Financial\ Companies/GDP$) $_t$. The effect of these macroeconomic variables in the R&D expending decision is an empirical issue which is addressed adding the variable $GDP\ Growth*(Cash\ Flow/Assets)_t$ that allows for different responses to the business cycle across firms depending on their cash flows, among the explanatory variables.

It is controlled by different economic sector effects within the manufacturing industries with the binary variable $Sector$ that takes the value of 1 if the firm belongs to manufacturing sub-sector j and 0

otherwise, for 20 manufacturing sub-sectors NACE class (two-digit) level. For robustness purposes, the empirical model will be estimated replacing the macroeconomic variables with time dummy variables, and the results will be compared.

The Equation (2) on the determinants of being externally financial constraint is written as:

$$\begin{aligned}
 Prob(\text{Don't Find Funding}_{it}) = & F(b_0 + b_1 \text{Log}(\text{Sales})_{it} + b_2 \text{Log}(\text{Age})_{it} + b_3 \text{Group Membership}_{it} + \\
 & b_4 \text{Owned Foreign Capital}_{it} + b_5 \text{Patents}_{it} + b_6 (\text{Debt with Cost/Liabilities})_{i(t-1)} + b_7 (\text{Cash} \\
 & \text{Flow/Assets})_{i(t-1)} + b_8 \text{Debt Average Cost}_{i(t-1)} + b_9 \text{Public Subsidies}_{i(t-1)} + b_{10} \text{Log}(\text{Investment in} \\
 & \text{Equipment})_{it} + b_{11} \text{GDPDeflator}_{t+1} + b_{12} \text{GDPGrowth}_t + b_{13} (\text{Debt Non-Financial Companies/GDP})_t + \\
 & b_{14} [\text{GDPGrowth} \cdot (\text{Cash Flow/Liabilities})]_t + \text{Sectorial Dummies}_{it} + \text{Error Term}_{it}
 \end{aligned} \tag{6}$$

All the variables have been defined above except *Patents_{it}*, a binary variable which takes the value of 1 if the firm says that it has patents and 0 otherwise, and *Public Subsidies_{it}*, a binary variable that takes the value of 1 if the firm receives subsidies for R&D activities and 0 otherwise.

The theory predicts a negative effect of size (sales as well as group membership and foreign ownership) and age in the likelihood that a firm is financially constrained as age and size contribute to reduce the problems from information asymmetries. High leverage and high cost of debt are expected to increase the likelihood of being externally financially constrained, and higher cash flow is expected to reduce it. Having patents will reduce the likelihood of being financially constrained if patents can be used as collateral and will increase it if patents are an indication of more intangible assets in the portfolio of assets of the firm. Public subsidies add funds to the pool of all funds available for investment (negative sign) while investment in tangible assets consumes funds from the pool (positive sign). The expected signs of the macroeconomic variables from the theory presented in the previous section are positive for the GDP deflator variable, negative for the GDP growth as well as for the aggregate leverage variable. Nothing can be said on whether the business cycle will affect differently the likelihood of being externally financial constrained to firms with different cash flows. Again the model will be estimated with time dummy variables substituting the macroeconomic variables for robustness purposes.

The Equation (3) on the determinants of doing R&D, sample selection, shares many of the variables of the equation on R&D expending, except being financially constrained. The effects of the explanatory variables on the dependent one are very much alike those expected for the variable of volume of expenditures.

$$\begin{aligned}
 Prob(\text{Do R\&D}_{it}) = & F(c_0 + c_1 \text{Log}(\text{Sales})_{it} + c_2 \text{Log}(\text{Age})_{it} + c_3 \text{Group Membership}_{it} + c_4 \text{Owned} \\
 & \text{Foreign Capital}_{it} + c_5 (\text{Debt with Cost/Liabilities})_{i(t-1)} + c_6 (\text{Cash Flow/Assets})_{i(t-1)} + c_7 \text{Debt Average} \\
 & \text{Cost}_{i(t-1)} + c_8 \text{Log}(\text{Investment in Equipment})_{i(t-1)} + c_9 \text{Export Activities}_{it} + c_{10} \text{Standardized Product}_{it} \\
 & + c_{11} \text{GDPDeflator}_{t+1} + c_{12} \text{GDPGrowth}_t + c_{13} (\text{Debt Non-Financial Companies/GDP})_t + c_{14} \\
 & [\text{GDPGrowth} \cdot (\text{Cash Flow/Liabilities})]_t + \text{Sectorial Dummies}_{it} + \text{Error Term}_{it}
 \end{aligned} \tag{7}$$

3.2. Empirical Results

3.2.1. Descriptive Information

First, some descriptive information on the values of the main variables of the model are provided. **Figure 1**, left vertical axes, shows the time evolution from 1998 until 2016 of the percentage of firms which report being engaged in R&D activities and, of these, the proportion of firms that report not finding external financing for their innovation activities (i.e. the proportion of firms externally financial

constrained). On the right vertical axes, it shows the intensity of R&D expenditures—expenditures divided by sales—on average for all firms active in R&D.

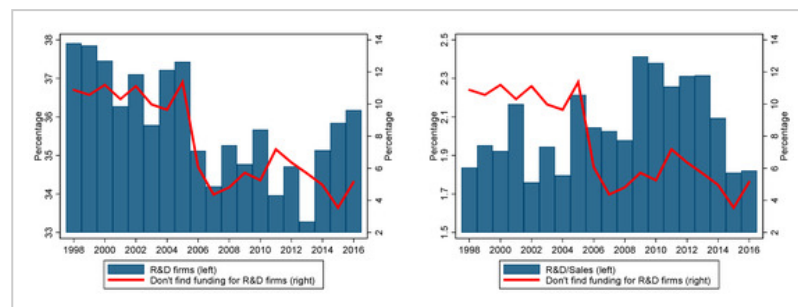


Figure 1. Frequency and intensity of R&D and percentage of firms not finding funding for R&D within the subsample of R&D active firms.

From 1998 to 2005, the proportion of firms engaged in R&D was approximately 37%; around 11% of these R&D firms reported being financially constrained. In the period immediately previous to the Great Recession, from 2005 to 2007, the proportion of firms engaged in R&D decreased three percentage points, on average, and the proportion of R&D firms reporting being external financially constrained decreased five percentage points to half the level of the previous period. But during the worst years of the Great Recession, from 2008 to 2011, the proportion of R&D firms reporting being external financially constrained increased. However from 2012 this proportion began to diminish while the proportion of firms engaged in R&D was increasing.

Since 1998, when Spain was a serious candidate to join the Euro zone, until 2007, with the start of the financial crisis, the Spanish economy went through a period of high growth fueled by the expansionary monetary policy of the European Central Bank in the last part of the period. Much of the expansion occurred as credit grew annually at two digit figures mainly credit to construction and real estate. From the numbers in the left vertical axes of **Figure 1** it seems that the expansionary credit to construction and real estate activities crowded out some manufacturing firms from doing R&D activities, particularly those that were financially constrained (the sharp decline in the proportion of financially constrained firms in 2006 coincides with the sharp decrease in the proportion of firms that did R&D). During the period of the crisis, 2008–2011, the proportion of manufacturing firms involved in R&D activities did not pick up again but stabilized at values around 34–35% of all manufacturing firms. However, the proportion of firms perceiving external financial constraints steadily increased during the crisis, confirming the opinion that the period of high liquidity and abundant credit, especially in 2003–2007, was followed by a period of severe credit contraction across the board for all firms and sectors in the Spanish economy. But the speech from the president of the European Central Bank, Mario Draghi, at the Global Investment Conference in London, on July 26, 2012 “*Within our mandate, the ECB is ready to do whatever it takes to preserve the euro. And believe me, it will be enough*”, did the risk premium on Spain’s debt begin to decrease.

Figure 1, on the vertical axes at the right, shows how during the years of the crisis, 2008–2013, R&D intensity increased despite the proportion of firms with financial constraints also steadily increasing. However, during the economic recovery from 2014 to 2016 R&D intensity decreased, while the proportion of firms with financial constraints was also decreasing.

Table 1 presents descriptive statistics, means and standard deviations, for all the variables in the empirical models (5)–(7), separately for all firms in the database and only for those firms that do R&D with a difference test. Firms that do R&D, on average, have higher volumes of sales, are older, and is more likely that they belong to a business group, have foreign shareholders, register patents and receive more public subsidies than the firms that do not do R&D. However, on average, the values of the financial variables (leverage, cost of debt, cash flows), among only R&D firms, are not different from those among the whole population of manufacturing firms.

Table 1. Descriptive statistics of principal variables.

(<https://www.cookiebot.com/en/what-is-behind-powered-by-cookiebot/>).

3.2.2. Results and Discussion of the Econometric Estimation

Now the results of the econometric estimation of Equations (1)–(3) extended in Equations (5)–(7) are reported; the estimation is performed using the procedure developed by [68]. The results appear in **Table 2**. The results of the estimation are repeated in **Table 3** but now substituting the macroeconomic variables by time dummy variables. Each table contains three blocks of estimations, the first one on the sample selection equation Do R&D, the second on the endogenously determined likelihood of being externally financial constrained, and the third one on R&D expending. Since the results on the estimated coefficients of the firm level variables are practically the same in the two estimations, with time dummy variables and with macroeconomic variables, reference will be made only to one table or the other in the discussion of the macroeconomic variables. **Show details** >

Table 2. Simultaneous mixed-process regression: model with macroeconomic variables.

Table 3. Simultaneous mixed-process regression: model with temporal dummies.

The estimated correlations among the residuals of the three equations are statistically jointly significant ($\chi^2(3) = 1222.66$ *** and $\chi^2(3) = 1225.86$ *** for **Table 2** and **Table 3**, respectively), which justifies the joint estimation of the three of them. The estimated correlation between the residuals of

the equation on being financially constraint and of the equation on R&D expending is positive, indicating that among firms that expend on R&D external shocks that induce higher expending increase the perception of tightness in financial constraint. The estimated correlation between the residuals of the equation that explains Do R&D, and the residuals of the equation on R&D investment is positive as might be expected: unobserved shocks that increase (decrease) the likelihood that a firm does R&D also have a positive (negative) effect on the level of R&D expenditure. Although the estimated correlations of the residuals of the equations Do R&D activity and being external financially constraint are not significant, the relevant feature is that the correlations of the residuals of each one of these two equations with of the equation on R&D expending are significant.

As for the estimated coefficients of the explanatory variables, firstly, the attention is focused on the equation concerning the determinants of R&D expenditures, that is, the third block of results of **Table 2** and **Table 3**. The estimated coefficient of the financial constraint variable is negative and highly significant, indicating that R&D expenditure is significantly lower among firms that are financially constrained than among those that are not. The estimated coefficient of -2.148 indicates that, controlling for other variables, the R&D expenditure of financially unconstrained firms is more than 200% higher than the expenditure of firms that say they are externally financial constrained.

The elasticity of R&D expenditure to the size of the firm, volume of sales, is 0.834, lower than one. This means that among the firms that undertake R&D, the intensity of R&D activity (R&D expenditure per euro of sales) decreases with the size of the firms. Larger firms are more likely to engage in R&D than small firms, but smaller firms expend more on R&D per unit of sales than large firms do. Age and group membership are positively associated with R&D expenditure. The estimated coefficients of the financial variables at the firm level provide very interesting information for an economic analysis. The coefficient of leverage is positive and statistically significant, which apparently is not very intuitive. However, if it is thought that R&D activity tends to follow the capacity expansion investment, the delayed leverage variable would have a positive impact on investment in R&D. On the other hand, the coefficient of the cash flow over total assets variable has a negative sign. Since in **Table 3**, with time dummy variables controlling for the time changing macroeconomic conditions, the estimated coefficient of the cash flow variable is not statistically significant, the combined results of **Table 2** and **Table 3** mean that the effect of the firms' cash flow variable on R&D investing is neutral along the business cycle, but has different signs in expansions and in contractions as it will discussed later.

Firms that invest more in tangible assets in period $t - 1$ are more likely to increase R&D expenditure in period t , so R&D activity tends to follow capacity expansion investment. The R&D expenditure is higher for exporters and lower for those firms that report producing and selling standardized products. These results are very much in line with those in the literature [22,23,60,62]. The estimated elasticity of R&D expenditure to investment in tangible assets is relatively low and clearly lower than one. This implies that the ratio of R&D expenditure to investment in tangible assets will be negatively associated with the level of investment in tangible capital. These results would suggest that at the firm level, expenditure on R&D, in relative terms to total capital expending, is counter-cyclical.

The estimated effects of the macroeconomic variables on the level of R&D expending is discussed now. The estimated coefficient of the inflation expectations is positive and statistically significant while the estimated coefficients of the GDP growth and aggregate leverage variables are

both negative and statistically significant. The negative estimated coefficient of the corporate sector leverage variable can be explained in a context of a decreasing trend in R&D intensity over time, coinciding with a period of increasing leverage in the corporate sector of the Spanish economy in parallel with the construction bubble. The huge volume of resources dedicated to construction and real estate activities made feasible by the high credit growth probably deterred manufacturing firms from expanding or even maintaining their R&D expending.

The estimated coefficient of the interaction term [$GDP\ growth * (Cash\ Flow/Assets)$] is positive and statistically significant, while, as said before, the estimated coefficient of the *Cash flow/Assets* variable is negative. Taken together, this means that the estimated coefficient of the *Cash flow/Assets* variable in the R&D expenditure equation is equal to $(-0.427 + 12.67 * GDP\ growth)$, positive for rates of GDP growth above 3.37% and negative for rates lower than 3.37%. As the mean growth rate of Spanish GDP is approximately 1.9% for analyzed period (see **Table 1**), the estimated coefficient of the cash flow ratio for the sample mean of GDP growth is -0.191 : there is no clear evidence from the sample mean value of GDP growth that firms are internally financially constrained. However, in periods with high rates of GDP growth, the estimated coefficient of the cash flow variable is positive, indicating that internal financial constraints may be binding for R&D expenditure in periods of high GDP growth (above 3.37%). In periods of low or negative economic growth, the effect of the cash flow variable on R&D expenditure is negative.

In periods of expansion, R&D expenditure competes for funds with investment in other assets, so firms less financially restricted internally (those with higher cash flows) are able to expend more on R&D than firms with less internal funding (recall that it is controlled by the external financial constraints and by the characteristics of firms). At the same time, in periods of recession, firms with lower profitability give priority to R&D expenditure with the expectation of increasing future profitability; this decision makes sense taking into account that in a recession period firms will cease investment that increases production capacity. However, in recession periods, firms with high cash flows and, therefore, with less pressure to increase future profits, reduce investment in both tangible and intangible assets.

Focusing now on the GDP growth variable, the estimated coefficient is $(-4.30 + 12.67 * Cash\ flow/Assets)$, positive for values of the cash flow variable above 0.34 and negative for values below this number. As the mean of the ratio of *Cash flow/assets* for the sample data is 0.09 (SD = 0.68) (**Table 1**), the estimated coefficient of the GDP growth ratio for the mean value of the cash flow variable is negative. These results indicate that R&D expenditure will show counter-cyclical behavior among firms with cash flow around the sample mean and, specifically, among firms with relatively low cash flow ratios, coinciding with the firms most likely to be financially constrained internally. On the other hand, among firms with relatively high cash flow ratios (above 34%), the estimated coefficient of the GDP growth rate variable will be positive, so among these firms the expenditures on R&D are procyclical. Overall, what the results show is that the sensitivity of R&D expenditure to the business cycle, measured by the time evolution of the GDP growth rate of the economy, increases with the ratio of cash flow over total assets.

The estimated coefficients of the binary variable *Time* decrease over time until 2008 when the coefficient takes the lowest estimated value for this period (**Table 3**). In the years 2009 to 2013, during the Great Recession, the intensity of R&D expending experiences a turnaround, while from 2014 to 2016, a phase of positive economic growth and expansive monetary policy, the intensity of

R&D decreases again. These data are consistent with the other evidence pointing to the counter-cyclical pattern of R&D expenditure at the aggregate level.

The second block of values shown in **Table 2** and **Table 3** include the estimated coefficients and statistical significance for the equation on the determinants of a firm being external financially constrained. Once again, the estimated coefficients of the explanatory firm level variables are very similar in the two estimations. The likelihood of a firm being externally financial constrained is lower among firms that belong to a business group and among firms owned and controlled by non-resident shareholders than among independent and national firms (although the estimated coefficient is significant only for the variable foreign ownership). Financial risks are positively associated with the likelihood of being financially constrained: the estimated coefficients of leverage and the cost of debt variables are both positive and statistically significant. Higher cash flows over total assets and having access to public subsidies lower the likelihood of a firm being financially constrained (negative estimated coefficients; the estimated coefficient of the cash flow variable is significant only in **Table 2**). This means the availability of other sources of funds lessens the likelihood that a firm will face external financial constraints. Investing more or less in tangible assets does not affect the likelihood that a firm will report being externally financially constrained to undertake innovation projects.

The estimated coefficient of the inflation expectation variable is positive and significant, which suggests that lenders anticipate the future tightening of monetary policies in current lending decisions. The estimated coefficients of the business and credit cycle variables, that is, GDP growth and (*Debt Non-Financial Companies/GDP*) are negative and significant. For a given level of credit quality, lenders relax credit conditions in a period of expansion in the business cycle and tighten them in periods of contraction. At the same time, as the credit cycle evolves with a greater accumulation of aggregate corporate debt, firms of a given credit quality find it easier to obtain external finance, confirming the predicted herd behavior of lenders, which is consistent with Minsky's financial instability hypothesis.

Show details >

Because the estimated coefficient of the interaction between the business cycle and the internal availability of funds [$GDP\ growth * (Cash\ flow/Assets)$] is positive and statistically significant, some of the previous results must be refined. On the one hand, as said before, the estimated coefficient of the *Cash flow/Assets* variable is negative. Taken together, the estimated coefficient of the *Cash flow/Assets* variable on probability of a firm being external financially constrained is equal to $(-0.30 + 8.28 * GDP\ growth)$, positive for rates of GDP growth above 3.36% and negative for rates lower than 3.36%. As the mean growth rate of Spanish GDP is approximately 1.9% for the period (see **Table 1**), the estimated coefficient of the cash flow ratio for the sample mean of GDP growth is -0.143 , that is, the effect of the cash flow variable on the probability do not find funding for R&D is negative. However, in periods with high rates of GDP growth, the estimated coefficient of the cash flow variable is positive, indicating that internal financial constraints may be binding for do not find funding for R&D activities in periods of high GDP growth (above 3.36%).

On the other hand, the positive and statistically significant coefficient of [$GDP\ growth * (Cash\ flow/Assets)$] means that the effect of the business cycle on the perception of external financial constraints vary with the availability of internal funds in each firm. The estimated coefficient of the GDP growth variable is $(-2.73 + 8.28 * Cash\ flow/Assets)$, positive for values of the cash flow variable above 0.33 and negative for values below this number. As the mean of the ratio of *Cash flow/Assets* for the sample data is 0.09 (SD = 0.68) (**Table 1**), the estimated coefficient of the GDP growth ratio for

the mean value of the cash flow variable is negative. Although lenders relax credit conditions in a period of expansion in the business cycle and tighten them in periods of contraction, for manufacturing firms with a very high cash flow ratio, the opposite is true. One possible reason is that companies with very high cash flows are likely to be those with more difficulties in accessing external financing, being usually companies with more intangible assets. Growing and riskier firms present growing cash flows too, therefore they have more cash holdings [69], and their managers do not need external financing [70]. Acharya, Almeida, and Campello [71] pointed when firms are subject to external financing restrictions, internal and external funds are more complementary than substitute forms of financing so they can have both high cash holdings and being leveraged. Cash is considered as a negative debt.

The time pattern of the estimated coefficients for the binary Time variable, **Table 3**, follows the pattern shown in **Figure 1** quite closely (note that the omitted binary variable is that of year 2007, so the estimated coefficients are differences from the estimated coefficient for the year 2007, the estimated constant). The estimated coefficients of the binary Time variable are positive and statistically significant, with similar values for all of them until the year 2005, and are non-statistically significant during the years between 2006 and 2010, which means that during all these years the level of perceived external financial constraints is similar. In 2011, the estimated coefficient is positive and statistically significant again so the overall perception of external constraints seems to increase again. All this evidence suggests that there was a time lag, between 2003 and 2006, before manufacturing firms perceived more relaxed external financial constraints in the period of high credit expansion, and a time lag between 2009 and 2011, in the middle of the financial crisis, before the proportion of firms reporting financial constraint increased again.

Finally, a discussion is held on the estimated values of the parameters of the selection equation on the probability that a firm undertakes R&D activities (first block of estimations in **Table 2** and **Table 3**). The estimated coefficients for the firm level variables are very similar in the two estimations and the sign and statistical significance of the estimated coefficients are the same in the two R&D variables, the one on the decision to do R&D and the other on the volume of R&D expending. Those factors that favor the decision to do R&D also contribute to more R&D expending.

Concerning the effect of macroeconomic conditions on the firms' decision of getting involved in R&D activities or not, the estimated coefficient of the inflation expectation variable is positive and significant, while the estimated coefficients of the business and credit cycle variables, that is, GDP growth and (*Debt Non-Financial Companies/GDP*) are negative and significant. If the lenders anticipate an increase in future inflation expectation, they will forecast a tough tightening monetary policy which will affect negatively to economic growth and tangible assets. Conversely, while manufacturing firms reduce capacity, they will decide of getting involved in R&D activities with the expectation of increasing future profitability.

The fact that R&D expenditure competes for funds with investment in other assets -construction, real estate and tangible assets- probably deterred manufacturing firms from getting involved in R&D activities. The negative effect of the conjunction of the real state and credit bubbles, observed before on R&D expending, shows up again affecting, in a similar manner, the doing R&D decision by manufacturing firms. The time pattern of the evolution of proportion of manufacturing firms involved in R&D activities shown by the estimated coefficients of the time dummy variables in **Table 3**, confirms a decreasing trend in this proportion since Spain joined the euro until 2004 where it remains until the

last year of the sample period. Maybe, with the Euro, some firms realized that their competitive advantage in an open economy was not on R&D and decided to stop their R&D activities. But the fact that the years when the proportion of R&D active firms decrease coincide with the years when the ratio of debt of non-financial corporations to the GDP of the Spanish economy experiences a high increase, supports the conclusion that high credit growth fueling, the huge expansion of the construction and real estate sector, contributed to relatively crowding out R&D activities and R&D expending among Spanish manufacturing firms.

4. Discussion: Firms' R&D Expenditures and Open Innovation in Externally Financial Constrained Situation

This paper examines the interplay between macroeconomic variables and decisions of individual firms by looking at the influence of a firm being externally financial constrained to undertake innovation projects, in the decision of how much each firm, that has decided to do R&D, invests in this activity. The data for the empirical part of the analysis comes from a representative sample of Spanish manufacturing firms in the period 1998–2016. Macroeconomic variables can potentially affect the R&D investment decision in a direct and in an indirect way. The direct influence will occur when, for example, each firm believes that, for the same competitive position in the product market, its own sales will grow faster in periods of overall economic expansion and slower in periods of contraction (hysteresis). The indirect one will show up if the likelihood of a firm being financially constrained to obtain external finance, depends on the general situation of the economy even though the internal financial and economic situation of the firm is the same in the two scenarios.

The research methodology involves jointly estimating one empirical model on the likelihood of a firm being financially constrained, as a function of firm level variables and of macroeconomic ones, and another one in the volume of R&D expending by each firm, where being constrained or not is one of the explanatory variables. Since how much to expend in R&D has been preceded by another one on doing R&D, a third sample selection equation is needed to explain the doing R&D decision, to complete the system of equations.

The results of the empirical estimation of the model with the Spanish firm level panel of data confirms that, controlling for characteristics of the firm that may determine their likelihood of obtaining external finance independent of business environment, being constrained or not also depends in a significant way of macroeconomic conditions such as inflation expectations, GDP growth and aggregate leverage. Considering the firm level variables, the likelihood of a firm being externally financial constraint decreases among firms controlled by non-resident shareholders, and is lower for riskier firms than for safer ones. Moreover, the availability of other sources of funds—higher cash flows and public subsidies—lessens the likelihood that a firm will face external financial constraints. It would be interesting to see if these results could be nuanced according to whether it belongs to an emerging industry, which is in its initial stage, or to a converted industry, which is in a growth stage [72]. With respect to the macro variables, the likelihood of being financially constrained is higher when inflation is expected to go up and it evolves in parallel to the business and the credit cycles (decreases with the GDP growth rate over time and with the aggregate leverage of non-financial corporations). However, the results obtained show something else: the effect of the business cycle on the perception of external financial constraints is subject to the availability of internal funds in each

firm. Therefore, although the sensitivity of does not find funding for R&D to the business cycle is negative, in a few cases, among firms with relative high cash flow over assets, above 33%, will be positive. These results would be consistent with Minsky's financial instability hypothesis according to which the access to external finance by firms, and probably their investment decisions are sensitive to the business and credit cycle beyond the sensitivity resulting from their own particular financial conditions.

The other empirical results have to do with the determinants of R&D expending by the firms in the sample. It is found that R&D expending intensity decreases with the sales of the firm (elasticity of R&D expending with respect to volume of sales less than one) and that R&D expending is positively associated with the volume of investment in tangible capital, i.e. investment in tangible and intangible assets appear being complementary. Although the argument about the effect of firm size on the effectiveness of R&D is still ongoing, different research [73,74] addressed the open innovation issue from a small and medium-sized enterprises (SMEs) perspective. Their results indicate networking as one effective way to facilitate open innovation among SMEs, and found SMEs pursue open innovation primarily for market-related motives such as meeting customer demands, or keeping up with competitors. Firms that say they are externally financial constraint have an R&D expending intensity half of that of firms non-externally constrained, controlling for the rest of explanatory variables. Firms more leveraged and with higher cost of capital invest less in R&D, while the sensitivity of R&D investment to the cash flow of the firm, gross profitability, is neutral over the business cycle, but has an opposite sign in periods of economic expansion (positive) and of contraction (negative).

These results suggest that in periods of high economic expansion, R&D investment decisions will probably face internal financial constraints because firms expand capacity and invest in all kind of assets at the same time. Then, firms with high cash flows can invest more in R&D than firms with low cash flows, ceteris paribus. On the other hand, in periods of economic contraction, R&D expenditure varies inversely with the level of cash flows of the firms: firms with low cash flows reduce R&D expenditure proportionally less than firms with high cash flows. Probably, in periods of low economic growth firms with low profitability view R&D expenditure as a way of improving future ones. In this case, companies should address how to develop their innovation processes, either from the acquisition of external technology, inbound open innovation; or through the development of outbound open R&D strategies, understood as outward transfer of technology. Lichtenthaler [75] studies under which environmental conditions open innovation strategies improve profitability. The level of cash flows of the firm will then mediate in the sensitivity of R&D expending to the phase of the business cycle: the effect of GDP growth on R&D expending by firms is higher among firms with high cash flows than among firms with low cash flows. Therefore, R&D expenditure is less procyclical among more profitable firms than among those less profitable, which is coherent with the presumption that firms with low cash flows invest in R&D investment as a way of increasing future profits. The R&D expending of firms is also negatively associated with the aggregate leverage ratio of the non-financial sector.

The macroeconomic conditions of the economy affect firm level decisions on R&D expending beyond the effects these conditions have in the likelihood of a firm being externally financial constrained, a situation that has an important effect on this expending. The effect of macroeconomic variables in the R&D investment decisions through their effect on the likelihood of a firm being financially constrained will probably have to do on how external financiers, suppliers of funds, adjust

their expectations and final financing decisions to the general situation of the economy. The direct effect of the macroeconomic variables in the R&D expending decision, even controlling for the being constrained variable, probably respond to how these variables affect the expectations and decisions on investment and demand of funds. Both effects add together with the result of macroeconomic conditions inducing volatility of business decisions, which in turn increase the volatility of the economic aggregates.

This research makes clear that at least from the evidence obtained with the Spanish data, business decisions, in particular R&D expending decisions, and macroeconomic variables, business and credit cycle, monetary policy, are strongly related. Further extensions of this research should seek a better understanding of these interrelationships with the aim of helping to design macroeconomic policies aimed at stabilizing the economy and reducing growth volatility. Reducing the sensitivity of firms that are financially constrained to the business cycle and to monetary policy, for example through macro-prudential regulation, seems a good starting point. In this sense, understanding the role of firms, industry, government, academia and society in R&D and to identify the cyclical dynamics of open innovation is crucial for business decisions and policy-makers [76]. This paper should serve as a starting point interlinking firm decisions, the business cycle, and the open innovation cycle.

Further research should combine the interrelationships between R&D expending decisions and business and credit cycles with the structure and mechanism of modern capital economic dynamics. [77] model the modern economy as an entrepreneurial cyclical dynamics of open innovation with three sub-economies such as market open innovation by SMEs and start-ups, closed open innovation by big business, and social open innovation. The main goals of entrepreneurial dynamic cycle of open innovation are, on the one hand, through regulations and control, prevent in advance future monopolistic positions of big enterprises; and, on the other, generate constantly new social open innovations that guarantee the growth of start-ups and SMEs, as well as the innovation of big businesses. Therefore, the roles of conglomerates and government investment are indispensable in sustaining constant and creative social open innovation above a certain level, just as macro-prudential regulation helps stabilizing the economy and reducing growth volatility. The main objective of future research, both theoretical and empirical, is to advance knowledge of the relationships between business decisions, the economic cycle, and the cyclical business dynamics of open innovation.

5. Conclusions

This paper is about financial constraints and how such constraints affect investment decisions but with important differences with respect to previous research. First, it examines the sensitivity of firms' R&D expenditures to being externally financial constrained to undertake innovation projects, considering that being constrained is endogenous. The estimation approach combines a selection equation, which evaluates the likelihood that a firm will engage innovative activity, with two equations in a mixed-process model. The data entering the selection equation comprise the full sample, while the data in the other two equations are limited to those firms for which there are measures of innovation available.

Second, it focuses mainly on the effect of macroeconomic variables related to the business and credit cycles and with the monetary policy, on the likelihood that a firm will be financially constrained, as well as on the direct effect of these variables in R&D investment decisions by firms. These effects are assessed in the paper using firm level data along a relatively long period of time and including the constraint of being financially constrained or not as one of the explanatory variables of R&D expending. The use of firm level data has the advantage, over using R&D expenditures on aggregate, that the effect of macroeconomic variables on the endogenous variables can be estimated controlling it by the firms characteristics.

Third, the variable that identifies if a firm is financially constrained or not is obtained, in this paper, from the response to a questionnaire in which firms in the sample are explicitly asked to answer yes or no to having difficulties in obtaining external finance. This way of identifying whether a firm is financially constrained or not, instead of using financial ratios, overcomes the difficulty in investment decisions of separating between the effects of being financially constrained from the effects of higher or lower profitability. However, at the same time, the firm that responds to the questionnaire will have its reasons and circumstances to answer yes or no to the posed question and, for this reason, being financially constrained or not will be itself endogenously determined. This means, from a methodological point of view, that the effect of being financially constrained in investment decisions cannot be evaluated in isolation from the factors that endogenously explain why a firm is financially constrained.

Fourth, the effect of being subject to external financial constraints in firms that invest in intangible assets, in particular firms that invest in R&D is examined. Although practically all firms invest in machinery or equipment at some time or another, doing R&D is restricted to a sub sample of firms that self-select into such activities. Since the sample of firms that expend positive amounts of funds in R&D is not a random sample of the population of all firms, the examination of the effect of financial constraints in R&D investment must be done controlling for the possible sample selection bias resulting from the endogenous decision of firms of doing R&D or not. Additionally, the low outside value of intangible assets and of knowledge related ones, in particular, limits the substitution among external and internal sources of funds to finance investment, increasing the interdependence between investment and finance decision beyond those observed in tangible assets.

The results obtained complement and improve those of previous research and they should help in designing macroeconomic policies aimed at stabilizing the economy and reduce growth volatility. Reducing the sensitivity of firms being financially constraint to the business cycle and to the monetary policy, for example through macro prudential regulation, seems a good point to start.

Future research should include the dynamics of open innovation into the interrelationships between R&D expending business decisions and economic and credit cycles. The aim is to advance knowledge of the relationships between business decisions, the economic cycle, and the cyclical business dynamics of open innovation.

Author Contributions

All authors have contributed equally. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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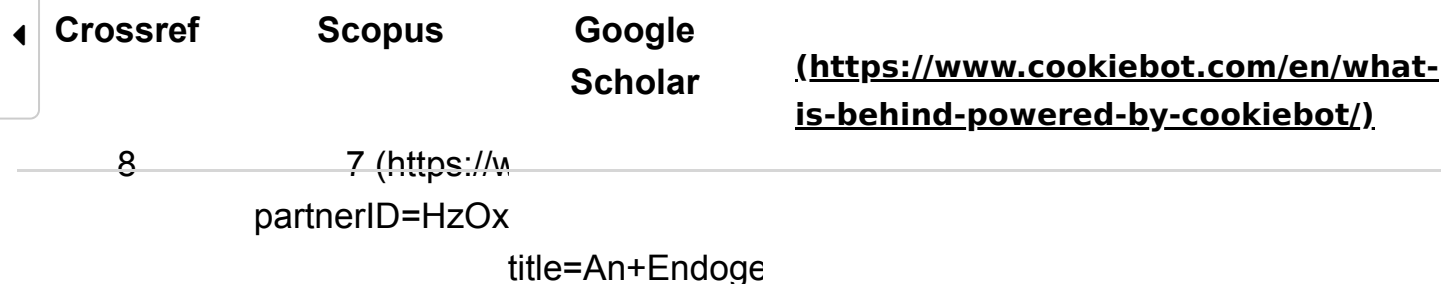
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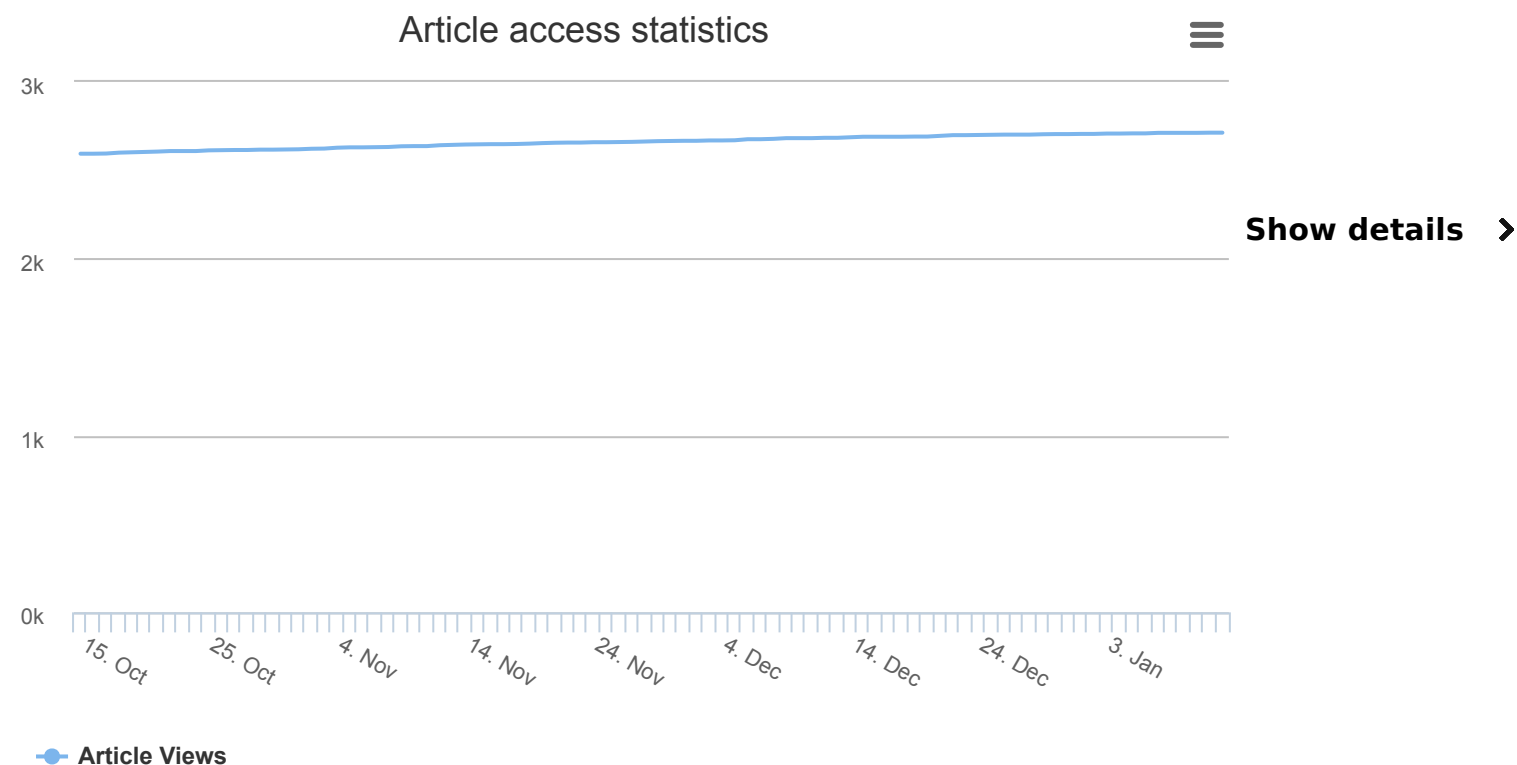
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