Máñez, J. A., Rochina-Barrachina, M. E., Sanchis-Llopis, J. A., & Vicente, O. (2014). Financial constraints and R&D and exporting strategies for Spanish manufacturing firms. *Industrial and Corporate Change*, *23*(6), 1563-1594.

https://doi.org/10.1093/icc/dtu034

Financial constraints and Spanish manufacturing firms' R&D and exporting strategies

Juan A. Máñez[a]
María E. Rochina-Barrachina
Juan A. Sanchis-Llopis
Oscar Vicente
Universitat de València and ERICES

ABSTRACT

The aim of this paper is analysing the role of internal and external financial constraints in the firms' joint decision to export and invest in R&D. Our empirical strategy consists of estimating a dynamic panel data bivariate probit that explicitly acknowledges that firms R&D and export decisions are interrelated. To account for financial constraints we use direct and objective measures at firm level: for internal credit constraints we use cash flow, and external constrains are proxied using financial costs. Further, we analyse both if firms size and the onset of the current economic crisis have an impact on the relationship between financial constraints and firms' R&D and export decisions. Using a representative sample of Spanish manufacturing firms for the period 1990-2011, we find that both internal and external finance constraints are relevant for the two firms' strategic decisions analysed.

Keywords: exports, R&D, financial constraints, manufacturing firms, dynamic panel data bivariate probit.

JEL Classification: F14, O32, G32, L60, C35

[a] Corresponding author: jamc@uv.es

1. INTRODUCTION AND RELATED LITERATURE

In its latest Economic Outlook (19-November-2013) the OECD pointed out that in Spain "*Demand for credit is weak, but the interest rates for new loans to small and medium enterprises have risen substantially, suggesting that credit supply restrictions also follow*". In the same line (and in the same week) the *troika* (European Commission, ECB and IMF) also warned that private banks would rather invest in public debt to lending, as they achieve very cheap loans, almost free, from the ECB and invest them in government bonds with a yield of 4% at 10 years.

In the same OECD report mentioned above, it is also noticed that "*Improving growth in export markets,… will help to foster a weak recovery in 2014 and 2015*".

However, this improvement in exports has occurred at the cost of an important internal devaluation that might not be the basis for a sustainable competitive advantage. Further, increasing difficulties to access financial markets may endanger export participation for SMEs, and so the growth of Spanish exports.

The only way to build a sustainable comparative advantage in the long run is increasing R&D investments that result in new process and product innovations, which would allow Spanish firms to compete in international markets. Furthermore, participation in international markets might reinforce the increase in the competitiveness of Spanish exporting firms.

However, firms' R&D and exporting activities share some features that make them likely to suffer from financial restrictions. Both activities involve important start-up costs that need to be paid upfront (before firms obtain any returns from these activities) and that are, up to a large extent, sunk.[1] Further, there are fixed cost to remain in those activities (Aw, Roberts and Xu,

[1] For exporting these start-up costs are related, among others, to: acquisition of knowledge about foreign markets, adaptation of products to foreign regulation or tastes, setting up a distribution network, etc. As for R&D investment, these costs may include creating an R&D department, purchasing specific physical assets, hiring or training specialized workforce, but also collecting information on new technologies, organizational changes and adjustments

2011). Firms starting or continuing exporting and/or undertaking R&D activities will need to cover these costs either by using own funds and/or borrowing. Furthermore, both exporting and performing R&D activities imply a higher associated risk as compared to other firms' activities. This is so as firms exporting (in contrast to selling in the domestic market) stand risks such as exchange rate fluctuations and contracts that cannot be easily enforced in foreign countries (Wagner, 2012). Moreover, R&D investments are risky *per se*, as their outcomes (product innovations, process innovations or patents) are uncertain. This higher risk associated to these activities adds to firms' liquidity needs. Therefore, firms' financial restrictions might be crucial in determining their ability to export or to perform R&D and, thus, those firms less credit constrained (either internally and/or externally) may enjoy an important comparative advantage.

On the basis of these particular features of firms' R&D and export strategies, the theoretical foundations of our analysis stem from three strands of the literature. The first analyses the relationship between financial constraints and firms' export decisions. In this strand of the literature, Chaney (2013), Muûls (2008) and Manova (2013) introduce the role of financial constraints into Melitz (2003) original model of heterogeneous firms. In Chaney (2013) model, firms must incur extra costs to access foreign markets, and if they face external credit constraints to financing these costs only those firms with sufficient internal funds will be able to export. Muûls (2008) finds that the higher the financial constrains faced by firms, the lower the probability of exporting. Analogously, in Manova (2013) financial constraints affect both the extensive and intensive export margins, as more financially constrained firms are less likely to export and, if they do, they export less. Greenaway *et al.* (2007) is the first of a growing number of empirical works analysing the link between credit constraints and exports using firm level data. Wagner (2012) offers an exhaustive survey of these empirical works that reveals as stylized fact that financial constraints are important for firms' export decisions –exporting firms are less financially

to new technologies.

constrained than non-exporters. Further, the analysis of the direction of this link reports that less constrained firms self-select into exporting, but participation in export markets does not contribute to relax firms' financial constraints.[2]

The second strand of the literature focuses on the analysis of the relationship between financial constraints and firms' R&D or innovation activities. The theoretical models predict a negative relationship between credit constraints and R&D, based on the existence of information asymmetries (Leland and Pyle, 1977), high adjustments and sunk costs (Arrow, 1962) and lack of collaterals.[3] However, the empirical evidence is ambiguous and far from conclusive (see Hall, 2002 and Hall and Lerner, 2010, for surveys).[4] In applied works, the most common strategy to identify the presence of financial constraints is using an indirect approach based on the differential sensitivity of R&D investments to cash flow (Fazzari *et al.*, 1988). Results indicating that R&D is sensitive to firms' cash flow are expected to signal a large wedge between internal and external costs of funds, what would imply firms being financially constrained. On the contrary, evidence of lack of sensitivity (or low sensitivity) is interpreted as if external access to finance does not represent any friction or does not come at a higher cost than the opportunity cost of internal finance.

However, this indirect procedure has important shortcomings and has been seriously criticized as per its ability to properly identify external financial constraints (Kaplan and Zingales, 1997). First, it considers that firms have a preference for internal finance, although there could be some firms that prefer external funding. Second, it assumes (when explaining R&D activities) that

[2] An exception to the direction of these stylized facts is Greenaway *et al.* (2007) who find opposite results.

[3] Gorodnichenko and Schnitzer (2013) propose a model where firms financial constraints may be an important factor preventing domestically owned firms from emulating foreign-owned firms' practices and techniques (for example implementing innovations), in a context of transition economies.

[4] More recent works such as Aghion *et al.* (2012), Mancussi and Vezzulli (2012), Beneito *et al.* (2013) or Brown *et al.* (2012) find evidence of a negative impact of financial constraints on R&D investments.

measures such as cash flow only reflect the sensitiveness of these investments to costlier external sources of finance. However, this is subject to important critiques as it could mean a larger scope of R&D investment opportunities or uncontrolled demand conditions in estimation that are both positively correlated with firms' internal finance and R&D decisions. Third, if firms extensively rely on external funds for investments and, simultaneously, the availability of both types of finance are correlated, then, there may exist an omitted variable bias when estimating the relationship between R&D and a measure of internal finance (Moyen, 2004, Beneito *et al.*, 2013). To deal with these issues, some studies consider including as explanatory variables both firms' internal and external financial constraints measures (see Brown *et al.*, 2009, Brown and Petersen, 2009, and Brown *et al.*, 2012, Gorodnichenko and Schnitzer, 2013, among others).

The final strand of the literature focuses on the interaction between exports and innovation. Within this literature, the theoretical works by Constantini and Melitz (2008), Atkeson and Burstein (2010), Ferguson (2010) and Long *et al.* (2011), among others, show how trade liberalization increases R&D returns and, therefore, creates incentives for firms' R&D investments. In these models, a firm increases its expected profits from exporting by investing in R&D, and exporting also contributes positively to the returns to R&D investments. In the empirical literature, Bustos (2011), Lileeva and Trefler (2010), Long et al. (2011), Iacovone and Javorcik (2012), Máñez-Castillejo *et al.* (2009b, 2014), Aw *et al.* (2007, 2008, 2011), Salomon and Shaver (2005), Liu and Buck (2007), Fafchmaps et al. (2008), Bratti and Felice (2012) and Damijan *et al.* (2010, 2012) find evidence about exporting being correlated with innovation. Further, Sterlacchini (1999), Basile (2001), Roper and Love (2002), Lachenmaier and Woesmann (2006), Becker and Egger (2013) and Cassiman *et al.* (2010), Cassiman and Golovko (2011) among others, find that firms introducing (product or process) innovations are more likely to export in the future. All in all, a crucial implication of these works is that R&D and export decisions are interrelated.

In line with this recent literature, we jointly analyse firms' simultaneous decisions of exporting and performing R&D when evaluating the effects of financial constraints. However, taking into account all the considerations previously discussed, we acknowledge that, in principle, firms may rely on external sources to finance exporting and R&D activities or that these sources represent, at least, a marginal way of financing these activities once firm's internal finance is exhausted. Therefore, we are interested on the effects that both internal and external financial constraints have on firms' productivity-enhancing investments (such as exporting and/or performing R&D activities). Should we find that the availability of internal finance and the ease to access external finance are relevant to explain firms' export and R&D decisions, this would be evidence in favour of the existence of financial constraints, as an increase of the availability of internal funds and/or better access to external funding would stimulate those activities. Differently to other works, we do not use self-reported indicators of financial constraints. In our work we include objective measures of firms' internal and external financial resources, which are considered to influence exporting and R&D decisions directly. Further, we do not rely either on innovation output measures –such as product and process innovation– that we consider an indirect way to capture the effects of credit constraints on the incentives to invest in R&D.

We estimate a dynamic panel data discrete choice model of the joint decision to export and perform R&D activities. We characterize these firms' decisions as depending on both firms' internal and external measures of financial constraints and other controls. Our estimation methodology takes into account the potential simultaneity in the two firms' decisions through the estimation of a bivariate probit, in which we also account for individual effects (Blundell *et al.*, 1999, 2002). The data used in this paper are drawn from the Spanish firms' manufacturing survey (ESEE hereafter) for the period 1990-2011. This is an annual survey sponsored by the Spanish Ministry of Industry and carried out since 1990 that is representative of Spanish manufacturing firms.

The main results of the paper are manifold. First, both internal and external finance constraints are relevant for the firms' strategic decisions of exporting and R&D. This highlights the relevance of the banking institutions to promote both exporting and innovation activities. Second, we do not confirm the existence of omitted variable bias when we do not include in the regressions measures for internal and external finance altogether, what could be driven by firms' not only using both types of resources to finance such investments but also by a certain specialization in the use of them for different components of the investments. Third, we find that SMEs are more financially constrained than their larger counterparts. This result is relevant for Spanish manufacturing as more than 90% of firms are classified as small (less than 200 employees). Fourth, our results also indicate that Spanish firms start suffering severely financial constraints from 2010, as a consequence of the world's financial crisis after 2007. From this year onwards, firms' investment in R&D became more sensitive to internal finance resources. This might be interpreted as a direct effect related to higher difficulties in accessing to bank credits.

The remainder of the paper is organized as follows. Section 2 describes the data, the main variables in the analysis, and presents some descriptive statistics. Section 3 highlights the estimation method and discusses the main results from our analysis. Finally, Section 4 concludes.

2. DATA AND DESCRIPTIVE ANALYSIS.

2.1. Data description.

The data used in this paper are drawn from the ESEE for the period 1990-2011. This is an annual survey sponsored by the Spanish Ministry of Industry and carried out since 1990 that is representative of Spanish manufacturing firms classified by industry and size categories.[5] It provides exhaustive information at the firm level. In particular, the ESEE provides information

[5] The ESEE provides information at industry 2-digit NACE level.

about firms' strategies, i.e., decisions firms take regarding their competition variables. The questionnaire covers information on: firm's activity, products and manufacturing processes; customers and suppliers; costs and prices; markets; technological activities; foreign trade; and, accounting data.[6]

The sampling procedure of the ESEE is the following. Firms with less than 10 employees were excluded from the survey. Firms with 10 to 200 employees were randomly sampled, holding around 5% of the population in 1990. All firms with more than 200 employees were requested to participate, obtaining a participation rate around 70% in 1990. Important efforts have been made to minimise attrition and to annually incorporate new firms with the same sampling criteria as in the base year, so that the sample of firms remains representative over time.

The original size of ESEE for the period 1991-2011 is 35,451 observations (corresponding to around 1,700 firms *per* year). From this sample, we sample out those firms' observations that fail to supply relevant information about all the variables involved in our analysis.[7] After cleansing the data we end up with a sample of 14,499 observations corresponding to 1,874 firms.

The ESEE provides information both about whether the firm exports and/or performs R&D activities. In particular for the firm's export status, we use the following question: "Indicate whether the firm, either directly, or through other firms from the same group, has exported during this year (including exports to the European Union)". The question we use for the firm's R&D status is: "Indicate if during this year the firm has undertaken or contracted any R&D activity".

[6] Please check the web page of the ESEE in Fundación SEPI for further information: http://www.fundacionsepi.es/esee/en/epresentacion.asp.

[7] As our TFP estimation method requires that firms supply information for at least three consecutive years, we remove all firms that do not accomplish this criterion.

Looking at the distribution of firms exporting and/or performing R&D in the data, we observe that 45.57% of firms neither export nor carry out R&D activities, 4.89% only perform R&D activities, 31.33% only export and, finally, those undertaking both activities represent 21.20%.

In what follows, we explain in detail the variables that we use to measure internal and external constraints.

2.2. The measurement of external financial constraints.

In Spain, and similarly to other countries like Italy, bank loans are the most common form of external financing for firms and constitute the bulk of firms' financial debt (Schiantarelli and Sembenelli, 2000).[8] Thus, we expect the cost of borrowing to be an important determinant of firms' financial constraints.

In this work, we use an objective measure (as opposed to self reported) of firms' financial costs. Following Beneito *et al.* (2013), we use the cost of firms' new long-term debt. This cost is calculated as a weighted average of the unit cost of debts the firm has borrowed in a given year both from banks (the bulk of debt) and from other long-term lenders:

$$\text{cost}_{it} = \frac{\left(\text{cost}_{it}^{Banks} \cdot Banks_{it}\right) + \left(\text{cost}_{it}^{Other} \cdot Other_{it}\right)}{Banks_{it} + Other_{it}} \quad (1)$$

where $Banks_{it}$ and $Other_{it}$ are firms' new long-term debts with banks and other long-term lenders, respectively, and cost_{it}^{Banks} and cost_{it}^{Other} stand for their associated costs (as a percentage). Figure 1 shows the general evolution of the average cost of firms' borrowing. As it can be seen, there has been a significant decrease in the average cost of debt, especially from 1990 until 1999. We also observe that this cost slightly increases in 2000 and in 2008.

[Insert Figure 1 around here]

[8] In our sample around 97% of firms are not listed in the stock market. Therefore financial institutions and, specially, the banking system are very important for financing firms' investments.

To avoid contamination from changing macroeconomic policies (such as overtime reductions of interest rate) in the link between the cost of debt and tighter financial constraints, in our estimation specifications we will introduce the financial cost variable as the deviation (*cost_d*$_{it}$) of the current firm's cost of financing with respect to the average cost paid by manufacturing firms in the same year:[9]

$$cost\_d_{it} = cost_{it} - \sum_{i} \frac{cost_{it}}{N_t} \quad (2)$$

Large and positive values of this variable should correspond to firms with high financial costs, and large negative values should correspond to firms that may access external financing at a lower cost. In our estimations, in the next section, negative values for the estimate of *cost_d*$_{it}$ should be interpreted as evidence in favour of the existence of external financial constraints.

We believe that using an objective measure of external financial constraints, as it is the financial cost of debt, is more accurate to capture firms' external credit constraints than using measures such as "payment incidents" (Aghion *et al.*, 2012), the self-reported measures of financial constraints used by Gorodnichenco and Schnitzer (2013), or the self-reported indicators of financial constraints available for some countries in the CIS survey. These indicators have the problem of being qualitative measures of financial constraints reflecting perceived financial constraints, Bovha-Padilla *et al.* (2009). One of the main drawbacks when using self-reported subjective measures in an economic study is that many researchers are sceptical of subjective questions, and therefore about the results obtained with these data. This is so as these data is subject to both measurement error, that might be correlated with the explanatory variables (Bertrand and Mullainathan, 2001), and that there might be endogeneity problems given that

[9] We have also experimented with an alternative measure where the deviation is calculated with respect to the industry average the firm belongs to. Results were qualitatively similar, but we consider our measure is more reliable as there can be industries with worse borrowing conditions, that would not be captured using industry averages.

some firms' characteristics (for example firm productivity) may affect the tendency to declare financial constraints

2.3. *The measurement of internal financial constraints.*

There is a plethora of works that use cash flow related measures as proxies for internal financial constraints. Firms' own funds availability is crucial in those situations in which access to external financing becomes difficult. In this line, both Manole and Spatareanu (2010) and Buch *et at.* (2010) use cash flow as a measure of internal constraints. Stiebale (2011), Ito *et al.* (2011) and Berman and Héricourt (2010) use the ratio of cash flow to assets or capital as a measure of internal constraints. Bellone *et at.* (2010) construct an index to measure firms' financial constraints and use, among other variables, firms ability to generate cash flow.[10] Guillou and Schiavo (2011) use profits as a measure of internal financial constraints, which are directly related to cash flow.

Our measure of firm's cash flow has been calculated as firm's sales minus the sum of purchases, external services and labour costs. This variable is deflated using industrial price indexes. Using similar arguments to those used for financial constraints, in estimation we will use our measure of internal financial constraints in deviations with respect to the average by industry and year.[11] Large negative values should correspond to firms facing tight internal financial constraints; large positive values should correspond to firms with a large availability of own funds. Therefore, we expect a positive sign for the estimate of the deviation with respect to the year and industry mean of the cash flow variable (TFP_d_{it}, respectively).

2.4. Some descriptives statistics.

[10] Other studies using cash flow as a measure of firm internal financing are, among others, Hall (2002), Harhoff (1998), Cincera (2002) and Bond *et al.* (2003).

[11] Cash flow is in logarithms.

In this section we provide the descriptive statistics of the main variables used in our analysis (see Table 1), and explore the relationship between exporting and R&D strategies (i.e., exporting only, performing R&D activities only, both or none) and our measures of financial constraints. For this purpose, we estimate the following reduced form equation:

$$y_{it} = \beta_0 + \beta_1 Export_{it} + \beta_2 R\&D_{it} + \beta_3 Both_{it} + controls_{it} + e_{it} \quad (3)$$

where the dependent variable y_{it} is alternatively the cost of new long-term borrowing and the log of cash flow. The variables $Export_{it}$, $R\&D_{it,}$ and $Both_{it}$ capture firms' export and R&D strategies. Thus, $Export_{it}$ is equal to one if the firm *i* only exports in *t* (and zero otherwise), $R\&D_{it}$ is equal to one if the firm *i* only undertakes R&D activities in *t* (and zero otherwise), and $Both_{it}$ is equal to one if the firm *i* both exports and engages in R&D activities in *t* (and zero otherwise). We also control for size (as measured by the number of employees), age, foreign capital participation, industry and year dummies.

The differences (in %) between firms with different exporting/R&D strategies for the variables in logs are computed from the estimated coefficients $\beta_{,}$ as 100(exp(β)-1). Table 2 shows that regardless of the combined export/R&D strategy, firms that perform any of these activities have larger cash flow than firms that neither undertake R&D nor export. Further, firms exporting or engaged in both activities have access to external financing at a lower cost than firms that neither export nor perform R&D.

[Insert Table 1 around here]

[Insert Table 2 around here]

Analogously, the joint consideration of the estimates in Table 2 and the pairwise tests in Table 3 suggests that firms that both export and undertake R&D have access to external finance at a lower cost and have a larger cash flow than firms that only export or only perform R&D activities. Our estimates and pairwise tests do not find significant differences (either in cash-flow

or external cost of financing) between firms that only export and those that only perform R&D.

[Insert Table 3 around here]

Finally, we have calculated the pairwise correlation between the variables cash flow and the cost of external finance (*Cash flow_d*$_{it}$ and *cost_d*$_{it}$) as defined above, as these are the main variables used to capture financial constraints in our estimations. The correlation between these two variables is -0.259 and highly statistically significant (we get a *p*-value=0.000) and, more importantly, shows the expected sign. Furthermore, firms ranked as more externally financially constrained are ranked simultaneously as firms with more internal financial constraints, what confirms the interpretation of our financial constraints variables in deviations as appropriate measures to rank firms from less to more external and/or internal financial constrained.

3. ESTIMATION RESULTS.3

3.1 Empirical model

We consider that a firm will decide to export (or/and perform R&D) in year *t* whenever the current increase to gross operating profits associated with the decision to export (or/and engage in R&D) plus the discounted expected future returns from being an exporter (or/and R&D performer) in year *t* exceed sunk costs. The presence of sunk costs is consistent with firms' current choices as regards R&D and exports depending on past respective choices. [12] Within this framework, our empirical model of the joint likelihood of exporting and performing R&D will be specified in terms of sunk costs (proxied by the lagged export and R&D status in the respective choice equations) and a reduced-form group of variables proxying for the payoffs to each activity and, hence, firms' capabilities to push their expected profits above sunk entry costs. Among them we pay special attention, for the purpose of this paper, to the role firms' internal and external

[12] See Sutton (1991), Aw *et al.* (2011), Mañez *et al.* (2009a) or Mañez *et al.* (2014) for a framework on the estimation of sunk costs for firms' export/R&D decisions

financial constraints variables. In econometric terms, the model is a dynamic panel data discrete choice model of the export and R&D decisions, in which the choice probabilities in year *t* are conditioned on the previous vector of state variables for that year:

$$E_{it} = \begin{cases} 1 & if \quad \theta_0^E E_{i,t-1} + \theta_1^E R\&D_{i,t-1} + \beta^E X_{it-1} + \gamma^E Z_{it-1} + \mu_t^E + \sigma_i^E + \varepsilon_{it}^E \geq 0 \\ 0 & otherwise \end{cases}$$

$$R\&D_{it} = \begin{cases} 1 & if \quad \theta_0^{R\&D} R\&D_{i,t-1} + \theta_1^{R\&D} E_{i,t-1} + \beta^{R\&D} X_{it-1} + \gamma^{R\&D} Z_{it-1} + \mu_t^{R\&D} + \sigma_i^{R\&D} + \varepsilon_{it}^{R\&D} \geq 0 \\ 0 & otherwise \end{cases} \quad (4)$$

where θ_0 identifies sunk costs for each one of the two considered activities; θ_1 accounts for firms' expected profits from exporting to be affected by firms' R&D decisions and *vice versa* (as theoretically justified by the structural model in Aw *et al.,* 2011); X_{it-1} is a vector of variables controlling for firms' internal and external financial constraints; Z_{it-1} is a vector of control variables (TFP, age, size, foreign capital participation, market share, demand conditions, number of competitors, sales to public administrations, appropriability conditions and proportion of skilled labour) that might affect firms' expected returns of exporting or performing R&D;[13] μ_t is a vector of year dummies and σ_i is a vector of industry dummies. Finally, ε_{it} is an error term that we assume has two components, a permanent firm-effect (α_i) and a transitory component (u_{it}).

3.2. Estimation results

We estimate eight bivariate probit specifications that sequentially incorporate additional features in estimation. We aim to analyse how taking into account different economic and econometric issues affect the estimates of the financial constraints variables. Our results are shown in Table 4.

The purpose of Specifications 1 to 4 is checking whether the correlations between a firm's external and internal financial constraints variables and its export and R&D decisions are

[13] The definition of these variables is in Appendix A.

robust to the inclusion of several observed heterogeneity controls that could hide spurious correlations. Specification 1 (columns 1 and 2) only includes the financial constraints variables (X_{it-1}) among regressors. We proxy for internal financial constraints with firms' cash flow and for external financial constraints with firm's cost of debt. These firms' variables are calculated in deviations, as explained in Section 2. Specification 2 (columns 3 and 4) adds time dummies (μ_t) to control for time varying factors affecting all firms equally, and Specification 3 (columns 5 and 6) further includes industry dummies (s_i). The results obtained are very robust (both in sign and absolute value) in these three specifications, and suggest that both internal and external financial constraints are relevant for the firms' export and R&D decisions. As expected, the cost of debt estimate has a negative effect while the cash flow estimate a positive one. Specification 4 (columns 7 and 8) adds as controls observable firms' characteristics (Z_{it-1}),[14] that are likely to have an effect both on export and R&D decisions and to be related to both external and internal firm's financial constraints. In Specification 4 the estimates of the external and internal financial constraints variables are still significant, keep the sign but markedly drop, remaining approximately a half for the cost of debt variable and a third for the cash flow variable (both for the export and R&D equations). This suggests that Specifications 1 to 4 suffer from an omitted variables bias that leads to overestimate the coefficients of the financial constraints variables. Controlling for firms' observed heterogeneity reduces this bias.

Specification 5 (columns 9 and 10) is already equation (4) but it does not control for firm's unobserved heterogeneity yet. It widens Specification 4 to accommodate both dynamics

[14] The TFP variable deserves special attention. It is included to account for a process of self-selection of the more productive firms into export markets (Melitz, 2003) and/or into R&D activities. TFP has been calculated by industry using the method proposed by Wooldridge (2009). This has been modified to consider and endogenous Markov process for the law of motion of productivity that allows current productivity to depend on past export and R&D experience (see Mañez *et al.,* 2014, for a detailed explanation). The TFP estimated input coefficients are available upon request.

(including firms' past export and R&D decision in the export and R&D equations, respectively) and firms' past R&D status (export status) when explaining the current probability to export (perform R&D). This slightly diminishes the magnitude of the estimates for the external and internal constraints variables. However, they still remain highly significant and keep the expected signs.

Specification 6 (columns 11 and 12) econometrically controls for correlated unobserved firms' heterogeneity using the fixed effect approach developed by Blundell *et al.* (1999, 2002). Following their approach, the pre-sample means of the dependent variables ($\bar{E}_{i0}$ and $\overline{R\&D_{i0}}$) are sufficient statistics for the unobserved fixed effects (α_i). Thus, to control for such correlated heterogeneity, we add pre-sample means as additional explanatory variables in each time period *t* in equation (4). As we use as pre-sample period 1990-1992 and the explanatory variables in equation (4) are lagged one period, we carry out estimation for the period 1994-2011.[15] We observe that the estimates of the financial constraints variables coefficients are almost identical for Specification 5 and 6.

Furthermore, Blundell *et al.* (1999) suggest that, given that not all the permanent effects are captured by the entry pre-sample mean of dependent variables, it might be convenient, when available, also including pre-sample mean values of regressors, to account for additional individual effects. Therefore, in Specification 7 (columns 13 and 14) we add to Specification 6 the pre-sample means of all the other remaining regressors (including the financial constraints variables). Both in Specifications 6 and 7 the estimates of the financial constraints variables remain highly significant, although there are some differences. Comparing these two specifications, we observe that the cash-flow estimates in Specification 7 are slightly lower, and the cost of debt estimate in the export equation is slightly larger (in absolute value) than the corresponding one in Specification 6.

[15] Results were qualitatively similar experimenting with different pre-sample periods.

Finally, to alleviate for possible unobservables that could still remain in Specification 7, in Specification 8 we instrument the first lags of the financial constraint variables in the export and R&D equations with their lagged values up to *t*-3 and all the other regressors (except those associated to dynamics in the model). We perform this instrumental variables procedure estimating by maximum likelihood a four equations model that in addition to the export and R&D equations includes two equations in which the cost of debt and the cash flow variables are regressed on their respective instruments.[16] The tests on the correlations of errors between regression equations for the cost of debt and the cash flow variables and the export and R&D equations indicate that our estimations of Specification 7 do not suffer from endogeneity problems (as regards the export equation the *p*-values for the tests are 0.329 and 0.529 for the cost of debt and the cash flow equations, respectively; as regards the R&D equation the corresponding *p*-values are 0.315 and 0.518), and so there is not need to use instrumental variables. Therefore, our preferred (baseline) specification for further analysis is Specification 7.

All in all, after controlling for: i) a rich set of observable firms' characteristics; ii) the dynamic nature of firms' exports and R&D decisions; iil) firms' fixed effects; and iv) other potential endogeneity problems related to unobservables, we can be quite confident in our estimates for the cash-flow and cost of debt variables as they keep their expected signs (negative in the case of the cost of debt and positive in the case of cash flow) and remain highly significant.

As for the interaction variables between internal and external financial constraints (*cost_d·Cash flow_d*), they are are not statistically significant in any specification of Table 4, suggesting that internal and external financial constraints are neither complementary nor substitutes. This result is reinforced by the fact that we did not confirm the existence of omitted variable bias when not including in the regressions controls for internal and external financial

[16] Estimation is performed using the Stata command *cmp* developed by Roodman (2011) for estimating fully observed recursive mixed-process models.

constraints simultaneously. [17] This may be the result of firms not only using both types of resources to finance exporting and R&D investments but also of a certain specialization in the use of them for different components of the investments. Additionally, it is important to note that the estimated correlations between the exports and R&D equations (coefficients ρ) are positive and significant (see the tests at the bottom of Table 4 for each Specification). This confirms the simultaneity of firms' export and R&D investment decisions and, hence, the convenience of jointly estimating the two decisions when analysing the role that financial constraints play on both of them.[18]

[Table 4 around here]

As regards results for some of the control variables included in our preferred specification (Specification 7), first, we detect high persistence both in the export and R&D decisions (although stronger for exports), which is consistent with the presence of sunk costs associated to these activities. The role of this persistence is reinforced by the positive and highly significant effect of their pre-sample means (capturing their permanent effect through firms' individual effects). Second, we find that exporting seems to affect positively the payoffs from performing R&D, provided lagged export status is positive and significant in the R&D equation. Pre-sample means, through their effect via individual effects, reinforce further the effect of exports on the R&D equation and also explain an indirect positive but weakly significant effect of R&D on the export equation. Third, it is confirmed that previously more efficient firms (according to TFP) are the ones that self-select into exporting. Fourth, the effect of age is positive and appears only weakly significant for the export decision. Fifth, the effect of size is positive and highly significant for both decisions (although stronger for R&D). Sixth, the effect of foreign capital participation is negative

[17] These results are not reported in the paper but are available from the authors upon request.

[18] We can be quite self-assured about this inference, in particular under Specification 7, since in all the previous ones there still remained omitted relevant variables for the export and R&D decisions, that were a part of the error terms in both equations and could justify the correlation between them.

and only significant for R&D what is compatible with foreign own firms developing R&D programs in the parent firm. Finally, facing an expansive demand, better appropriability conditions for innovation, and higher proportions of both medium and high skilled labour are positive and only statistically significant for the R&D decision.

To assess the goodness-of-fit of our baseline estimation we predict the probabilities of exporting and performing R&D for each firm in the sample (using our estimates) and compare them with the sample figures from the data. We obtain that our model predicts well 86.66% and 87.37% of the actual patterns of export an R&D decisions, respectively. Therefore, our model predicts quite closely the observed firm's decisions.

3.3. Some robustness checks of the baseline results.

The role of size

Our results suggest that both internal and external financial constraints are important in shaping firms' exporting and R&D investment decisions. However, we consider that further insight is needed to check whether the impact of financial constraints might be different for SMEs and large firms.[19]

Damijan and Kostevc (2011) discuss why the effect of financial constraints for SMEs and large firms on the export decision might be different. First, large firms usually have larger internal funds than SMEs, and have better access to financial markets both in terms of volume of funds they can borrow, and the cost of these funds. Second, SMEs are usually more risk averse, which may make them to refuse taking external debt to finance exporting ventures. In this line, Bonnet *et al.* (2005), using a French sample to analyse how financial constraints affect new firms, find that there is a non-negligible share of firms that even when facing internal constraints do not

[19] Following the ESEE classification, we will consider as SMEs those firms with less or equal than 200 workers and as large those with more than 200 workers.

resort to external loans, and when they do, they borrow a smaller amount than the one corresponding to their size. These self-imposed constraints generate a vicious circle reducing the ability of SMEs to export more than what their size would imply. Further, SMEs' reluctance to have leverage levels similar to large firms (even when external funds are available) might be explained by the concentration of risk in exporting few products, in comparison to the larger exporting portfolio of large firms. This concentration of risk means that failure of one of the projects could endanger firm's survival itself.[20]

Among the papers that empirically analyse whether firms' size plays a role in the relationship between exporting and financial constraints, we highlight Forbes (2007) who shows, for a sample of Chilean firms, that in a period of raising capital flow taxes, small firms suffer more from financial constraints. Further, these financial constraints loosen with the size of the firm. In the same line, Zia (2008), using a loan-level dataset for Pakistan, shows how the removal of subsidized export loans reduced the exports of small firms but did not affect those of large firms. Damijan *et al.* (2010), using a sample of Slovenian firms, find that an improvement in the access to external funds implied a higher increase of the intensive margin (export sales) for small firms than for medium and large firms, which points to the fact the small firms are more sensitive to better external access to finance.

In relation to innovation activities, Harhoff (1998), Hall (2002), Canepa and Stonemann (2008), Ughetto (2008) and Ayyagari *et al.* (2011), among others, point that firm's size plays an important role as regards to financial constraints for R&D. First, smaller firms are characterized by idiosyncratic risk, which would raise the cost of external finance, and among small firms there is a relatively large group of young firms, hence outside invertors may not have sufficient information to distinguish good from bad performers. Second, SMEs are more limited to access

[20] Eaton *et al.* (2008), Bernard *et al.* (2007, 2009) and Damijan *et al.* (2010) show that small firms usually export to one or two countries and a little number of products, being then more vulnerable to foreign market failures.

external financial markets, particularly in countries where entry into the stock market by young and small firms is a rare event. Third, small firms have less collateral to be used to obtain external loans.

As for the papers that analyse whether firms' size has any impact on the R&D investment sensibility to financial constraints, Hao and Jaffe (1993), using a panel of high-technology industries, find that the firm's financial condition, measured as cash flow, the stock of liquid assets or the ratio of liquid assets to current liabilities, affects the R&D spending of small firms, but there is not any effect for larger firms. For German firms, Harhoff (1998) concludes that only small firms R&D investments are sensitive to cash. Ughetto (2008) using a sample of (small, medium and large) Italian firms concludes that R&D is sensitive to cash flow only in the case of small firms. Czarnitzki and Hottenrott (2011), using a sample of German manufacturing SMEs, show that whereas smaller firms' R&D investments are sensitive to improvements in the access to financial markets, larger firms' R&D investments are not.

To check whether size has an impact on the relationship between financial constraints and R&D/export decisions for Spanish manufacturing firms, we widen our preferred specification (Specification 7 in Table 4) to allow the cost of debt and the cash flow, and their pre-sample means, variables coefficients to vary by firms' size group.[21] These results are reported in Table 5. The main implications of our estimates are as follows: i) for SMEs both internal and external financial constraints are relevant in R&D and export decisions (the estimates of the variables capturing financial constraints have the expected signs and are significant at conventional levels); ii) for large firms, external financial constraints are an important determinant in the decision to export (the estimates for the cost of debt variable for SMEs and large firms are statistically indistinguishable as the test of equality renders a *p*-value=0.601) ; iii) the export decision for large

[21] From Table 5 onwards, we do not include estimates for the crossed product between internal and external financial constraints variables, since they never render statistical significance.

firms seems to be unaffected by internal cash flow, either suggesting that large firms are not internally financially constrained and/or that they mainly rely on external funding to finance their exporting activities; iv) the R&D decision of large firms is conditioned by cash flow availability, further the estimate of the cash flow variable for large firms is not significantly different to that corresponding to SMEs; and, v) the R&D decision for large firms seems to be unaffected by the cost of debt, indicating that large firms are more likely to rely on internal sources than on external funding to finance their R&D activities.[22] These results are in line with the literature revised above: SMEs are more sensitive to credit constraints than large firms.

Consequently, our results indicate that measures addressed to relax internal and external financial constraints would increase the extensive R&D and export margins among SMEs in Spain, where SMEs represent more than 90% of the total number of firms. For large firms, and in relation to the export decision, alleviating external debt costs is relevant. However, what is relevant for large firms R&D decision is the availability of internal cash flow. It is important to highlight that our analysis discriminates the way of financing investments in R&D and exporting between large firms and SMEs. On the one hand, the fact that both financial constraints are binding for SMEs suggest that they use both types of resources to finance these investments. On the other hand, large firms seem to have a preference for external debt to finance export investments and for internal resources to finance R&D investments.

[Table 5 around here]

Sensitiveness to the recent financial crisis

[22] As put forward by Hall and Lerner (2010), firms may have preference for internal fund as there is a gap between the external and internal costs resources due to the existence of asymmetric information between the inventor and the investor, moral hazard arising from the separation ownership and management and tax considerations that drive a wedge between external finance and finance by retained earnings.

The second sensitiveness check we address is related to the financial crisis. In particular, we aim to test whether the world financial and economic crisis that started in the second half of 2007 has had any impact on the relationship between financial constraints and firms' export and R&D decisions. As we plot in Figure 2, the Spanish rate of growth of loans to non-financial institutions starts decelerating from 2007, becoming negative by the end of 2009. This evidence suggests that the Spanish economy suffered from severe financial constraints since 2009, being especially harsher from 2010 onwards.[23]

In order to check whether the worsening of the financial crisis magnifies or moderates the effect of financial constraints on export and R&D decisions, we perform the following sensitivity analysis. We sequentially estimate an augmented version of our preferred (baseline) specification in Table 4 including interaction terms between the financial constraints variables and two different time dummies: i) a dummy variable that takes on value 1 for the years beyond 2008 (*D09_11* variable); and, iii) a dummy variable that takes on value 1 for the years beyond 2009 (*D10_11* variable). These results are reported in table 6.

The estimates for internal and external financial constraints variables maintain their expected signs and significance both for the export and the R&D equations. The analysis of the effects of the crisis deepening requires checking the sign and significance of the interaction terms between our two financial constraints variables and, *D09_11* and *D10_11*. They capture the differential effects of the financial variables for the two periods defined above.

As regards the export equation, none of the interaction terms for any period are significant. For the period 2009-2011, in the R&D equation the estimate of the interaction term of the external constraints variable (*cost_d·D09_11*) is negative and significant, suggesting an increased sensibility of the R&D investment decision to the financial cost (in comparison to the pre-crisis years). However, the estimate of the interaction term of the cash flow variable is non-

[23] For an analysis of the causes of this credit crunch see Carbó (2009).

significant and, therefore, it suggests no changes in the sensibility of firms' R&D decision to internal financial constraints. For the period 2010-2011, nevertheless, the financial cost interaction variable turns out non-significant, whereas the interaction with cash flow (*Cash Flow_d·D010_11*) becomes significant. The different results obtained by the two periods considered suggest that: on the one had, in its initial years the crisis increased the sensibility of firms' R&D decision to the cost of debt; and, on the other hand, since 2010 this extra-sensibility to the cost of debt is no longer significant, and firms R&D decisions became more sensitive to internal funds. This is probably related to the especially tougher conditions of accessing to credit, independently of its cost, since 2010, what made firms more dependent on their own capacity to generate internal funds to finance their R&D investments.

[Table 6 around here]

4. CONCLUDING REMARKS.

Exporting and R&D activities share some features that make them likely to be subject to financial constraints. In this paper, we investigate the relationship between financial constraints and the firms' simultaneous decisions to export and perform R&D activities, acknowledging that, in principle, firms may access both to internal and external sources of finance. For this purpose, we estimate a discrete choice model of exporting and R&D in which we characterize the firms' joint decisions as depending on firms' internal and external measures of finance and other controls. The data used in this paper are drawn from the Spanish firms' manufacturing survey (ESEE) for the period 1990-2011. The results we obtain are manifold. First, both internal and external finance constraints are relevant, highlighting the relevance of the banking system for promoting such investments in the case of Spanish manufacturing firms, and also that firms, very likely, do

not only use both types of resources of finance but also have a certain specialization in their use for different components of the investments. Second, we find that small firms are in general more financially constrained. Third, we also obtain that Spanish firms start suffering severely financial constraints, as a consequence of the world's financial crisis that started in 2007, especially after 2009. From this year onwards, firms' investment decisions became more sensitive to internal finance resources as a consequence of tougher access to bank credits, independently of the cost of new debt.

These results recommend economic policies aimed as easing firms' access to external finance, especially targeting SMEs as those firms are the ones suffering more in hardship periods. Promoting firms exports and R&D strategies might ensure a sustainable comparative advantage in the long run, which would allow Spanish firms to improve their competitiveness in international markets.

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498-527.

Figure 1. Evolution of the cost of borrowing (cost of new long-term debt), 1990-2011.

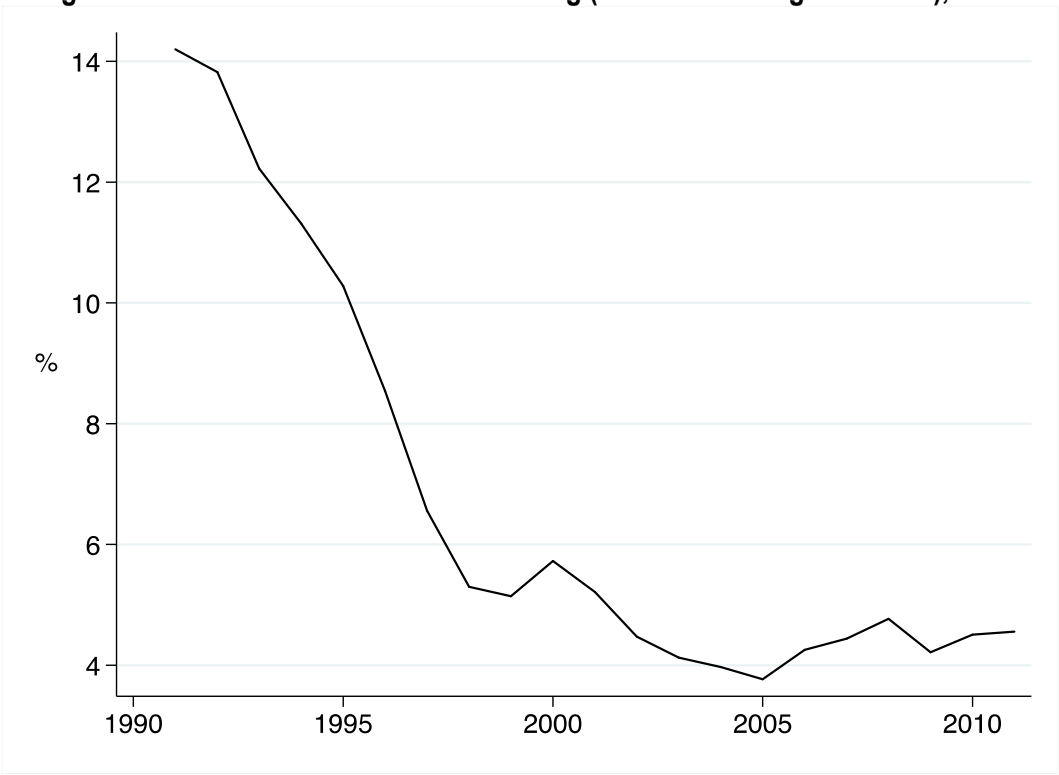

Figure 2. Yearly growth of loans to non-financial institutions, 1990-2013.

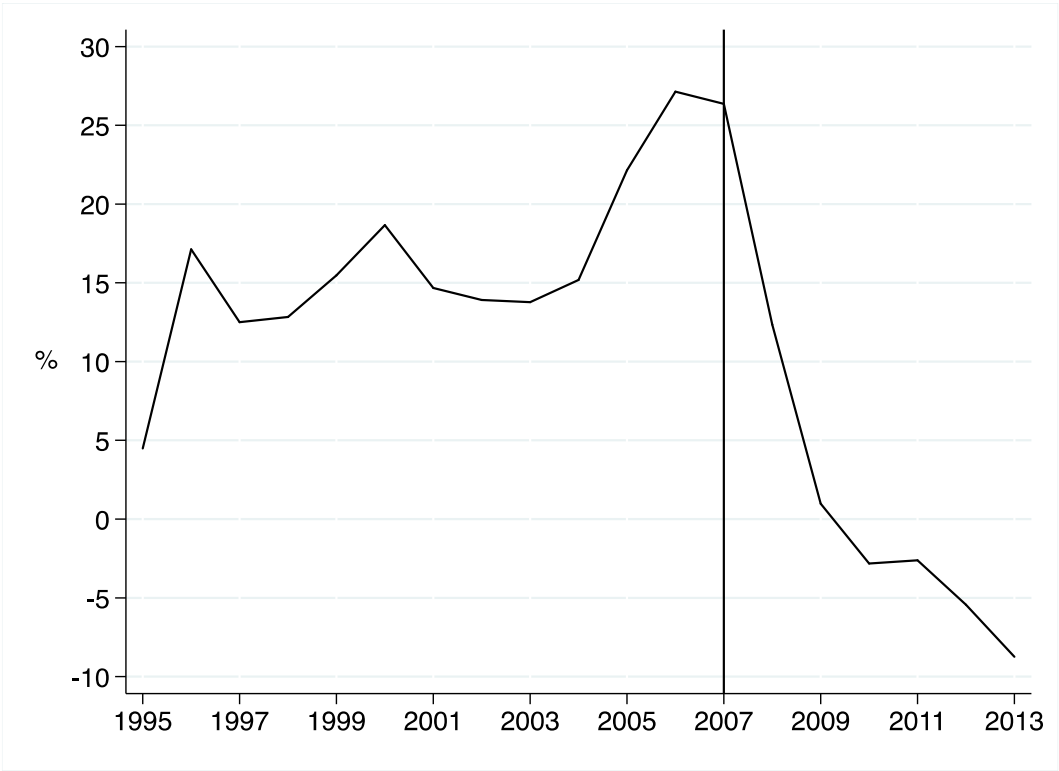

Table 1. Descriptive statistics.

	Mean value	s.e.
Cost of new long-term debt	0.056	0.024
Cash Flow	12.749	1.745
TFP	3.938	0.952
Age	24.077	18.326
Size	63.433	153.326
Foreign participation	8.582	26.776
Market share	8.834	11.804
Expansive demand	0.243	0.429
Recessive demand	0.240	0.427
Num. of competitors 0-10	0.503	0.500
Num. of competitors 10-25	0.152	0.359
Num. of competitors>25	0.160	0.367
Sales to public admin.	0.174	0.380
Appropriability	0.630	0.952
High skill labour	4.309	6.956
Med skill labour	5.780	9.036

Table 2. Differences across export and R&D strategies undertaken by firms.

	Export	R&D	Both
Cost of new long-term debt	-0.033**	-0.038**	-0.115***
Cash flow	49.34**	46.40**	75.91**

Note:

1. These regression control for age, size, foreign ownership, industry and year dummies.
2. Number of observations 14,499 (1,874 firms).
3. ***, ** mean significance at the 1% and 5% level, respectively.

Table 3. Test of the differences across export and R&D strategies undertaken by firms.

	Coefficient	*p*-value
Cost of new long-term debt		
Both *vs.* Export	-0.08**	0.059
Both *vs.* R&D	-0.08***	0.000
Export *vs.* R&D	-0.01	0.894
Cash flow		
Both *vs.* Export	26.57***	0.000
Both *vs.* R&D	29.51***	0.000
Export *vs.* R&D	2.94	0.704

Note: ***, ** mean significance at the 1%, 5% and10% level, respectively.

Table 4. The effect of financial constraints on export and R&D decisions.

	Specification 1		Specification 2		Specification 3		Specification 4		Specification 5		Specification 6		Specification 7		Specification 8	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Variables	**Export**	**R&D**	**Export**	**R&D**	**Export**	**R&D**	**Export**	**R&D**	**Export**	**R&D**	**Export**	**R&D**	**Export**	**R&D**	**Export**	**R&D**
Constant	0.432***	-0.366***	0.189***	-0.373***	0.206**	-0.715***	-2.123***	-2.605***	-2.729***	-2.353***	-2.559***	-2.322***	-2.323***	-2.289***	-2.135***	-2.132***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.023)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)
$Export_{t-1}$	-	-	-	-	-	-	-	-	3.011***	0.322***	2.585***	0.168***	2.557***	0.145**	2.552***	0.144**
									(0.000)	(0.000)	(0.000)	(0.005)	(0.000)	(0.017)	(0.000)	(0.018)
$R\&D_{t-1}$	-	-	-	-	-	-	-	-	0.226***	2.375***	0.055	2.096***	0.049	2.085***	0.047	2.083***
									(0.000)	(0.000)	(0.342)	(0.000)	(0.399)	(0.000)	(0.421)	(0.000)
Cost_d	-0.106***	-0.137***	-0.106***	-0.136***	-0.088***	-0.104***	-0.041***	-0.059***	-0.041**	-0.044***	-0.041**	-0.044***	-0.047**	-0.044***	-0.098*	-0.084**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.005)	(0.000)	(0.031)	(0.004)	(0.047)	(0.006)	(0.021)	(0.006)	(0.073)	(0.046)
Cash Flow_d	0.328***	0.326***	0.330***	0.327***	0.338***	0.347***	0.120***	0.097***	0.055***	0.070***	0.055***	0.067***	0.049**	0.061***	0.064**	0.074***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.002)	(0.000)	(0.012)	(0.000)	(0.039)	(0.008)
Cost_d·Cash Flow_d	0.004	0.004	0.002	0.005	-0.003	0.004	0.006	0.007	0.002	0.009	0.003	0.008	0.002	0.007	0.000	0.008
	(0.673)	(0.663)	(0.862)	(0.625)	(0.745)	(0.671)	(0.457)	(0.385)	(0.858)	(0.270)	(0.823)	(0.368)	(0.867)	(0.402)	(0.980)	(0.363)
TFP	-	-	-	-	-	-	0.093	-0.081	0.196**	-0.065	0.186**	-0.054	0.233**	-0.051	0.231**	-0.053
							(0.390)	(0.438)	(0.013)	(0.389)	(0.039)	(0.521)	(0.023)	(0.601)	(0.024)	(0.590)
Age	-	-	-	-	-	-	0.142***	0.087**	-0.034	0.020	-0.037	0.020	0.127*	0.080	0.123*	0.079
							(0.004)	(0.046)	(0.236)	(0.446)	(0.272)	(0.483)	(0.056)	(0.185)	(0.065)	(0.188)
Size	-	-	-	-	-	-	0.316***	0.433***	0.113***	0.177***	0.060**	0.137***	0.185***	0.243***	0.165***	0.227***
							(0.000)	(0.000)	(0.000)	(0.000)	(0.044)	(0.000)	(0.000)	(0.000)	(0.004)	(0.000)
Foreign participation	-	-	-	-	-	-	0.007***	-0.002*	0.002***	-0.001***	0.001	-0.002***	-0.000	-0.002**	-0.000	-0.002**
							(0.000)	(0.076)	(0.003)	(0.008)	(0.423)	(0.003)	(0.960)	(0.049)	(0.942)	(0.047)
Market share	-	-	-	-	-	-	-0.004**	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000	0.000	-0.000	0.000
							(0.037)	(0.720)	(0.288)	(0.800)	(0.943)	(0.746)	(0.886)	(0.980)	(0.990)	(0.919)
Expansive demand	-	-	-	-	-	-	0.171***	0.220***	0.081*	0.119***	0.070	0.092**	0.047	0.096**	0.045	0.093**
							(0.000)	(0.000)	(0.068)	(0.001)	(0.140)	(0.015)	(0.335)	(0.015)	(0.359)	(0.019)
Recesive demand	-	-	-	-	-	-	0.089*	0.116**	-0.003	0.077*	-0.023	0.066	-0.021	0.066	-0.020	0.070
							(0.058)	(0.014)	(0.945)	(0.080)	(0.677)	(0.154)	(0.708)	(0.157)	(0.725)	(0.135)
Num. of competitors 0-10	-	-	-	-	-	-	0.134*	0.153**	0.047	0.047	0.027	0.025	-0.034	-0.011	-0.035	-0.012
							(0.063)	(0.018)	(0.373)	(0.347)	(0.649)	(0.648)	(0.580)	(0.854)	(0.564)	(0.833)
Num. of competitors 10-25	-	-	-	-	-	-	0.068	0.236***	0.022	0.123*	0.003	0.097	-0.066	0.067	-0.065	0.066
							(0.430)	(0.005)	(0.740)	(0.051)	(0.964)	(0.150)	(0.372)	(0.341)	(0.379)	(0.345)
Num. of competitors >25	-	-	-	-	-	-	0.102	0.001	0.003	0.003	-0.019	-0.005	-0.104	-0.013	-0.100	-0.011
							(0.206)	(0.986)	(0.966)	(0.960)	(0.784)	(0.943)	(0.144)	(0.864)	(0.160)	(0.880)
Sales to public admin.	-	-	-	-	-	-	-0.400***	-0.207***	-0.205***	-0.071	-0.154***	-0.015	-0.094	-0.018	-0.093	-0.016
							(0.000)	(0.005)	(0.000)	(0.142)	(0.005)	(0.769)	(0.166)	(0.784)	(0.170)	(0.806)
Appropriability	-	-	-	-	-	-	0.108***	0.156***	0.068**	0.069**	0.061*	0.054*	0.059	0.053*	0.058	0.052*
							(0.003)	(0.000)	(0.045)	(0.011)	(0.094)	(0.059)	(0.112)	(0.075)	(0.117)	(0.079)
High skill labour	-	-	-	-	-	-	0.006	0.020***	-0.001	0.010***	-0.001	0.008***	0.000	0.008**	0.000	0.007**
							(0.246)	(0.000)	(0.744)	(0.001)	(0.665)	(0.006)	(0.909)	(0.040)	(0.930)	(0.044)
Med skill labour	-	-	-	-	-	-	0.011***	0.021***	0.004*	0.010***	0.005**	0.009***	0.003	0.007***	0.003	0.007***
							(0.001)	(0.000)	(0.076)	(0.000)	(0.027)	(0.000)	(0.160)	(0.001)	(0.173)	(0.001)

Presample mean values																
Mean export	-	-	-	-	-	-	-	-	-	-	0.968***	0.137**	1.010***	0.159**	1.010***	0.159**
											(0.000)	(0.047)	(0.000)	(0.019)	(0.000)	(0.019)
Mean R&D	-	-	-	-	-	-	-	-	-	-	0.128*	0.697***	0.141*	0.711***	0.140*	0.710***
											(0.088)	(0.000)	(0.069)	(0.000)	(0.071)	(0.000)
Mean Cost_d	-	-	-	-	-	-	-	-	-	-	-	-	0.017	-0.008	0.021	-0.006
													(0.035)	(0.312)	(0.037)	(0.299)
Mean Cash Flow_d	-	-	-	-	-	-	-	-	-	-	-	-	0.033	0.024	0.029	0.021
													(0.180)	(0.324)	(0.245)	(0.395)
Mean TFP	-	-	-	-	-	-	-	-	-	-	-	-	-0.113	-0.020	-0.131	-0.035
													(0.327)	(0.855)	(0.263)	(0.749)
Mean age	-	-	-	-	-	-	-	-	-	-	-	-	-0.105**	-0.042	-0.104**	-0.043
													(0.035)	(0.312)	(0.037)	(0.299)
Mean size	-	-	-	-	-	-	-	-	-	-	-	-	-0.160***	-0.132***	-0.159***	-0.132***
													(0.003)	(0.008)	(0.004)	(0.008)
Mean foreign participation	-	-	-	-	-	-	-	-	-	-	-	-	0.001	0.000	0.001	0.000
													(0.538)	(0.713)	(0.539)	(0.719)
Mean market share	-	-	-	-	-	-	-	-	-	-	-	-	0.003	-0.004	0.002	-0.004
													(0.454)	(0.146)	(0.476)	(0.140)
Mean expansive demand	-	-	-	-	-	-	-	-	-	-	-	-	0.094	-0.048	0.093	-0.050
													(0.250)	(0.485)	(0.252)	(0.464)
Mean recessive demand	-	-	-	-	-	-	-	-	-	-	-	-	0.059	0.026	0.055	0.023
													(0.477)	(0.732)	(0.504)	(0.769)
Mean num. of competitors 0-10	-	-	-	-	-	-	-	-	-	-	-	-	0.138	0.140	0.137	0.141
													(0.100)	(0.115)	(0.101)	(0.111)
Mean num. of competitors 10-25	-	-	-	-	-	-	-	-	-	-	-	-	0.144	0.088	0.149	0.092
													(0.158)	(0.372)	(0.141)	(0.351)
Mean num. of competitors >25	-	-	-	-	-	-	-	-	-	-	-	-	0.234**	0.106	0.236**	0.109
													(0.025)	(0.340)	(0.024)	(0.325)
Mean sales to public admin.	-	-	-	-	-	-	-	-	-	-	-	-	-0.112	0.006	-0.115	0.004
													(0.134)	(0.927)	(0.124)	(0.949)
Mean appropriability	-	-	-	-	-	-	-	-	-	-	-	-	-0.016	-0.003	-0.016	-0.003
													(0.147)	(0.724)	(0.152)	(0.734)
Mean high skill labour	-	-	-	-	-	-	-	-	-	-	-	-	-0.003	-0.002	-0.003	-0.002
													(0.554)	(0.702)	(0.535)	(0.684)
Mean med skill labour	-	-	-	-	-	-	-	-	-	-	-	-	0.004	0.003	0.004	0.003
													(0.286)	(0.295)	(0.308)	(0.316)
	N observations: 14,499 N firms: 1874 ρ = 0.469 (s.e. = 0.028) LR test ρ = 0, $\chi2(1)$ = 189.25, p-val.=0.000		N observations: 14,499 N firms: 1874 ρ = 0.470 (s.e. = 0.028) LR test ρ = 0, $\chi2(1)$ = 188.38, p-val.=0.000		N observations: 14,499 N firms: 1874 ρ = 0.442 (s.e. = 0.030) LR test ρ = 0, $\chi2(1)$ = 159.39, p-val.=0.000		N observations: 14,499 N firms: 1874 ρ = 0.361 (s.e. = 0.035) LR test ρ = 0, $\chi2(1)$ = 88.23, p-val.=0.000		N observations: 14,499 N firms: 1874 ρ = 0.144 (s.e. = 0.040) LR test ρ = 0, $\chi2(1)$ = 12.406, p-val.=0.000		N observations: 14,499 N firms: 1874 ρ = 0.109 (s.e. = 0.041) LR test ρ = 0, $\chi2(1)$ = 6.916, p-val.=0.008		N observations: 14,499 N firms: 1874 ρ = 0.103 (s.e. = 0.041) LR test ρ = 0, $\chi2(1)$ = 6.237, p-val.=0.012		N observations: 14,499 N firms: 1874 ρ = 0.106 (s.e. = 0.042) LR test ρ = 0, $\chi2(1)$ = 6.440, p-val.=0.011	

Notes:

1. Specification 1 does not include industry or time dummies; Specification 2 includes time dummies; Specification 3 and the following include industry and time dummies.
2. Robust *p*-values in parentheses.
3. ***, ** and * mean significant at the 1%, 5% and 10% level of significance, respectively.

Table 5. The effect of financial constraints on export and R&D decisions by size group.

Variables	(1) Export	(2) R&D
Constant	-2.316***	-2.289***
	(0.000)	(0.000)
$Export_{t-1}$	2.551***	0.145**
	(0.000)	(0.018)
$R\&D_{t-1}$	0.055	2.085***
	(0.345)	(0.000)
Cost_d_Small	-0.047**	-0.045**
	(0.032)	(0.018)
Cash Flow_d_Small	0.053**	0.056***
	(0.010)	(0.006)
Cost_d_Large	-0.072*	-0.037
	(0.097)	(0.147)
Cash Flow_d_Large	0.029	0.070***
	(0.540)	(0.007)
TFP	0.224**	-0.054
	(0.028)	(0.581)
Age	0.133**	0.081
	(0.047)	(0.182)
Size	0.206***	0.248***
	(0.000)	(0.000)
Foreign participation	-0.000	-0.002**
	(0.823)	(0.045)
Market share	0.000	0.000
	(0.976)	(0.973)
Expansive demand	0.048	0.096**
	(0.322)	(0.015)
Recessive demand	-0.020	0.065
	(0.725)	(0.164)
Num. of competitors 0-10	-0.039	-0.011
	(0.524)	(0.845)
Num. of competitors 10-25	-0.069	0.066
	(0.358)	(0.349)
Sales to public admin.	-0.088	-0.017
	(0.194)	(0.792)
Appropriability	0.059	0.053*
	(0.114)	(0.079)
High skill labour	0.001	0.008**
	(0.870)	(0.040)
Med skill labour	0.004	0.007***
	(0.139)	(0.001)
	N observations: 14,499; N firms: 1874	
	ρ = 0.104 (s.e. = 0.041)	
	LR test ρ = 0, $\chi^2(1)$ = 6.245, *p*-val. = 0.12	

Notes:
1. All specifications include pre-sample mean variables, industry and time dummies.
2. Robust *p*-values in parentheses.
3. ***, ** and * mean significant at the 1%, 5% and 10% level of significance, respectively.

Table 6. The effect of financial constraints on export and R&D decisions: The effect of the on-going financial crisis.

Variables	(1) Export	(2) R&D	(3) Export	(4) R&D
Constant	-2.295***	-2.529***	-2.295***	-2.515***
	(0.000)	(0.000)	(0.000)	(0.000)
$Export_{t-1}$	2.519***	0.197***	2.518***	0.198***
	(0.000)	(0.002)	(0.000)	(0.002)
$R\&D_{t-1}$	0.084	2.071***	0.084	2.071***
	(0.161)	(0.000)	(0.161)	(0.000)
Cost_d	-0.052**	-0.031*	-0.050**	-0.034**
	(0.012)	(0.052)	(0.015)	(0.030)
Cash Flow_d	0.050**	0.054***	0.051***	0.056***
	(0.012)	(0.002)	(0.010)	(0.002)
Cost_d·D09_11	0.051	-0.129**	-	-
	(0.569)	(0.033)		
Cash Flow_d·D09_11	0.029	0.046	-	-
	(0.489)	(0.144)		
Cost_d·D10_11	-	-	-0.013	-0.086
			(0.779)	(0.155)
Cash Flow_d·D10_11	-	-	0.017	0.130*
			(0.798)	(0.079)
TFP	0.241**	-0.040	0.241**	-0.041
	(0.024)	(0.700)	(0.024)	(0.694)
Age	0.179**	0.304***	0.176**	0.298***
	(0.019)	(0.000)	(0.021)	(0.000)
Size	0.185***	0.237***	0.186***	0.236***
	(0.001)	(0.000)	(0.000)	(0.000)
Foreign participation	-0.000	-0.002**	-0.000	-0.002**
	(0.888)	(0.047)	(0.892)	(0.044)
Market share	-0.000	0.001	-0.000	0.001
	(0.812)	(0.627)	(0.831)	(0.629)
Expansive demand	0.051	0.113***	0.051	0.112***
	(0.302)	(0.005)	(0.299)	(0.005)
Recessive demand	0.009	0.072	0.008	0.071
	(0.886)	(0.146)	(0.892)	(0.154)
Num. of competitors 0-10	-0.029	-0.003	-0.030	-0.005
	(0.638)	(0.953)	(0.627)	(0.927)
Num. of competitors 10-25	-0.059	0.075	-0.060	0.074
	(0.441)	(0.292)	(0.434)	(0.303)
Num. of competitors>25	-0.079	0.004	-0.081	0.000
	(0.302)	(0.955)	(0.290)	(0.996)
Sales to public admin.	-0.099	-0.039	-0.099	-0.038
	(0.163)	(0.566)	(0.162)	(0.574)
Appropriability	0.045	0.069**	0.045	0.065*
	(0.284)	(0.042)	(0.283)	(0.054)
High skill labour	0.000	0.010**	0.000	0.010**
	(0.921)	(0.021)	(0.925)	(0.020)
Med skill labour	0.004	0.008***	0.004	0.008***
	(0.163)	(0.001)	(0.166)	(0.001)
	N observations: 14,499		N observations: 14,499	
	N firms: 1874		N firms: 1874	
	ρ = 0.132 (s.e. = 0.042)		ρ = 0.132 (s.e. = 0.042)	
	LR test ρ = 0, $\chi^2(1)$ = 9.49, p-val.=0.000		LR test ρ = 0, $\chi^2(1)$ = 9.59, p-val.=0.002	

Note: See notes to table 5.

Appendix A. Production function and TFP estimation.

A.1. Productivity estimation.

We assume that firms produce using a Cobb-Douglas technology:

$$y_{it} = b_0 + b_l l_{it} + b_k k_{it} + b_m m_{it} + \mu_t + w_{it} + h_{it} \quad \text{(A.1)}$$

where y_{it}, l_{it} and, k_{it} denote the natural logarithm of production, labour and capital, respectively. μ_t are time effects. As for the unobservables, w_{it} is the productivity (not observed by the econometrician but observable or predictable by firms) and h_{it} is a standard *i.i.d.* error term that is neither observed nor predictable by the firm.

It is also assumed that capital evolves following a certain law of motion that is not directly related to current productivity shocks (i.e. it is a state variable), whereas labour and intermediate materials are inputs that can be adjusted whenever the firm faces a productivity shock (i.e. they are variable factors).[24]

Under these assumptions, Olley and Pakes (1996, hereafter OP) and Levinshon and Petrin, (2003, hereafter LP) propose methods to estimate firm productivity that use proxy variables to control for unobserved heterogeneity. Both methods use a two-step estimation semiparametric procedure to obtain consistent estimates for the coefficients of the inputs of the production function. Wooldridge (2009) propose a one-step GMM estimation of the TFP that overcomes some limitations of OP and LP including correction for simultaneous determination of inputs and productivity, no need to maintain constant returns to scale, and robustness to the

[24] The law of motion for capital follows a dynamic process according to which $k_{it} = (1-\delta)k_{it-1} + I_{it-1}$. Thus, it is assumed that the capital the firm uses in period *t* was actually decided in period *t-1* (it takes a full production period for the capital to be ordered, received and installed by the firm before it becomes operative). Labour and materials (unlike capital) are chosen in period *t*, the period they actually get used (and, therefore, they can be a function of ω_{it}). These timing assumptions make them non-dynamic inputs, in the sense that (and again unlike capital) current choices for them have no impact on future choices.

Ackerberg, Caves and Frazer (2008) critique on identification of the variable input (labour) coefficient (Vons-Rosen *et al,* 2013).

Wooldridge (2009) that argues that both OP and LP estimation methods can be reconsidered as consisting of two equations which can be jointly estimated by GMM: the first equation tackles the problem of endogeneity of the non-dynamic inputs (that is, the variable factors); and, the second equation deals with the issue of the law of motion of productivity. Next we consider each in detail.

We start considering first the problem of endogeneity of the non-dynamic inputs. Correlation between labour and intermediate inputs with productivity complicates the estimation of equation (2), because it makes the OLS estimator biased and the fixed-effects and instrumental variables methods generally unreliable (Ackerberg *et al.*, 2006). Both OP and LP's methods use a control function approach to solve this problem, by using investment in capital and demand of materials, respectively, to proxy for "unobserved" firm productivity.

In our work, we write the materials demand as a function of the capital and the productivity as in LP. However, materials demand depends not only on capital and productivity (w_{it}) but also on whether the firm exports and/or performs R&D. If a firm exports and/or performs R&D it will have an effect on the residual demand of the firm, given its level of productivity, and therefore on the firm's optimal demand of intermediate materials. Thus, we write the demand of intermediate materials as $m_{it} = m_t\left(k_{it}, w_{it}, d_{it}, e_{it}\right)$ where d_{it} and e_{it} are dummy variables that take value one if the firm performs R&D or exports, respectively. If intermediate materials demand, conditional on productivity and exports and R&D decisions, is increasing in productivity, one can invert the this demand and express productivity as a function of observables to obtain the inverse demand function of materials $w_{it} = g_t\left(k_{it}, m_{it}, d_{it}, e_{it}\right)$.[25]

[25] See De Loecker, 2007, 2013, for similar arguments applied to export dummies.

Then, substituting expression the inverse demand function of materials into the production function (2) we get our first estimation equation for the production function:

$$y_{it} = b_0 + b_l l_{it} + m_t + h_t\left(k_{it}, w_{it}, d_{it}, e_{it}\right) + h_{it} \quad \text{(A.2)}$$

where $h\left(m_{it}, k_{it}\right) = b_k k_{it} + b_m m_{it} + g_t\left(k_{it}, w_{it}, d_{it}, e_{it}\right)$

In the estimation, we proxy $h_t()$ in (3) are proxied by including a second-degree polynomials in materials and capital where each term is interacted with the export and R&D dummies.

Notice, however, that we cannot identify β_k *and* β_m from (2). This is achieved by the inclusion of a second estimation equation in the GMM-system that deals with the law of motion for productivity. We follow the standard OP/LP assumption that the productivity follows a first-order Markov process but as in Aw, Roberts and Xu (2013), DeLoecker (2007, 2013) or Doraszelski and Jaumandreu (2013) we endogenise this process. In particular, we assume that firms past R&D and export decisions can impact productivity evolution. Therefore, productivity in year *t* is a function of lagged productivity as well as lagged R&D and export dummies, i.e. $w_{it} = f\left(w_{it-1}, d_{it-1}, e_{t-1}\right) + x_{it}$, where d_{it-1} and e_{it-1} indicate whether the firm exports and/or performs in period *t-1*, respectively. ξ_{it} is an innovation term uncorrelated by definition with k_{it}.

Consequently, one can rewrite the production function in (2) using the law motion of productivity:

$$y_{it} = b_0 + b_l l_{it} + b_k k_{it} + m_t + f\left(w_{it-1}, d_{it-1}, e_{t-1}\right) + u_{it} \quad \text{(A.3)}$$

where $u_{it} = u_{it} = \xi_{it} + \eta_{it}$ is a composed error term. Recall that since $w_{it} = g\left(k_{it}, m_{it}, d_{it}, e_{it}\right)$,

$$f_t\left(w_{it-1}, d_{t-1}, e_{t-1}\right) = f\left(g\left(k_{it-1}, m_{it-1}, d_{t-1}, e_{t-1}\right), d_{t-1}, e_{t-1}\right) = f\left(g\left(k_{it-1}, m_{it-1}, d_{t-1}, e_{t-1}\right)\right) \quad \text{(A.4)}$$

Plugging equation (5) into equation (4) gives our second estimation equation:

$$y_{it} = b_0 + b_l l_{it} + b_k k_{it} + b_m m_{it} + m_t + g\left(f\left(k_{it-1}, m_{it-1}, d_{it-1}, e_{t-1}\right)\right) + u_{it} \quad \text{(A.5)}$$

In the estimation, we approximate the $f\left(g(\ )\right)$ by second-degree polynomials in *k* and *m*, where each term is interacted with the lagged export and R&D dummies.

Wooldridge (2009) proposes to estimate jointly the system of equations (3) and (6) by GMM using the appropriate instruments and moment conditions for each equation.

Using the method described above we obtain, for each one of the 9 considered industries,[26] both the coefficient estimates of the production function and firms' productivity estimates as:

$$\hat{\omega}_{it}^{s} = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_k k_{it} - \hat{\beta}_m m_{it} - \hat{\mu}_{it} \quad \text{(A.6)}$$

where $\hat{\omega}_{it}^{s}$ is the estimated log of the TFP for firm *i* at time *t,* for industry *s*.

A.2. Production function estimates.

Table A1 in provides estimates of the production function (A.1) by GMM with an endogenous Markov process for the law of motion of productivity. We also report the estimates obtained by OLS and by GMM with an exogenous Markov process for the law of motion of productivity. From the comparison of these results, we can conclude that the estimated coefficients for labour and materials are quite similar across methods and, therefore, they seem to be quite robust to the estimation method. As regards the estimated coefficients for capital, they are quite similar between the GMM estimators assuming either an exogenous or endogenous Markov process for productivity. Some differences are found between these two methods and the OLS estimation: (i) The coefficient for capital is a bit smaller in OLS for metals and metal products, chemical products and paper and printing products; and, (ii) it is higher for non-metallic minerals, transport equipment, food, drink and tobacco, textile, leather and shoes, agricultural and industrial

[26] Following Doraszelski and Jaumandreu (2013) we group the 20 industries in which the ESEE classifies firms into 9 industries. The aim is to get enough observations to carry out industry-by-industry estimations.

machinery and timber and furniture. For the two last sectors (agricultural and industrial machinery, and timber and furniture), the capital coefficient is even non-significant under the two GMM estimates. In agreement with all these estimation results, without splitting the sample in different industries, we obtain that the labour and materials coefficients are quite similar among methods and that the one for capital is a bit larger under OLS estimation (0.085 vs. 0.058 and 0.0059 in the GMM estimates). The coefficient for capital seems lower than for other countries. However, this coefficient (and also the ones for labour and materials) is in line with other studies with the ESEE (Martín and Suárez, 1997; Beneito, 2001; Añón Higón et al., 2011) and robust to time period considered (see Mañez *et al*. 2014, p. 29).

Table A1: Production function estimates

	OLS	GMM (Ex. Markov Process)	GMM (End. Markov Process)	OLS	GMM (Ex. Markov Process)	GMM (End. Markov Process)	OLS	GMM (Ex. Markov Process)	GMM (End. Markov Process)
	β_k	β_k	β_k	β_l	β_l	β_l	β_m	β_m	β_m
1. Metals and metal products	0.062***	0.108***	0.105***	0.331***	0.292***	0.286***	0.615***	0.528***	0.517***
	(0.014)	(0.022)	(0.023)	(0.010)	(0.006)	(0.007)	(0.006)	(0.076)	(0.075)
2. Non-metallic minerals	0.115***	0.034*	0.042**	0.148***	0.119***	0.116***	0.738***	0.802***	0.792***
	(0.007)	(0.020)	(0.022)	(0.008)	(0.005)	(0.005)	(0.007)	(0.016)	(0.067)
3. Chemical products	0.081***	0.124***	0.111***	0.191***	0.210***	0.212***	0.728***	0.692***	0.692***
	(0.008)	(0.042)	(0.041)	(0.013)	(0.009)	(0.009)	(0.012)	(0.103)	(0.097)
4. Agric. and ind. machinery	0.061***	0.001	0.007	0.268***	0.219***	0.229***	0.638***	0.604***	0.570***
	(0.008)	(0.040)	(0.040)	(0.019)	(0.012)	(0.015)	(0.014)	(0.163)	(0.164)
5. Transport equipment	0.096***	0.041**	0.041**	0.221***	0.220***	0.220***	0.706***	0.712***	0.704***
	(0.005)	(0.018)	(0.018)	(0.011)	(0.006)	(0.006)	(0.008)	(0.067)	(0.065)
6. Food, drink and tobacco	0.095***	0.048**	0.041**	0.259***	0.242***	0.236***	0.667***	0.668***	0.663***
	(0.005)	(0.024)	(0.019)	(0.009)	(0.006)	(0.006)	(0.009)	(0.056)	(0.054)
7. Textile, leather and shoes	0.088***	0.045**	0.046***	0.285***	0.272***	0.273***	0.632***	0.612***	0.610***
	(0.005)	(0.016)	(0.016)	(0.009)	(0.007)	(0.007)	(0.007)	(0.063)	(0.058)
8. Timber and furniture	0.033***	0.041	0.059	0.419***	0.367***	0.334***	0.590***	0.630***	0.630***
	(0.014)	(0.047)	(0.048)	(0.036)	(0.014)	(0.018)	(0.027)	(0.145)	(0.129)
9. Paper and printing products	0.058***	0.075**	0.073***	0.299***	0.317***	0.319***	0.668***	0.731***	0.698***
	(0.010)	(0.030)	(0.029)	(0.023)	(0.013)	(0.012)	(0.016)	(0.072)	(0.070)
All industries	0.085***	0.058***	0.059***	0.270***	0.247***	0.244**	0.662***	0.669***	0.657***
	(0.002)	(0.010)	(0.010)	(0.004)	(0.003)	(0.003)	(0.003)	(0.032)	(0.031)

Notes:
(i) Robust standard errors are in parenthesis.
(ii) The overall production function estimates control for industry dummies.

(iii) ***, ** and * mean significant at the 1%, 5% and 10% level of significance, respectively

Appendix B.

Definition of the explanatory variables (except financial constraints variables).

Age	Log of the number of years since the firm was born.
Size	Log of the number of the firm's employees.
Foreign	Dummy variable taking value 1 if the firm's capital is participated by a foreign firm.
Foreign participation	Proportion of the firm's capital participated by a foreign firm.
Market share	The firm's market share in its main market (in %).
Stable demand	Dummy variable taking value 1 if the firm declares to face a stable demand.
Expansive demand	Dummy variable taking value 1 if the firm declares to face an expansive demand.
Recessive demand	Dummy variable taking value 1 if the firm declares to face a recessive demand.
Number of competitors 0-10	Dummy variable taking value 1 if the firm asserts to have less than (or equal to) 10 competitors with significant market share in its main market.
Number of competitors 10-25	Dummy variable taking value 1 if the firm asserts to have more than 10 and less than (or equal to) 25 competitors with significant market share in its main market.
Number of competitors > 25	Dummy variable taking value 1 if the firm asserts to have more than 25 competitors with significant market share in its main market.
Atomistic market	Reference category for the previous ones in estimation. Dummy variable taking value 1 if the firm asserts to be in a market where no firm has significant market share.
Sales to public admin.	Dummy variable taking value 1 if more than 25% of firm's sales go to the public sector.
Appropriability	Ratio of the total number of patents over the total number of firms that assert to have achieved innovations in the firms' industry (20 industries of the two-digit NACE-93 classification) (in %).
High skill labour	Proportion of engineers and graduates in the firm's labour force.
Med skill labour	Proportion of technical engineers, experts and qualified assistants in the firm's labour force.
Year dummies	Dummy variables taking value 1 for the corresponding year.
Industry dummies	Industry dummies accounting for 20 industries of the NACE-93 classification.