Firm's Financial Conditions and the R&D-Export trade-off

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Abstract[1]

This paper adds new empirical evidence on the relationships between financial constraints, exports and innovation at the firm level through an instrumental variable approach. The empirical analysis capitalizes on a representative and cross-country comparable sample of manufacturing firms (EFIGE) stemming across seven European countries (Austria, France, Germany, Hungary, Italy, Spain and UK). Results show a positive correlation between the financial health of a firm and its export activities, with this result however not robust to the inclusion of total factor productivity (TFP) once endogeneity is controlled for. Financial constraints do not affect innovation activities, which tend to be internally financed by the firm. The complex relations between productivity, R&D and financial conditions, and their joint impact on the exporting activity of a firm, point at a trade-off between the internationalization vs. innovation activities of firms. Specifically, exploiting the large supply shock to external credit that took place in some EU countries during the most recent financial crisis, we find that exporting firms, when faced with a credit crunch, tend to channel the internal resources previously used to finance their R&D activities towards the financing of their exporting activities. Thus, in times of external credit scarcity, firms appear to prioritize their internationalization activities over their innovation activities.

Key words: financial constraints, R&D, export, total factor productivity

JEL classification: F10, G20.

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1. Introduction

In this paper we explore the linkage between firms' access to finance and their export and innovation activities. We start from some stylized facts that we are able to measure in our data: firms tend to use external financial sources to finance their export activities; firms report to finance innovation (R&D) activities prevalently with internally-generated funds; firms characterized by higher productivity are more likely to export, innovate as well as to have better access to (although not necessarily use) external financial sources. These stylized facts point at a potential trade-off between exports and innovation in the presence of an exogenous financial shock: if credit conditions become tighter, conditional on productivity firms might be forced to trade-off innovation vs. (cash-generating) export activities, as both will have to be financed internally. The latter suggests that a credit shock might hamper long-run growth through the negative effect it has on the rate of innovation, with the latter being mediated by the extent of the export activities. Or, along the same lines, that investment in innovation will react more than exports to a credit shock.

In order to properly identify the trade-off and the causal events that a financial shock triggers on innovation and exports, we first need to disentangle the complex, potentially endogenous relations between access to finance, export, productivity and innovation. The literature encompassing financial conditions and how they affect exporting and innovation activities at the firm-level is still developing. Aw et al. (2011) is one of the first paper that jointly considers a firm's decision to export and to engage in R&D, but the authors do not consider the role of financial conditions. Minetti and Zhu (2011), Manova (2013) and Manova et al. (2015) are amongst the papers that consider the role of firm-level credit constraints and how it affects selection into exporting, but in turn they do not consider the role of innovation as a determinant of exporting, while only marginally discussing the potential correlation between credit constraints and productivity.

The purpose of this paper is to make a first bridge between these strands of literature, and derive the ensuing implications. Due to the nature of our data, we apply a reduced-form approach similar to Manova et al. (2015), studying financial health as a determinant of exporting in a framework considering explicitly the role of productivity and innovation. We solve the endogeneity of the above relations between our four variables of interest through a proper set of instrumental variables. Indeed, to consider the role of financial variables jointly with exporting, innovation and productivity at firm-level requires a dataset that has information on all these items, which is rare. Moreover, since all the variables are likely to be highly endogenous, additional information is needed to construct relevant instruments. Ideally such a dataset also has information on firms in different countries to allow for country-level controls that account for different institutional settings, financial and other, that may affect the relationships between the firm-level variables.

For this purpose we turn to a pan-European dataset of firm-level data that holds information on firms' financial health as well as information on exporting status, innovation activities and productivity. The data consist of European company accounts data (2001-2009)[2] which are merged to survey data with information for the year 2008. The survey (EFIGE) was constructed so as to obtain a representative sample of around 15,000 (anonymized) firms operating in the manufacturing

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[2] The company accounts data come from the commercially available Amadeus dataset of BvD, a repository of balance sheet data for millions of European companies across countries and years.

industry of seven European countries. [3] Survey questions collected additional information on innovation, exporting and financial issues that are not available in the company accounts. The new stylized facts arising from this data allows for the construction of novel instruments for the purpose of better identifying the causal relation that may exist between a firm's financial health and its exporting activities.

When estimating an IV export equation, we find that the well-known positive correlation between the financial health of a firm and its export activities is not robust to the inclusion of total factor productivity (TFP), once the endogeneity of access to finance is controlled for. The latter is a first result of the paper, confirming some evidence already hinted at by the relevant literature, though not extensively discussed (Minetti and Zhu, 2011). This first finding tells us that firms' exporting depends only indirectly on the financial health of the firm. This conclusion may appear to be in contrast with earlier literature that points out a link between financial conditions and exporting. The main difference lies in the econometric specification and the regressors. When we account for firm-productivity, financial health variables offer little additional explanatory power for the exporting decision. We come to this conclusion by exploiting a new stylized fact that emerges from our data, i.e. that financial health and firm productivity are highly correlated. This suggests that more productive firms are better able to attract financing which in turn permits the firm to boost productivity. The strong correlation between financial health and productivity warrants the use of an alternative productivity measure which acknowledges that financially constraint firms may endogenously differ in their input choices. For this purpose we extend the Levinsohn-Petrin algorithm for estimating TFP by inserting a measure of financial health in the estimation of the production function. To address the potential endogeneity of financial health of a firm, we also create a new instrument that exploits information on the firm-bank relationship arising from our survey data. Our econometric specification shows no additional direct effect of financial health on exports, other than through the productivity channel. This conclusion is also confirmed through an alternative methodology, i.e. mediation analysis. We consider this to be an important qualification of earlier results of the literature.

In the IV export equation, productivity and innovation are in turn both important: although highly correlated in the data, including both as regressors to explain exporting and treating them with appropriate instruments, does not hamper the role of innovation as a residual determinant of firm-level export status. This is in line with the literature. Aw et al (2011) shows that the interactions between R&D, productivity and exporting are indeed complex. Their dynamic model assumes that a firm's productivity evolves over time like a Markov process that depends on its own past investments in R&D and on its participation in the export market and interaction effect between R&D and exporting. Thus, Aw et al (2011) assume that current productivity of a firm positively affects both its propensity to export in future and its propensity to engage in future R&D, which is what they call "selection equations". In their dynamic framework they also allow for "feedback" effects, running from past exporting and past R&D outlays back into current firm-level productivity. In the current paper, due to the cross-sectional nature of our data we do not estimate a dynamic structural model, but we take the sequencing of Aw et al (2011) as given.

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[3] The "European Firms in the Global Economy" (EFIGE) project, and related survey and data collection, was financed by the 7th Research Framework Programme of the European Commission. The dataset is the first representative sample of some 15,000 manufacturing firms harmonized across the following countries: Austria, France, Germany, Hungary, Italy, Spain, and the United Kingdom. The data include quantitative as well as qualitative information on around 150 variables. These cover international strategies, R&D, innovation, employment, financing and organizational activities of firms. The anonymized firm-level data are publicly available at http://bruegel.org/publications/datasets/efige/

A second result that we obtain in our framework is that financial variables do have a role in affecting innovation activities, but only indirectly. A stylized fact arising from our data is that innovation activity is mainly financed through internal funds and does not rely much on the financial position of the firm, i.e. not on external financing. This finding is well known in the literature (Hall and Lerner, 2010) and robust across industries and countries in our sample. One potential explanation for this may lie in the fact that R&D outlays typically have more uncertain outcomes and cannot be easily collateralized. These characteristics end up in a higher cost of external finance for innovation, and thus rule out its use. Consistently, we do not find a direct significant effect of access to external finance on innovation activities in our sample. However, as pointed out by Gorodnichenko and Schnitzer (2013), as innovation depletes internal funds, it increases the likelihood of actually encountering financial constraints. Our encompassing framework goes one step further, showing that the emergence of exogenous financial constraints can generate a trade-off between the internationalization vs. innovation decisions of firms. To that extent, we exploit the large supply shock to external credit that took place in some EU countries during the most recent financial crisis. Our findings show that, when faced with a credit crunch, exporting firms channel the internal resources previously used to finance their R&D activities towards the financing of their exporting activities. Thus, in times of external credit scarcity, firms appear to prioritize their internationalization activities over their innovation activities. This trade-off on the use of internal funds away from R&D activities is likely to negatively impact firms' future productivity growth, which in turn can seriously impact the feedback effects described in the structural model by Aw et al (2011).

Section 2 of this paper provides a literature review on the known interrelations between our variables of interest, namely financial health, TFP and R&D, and their effects on exports. Section 3 presents a description of the data sources and variables. In session 4 we present a set of instrumental variables that we use to address the endogeneity of the relations between our covariates, together with some robustness checks. The R&D - export trade-off is discussed in detail in section 5. Section 6 concludes.

2. Literature

The relationship between financial constraints and exports has been analysed in both directions. On the one hand, the literature agrees on the relationship from financing constraints to exporting as the origin of a self-selection mechanism generated by the costs associated to the export activities. Bellone et al. (2010) and Manova et al. (2015) show how high sunk cost hamper financially constrained firms from participating to the international markets, while Manova (2013) studies the mechanisms through which credit constraints affect trade on both the extensive and the intensive margins. Minetti and Zhu (2011) provide evidence that limited access to bank debt decreases firms' export. On the other hand, a literature exists showing how having access to international markets might imply a significant decrease in the financing constraints of a firm. Exporters might in fact have an easier access to international financial markets, widening the possibility of credit supply they can rely on. Campa and Shaver (2002) show how, by exporting, firms operates in markets whose business cycles are perfectly correlated, increasing the probability of having more stable cash flows. This expectation of more stable future cash flows and the information signal from exporting activities can lessen the severity of credit constraints for exporters with respect to non-exporter.

The relationship between firm productivity and export is also traditionally studied in both ways. On the one hand, the effects of TFP on export activities stem from the self-selection of the most productive firms into exports as theorized by Melitz (2003) and empirically shown in the pioneering work of Pavcnik (2002). The general finding of this nowadays vast literature is that only few, large and productive firms are productive enough to sustain the costs associated with a deep integration in the global economy. On the other hand, a more limited number of works study the effects of exporting activities on productivity, or learning by exporting. This stream of literature (e.g. De Loecker, 2007), outlines how, under certain circumstances, higher international involvement can be associated to higher productivity levels of firms.

A circular link seems to exist as well between innovation and exporting. Earlier papers by Van Beveren and Vandenbussche (2010), Cassiman and Golovko (2011) and Rubini (2014) show how investments on innovation directly affect the probability of a firm's starting to export. Evidence supporting the opposite direction of causality (from exports to innovation) also exists but is more scant (Salomon and Shaver, 2005; Damijan and Kostevc, 2010; Bratti and Felice, 2012). More in general, there is a growing consensus that both innovation and exporting are the result of the endogenous choices of firms (Constantini and Melitz, 2008). Therefore, they are inextricably linked and their drivers are a priori unclear: firms may conduct innovation activity in anticipation of exports, or may start exporting after successfully innovating. In this case, innovation is a type of 'signal', in preparation to embark on export activity, which gives rise to self-selection. Evidence from Canada collected by Lileeva and Trefler (2010) show that the export-innovation link indeed seem to run in both ways. Bustos (2011) finds supporting evidence for this effect in the case of Argentina and Mercosur.

Some authors have started to combine some of the above mentioned channels in a more comprehensive framework. Aw, Roberts and Winston (2007) analyse the relationship between TFP, R&D and export. On the one hand they confirm that export market participation exhibits persistence and is fundamentally related to firm-level variation in productivity due to self-selection. On the other hand, they find that exporting firms benefit from technology transfers from foreign customers e.g. firm's export market participation positively and significantly affect its future productivity, and this is particularly true when the firm invests in R&D. Aw et al. (2011) estimate a dynamic structural model of a producer's decision to invest in R&D and export, allowing both choices to endogenously affect the future path of productivity. Both activities are found to have a positive effect on the plant's future productivity. They also find that sunk and fixed costs of investing in R&D are greater than the sunk and fixed costs of exporting, which results in a larger proportion of plants choosing to export than to conduct R&D.

Finally, a literature exists documenting the effects of financial frictions on R&D expenditures (for a review, see Hall and Lerner, 2010 or Gorodnichenko and Schnitzer, 2013). Endogeneity issues are also present in this area of research, as innovating firms might require more external financing and thus could be more likely to run into financial obstacles; one would then observe a positive correlation between rates of innovation and the degree to which financial obstacles are binding, even though a negative correlation is expected. Indeed, Hajivassiliou and Savignac (2007) find that innovation and financial constraints are positively correlated in their full sample of French firms, but that the correlation turns negative when the sample is restricted to firms they classify as likely innovators.

Finally, and to the best of our knowledge, only two contributions exist in the literature that try to study the effect of financial constraints on export and innovation jointly. Gorodnichenko and Schnitzer (2013) show how financial constraints adversely affect the ability of domestically owned firms to innovate and to export in developing economies. Furthermore, they also find that the negative effect of financial constraints on productivity is amplified as these constraints force export and innovation activities to become substitutes, even when these activities are natural complements. Similar findings are reported by Ji and Luon study that financial constraints produce negative

impact not only on export, but also on innovation, weakening the complementarity between the two. However, the latter study focuses on the Chinese case, and is entirely built relying on a single measure of financial constraint, namely the SA index (Hadlock and Pierce, 2010). In our work, as described above, we propose a cross-country analysis, which allows us to account for specific country-level controls and we propose a series of indices to evaluate the financial situation of each specific firms.

In the remaining of the paper, we set out to explore in detail the relationship of credit constraints, productivity, and innovation vs. the export activities of firms in a single framework, then using this exogenous and robust estimation procedure to study the potential trade-off between export and innovation in the presence of an exogenous financial shock.

Papers like the one by Aw et al. (2007 and 2011) provide evidence of a link between R&D activities of a firm and exporting as resulting from endogenous firms' choices that affect productivity (see Lileeva and Trefler 2010, Bustos 2011), but do not look at the financial dimension of the firm. Manova et al. (2015) and Minetti and Zhu (2011) are papers that argue that a firm's financial health matters for exporting activities but do not consider innovation activities, while a priori the financial conditions of a firm may affect both its export as well as its innovation decision, and its productivity levels. The above two strands of literature have not been systematically explored together.

3. European wide firm-level data

Our main data source is the survey on European Firms in a Global Economy (EFIGE). EFIGE is a research project, funded by the European Community's Seventh Framework Programme (FP7/2007-2013). The project aims at analysing the competitive performance of European firms in a comparative perspective. This dataset is a harmonized cross-country dataset containing quantitative as well as qualitative information on around 150 items for a representative sample of some 15,000 manufacturing firms in the following countries: Austria, France, Germany, Hungary, Italy, Spain, and the United Kingdom. These items include amongst others questions on firms' international strategies such as whether they are exporters, their R&D and innovation activities, as well as their financing activities.

The EFIGE survey was held in the year 2010 and covers a broad array of questions that allow us to address several crucial issues linked to the relation between credit rationing and ownership nature. Most questions relate to the year 2008, with some questions requesting information for the reaction of firms to the crisis in 2009/10 while other questions track the persistency of some variables in the years before 2008. The questionnaire has been administered between January and April 2010 via either CATI (Computer Assisted Telephone Interview) or CAWI (Computer Assisted Web Interview) procedures.[4]

An interesting characteristic of the EFIGE dataset is that, survey data can be matched with balance sheet figures. More precisely, EFIGE data has been integrated with balance-sheet data drawn from the Amadeus database managed by Bureau van Dijck, retrieving nine years of usable balance-sheet information for each surveyed firm, from 2001 to 2009. This data in particular enables the calculation of firm-specific measures of productivity and a number of financial health indicators, measured over time.

The EFIGE dataset includes about 3,000 firms operating in Germany, France, Italy and Spain, some 2,200 firms in the United Kingdom, and about 500 firms for Austria and Hungary. More information on the distribution of firms surveyed in each country as well as the representative stratification of the sample by industry region and firm size can be found in appendix A.1.

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[4] The complete questionnaire is available on the EFIGE web page, www.efige.org. A discussion of the dataset is available in Barba Navaretti et al (2011), while Békés et al (2011) discusses explicitly the reaction of firms to the crisis as measured in the survey. Related to this paper, Altomonte et al. (2013) have used EFIGE data to monitor the relations between internationalization and innovation activities of firms.

For validation purposes, we compare firms' characteristics from EFIGE, aggregated at country level with official statistics provided by Eurostat (Structural Business Statistics for manufacturing firms >10 employees). The correlations in terms of "number of employees", "the cost of labour" and "the value of labour productivity", are highly positive significant and range between .6 and .85 per cent depending on the country.[5] Due to this country-heterogeneity in terms of coverage and correspondence to official statistics, we always control for country fixed effects when presenting our econometric result.

4. Stylized Facts

In this section we document three important stylized facts arising from the survey data which will help us later on to specify our empirical model to be estimated.

4.1. *Exporting is mainly financed with external financing*

In the survey data, a survey question allows us to verify whether firms applied for external financing in the year in which they report to be an exporter. With a probit regression, we then analyse the correlation between exporting status and the use of external financing through the following specification:

$$External\ financing = \alpha + \alpha_1 EXP + \alpha_2 Productivity + \alpha_3 EXP * Productivity + \epsilon$$

The dependent variable is a dummy variable taking a value of one if the firm applied for external financing and a value of zero if not.[6] This is regressed on the exporting status (EXP) of a firm as well as its productivity and on their interaction (EXP*Productivity). The interaction term captures the extent to which more productive firms demand external financing for exports.

The productivity measure that we use is the Levinsohn-Petrin measure of Productivity where we consider each sector (Nace rev. 2 two digit) to be characterised by a different technology and production function coefficients are allowed to differ for each sector. When applying this value-added semi-parametric production function approach, we also include country and year fixed effects in the productivity estimations.[7] We find the exporting status of a firm to be highly correlated (α_1>0) with the demand for external financing, but that within the group of firms that demand for external financing, the highly productive ones demand relatively less (α_3<0), as reported in Table 1. One interpretation of these findings can be that firms use external finance to cover the fixed costs of export, and more productive firms are likely to have a higher ability to repay internally these costs and thus require marginally less external finance.

4.2. *R&D is mainly financed by internal financing, for both exporters and non-exporters*

In the survey data, one of the questions regarding R&D financing is as follows: "How have R&D activities on average been financed in the last three years (2007-2009)?". In their responses, firms were given the option to choose between "self-financing", "intra-group financing", "venture capital", "bank credit", "public funding", "leasing and factoring" and "other". Table 2a reports results by EU country. From the responses in the survey it is clear that most firms finance their

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R&D activities through "self-financing" and this is the case for all the different EU countries that were sampled.

Table 1 - Probit model with marginal effects

Dependent variable	Probit External Financing (dummy 0/1)
EXP	0.0410***
	(0.0138)
Productivity	-0.0392
	(0.0260)
EXP * Productivity	-0.0738***
	(0.0317)
Observations	7,523
Country dummy	YES
Sector vulnerability dummy	YES
Asset tangibility dummy	YES

When we next break down the responses by firms' exporting status, as we do in Table 2b, it can be verified that this holds both for exporting and non-exporting firms e.g. there is no significant difference between the financing of R&D between exporters and non-exporters. This first stylized fact already suggests that when we explore the relationship between access to external finance and Innovation activities, as we do more rigorously in section 4, we do not expect it to show up significantly.

Table 2a - *R&D financing by country*

	How have R&D activities been financed on average in the last three years (2007-2009)? (Answers in %)						
Country	Self-financing	Intra-group financing	Venture capital	Bank credit (short/long)	Public funding	Leasing and factoring	Other
Austria	84.05	4.13	2.47	1.53	6.58	2.67	2.67
France	79.62	4.49	0.33	7.74	4.83	1.55	1.55
Germany	84.80	2.78	0.32	2.62	6.13	2.96	2.96
Hungary	90.95	0.24	0.00	0.00	3.33	5.48	5.48
Italy	86.28	0.48	0.11	6.53	4.10	1.76	1.76
Spain	85.31	3.94	0.00	18.68	24.70	20.91	20.91
United Kingdom	87.88	2.05	0.36	0.42	4.24	4.71	4.71

Table 2b - *R&D financing by exporting status*

	How have R&D activities been financed on average in the last three years (2007-2009)? (Answers in %)						
Export status	Self-financing	Intra-group financing	Venture capital	Bank credit (short/long)	Public funding	Leasing and factoring	Other
Exporting firm	82.53	2.97	0.60	6.89	4.85	4.11	4.11
Non exporting firm	83.84	3.00	0.21	5.81	6.34	2.64	2.64

4.3. *More productive firms have a higher propensity to obtain external credit.*

Another question in the survey data, informs us of which firms were applied for financing and obtained it in the previous year. The correlation between the "having required and obtained credit" variable (direct question in EFIGE survey) and productivity turns out to be strong and positive ($\beta = 0.82^{***}$). Using a more general and widely used in the literature index of financial health, i.e. the Whited & Wu (2006) index, the above effect is confirmed and magnified for exporters. This indicator of financial health combines company accounts information on cash-flow, dividends, long-term debt, industry sales and its growth and total assets. The higher the WWr index - where "r" stands for "reversed", because with respect to the original Whited and Wu (2006) paper, we reverse the way to read it to ease interpretations in our framework - the stronger the financial health of the firm considered. A detailed description of the WWr index estimation as well as descriptive statistics are available in appendix A.2.

Important to note is that this WWr index has been shown to be associated to banks' decision-making process on whether or not to grant a firm credit. Therefore we can interpret this index as an indicator of the propensity to obtain external credit: the higher the index, the more likely that credit supply will be granted. We can then specify an alternative equation where we correlate financial health of a firm with its exporting status, its TFP and the interaction between the last two variables, to see if higher productivity is correlated with stronger financial health which in turn is expected to correlate with a higher propensity to get credit.

$$WWr = \alpha + \gamma_1 EXP + \gamma_2 Productivity + \gamma_3 EXP * Productivity + \epsilon$$

We find that more productive as well as exporting firms have a higher propensity to obtain external credit. The interaction (γ_3) is also positive and significant as shown in Table 3.

Table 3 – Comparison credit needs and WWr

	Ols
Dependent variable	WWr
EXP	0.0305***
	(0.00248)
Productivity	0.109***
	(0.00407)
EXP * Productivity	0.0509***
	(0.00484)
Observations	4,251
Country dummy	YES
Sector vulnerability dummy	YES
Asset tangibility dummy	YES

These three stylized facts give us novel hints on the complex relations between four main variables: access to finance, export, productivity and innovation. Indeed, survey evidence documented in the stylized facts, suggests that firms predominantly rely on external financing to finance their export activities, but it also tells us that more productive firms are super-modular when it comes to attracting external credit and can get external credit more easily. This evidence implies that credit constraints are endogenous to the type of firm and its productivity. Put differently, our

factual finding that "more productive firms are less credit constraint" casts serious doubt on the positive and significant correlation between credit constraints and export activities that has been reported in earlier literature. The effect of credit constraints on exporting is expected to disappear or heavily weakened with the inclusion of productivity. Minetti and Zhu (2011) and Manova (2013) engaged in a first attempt to jointly study the relationship between credit constraints, productivity and exporting. Minetti and Zhu (2011) find the effect of credit constraints on exporting to lose its significance once labour productivity is controlled for. Manova (2013) finds that when controlling for productivity through "physical capital per worker", halves the role of credit constraints (when interacted with asset tangibility). Both these studies did not aim to consider a comprehensive framework to explain the role of productivity in the relationship between credit constraints and exporting, but considered productivity as a mere control variable in their main specification on the relationship between credit constraints and exporting. In the current paper we use a more sophisticated productivity measure, and show that as a result financial constraints can no longer be considered a significant determinant of exporting. We also demonstrates the need to instrument productivity, because of the strong correlation that we find between productivity and the financial health, suggesting that more productive firms may better be suited to attract financing.

The results that will be presented in this paper, confirm that the correlation between credit constraints and exporting is not robust to the inclusion of (a more sophisticated) measure of productivity e.g. total factor productivity (TFP), both with and without controlling for the potential endogeneity of credit constraints through a novel instrument in which we use information on the firm-bank relationship to make inferences about credit constraints. This first part of the empirical analysis is focused on solving the endogeneity of the access to finance, productivity, R&D an export relations (through a proper set of instrumental variables), while the second part, relying on the first one, studies in a robust way the firms' innovation vs. export trade-off during the crisis.

5. Empirical model

5.1. Variables and Correlations

The first step of our analysis consists in disentangling the relationship between our four variables of interest e.g. financial health, productivity, exporting and R&D of a firm. In this section we first explain the variables that we use to measure each. Next we will show that any empirical model involving these four variables is likely to be plagued by substantial reverse causality. This will become clear when we regress each of the above variables on all others in a contemporaneous way. Descriptive statistics of all the main variable of interest can be found in appendix A.3.

5.1.1. Financial Health

The way financial constraints are measured is strongly debated in the literature. Theory offers only limited guidance in this area, and hence there is no clear-cut consensus on the best variable to use empirically to this extent, as also emerging from the empirical survey of Wagner (2014). In the stylized facts session above, we used a popular index (WWr) often used in the literature on financial health, but there are other measures around, such as a firm's indebtedness (ratio of non-current liabilities over total assets) or its ability to repay its interests (ratio of cash flow over interest paid). Table 4 displays country-level average values for each of these financial health indicators. To minimize the measurement error stemming from each and to account for the information overlap when considering all of them, we create a synthetic index of financial health (FH) for each firm which was obtained through a principal component analysis of all three measures capturing different aspects of financial soundness. The index has a straightforward interpretation: the higher the FH factor, the financially healthier the firm.

Table 4 - Financial Health factor component descriptive by country, 2008

|	WWr	Indebtness	Interest Repayment Ability
Austria	0.848	0.678	90.479
France	0.676	0.602	29.157
Germany	0.764	0.685	29.783
Hungary	0.652	0.592	31.866
Italy	0.691	0.715	22.570
Spain	0.675	0.629	19.688
United Kingdom	-	0.615	51.051

Source: EFIGE data

Note that a principal component analysis is not the same as addressing the potential endogeneity of the financial health variable. Thus in a later phase we will go in search of an appropriate instrument for financial health.

5.1.2. Total Factor Productivity

Our measure of Total Factor Productivity used above is the Levinsohn and Petrin (2003) semi-parametric production function estimation algorithm, but now instead of using the traditional TFP algorithm proposed by Levinsohn and Petrin (2003), in the remainder of this paper we also consider the possibility that financially constrained firms might endogenously differ in their input choices, thus biasing the traditional measure of productivity.

Figure 1 – Comparison Levinsohn and Petrin (2003) TFP and our correction for financial constraints
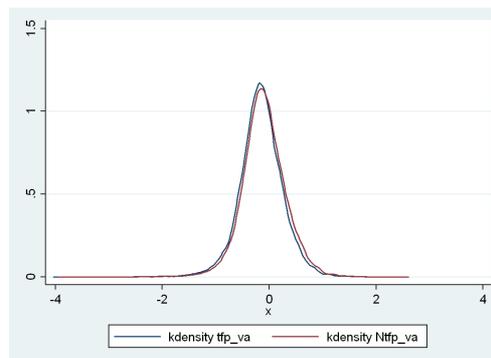
To control for this potential bias, we use the information on financial health of a firm through the financial health index[8] and insert it as an additional control when estimating TFP[9]. As a result of this additional control, we expect the power of our regressors to increases and thus, in principle, the error term (namely, our TFP) to decrease. Put differently, if a firm is financially constrained but has obtained the observationally equivalent level of predicted output of a non-

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[8] We used the WWr index for this purpose, but similar results are obtained when using the synthetic financial health index obtained through a principal component analysis of three popular measures of financial health.
[9] More specifically, what we are doing is to we add a state-specific dummy in the polynomial expansion used to calculate TFP, assigning each _rm to a given quartile of the WWr distribution, calculated for the entire period 2001-2009. The idea is that ex-ante financially constrained firms might endogenously differ in their input choices, thus biasing our measure of productivity. Therefore, our algorithm takes into account also the initial level of potential credit constraints faced by the firms in order to avoid this bias.

financially constrained firm, the latter implies that the same firm should end up in having a larger TFP. To control for financial health of a firm is therefore expected to shift the TFP distribution to the right compared to a more traditional TFP approach. This is confirmed by a T-test showing that the two TFP distributions (with and without financial constraintness indicator) are significantly different in their first moment (p-value=0.000), but with an almost identical shape, see Figure 1 below. We label this new version of TFP with Ntfp, which stands for "NewTFP".

In Table 5 we provide descriptives for the TFP distribution by country and size class in 2008.

Table 5- TFP mean distributions by country and size class, 2008

Country	Size Class			
	1	2	3	4
Austria	0.646	-0.531	0.094	0.622
France	-0.205	-0.124	-0.030	0.083
Germany	-0.206	-0.110	0.010	0.229
Hungary	-0.290	-0.212	0.043	0.178
Italy	-0.313	-0.176	0.045	0.317
Spain	-0.250	-0.133	0.064	0.332
United Kingdom	-0.388	-0.162	-0.075	0.004

5.1.3. Export and Innovation Variables

Information on firm's R&D activities and export are directly provided by the EFIGE questionnaire. In line with the previously quoted studies that use this variable from EFIGE, we define a dummy variable *R&D* assuming value one for those firms that declare having had a positive number of employees involved in R&D activities in 2008. We set a dummy variable *EXP* which is equal to one if, in 2008, the firm sold abroad directly from the home country some or all of its own products/services. The following tables provide some descriptive statistics for these variables. As we can observe in Table 6, both the percentage of exporters and R&D investing firms grow with TFP. Note that both the percentage of exporters and R&D investing firms grow also with size for all countries (see Appendix A.3).[10]

Table 6 - Percentage of firms exporting and investing in R&D by TFP quartiles, 2008

	% firms EXP	% firms R&D
1° TFP quartile	53	51
2° TFP quartile	55	59
3° TFP quartile	60	62
4° TFP quartile	68	68

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[10] Similar trends are identified for export by OECD national statistics.

5.1.4. Control Variables

To properly assess the role of firm productivity, it is important to control for firm size (see for example Hadlock and Pierce, 2010). For this purpose, we create a categorical variable *Size-Class*, varying from 1 to 4. Size-class assigns a value of 1 to firms with a number of employees between 10 and 19, a value of 2 is assigned to firms with 20-50 employees, a value of 3 to firms with 50-249 employees and a value of 4 to firms with more than 250 employees. As an alternative control for firm size we verify also our results when we substitute *Size-class* by the natural log of the number of employee, *log(employees)*.

Manova (2013) pointed out the importance of two additional variables that may impact firms' access to finance. One variable is *Asset Tangibility,* which captures the extent to which a firm operates with fixed tangible assets, computed as tangible fixed assets over total assets. To account for this we compute asset tangibility for each firm from the company accounts data and then we create a categorical variable (varying from 1 to 4) depending on where the firms stands in the distribution of *Asset Tangibility*. The intuition is that industries characterized, for technological reasons, by a higher employ of tangible assets that can serve as collateral, such as real estate, plants and machinery, show easier access to external credit (Claessens and Laeven, 2003; Braun, 2003). The second variable is *Financial Vulnerability,* which captures the extent to which a firm relies on outside capital for its investment. Financial vulnerability is computed as the share of capital expenditure of firms not financed with cash flows from operations. This second variable, which defined at sector-level and averaged over time to avoid endogeneity issues, is retrieved from Manova (2012) and will serve as a control variable in our analysis. Indeed, in industries where all necessary investments can be funded with internal cash flows, access to external funds matters little since firms do not need to borrow in order to finance their activities. However, the higher the sector's dependence on external finance, the higher importance of the availability of outside capital (Rajan and Zingales, 1998).

5.2. Correlations

Very few datasets have simultaneous information on the four variables of our interest e.g. financial health, productivity, exporting and R&D. Even fewer datasets offer information on all four variables in a cross-country setting. The EFIGE data, therefore seem to offer a unique possibility to study the relationship between all four variables since it has information on all. Unfortunately the data on exporting and R&D activity are only available in a cross-section which is a serious limitation and prevents us from estimating a dynamic structural model. Still, even the cross-sectional information allows us to highlight some important aspects of the reduced-form relationship between these four variables, not available before.

A first observation is that the relationship between the regressors financial health, productivity and R&D is plagued by endogeneities. This can be seen in Table 6 where we regress each of the variables on all others. In the first column, the dependent variable is productivity which is regressed using ols on R&D, financial health, size classes as well as country dummies and the Manova categorical variables on asset tangibility and financial vulnerability at sector-level. From the results in column 1, it can be noted that productivity is correlated with R&D, Financial health and firm size. In the second column we run a probit regression of R&D on all other variables and we find firm productivity and firm size to be positively and significantly correlated with R&D. Finally in column 3, we run a probit regression of financial health on all the other three regressors of interest and find only a positive correlation with firm productivity but not with R&D nor with the firm's size class. These preliminary results are consistent with the idea that ex-ante more productive firms tend to enjoy better financial conditions, but their R&D activities tend to be internally financed. The correlation does not say anything about how the causality runs e.g. financially

healthier firms may have the opportunity to heavily invest more both in physical capital (machinery, equipment etc.) and organizational capital which can increase a firm's productivity. At the same time, a firm's productivity levels are potentially determining its financial health resulting in the reverse causality problem. Whatever the direction of the link, the correlation between financial health and productivity would show up as being positive.

The results in Table 7 clearly show that all these firm-level variables are highly endogenous and need to be instrumented for. However, most datasets lack information for any kind of instrumentation of more than one variable, which is no doubt why the literature hitherto has never looked at the four variables together but has either left out financial constraints (Aw et al., 2011) or has left out productivity and R&D as in (Manova and Zhang, 2015; Minetti and Zhu, 2011). While not perfect, the data that we use here seem to offer a larger potential to address the endogeneity of our variables, given the richness of the survey questions. We then propose an instrumental variable approach to solve several of the endogeneity issues at the same time.

Table 7 - Relations between FH-TFP-R&D

	(1) Ols	(2) Probit	(3) Probit
Dependent variable	Ntfp	R&D	FH
R&D	0.0342***		-0.00120
	(0.0107)		(0.0319)
Financial Health	0.0792***	-0.00765	
	(0.00530)	(0.00866)	
Size Class	0.125***	0.106***	-0.0416*
	(0.00742)	(0.0116)	(0.0223)
Ntfp		0.0672**	1.052***
		(0.0286)	(0.0503)
Observations	4,105	4,373	3,943
Country dummy	YES	YES	YES
Sector vulnerability dummy	YES	YES	YES
Asset tangibility dummy	YES	YES	YES

5.3. Instrumental variables

Ultimately we are interested in analysing the importance of financial health, productivity and R&D as determinants of exporting, in order to use a proper set of instruments to lately study the innovation vs. export trade-off. But from the previous section it is clear that endogeneities are potentially biasing the estimates, hindering the proper interpretation of the regression coefficients and preventing us to establish the direction of the causal link between the variables involved.[11] In order to address these endogeneity issues, we exploit the richness of our data and build instruments for the three regressors of interest, namely financial health (FH), productivity (Ntfp) and innovation activities (R&D).

5.3.1 Instruments for Financial health

Our survey data contain information on the stability of a firm's relationship with its main bank. Specifically, firms were asked the length in years of the relationship with their main bank.[12]

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[11] The reverse causality issue can be potentially found between R&D and Ntfp, Ntfp and exports and R&D and exports. See literature review for details.
[12] The EFIGE survey questions is: "*For how many years has this bank been the firm main bank?*"

Based on this information we create a dummy variable that takes value 1 if the relationship with the main bank is stable, i.e. the relationship has a length above the average of the variable distribution in our sample. The idea is that a long lasting relationship with the main bank is a signal of both ex-ante better financial shape of a firm (the bank keeps the firm as a client) as well as of the ability of a firm to access financial resources at better conditions (the bank has less informational asymmetries in providing credit), giving the same firm the possibility to invest more in physical and intangible assets, and thus improve productivity. In this sense, a stable financial relationship with the firm's main bank should affect the same firm's TFP only through the impact that this stable relation has on a firm's financial health, and thus is a good candidate for an instrument.

A second potential instrument arising for financial health arising from our survey data is related to firms' number of banks.[13] We create a dummy variable assuming value one if the firm has a significantly high (greater than the 50th percentile of number-of-firms'-banks distribution) number of banks. We expect a negative correlations between this instrument and the financial health variable, signalling that firms which need to be in contact and have relations with multiple banks are not able to convince their main bank of the robustness of the business they are running. This could also signalling the need to split the need for credits between multiple credit lines, due to a low willingness of a single bank institution to take all the risk needed by the firm.

In the IV specification of our empirical model, we will also add the fourth lag of a firm's financial health, in order to avoid contemporaneous autocorrelation with the TFP measure, which enters in our main specification with a three year lag (to avoid in turn contemporaneous correlation with the export status).

5.3.2. Instrument for Innovation

The entire literature on "learning by exporting" shows, R&D activities do not only affect the probability of export of a firm, but exporting in turn may have an effect on future innovation activities. In order to tackle this endogeneity issue which could bias our estimations, in a cross-section we need to instrument the *R&D* variable and we do so by considering three potential instruments.[14]

The first instrument is an in-sample variable indicating the share of *other* firms doing R&D activities in the same region of the considered firm (defined at the NUTS-2 level of territorial aggregation as defined by Eurostat). We expect a positive correlation between this instrument and the firm-level R&D variable via the presence of geographically concentrated knowledge that spills over across firms. In theory, it is also possible that other features like market structure affects innovation and the probability of exporting of a firm. However, this is accounted for by country and, most importantly, industry specific effects included in the analysis (see infra).

The second instrument we use is an out-of-sample proxy for R&D intensity computed from OECD data, as the share of investment in R&D over the value added of a given (NACE 2 digits) industry and country for the years 2002-2006. The idea is to capture the general (past) R&D intensity of a specific country/industry cell to which a given firm belongs. Altomonte et al. (2013) used this instrument and show how this variable is positively correlated to contemporaneous R&D activities, as it proxies for the likelihood of an average firm belonging to a given country/industry pair to engage in research activities, but is only weakly correlated with contemporaneous internationalization choices of firms.

A third instrument that we experiment with comes directly from the EFIGE survey, namely whether the firm has claimed a copyright in the past three years.[15] The idea being that, the claim of a copyright in the past signals the likelihood of an average firm to engage in research activities,

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[13] The EFIGE survey question is: "*Number of banks?*"

[14] It is well known that *R&D* positively and significantly affects *TFP* levels, and the same is true in the opposite direction. As our focus is their joint impact on the export activities of firms, we are not interested in claiming any direction of causality among these two variables.

[15] The EFIGE survey question was stated as follows: "In the last three years (2007-2009) the firm claimed copyright", possible answer Yes/No

with the same variable being however weakly correlated with contemporaneous internationalization choices, thus potentially making it a good candidate instrument.

5.3.3. Instrument for control variables

To instrument productivity, we exploit the fact that for this variable we have information over time which allows us to use lagged values. Thus, we take the three-year lagged firm-level variable, with the aim to avoid autocorrelation with the R&D measure and the FH factor given the panel structure of our data.[16] Similarly for firm size, we instrument the log of employees with a three-year lagged firm-level variable.

5.4 Empirical analysis

As anticipated, the empirical work is divided in two steps. In the first step, we solve the endogeneity of the FH-TFP-R&D-EXP relations through a proper set of instrumental variables and presenting several robustness checks, section 5.4.1. In the second step, we build on the results obtained in section 5.4.1, in order to analyze the firms' innovation/export trade-off during the crisis, again followed by its relative robustness checks, section 5.4.2.

5.4.1 Empirical model and robustness checks for the FH-TFP-R&D-EXP relations

This main specification aims to establish the role of financial health, productivity and R&D as determinants of exporting at firm-level. It is reported in Table 7. We start by reporting simple probit export regressions where our variables of interest are progressively added as independent variables. The last column of the Table reports the instrumental variable regression e.g. the second stage results with productivity (Ntfp), Innovation (R&D) and financial health (FH) jointly considered and instrumented (see appendix A.4 for a schematic view of all the instruments used).

In line with the literature, exporting is driven by firm-level productivity (column 1), a result robust to the inclusion of firm size (column 2). Results show that the probability to export rises when firm are bigger and have higher productivity. In columns (3) and (4) we respectively add the financial health variable and the productivity variable to the export equation. Once we control for productivity (Ntfp), the financial health (FH) variable loses its significance and no longer is a significant determinant of exporting. When we add Innovation (R&D) to the specification as we do in column 5, we find it to have a positive and significant effect on exporting (EXP) without affecting the other determinants of exporting e.g. leaving intact the importance of productivity and size as determinants of exporting.

Before we discuss the second stage results of the IV regression reported in Column 6 of Table 8, we need to establish the validity of our instruments by reporting the first stage regressions. The results, reported in appendix A.5, confirm that the chosen instruments are significant at any statistical conventional level and with the expected coefficient. For the innovation variable, we took the first instrument considered e.g. the share of *other* firms doing R&D activities in the same region of the considered firm. The next section looks into robustness checks where we also consider the use of alternative instruments. Financial health turns out to be positively correlated with a long-lasting relation with the firm's main bank, while as expected it is negatively correlated with a particularly high number of firm's banks, signalling financial instability. The two R&D instruments, present both a positive correlation with the instrumented variables, and the same is true for the lag of the productivity variable used as instrument for the Ntfp. The F-test statistic is always much above the conventional critical level of 10, signalling the strength of the instruments and the efficiency of our estimations. The Hansen J-statistic has a p-value well above the significance level, thus confirming the exogeneity of the instruments.

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[16] Experimenting with the second or the fourth lag of Ntfp yielded similar results in terms of power of the instrument.

The second stage results of the IV specification reported in column 6 where we instrument productivity, innovation and financial health, confirm the earlier obtained simple probit regressions. The IV results confirm the positive correlation between the financial health of a firm and its export activities traditionally found in the literature, they also shed a new light on the role of financial health. Our IV specification shows that TFP and R&D jointly drive the probability of exporting but that the role of financial health and access to finance is no longer critical as a determinant for exporting, once productivity is controlled for.

Table 8 – Main specification for the FH-TFP-R&D-EXP relations

Dependent variable	(1) Probit EXP	(2) Probit EXP	(3) Probit EXP	(4) Probit EXP	(5) Probit EXP	(6) IV EXP
Ntfp	0.159***	0.0856***	0.127***		0.119***	0.107*
	(0.0150)	(0.0160)	(0.0317)		(0.0317)	(0.0576)
Size Class		0.109***	0.0920***	0.105***	0.0749***	0.0623***
		(0.00768)	(0.0153)	(0.0151)	(0.0144)	(0.0164)
Financial Health			0.0105	0.0300***	0.0119	0.0206
			(0.00866)	(0.00829)	(0.00876)	(0.0173)
R&D					0.199***	0.238***
					(0.0251)	(0.0782)
Observations	7,685	7,685	4,373	5,139	4,373	2,578
Pseudo R-squared	0.0775	0.0974	0.0929	0.0962	0.1195	0.0667
Country dummy	YES	YES	YES	YES	YES	YES
Sector vulnerability dummy	YES	YES	YES	YES	YES	YES
Asset tangibility dummy	YES	YES	YES	YES	YES	YES
HansenJ test of Identification						0.323
First stage F-test for instruments						
Ntfp						100.38
Financial Health						172.29
R&D						29.44

In (6) we instrument:

* *Ntfp*, with its t-3 value;

* *Financial Health*, with a dummy variable assuming value 1 if the firm has a long-lasting relation (>50th percentile of bank-duration-relation distribution) with its main bank, a dummy assuming value 1 if the firm has a significantly high (>50th percentile of number-of-firms'-banks distribution) number of banks , together with its t-4 value, to avoid dimultaneous correlation with the Ntfp's lag;

* *R&D*, with a dummy indicating if the firm in the last three years claimed a copyright and the share of other firms doing R&D activities in a given firm's region.

To verify the robustness of our results, we also experiment two alternative approaches.

The first approach is with alternative instruments. In column 1 of Table 9 below we now substitute the second instrument used for *R&D* in our baseline equation (copyright) with the R&D intensity at the country-industry level derived from the OECD. All our results are confirmed, showing that they are not instruments-specific. In the remaining columns of Table 8 we perform additional checks to control the robustness of our results. In column 2, we reduce the sample to the three countries that are best covered by the survey e.g. Italy, Spain and France e.g. that display a significant percentage of surveyed firms with non-missing balance sheet information, and an overall correlation with aggregate Eurostat variables above 90 per cent. Earlier results are confirmed and are also robust to the adding of the firm's age which is included as an additional control in column 3. In column 4 we restrict our analysis to firms which export outside the EU-28, i.e. we exclude firms that only export in the EU. Again our main results are confirmed. We do observe a stronger role of innovation on export (a coefficient of .39 vs. .33 in the baseline, significantly different: T-test with t=-33.38 and p-value=0.000). This is consistent with Aghion et al. (2005) who argue that in markets where competition is tougher, we are more likely to observe a neck-to-neck competition where

innovation is relatively more important. If we consider export markets outside the EU to be characterised by stronger competition, this can rationalize the stronger role of innovation on exporting in these markets.

Table 9 - Robustness checks on R&D variable and Main Specification

Dependent: Prob(Exp=1) in year 2008	Main Specification	Robustness checks			
		(1)	(2)	(3)	(4)
		Out of sample instrument for R&D	Only ITA, SPA, FRA	Only ITA, SPA, FRA and control for Age	Excluding only-EU28 exporters
Ntfp	0.107*	0.0958*	0.0977	0.109*	0.118*
	(0.0576)	(0.0574)	(0.0607)	(0.0608)	(0.0696)
Size-Class	0.0623***	0.0657***	0.0639***	0.0526***	0.103***
	(0.0164)	(0.0168)	(0.0171)	(0.0173)	(0.0191)
Financial Health	0.0206	0.0256	0.0221	0.00317	0.0256
	(0.0173)	(0.0174)	(0.0179)	(0.0183)	(0.0194)
R&D	0.238***	0.230***	0.261***	0.254***	0.323***
	(0.0782)	(0.0802)	(0.0806)	(0.0807)	(0.0878)
lnAge				0.0913***	
				(0.0170)	
Observations	2,578	2,519	2,463	2,403	1,750
R-squared	0.0667	0.069	0.066	0.077	0.132
Country dummy	YES	YES	YES	YES	YES
Sector vulnerability dummy	YES	YES	YES	YES	YES
Asset tangibility dummy	YES	YES	YES	YES	YES
HansenJ test of Identification	0.323	0.529	0.456	0.295	0.140
First stage F-test for instruments					
Ntfp	100	98	91	87	89
Financial Health	172	167	160	140	110
R&D	29	27	28	28	21

In Main Specification we instrument:

* *Ntfp*, with its t-3 value;

* *Financial Health*, with a dummy variable assuming value 1 if the firm has a long-lasting relation (>50th percentile of bank-duration-relation distribution) with its main bank, a dummy assuming value 1 if the firm has a significantly high (>50th percentile of number-of-firms'-banks distribution) number of banks , together with its t-4 value, to avoid dimultaneous correlation with the Ntfp's lag;

* *R&D*, with a dummy indicating if the firm in the last three years claimed a copyright and the share of firms doing R&D activities in firm's region.

In (1) we substitute the copyright instrument for R&D with a OECD variable measuring the percentage of R&D investment over GDP, on a country-year-sector basis.

In (2) we restrict our sample to only Italy, Spain, France.

In (3) we add a firm age control on the restricted sample of specification (2).

In (4) we exclude the only-EU28 exporters, therefore testing that innovation is less important in more competitive markets. T-test between R&D coefficients in Main Specification and specification (4): t= -33.38 (p-value=0.000).

The second approach we propose to check the robustness of our results on the FH-TFP-R&D-EXP relations is through a mediation analysis. One of the main finding arising from this first econometric specification of section 5.4 is that financial health no longer affects the exporting activity once productivity of the firm is accounted for. If productivity is not included as a control variable, the link between financials and exporting is positive and significant (as in Manova and Zhang and Minetti and Zhu), but when productivity is included in the specification, financial conditions lose their direct impact on exporting, which leads us to conclude that financial conditions are mainly serving firm-level productivity but have no residual explanatory power on exporting. This corresponds to saying that in Figure 2 below, the total effect of financial health on exporting (given by arrow c) is mediated by the indirect effect that goes through firm productivity (combination of arrow a and b) and how much is left for the residual indirect effect (given by arrow c').

Figure 2 - Mediation Analysis
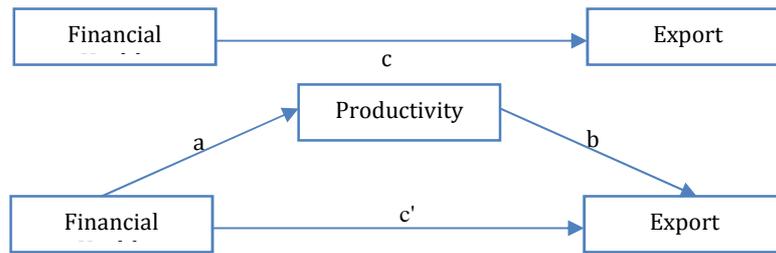
The relationships in Figure 2 can be analysed by what is called *mediation analysis* (Fiske, Kenny and Taylor, 1982; Judd and Kenny, 1981; James and Brett, 1984; Baron and Kenny, 1986). Mediation analysis is a statistical approach that allows us to quantify how much of the *total effect* (arrow c) of financial health's role on exporting probability is mediated by the *indirect effect* (the combination of arrow a and b) that goes through firms' productivity, and how much instead is left to a residual *direct effect* (arrow c'). In Table 7 we show that the *independent variable,* financial health, is positively and significantly correlated with exports when considered alone: this step establishes that there is an effect that may be mediated. In fact, we have shown that financial health is significantly correlated with the *mediator*, productivity, and that the same *mediator*, productivity, strongly and significantly correlates with the *dependent variable*, export. Finally, controlling for productivity in the financial health-export relation, we have shown that the coefficient of financial health more than halves and, moreover, completely loses its significance. The retrieved evidence excludes that the *mediator* (TFP) and the *dependent* variable (Export) may be correlated just because they are both caused by the *independent variable,* financial health. Rather, they indicate a significant role for the *indirect effect* of financial health on exports that goes through firms' productivity. To quantify the latter, we follow the procedure of Baron and Kenny (1986), which is a generalization of the more common formal test of indirect effect known as *Sobel test* (1982). The authors, using the multivariate delta method, provide an approximate estimate of the standard error of the indirect effect[17]. The Sobel test with our data confirms that 85% (significant at 1%) of the *total effect* of financial health is mediated through the *indirect effect* of productivity. This percentage remains basically the same (82%, significant at 1%) if we include in the analysis the covariates Size Class and R&D as in our main specification.

In order to take into account possible feedback effects, as proposed by Smith (1982) we also perform the Sobel test with an instrumental variables approach. First, we compute the first stages of our variables of interest in the mediation chain, namely financial health and productivity. To do so, we regress these variables on the set of exogenous variables: the instruments (their instruments used in the main specification) and the controls (Size Class, as well as country fixed effects an fixed effects on financial vulnerability and asset tangibility). Then, we use the estimates obtained from these first stages to generate a new set of values for the two regressors. In other words, we estimate the predicted variables $\widehat{FH}$ and $\widehat{TFP}$. Finally, we use them to perform again the mediation analysis, this time avoiding the potential endogeneity between our variables, and obtain that 92% (significant at 1%) of the *total effect* of firm's financial health on the probability of exporting is indeed mediated through the *indirect effect* of firm's productivity.

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[17] The multivariate delta method states that the variance of a multi-parameter function is equal to the matrix of variance-covariance between the parameters (call it V) pre- and post-multiplied for the vector of the function's prime partial derivatives with respect to the single parameters (D). In other words, the variance of $f(a, b, c, …, z) = D'xVxD$. Consider the indirect effect that goes from financial health to productivity (denoted a, i.e. the coefficient of the regression of productivity on financial health, controlling for all the others controls in the main specification), and from productivity to exports (denoted b, i.e. the coefficient of the regression of exports on productivity, again with all controls accounted for). The approximate standard error of the $a*b$ relation (which is the product of the two coefficients) is $e_{ab} = \sqrt{a^2 se_b^2 + b^2 se_a^2}$, where se_b and se_a are the standard error of the b and a coefficients, respectively. The test statistics for the indirect effect is obtained by dividing $a*b$ by the above standard error, and treating the ratio as a Z test.

A weakness of the Sobel test is that the sampling distribution of *a*b* is positively skewed, since the mass of the distribution is concentrated on the left of the distribution, namely between 0 and *a*b*. This is due to the fact that large values of *a*b* are more variable than small values (i.e. zero). Because the Sobel test uses a normal approximation which presumes a symmetric distribution, it falsely presumes symmetry which leads to a conservative test. Hence, bootstrapping has replaced the more conservative Sobel test in recent analyses. This method of testing the indirect effect is a non-parametric method based on resampling with replacement, which is performed many times. From each of these samples the indirect effect is computed and a sampling distribution can be empirically generated. With our data, by resampling five thousand times, both controlling and not controlling for the covariates Size Class and R&D, we can affirm with strong statistical significance (p-value=0.000) that the value zero for the *indirect effect* does not belong to the 95% confidence interval. Therefore, again, we can be confident that the *indirect effect* is different from zero.

5.4.2 Empirical model for the R&D-export financing trade-off

In this section we build on the two main findings of the previous section (i.e. new and robust instruments for our variables of interest, and the fact that financial conditions affect probability of export only via their impact on productivity, once endogeneity is properly controlled for) we analyse to what extent an external supply shock of credit affects the within-firm allocation of financial funds. For this purpose we turn to the initial years of the most recent financial crisis in Europe which was characterised by a large reduction in the availability of credit to firms. This credit crunch was particularly severe in Spain and Italy (Stress-countries dummy) with more bank deleveraging for both exporters and non-exporters than in other EU countries (Berthou, 2014). The main question of interests is whether in credit crunch countries, where firms suddenly faced tightened collateral requirements for obtaining external financial resources, a trade-off emerged between financing their innovation vs. their export activities. Data concerning the level of collateral pre and during the crisis are obtained from the ECB Bank Lending Survey: collateral requirements of banks, share of respondents on a -100/+100 percentage scale for a given country in a given year. Exporting activities largely rely on external financing, whereas innovation activities are mainly financed through internal funds. A priori we would therefore expect a credit crunch to mainly affect a firm's exporting activities, unless firms safeguard their exporting activity by re-orienting internal funds away from innovation activities and towards exporting activities.

The scope of this analysis is to embed this new set of results obtained in section 5.4.1 in a quasi-natural experiment. We use the crisis as exogenous variation (Italy & Spain having tighter credit conditions than France and Germany, in principle), and we exploit the fact that firms finance internally R&D and externally exports: in countries where the credit crunch has been particularly severe (Italy & Spain) the latter might generate a trade-off. In Table 10 we can observe that in our sample without Italy and Spain, 54.7% of firms whose exports were constant or rising between 2008 & 2009 were also able to maintain constant or increasing R&D activities. This share drops to 40.9% when looking at firms in Italy and Spain.

Table 10 - Natural experiment

Sample without Italy and Spain		Reduced innovation			Italy and Spain		Reduced innovation	
		1	0				1	0
Constant or	1	20.5%	54.7%		Constant or	1	27.6%	40.9%
increased Export	0	9.9%	14.8%		increased Export	0	15.1%	16.5%

The key question of this section is: is this a significant difference controlling for all other firms

characteristics? The following survey question in EFIGE gives us more information on that. It asks whether, "*During 2009 the firm has decided to postpone (decrease) investments in innovation activities*". We generate a dummy equal to 1 when firms report a decrease in their R&D activity. Also from EFIGE we know whether a firm during 2009, "*Increased, decreased or kept constant its Exports with respect to 2008*".[18] This in-sample information allows us to regress the reduced innovation in 2009, on the productivity (TFP) and the financial health of firms and on whether the firm, in the same period, has increased or kept constant its exports. Not surprisingly, we find that more productive and financially healthy firms are less likely to reduce innovation during the crisis in the countries undergoing a credit crunch, which is shown in Table 11. The negative and significant coefficient of the *Increased or constant Export* variable also underlines the fact that, on average across countries, firms that kept exporting during the crisis were also less likely to reduce their investments in innovation. When we interact our variable measuring the level of collateral requirements with the *Increased or constant Export*, we find a positive and significant effect on the dependent variable of "reduced innovation". Put differently, firms that maintain their export operations experience an *increase* in the probability of reducing innovation in countries where the credit crunch was particularly severe. In these countries it appears that firms have been less able to keep exporting and investing in innovation at the same time during the crisis. Put differently, being able to keep exports constant during the crisis (i.e. being a good firm), reduces the probability of reducing innovation during the crisis, but the effect is, opposite in countries affected by a credit crunch (positive sign of interaction). The emergence of (exogenous) credit constraints resulted in a drain of external finance that seems to imposes a trade-off on the use of these internally generated flows, thus giving rise to potentially relevant allocative effects. In the face of reduced access to external financing, firms appear to lower their innovation activities to continue to finance their exporting ability.

Table 21 - Stress Countries analysis

	(1)	(2)	(3)	(4)	
	Probit	Probit	IV	Bivariate Probit	
Sample	All sample	Only firms doing R&D	Only firms doing R&D	All sample	
Dependent variable	Postponed Innovation	Postponed Innovation	Postponed Innovation	Postponed Innovation	R&D
Ntfp	-0.0363	-0.0674*	-0.0801	-0.0922	0.3902***
	(0.0265)	(0.0352)	(0.0673)	(0.0693)	(0.0691)
Financial Health	-0.0450***	-0.0452***	-0.0442*	-0.1188***	0.0003
	(0.00864)	(0.0116)	(0.0230)	(0.0226)	(0.0218)
Collateral requirements	0.238***	0.279***	0.217***	0.6219***	0.1235
	(0.0525)	(0.0669)	(0.0772)	(0.1374)	(0.1435)
Increased or constant export	-0.168***	-0.180***	-0.182***	-0.4317***	-0.4587***
	(0.0270)	(0.0347)	(0.0433)	(0.0696)	(0.0702)
Collateral requirements * Increased or constant export	0.144**	0.175**	0.168*	0.3753**	0.4117**
	(0.0621)	(0.0812)	(0.0940)	(0.1625)	(0.1673)
Observations	4,313	2,522	1,517	4,320	4,320
Sector vulnerability dummy	YES	YES	YES	YES	YES
Asset tangibility dummy	YES	YES	YES	YES	YES
HansenJ test of Identification			0.491		
First stage F-test for instruments					
Ntfp			127		
Financial Health			168		
Correlation coefficient between the error terms of the two regressions (rho)				0.21	
Likelihood-ratio test of rho=0				Strongly rejected	
				(prob>chi2 = 0.000)	

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[18] This is another EFIGE question: "During 2009, did you experience a reduction or an increase in terms of value of your export activities in comparison with 2008?" with possible answer: "Yes, an increase of …" or "Yes, a decrease of …" or "No, we did not experience any change".

Our results are confirmed by a series of robustness checks. In column 2 we are restricting the analysis only to firms engaged in R&D activities, and as we can observe both the *Increased or constant export* and the interaction term keep a positive and a negative sign respectively. Column 3 is the key column of this table, because here we use what we learn from the previous section, instrumenting the financial health variable and the productivity variables with the same instrument we used before. This choice, thanks to the analysis presented in section 5.4.1, allows us to affirm that the trade-off between innovation vs. exporting activities exist, spurious of endogenous correlations. As we can observe, also here the F-test are strongly above 10 and the Hansen-J test confirms the robustness of our specification. In column 4, as additional robustness check, we propose a bivariate probit, where we simultaneously estimate two regressions, one having the *postponed innovation* variable as dependent, while the other having the *R&D* one. This estimation procedure performs two probit regressions simultaneously, assuming the error terms of the two to be correlated. In the output of the biprobit regression we can observe the correlation coefficient between the error terms of the two regressions, namely ρ, and the test of hypothesis of having a $\rho = 0$. In our case, the hypothesis of having a $\rho = 0$ is strongly rejected (prob>chi2=0.000). This approach, on top of confirming again our results, give us additional support to our claim that financial health condition of a firm does not affect its innovation decision, once all the other relevant variable are accounted for (see the non-significance of the financial variable on the very last column of Table 10).

7. Conclusions

In this paper we exploit the availability of a very detailed set of information available for representative samples of manufacturing firms across seven European countries (the EFIGE survey) in order to study the possible trade-off arising due to a tightening of credit conditions. To doso, we first need to disentangle the potential relations between exports, R&D and financial constraints at the firm level, as mediated by Total Factor Productivity (TFP). In particular, our data offer the possibility to introduce novel instruments for R&D and the financial health of a firm, while controlling at the same time for past TFP levels and the export status. Moreover, we are able to control these effects in a cross-country context, thus purging these relations from unobserved heterogeneity stemming from country-specific institutional contexts.

Our results confirm the positive and significant correlation between the financial health of a firm and its export activities traditionally found in the literature. However, we also find that this correlation is not robust to the inclusion of total factor productivity once the endogeneity of the financial variable (ex-ante more productive firms tend to enjoy better financial conditions) is properly controlled for. Access to finance by firms is however a potentially very important variable in terms of its allocative effects. In fact, in countries where credit has been particularly crunched, we find that firms have been less able to keep exporting and investing in innovation at the same time during the crisis. The emergence of (exogenous) credit constraints thus results in a drain of external finance that imposes a trade-off on the use of these internally generated flows, giving raise to potentially long-term negative effects for the growth of these firms. In this sense, proper access to credit might represent, although indirectly, an important driver of the ability of a firm to innovate, and thus to grow.

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Appendix

A.1 EFIGE Database

The distribution of surveyed firms in EFIGE is reported in Table 12 below.

Table 32 - EFIGE sample size, by country

Country	Number of firms
Austria	443
France	2973
Germany	2935
Hungary	488
Italy	3021
Spain	2832
United Kingdom	2067
Total	14759

The sampling design follows a stratification by industry, region and firm size structure. Firms with less than 10 employees have been excluded from the survey. An oversampling of larger firms with more than 250 employees allows for adequate statistical inference for this size class. Detailed information on the distribution of firms by country/size class and industry can be retrieved on the EFIGE website (http://www.bruegel.org/datasets/efigedataset). In order to take into account the oversampling and to retrieve the sample representativeness of the firms' population, a weighting scheme (where weights are inversely proportional to the variance of an observation) is set up according to firm's industry and class size.

A.2 Withed and Wu index estimation

This index of financial health comprises information on firm-level cash-flow, dividends, long-term debt, firm sales and industry sales and their growth and total assets.

The original index developed by Whited and Wu (2006) was estimated with a GMM estimation, using firm-level data from the quarterly, 2002 Standard and Poor's COMPUSTAT industrial files. The authors selected the sample by first deleting any firm-year observations with missing data or for which total assets, the gross capital stock, or sales are either zero or negative. To eliminate coding errors, the authors deleted any firm for which reported short-term debt is greater than reported total debt or for which reported changes in the capital stock cannot be accounted for by reported acquisition and sales of capital goods and by reported depreciation. Another deletion concerned any firm that experienced a merger accounting for more than 15% of the book value of its assets. Firms whose primary SIC classification is between 4900 and 4999 or between 6000 and 6999 were omitted, since the investment model proposed in their paper is inappropriate for regulated or financial firms. Authors only included a firm if it has at least eight consecutive quarters of complete data and if it never has more than two quarters of negative sales growth. This last criterion is important considering we are interested in identifying firms that face external finance constraints rather than firms that are in financial distress.

These screens finally resulted in an unbalanced panel of between 131 and 1390 firms per quarter. The sample period runs from January, 1975 to April, 2001. The specification of the Whited and Wu index and the estimated coefficients are as follows:

$$WWI = -0{,}091 CF - 0{,}062\ DIV\ POS + 0{,}021\ TLTD - 0{,}044\ LNTA + 0{,}102\ ISG - 0{,}035\ SG$$

where CF is Cash Flow / Total Assets), DIV POS =1 if paid cash dividends), TLTD is long term Debt / Total Assets), LNTA is the log of Total Assets ISG is the industry sales' g0rowth while SG is a firm's sales growth).

For the analysis in this paper, we take the same coefficients as the one estimated by Whited and Wu, but we replace the relevant firm-level information for the EFIGE firms in our sample. We need to instrument the DIV POS variable, because only 5% of our firms are listed firms and report dividend payments. Data on dividends are obtained from two alternative approaches as in Mancusi and Vezzulli, (2010). In the first approach, we instrument the dividend dummy with capital, creating a variable which is 1 if the value of the firm's capital at time *t* is lower than the value of capital at time *t-1* plus their profit at time *t*. The second approach consists in carrying out the same procedure, but substituting capital with net asset (defined as total assets minus liabilities). Concerning the ISG variable, we evaluate it dividing for country, year and sector (using *Nace Revision 1*, two digit). Now we have two different indexes, one using capital as instrument for the DIV POS variable, and another one using net assets. The correlation between these two approaches turn out to be very high (0.9911), therefore from now on we only keep the *WW* index. To ease the interpretation of the index (that in the original specification was higher for those firms displaying a higher level of financial constraints) we normalize the values in the range 0-1 and invert the order, obtaining the *WWr* index. The way to read this index is then, the higher the index, the financially healthier the firm. Note that 0 is just a theoretical minimum, since the lowest observed value is approximately 0.40.

A.3 Additional descriptive statistics

Table 43 - Export and R&D descriptives by Country and Size Class,2008

Country	Size Class 1		Size Class 2		Size Class 3		Size Class 4	
	%EXP	%R&D	%EXP	%R&D	%EXP	%R&D	%EXP	%R&D
Austria	53	39	52	58	84	77	87	80
France	40	47	52	56	69	72	84	86
Germany	35	57	46	68	62	79	67	91
Hungary	47	17	57	28	71	34	93	44
Italy	60	41	69	55	84	68	94	83
Spain	43	52	57	63	73	71	84	82
United Kingdom	53	56	58	60	73	68	77	69

Table 54 – Descriptive statistics of the main variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Ntfp	8743	-0.0990	0.4160	-3.9447	2.6061
Financial Health	5299	0.0725	1.0153	-1.7005	7.5113
WWr	6555	0.6918	0.0980	0.4358	1
Indebtness	11226	0.6487	0.2007	0.2360	0.9972
Interest repayment ability	6941	21.7053	51.7010	0.3381	487
R&D	14759	59.90%	0.4901	0	1
Employees	9602	66.44	113.6156	10	1044
Age	13931	32.11	20.4012	3	102

A.4 Instrumental variables

Ntpf is instrumented with its *t-3* value, to avoid persistency issues;
FH is instrumented through:
- a dummy variable assuming value 1 if the firm has a long-lasting relation (>50th percentile of bank-duration-relation distribution) with its main bank
- a dummy assuming value 1 if the firm has a significantly high (>50%th percentile of number-of-firm's-banks distribution) number of banks
- its t-4 value (to avoid simultaneous correlation with the Ntfp's lag);

R&D is instrumented with:
- dummy indicating if the firm in the last three years claimed a copyright (direct question in EFIGE survey)
- the share of firms doing R&D activities in your region[19], computed as

$$\frac{(number\ of\ firms\ doing\ R\&D\ in\ the\ firm\ region - 1)}{total\ number\ of\ firms\ in\ the\ firm\ region}$$

A.5 Fist stage regressions

We present here the first stages of our IV estimation (column 6 in Table 8).

Table 6- First-stage regressions

Dependent variable	(1) Ntfp	(2) Financial Health	(3) R&D
Size Class	0.0803***	-0.0009	0.0844***
	[0.007]	[0.014]	[0.013]
Ntfp t-3	0.5384***	0.1650***	0.0181
	[0.029]	[0.034]	[0.029]
Share of firms doing R&D activities in firm's region	0.0696***	0.0397	0.5960***
	[0.023]	[0.048]	[0.048]
The firm in the last three years claimed a copyright	-0.0106	0.0795	0.2107***
	[0.032]	[0.119]	[0.065]
Categorical variable for lenght of relation with main bank	-0.0161*	0.0444**	-0.0231
	[0.008]	[0.018]	[0.018]
Categorical variable for number of banks	0.0215	-0.2202***	0.0744
	[0.017]	[0.078]	[0.048]
Financial Health t-4	0.0331***	0.7430***	0.0151
	[0.007]	[0.027]	[0.013]
Observations	2,578	2,578	2,578
R-squared	0.518	0.640	0.086
Country dummy	YES	YES	YES
Sector vulnerability dummy	YES	YES	YES
Asset tangibility dummy	YES	YES	YES

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[19] Our results are robust also substituting the variable on copyright with a OECD variable measuring the percentage of R&D investment over GDP (country-year-sector)