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R&D investments, financing constraints, exporting and productivity

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ABSTRACT

This paper adds new empirical evidence on the mutual relationships between credit constraints, total factor productivity, Research and Development (R&D) investments and exporting, by jointly considering them in a simultaneous equation framework. Our empirical analysis focuses on a large sample of manufacturing firms from France, Germany, Italy and Spain. Our results confirm the well-known mutual positive correlation among exporting, R&D and firm's productivity. They also show the existence of a mutual relationship between exporting, productivity and credit constraints: exporters and high productivity firms are less likely to be credit constrained, while better access to credit is associated with larger productivity and a higher probability of exporting. By contrast, we find no significant relation between investing in R&D and the probability to be credit constrained, conditional on exporting. This suggests that efficiency-improving strategies, mediated by the existence of credit constraints, are at the core of firm growth achieved through exporting and innovation.

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1. Introduction

Europe's 'growth and jobs' strategy sits high on the agenda of European policy-makers. A key point of this debate is that Europe, and especially its Southern periphery, should foster 'competitiveness', that is, the rate of growth of productivity, in order to leave behind the legacy of the financial crisis and avoid a 'lost decade' scenario (Lopez-Garcia et al. 2014). To this extent two sets of policies are often advocated, among others: to encourage internationalization of local firms, with the implicit understanding that internationalization is associated with productivity growth and hence economic growth; and to increase the rate of innovation in the domestic economy, as the latter is a channel through which productivity growth takes place (Onodera 2008). Moreover, it has been recently highlighted how innovation itself is a key determinant for internationalization, with Research and Development (R&D) investments amplifying the reaction of trade volumes to a drop in tariffs (Aw, Roberts, and Xu 2011; Rubini 2014).

While there is a growing and ample debate in the economic literature on the interconnection between internationalization and innovation activities (Altomonte et al. 2013), and their relationship with productivity, in the recent years both activities have taken place in a context of tighter financial constraints for firms. As such, the potential productivity-enhancing effects of related policies, traditionally identified by the literature, might fail to materialize or they might materialize under a

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different set of conditions. The economic literature has already identified the links among financial constraints, productivity and exporting, as well as those among productivity, financing constraints and R&D investment/innovation. However, to date there are no studies that systematically explore the simultaneous interactions of all these variables in a comprehensive framework.

The main aim of this paper is thus to provide a contribution to a now growing, but still incomplete, literature on the relationships among productivity, innovation, exporting and financial constraints, being able to jointly account for their mutual interaction. To this extent, we capitalize on a unique firm-level representative sample of manufacturing firms drawn across the four largest euro area countries – France, Germany, Italy and Spain. The dataset is retrieved from the first survey on European Firms In a Global Economy (EFIGE), a survey carried out in 2010 and spanning a large array of questions with both qualitative and quantitative data on firms' characteristics and activities, including information on innovation and export[1]. The survey also includes a few questions aimed at evaluating the firms' need and ability to obtain credit from the banks, which we use to obtain the predicted probability to be denied credit after accounting for the self-selection of firms asking for more credit. This predicted probability is then linked to firms' total factor productivity (TFP), as well as to firms' extensive and intensive margins of export and to innovation output. Finally, we use a seemingly unrelated regression (SUR) model to analyze the mutual correlations among exporting, R&D, the predicted probability to be denied credit and TFP, controlling for other relevant firm characteristics, as well as industry and location effects. Results confirm the well-known positive mutual correlation among exporting, R&D and productivity, as well as among exporting, productivity and financial constraints: *ceteris paribus*, exporters, as well as firms with higher productivity, are less likely to be credit constrained; in turn better access to credit is associated with higher productivity and probability of exporting. By contrast, we find no significant relation between investing in R&D and financial constraints, conditional on exporting.

The structure of the paper is as follows: Section 2 reviews three main strands of literature that have explored the relationships among financial constraints, exporting, R&D and firm's productivity. Section 3 discusses the data and our main variables of interests. Section 4 presents and discusses the econometric analysis, including robustness checks as well as a potential causal interpretation of our results. Section 5 concludes.

2. Literature review

This paper builds upon three different streams of literature. The first one focuses on the relationship between financing constraints and innovation. Although a number of theoretical contributions suggest a negative relationship between financing constraints and R&D investment, motivated by the presence of information asymmetries (Myers and Majluf 1984), lack of collateral and high adjustment and sunk costs (Arrow 1962), the empirical evidence is still ambiguous. Indeed, a number of contributions have found that R&D investment is sensitive to financial constraints, although some of them claim that internal sources of funds are more important for R&D than for ordinary investment (Himmelberg and Petersen 1994; Czarnitzki and Hottenrott 2011), while others have found that R&D investment is as sensitive to financial constraints as ordinary investment appears to be (e.g. Mulkay, Hall, and Mairesse 2001). By contrast, other contributions do not find R&D investment to be sensitive to financial constraints (e.g. Bond, Harhoff, and Van Reenen 2005). This lack of sound evidence is partly the consequence of the nature of R&D investment and partly the result of measurement and methodological problems. Difficulties related to the nature of R&D investment arise because establishing an R&D program involves significant sunk costs and large fluctuations in the level of spending in existing research programs are very costly. This is primarily due to expenditures in R&D being predominantly payments to scientists, engineers and other specialists, who are depository of the firm's knowledge base and whose supply is far from being perfectly elastic. These features add to methodological problems on the measurement and identification of financing constraints. Typically, these are proxied using indirect measures, such as investment sensitivity to cash flow

(Fazzari, Hubbard, and Petersen 1988). This approach presents several drawbacks, as most of these indicators are partially endogenous to firms' activities; hence their effectiveness to detect unambiguously the presence of financing constraints has been severely criticized (Kaplan and Zingales 1997). Several studies try to overcome these limitations and use direct measures of financing constraints. When doing so, some of these papers have shown a negative effect of financing constraints on R&D investment (Aghion et al. 2012; Brown, Martinsson, and Petersen 2013; Mancusi and Vezzulli 2014) and innovation (Savignac 2008; Gorodnichenko and Schnitzer 2013). Nevertheless, some recent research suggests that financial constraints affect innovation mostly indirectly, rather than directly, by reducing entry and competition (Caggese 2014). To overcome these potential criticisms, in this paper we adopt a direct measure of financing constraints, which we obtain exploiting the information on bank credit rationing from our survey data, but also an indirect measure of financing constraints, based on the index proposed by Whited and Wu (2006). Although bank financing might not represent the preferred external financial channel to fuel R&D investments (Brown, Martinsson, and Petersen 2013),[2] it still represents the primary source of financing in European bank-centered financial systems, particularly for SMEs, so it is particularly relevant in our context.[3]

The second stream of literature focuses on the relationship between financing constraints (and credit rationing) and firms' international activities (most often export). Also in this case the relationship is ambiguous, because of two potentially contrasting effects. On the one hand, a causal relationship from financing constraints to exporting originates in the self-selection mechanism generated by the high sunk costs of export, which prevents financially constrained firms from participating to international markets (Bellone et al. 2010; Manova, Wei, and Zhang 2015), or by high variable trading costs, which hamper the intensive margin of export (Manova 2013). Along these lines, and focusing on credit rationing, Minetti and Zhu (2011) provide evidence that limited access to bank debt does have a negative impact on a firm's export. Similarly, credit constraints lower the response of trade volumes to trade liberalization, as pointed out by Brooks and Dovis (2013). Miao and Wang (2012) however show that credit constraints can also affect total factor productivity (TFP), distorting a correct reallocation of capital toward the most efficient firms. Since we know from Melitz (2003) that firms self-select into international activities, with only the most productive firms engaging in trade, it then follows that a crucial role in the relation between financing constraints and export can be played also by productivity itself. On the other hand, a case can be made of exporting leading to less binding financing constraints for the firm, as exporters usually have an easier access to international financial markets, widening the credit supply they can draw from. Moreover, revenues from export are generally more stable due to international diversification in sales, thus improving the liquidity status of exporting firms (Greenaway, Guariglia, and Kneller 2007). Also under this reverse causality from export to credit constraints, productivity can be instrumental in driving the relation: due to self-selection, higher international involvement is associated with a higher productivity. Hence, the exporter status can act as a signal for quality, thus lowering information asymmetry and, consequently, the severity of financial constraints (Campa and Shaver 2002).

The third and final stream of relevant literature focuses on the circular link between innovation and exporting. Here again TFP plays a crucial role. The main theoretical argument is that innovation fosters firm's productivity and therefore promotes export, while learning by exporting and the access to foreign knowledge sources, in turn, feeds back into innovation (see Castellani and Zanfei [2007] for a review) and productivity. In most cases, empirical contributions focus on one of the two sides of the innovation–export relationship. On the one hand, Vanbeveren and Vandenbussche (2010) and Cassiman and Golovko (2011) show that product innovation has a positive impact on the decision to enter a foreign market. On the other hand, contributions focusing on learning by exporting find contrasting results. In particular, Keller (2004) finds little evidence of this phenomenon, while more recent studies, such as Damijan, Kostevc, and Polanec (2010) and Bratti and Felice (2012), find the opposite. Other relevant studies are Bustos (2011), which shows that trade liberalization induces firms to take actions (export and innovation) that can increase their productivity, and Melitz and Costantini (2007), which simultaneously endogenizes innovation and exporting decisions, explaining them as

an adjustment to trade liberalization shocks. Finally, Harris and Moffat (2011) study how R&D, innovation and the decision to sell abroad are interrelated.

3. Data and variables

Our main data source is the first survey on EFIGE, a unique dataset of manufacturing firms located in seven European countries (Austria, Hungary, UK, France, Germany, Italy and Spain). The dataset, fully comparable across countries, is a stratified sample according to the manufacturing structure of the representing country. In particular, the sampling design follows a stratification by industry, region and firm size. Firms with less than 10 employees have been excluded from the survey, whereas larger firms with more than 250 employees have been oversampled to allow for adequate statistical inference for this size class. In order to take into account this sampling scheme and retrieve the sample representativeness of the firms' population, a weighting scheme is set up according to firm's industry and class size.[4] All tables and econometric results in this paper are computed using this weighting scheme, except where otherwise specified.[5]

The EFIGE survey was carried out in 2010 and mostly concerns firm's activities performed in year 2008. It provides detailed qualitative and quantitative information on several firms' characteristics (such as ownership, internal structure, investment, innovation, internationalization, financial structure, market and pricing strategies) and has been integrated with firm's balance sheet data for the years 2001–2009 from Amadeus, a database developed and maintained by Bureau van Dijk. The availability of firm's balance sheet data from Amadeus database varies significantly among countries. In particular, only for the four largest euro area countries (France, Germany, Italy and Spain) the percentage of surveyed firms with non-missing balance sheet information is at least 50%. Thus, we restrict our analysis to these four countries (accounting for a total of 11,761 manufacturing firms surveyed) and in particular to a sub-sample of 5573 firms for which full balance sheet data are available (henceforth referred as the 'final sample'). Despite the reduction in the sample size, the final sample broadly maintains the original sample representativeness in terms of size classes and sectors for each country (see Tables 1 and 2).[6]

In the next sections we introduce and describe the variables used in our analysis.[7]

3.1. *Innovation and export variables*

Information on firm's R&D activities and export is directly provided by the EFIGE questionnaire.

We define a dummy variable *RD* which takes the value of one for those firms that have undertaken R&D activities of any kind (in-house or outsourced) in the period 2007–2009 and that declare they had a positive number of employees involved in R&D activities in 2008. Similarly, we define 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 or services. More than half of firms included in our sample engage in exporting activities (55.1%), while the share of firms investing in R&D is lower (43.9%).

Table 3 shows that, for the four countries, both the percentage of exporters and R&D investing firms grow with size.[8] Italy displays the highest share of exporting firms, with the majority of firms engaging in this activity (64%). Germany instead is the country with the highest share of firms

Table 1. Distribution of firms by country and size class.

Size classes	FRA		GER		ITA		SPA		Total
Empl. (10–19)	278	28% (34%)	191	17% (24%)	738	41% (34%)	591	36% (37%)	1798
Empl. (20–49)	366	37% (39%)	410	36% (38%)	714	39% (47%)	734	45% (44%)	2224
Empl. (50–249)	263	27% (20%)	404	35% (27%)	277	15% (14%)	243	15% (14%)	1187
Empl. (250 and over)	70	7% (7%)	134	12% (11%)	80	4% (5%)	80	5% (5%)	364
Total	977		1139		1809		1648		5573

Notes: Shares refer to size class at the national level. Shares reported in parenthesis refer to the original EFIGE survey sample.

Table 2. Distribution of firms by country and sector.

Sector	FRA		GER		ITA		SPA		Total
Food/Tobacco	84	9% (8%)	107	9% (12%)	171	9% (8%)	331	20% (16%)	693
Textiles	33	3% (7%)	44	4 (4%)	267	15% (14%)	67	4% (5%)	411
Wood/paper	64	7% (6%)	67	6% (6%)	106	6% (5%)	180	11% (8%)	417
Printing	52	5% (5%)	88	8% (7%)	70	4% (3%)	0	0% (4%)	210
Chemicals/coke	52	5% (4%)	48	4% (3%)	79	4% (4%)	94	6% (4%)	273
Plastic/rubber	92	9% (8%)	93	8% (7%)	122	7% (6%)	116	7% (5%)	423
Glass/ceramics	61	6% (6%)	45	4% (3%)	117	6% (6%)	114	7% (6%)	337
Metals	335	34% (33%)	250	22% (19%)	447	25% (23%)	507	31% (23%)	1539
Machinery	105	11% (9%)	230	20% (17%)	276	15% (13%)	0	0% (11%)	611
Electrical/medicals	84	9% (10%)	85	7% (13%)	133	7% (9%)	25	2% (4%)	327
Vehicles	9	1% (3%)	9	1% (2%)	21	1% (3%)	25	2% (4%)	64
Furnitures/others	6	1% (1%)	73	6% (7%)	0	0% (8%)	189	11% (10%)	268
Total	977		1139		1809		1648		5573

Notes: Shares refer to sector at the national level. Shares reported in parenthesis refer to the original EFIGE survey sample.

Table 3. Percentage of firms engaging in R&D and exporting sorted by country and size.

	Employees (10–19)		Employees (20–49)	
Country	Firms with RD = 1	Firms with EXP = 1	Firms with RD = 1	Firms with EXP = 1
FRA	31% (34%)	33% (34%)	44% (44%)	47% (45%)
GER	35% (30%)	36% (29%)	48% (46%)	44% (40%)
ITA	31% (31%)	55% (55%)	46% (45%)	68% (65%)
SPA	30% (30%)	38% (37%)	40% (42%)	50% (50%)
	Employees (50–249)		Employees (250 and over)	
Country	Firms with RD = 1	Firms with EXP = 1	Firms with RD = 1	Firms with EXP = 1
FRA	61% (61%)	63% (61%)	76% (74%)	82% (76%)
GER	63% (63%)	57% (55%)	75% (75%)	56% (58%)
ITA	61% (63%)	83% (80%)	85% (79%)	84% (87%)
SPA	57% (55%)	66% (67%)	66% (69%)	79% (83%)

Notes: Shares reported in parenthesis refer to the original EFIGE survey sample.

investing in R&D (51%). Importantly, the distribution of investing and exporting firms across countries and size classes reflects the distribution reported using the original EFIGE sample; thus, no important distortions are introduced when we focus on these variables for the final sample of firms with full accounting data.

Table 4 reports the joint distribution of the dummy variables *RD* and *EXP*. As expected and suggested by economic theory, the majority of firms investing in R&D are also exporters (68.96%), as well as the majority of exporting firms also invest in R&D (54.92%).

3.2. *Total factor productivity*

From balance sheet data we retrieve information on firm's TFP. To calculate TFP, we run separately for each sector (using the NACE Rev.2 two digit classification) the Levinsohn and Petrin (2003) semi-parametric production function estimation algorithm, controlling for country and year fixed-effects. As in Altomonte, Aquilante, and Ottaviano (2012), variables included in the estimation of the production function are: value added, deflated using industry-specific (NACE rev 1.1) price indexes retrieved from Eurostat, as a proxy for outcome; number of employees as a proxy for labor input; value of tangible fixed assets deflated using the GDP deflator as a proxy for capital;

Table 4. Number of exporting and innovating firms.

Number of firms with:	EXP = 0	EXP = 1	Total
RD = 0	1744	1384	3128
RD = 1	759	1686	2445
Total	2503	3070	5573

Table 5. Average TFP in 2008 by size classes, EXP and RD variables.

Size classes	EXP = 0	EXP = 1	RD = 0	RD = 1
Employees (10–19)	0.755 (0.333)	0.831 (0.490)	0.764 (0.363)	0.847 (0.505)
Employees (20–49)	0.876 (0.539)	0.989 (0.919)	0.877 (0.539)	1.016 (0.991)
Employees (50–249)	1.030 (0.597)	1.134 (0.738)	1.050 (0.832)	1.132 (0.591)
Employees (250 and over)	1.463 (1.402)	1.746 (1.275)	1.657 (1.160)	1.662 (1.367)
Total	0.856 (0.522)	1.003 (0.813)	0.860 (0.550)	1.036 (0.847)

Note: Standard deviations in parenthesis.

cost of materials, deflated by average industry-specific Producers Price Indexes weighted by ESA95 Input–Output table coefficients (also retrieved from Eurostat).

The values computed for 2008 TFP range from a minimum of 0.018 to a maximum of 19.370, with an average of 0.937, that is slightly lower than the average value for 2007 (see Table 8 at the end of this section for the descriptive statistics). Table 5 shows that, consistently with the theory, firm's productivity in year 2008 increases with firm's size. Average TFP is also higher for firms engaging in exporting activities vs. those not exporting, and the same is true for firms engaging in R&D.

3.3. *Credit constraints and firm-level control variables*

A first proxy for firm's credit constraints can be retrieved from a direct indicator of credit rationing available in the survey. This is defined on the basis of the answer to the following question: 'During the last year (2009), did the firm apply for more credit?'. We use the firm's answer to this question to build a dummy variable *DENIED* which takes the value of one (*DENIED* = 1) for firms answering 'Yes, applied for it but was not successful' and zero (*DENIED* = 0) for firms answering either 'Yes, applied for it and was successful' or 'No, did not apply for it'. The question was asked only to firms answering 'yes' to a previous question in the survey: 'During the last year (2009), was the firm willing to increase its borrowing at the same interest rate of its current credit line?'. Therefore, we have a direct indicator of credit rationing only for a fraction of firms in the sample. This fraction is relatively small (18% in the original sample, and 20% in the final sample) and we clearly face a sample selection problem, which we need to address in order to improve the identification of credit constrained firms. To circumvent this issue, we have obtained the predicted probability of being credit rationed from the following probit model with sample selection (Van de Ven and Van Pragg 1981; Greene 1998):

$$\begin{cases} \text{MORECRED}_i = 1\ [X_{1i}\beta_1 + u_{1i} > 0], & \text{(1a)} \\ \text{DENIED}_i = 1\ [X_{2i}\beta_2 + u_{2i} > 0], & \text{(1b)} \end{cases}$$

where 1[ ] is an indicator function that takes the value of 1 when its argument in squared brackets is satisfied and 0 otherwise.

The model specification we adopt is similar to the one used by Piga and Atzeni (2007). The dependent variable of the first-stage selection Equation (1a) *MORECRED* is a dummy variable which takes the value of 1 if the firm answered 'yes' to the question 'During the last year (2009), was the firm willing to increase its borrowing at the same interest rate of its current credit line?' and 0 otherwise. The set of explanatory variables X_1 includes a constant term; the firm's sector and country dummy variables; the logarithm of the firm's number of employees (*logSIZE*); the logarithm of the firm's number of years since its foundation (*logAGE*); the ratio of firm's cash flow over total assets (*CF*)[9]; the firm's yearly sales growth rate (*SG*); the logarithm of firm's total factor productivity (*logTFP*). All explanatory variables refer to year 2008 (i.e. they are lagged by one year with respect to the dependent variable *MORECRED*), with the exception of *logTFP* which refers to year 2007.[10]

The dependent variable *DENIED* in the second-stage probit Equation (1b) is observed only when *MORECRED* = 1 and it is explained by a set of covariates X_2 including again: the constant term; dummy variables for the firm's sector and country; the ratio of firm's cash flow over total assets (*CF*); firm's yearly sales growth rate (*SG*); some other firm's observable financial characteristics that may influence the bank's decision to grant or deny credit to the firm, such as the ratio of firm's long-term debt over total assets (*LTDEBT*), the ratio of firm's current liabilities over total assets (*CLIABILITIES*), the ratio of firm's net hirings over total employees (HIRINGS) and the logarithm of firm's sales (*logSALES*).[11] As in Equation (1a), all these variables refer to year 2008 (i.e. they are lagged one year with respect to the dependent variable *DENIED*), since these financial characteristics should be observable by the bank when deciding to grant or deny credit to the firm.

The error terms u_1 and u_2 are assumed to follow a bivariate standard normal distribution $(u_1,u_2) \sim N(0,1)$ with correlation coefficient $\rho = \text{corr}(u_1,u_2)$.

Results from the probit model with sample selection are presented in Table 6. Only 52% of firms included in our final sample answered the question about their willingness to increase their borrowing. More than half of these answered negatively, and therefore were not asked about having being denied credit. Thus, only 20% of firms included in our final sample answered the question about being credit rationed.[12] To improve the accuracy of the estimates, the probit model with sample selection is therefore run over the full set of firms for which the variable *MORECRED* is observable, independently from them being in our final sample. The probit model with sample selection is therefore estimated using a sub-sample of 3867 firms, out of 11,761.

From column (1) we can see that big and young firms are, *ceteris paribus*, more likely to ask for additional bank financing. By contrast, as expected, firms with higher productivity and higher cash flow show less need for additional external finance. The availability of internally generated cash

Table 6. Estimation results of the probit model with sample selection.

Variables Equations	(1) MORECRED (1a)	(2) DENIED (1b)
CF	−0.928***	−0.095
	(0.204)	(0.445)
SG	−0.116	−0.165
	(0.095)	(0.146)
logTFP (2007)	−0.293***	
	(0.063)	
logAGE	−0.083***	
	(0.026)	
logSIZE	0.133***	
	(0.026)	
LTDEBT		0.447*
		(0.245)
HIRINGS		0.000
		(0.000)
CLIABILITIES		0.948***
		(0.274)
logSALES		−0.090**
		(0.040)
Constant	−1.377***	−0.192
	(0.157)	(0.719)
Rho	−0.799* (0.459)	
Observations	3867	

Notes: Dummy variables for sectors and countries included.
LR test of indep. eqns. ($\rho = 0$): $\chi^2(1) = 2.97$ Prob > $\chi^2 = 0.08$.
Standard errors in parenthesis.
*$p < .1$.
**$p < .05$.
***$p < .01$.

flow seems also to neutralize the possible increased propensity to ask for more credit during expansion periods, given that sales growth is not statistically significant. Results reported in column (2) show that, as expected, credit applications by highly indebted firms are more likely to be rejected.[13] In particular, firms with high current liabilities and long-term debts are more likely to have their credit requests denied. The firm's volume of sales positively affects the bank's decision to grant credit, while its yearly growth rate, the percentage increase in the number of employees and cash flow do not seem to affect this decision.

The null hypothesis that ρ is equal to zero is rejected at the 10% level. This confirms that the probit with sample selection has to be preferred to a single equation probit model not taking into account the selection process generated by firms applying for more credit. Therefore, we use the estimates from this model to compute the marginal predicted probability to be denied more credit (*DENIEDpred*). This predicted value is used, for each firm in our final sample, as a proxy for the firm's probability to face credit constraints once its willingness to increase its borrowing is taken into account.

The average predicted probability of having a credit application denied equals to 47.18%, with small firms presenting a higher predicted rejection rate than large ones (see Table 7). On average, German firms have the lowest predicted probability to be credit constrained whereas Italian firms are the more credit constrained. The average predicted probability to be denied credit is higher for firms that were actually denied credit (56.67%) than for firms that received credit (49.92%).

3.4. *Control variables at the industry and regional level*

In addition to the set *X* of firm-level control variables introduced in the previous section, we also create a set *Z* of variables defined at the industry-regional level. The first variable, *share_EXP*, is computed as the share of exporting firms located in the same region (defined at the NUTS 2 level) and operating in the same industry (defined at the NACE 2 digit level) as the focal firm *i*.[14] A similar methodology has been adopted by Laeven and Levine (2009) in order to build instrumental variables (IVs) aiming at capturing 'peers' spillover effects, where the group of 'peers' is identified as the firms operating in the same 'environment' (region and industry) as the focal one.

The second variable, *share_RD*, is computed in the same vein as the previous one, but considering the share of R&D active firms instead of the share of exporting ones. The third variable (*share_EXP_incent*) is computed as the region-industry share of firms answering 'yes' to the following question: 'Has the firm benefited from any kind of tax allowances and financial incentives on export?'. The fourth variable (*share_RD_incent*) is computed in the same way, but considering tax allowances and financial incentives on R&D instead of export. The last variable (*ext_fin_dep)*, is defined as the average score that firms located in the same region and operating in the same industry as the focal one (*i*) gave when answering the following question: 'In the industry where your firm is active, how dependent are companies on external financing? To give your answer please use a score from 1 (not dependent all) to 5 (Extremely dependent)'.

Table 8 summarizes the main descriptive statistics for the complete set of dependent and control variables. Averages for *share_EXP* and *share_RD* are similar to overall averages (0.551 and 0.439, respectively), from which they differ just because of the exclusion of the focal firm. On average,

Table 7. Predicted probability to be denied credit (*DENIEDpred*) sorted by country and firm size.

Size classes	FRA	GER	ITA	SPA	Total
Employees (10–19)	52.54%	34.13%	55.90%	50.80%	51.44%
Employees (20–49)	51.94%	31.65%	53.27%	48.50%	46.83%
Employees (50–249)	48.81%	29.11%	50.29%	44.76%	40.92%
Employees (250 and over)	49.92%	28.96%	49.40%	42.35%	39.01%
Total	51.28%	31.26%	54.01%	48.68%	47.18%

Table 8. Descriptive statistics for dependent variables, control and regional/industry characteristics.

Variable	Observations	Mean	Std. dev.	Min	Max
EXP	5573	0.551	0.497	0	1
RD	5573	0.439	0.496	0	1
DENIEDpred	5573	0.472	0.134	0.120	0.885
TFP	5546	0.937	0.701	0.018	19.370
logTFP	5546	−0.191	0.466	−4.037	2.964
CF	5573	0.057	0.164	−0.764	0.530
SG	5573	0.022	0.214	−0.508	1.041
TFP (2007)	5573	0.939	0.601	0.055	11.939
logTFP (2007)	5573	−0.175	0.447	−2.903	2.480
logAGE	5573	3.181	0.837	0	5.236
logSIZE	5573	3.429	0.868	2.303	9.903
LTDEBT	5573	0.137	0.192	0	0.949
HIRINGS	5573	48.363	97.836	7	966
CLIABILITIES	5573	0.437	0.247	0	1.105
logSALES	5573	8.408	1.194	6.051	12.507
share_EXP	5573	0.537	0.231	0	1
share_EXP_incent	5440	0.153	0.174	0	1
share_RD	5573	0.438	0.204	0	1
share_RD_incent	5433	0.299	0.232	0	1
ext_fin_dep	5573	2.754	0.535	1	5

around 30% of firms benefit from R&D incentives, whereas the share of firms benefiting from tax allowances and financial incentives on export is definitely lower (15.3%).

4. Empirical findings

We first estimate a set of single equation models in order to explore signs and magnitudes of the correlations amongst the variables of interest (Section 4.1). In Section 4.2, we take into account the mutual relationships that characterize our variables by adopting a recursive simultaneous equation model with correlated error terms. In Section 4.3, we provide some robustness exercises on an alternative measure of financing constraints, not necessarily associated with bank financing, as well as on the intensive margins of both export and R&D. Although we miss a sufficient number of reliable instruments to fully estimate causal effects in our framework, in Section 4.4 we address endogeneity concerns through a combination of lagged variables and IVs, thereby providing a plausible causal interpretation of some of our results.

4.1. *Single equation regressions*

Table 9 shows the results from the single equation regressions where the dependent variable are, respectively, the dummy for being an exporter (*EXP*), the dummy for investing in R&D (*RD*), the predicted probability of being credit constrained (*DENIEDpred*) and the log of total factor productivity (*logTFP*). All dependent and control variables are evaluated in year 2008 and equations are estimated using OLS and, where relevant, maximum likelihood probit.[15] Since *DENIEDpred* is the marginal predicted probability generated from model (1b), we apply robust standard errors in all regressions.[16] All equations include the set *Z* of firm and industry-region control variables.[17] Time invariant control dummy variables for firm's industry and firm's country have also been added, in order to control for possible differences across industries or countries (e.g. in the national fiscal framework).

Results, reported in Table 9, show that, *ceteris paribus*, the probability of exporting is positively associated with R&D investment and TFP. By contrast, a negative correlation is found between TFP and exporting, on one side, and the predicted probability of being credit constrained on the other, with no correlation detected between credit constraints and R&D.

The share of exporting firms located in the same region and operating in the same sector (*share_EXP*) has a positive and significant effect on the focal firm's propensity to export and on its

Table 9. Single equation regression models (obs. 5340).

Dependent variable	(1) *EXP*	(2) *EXP*	(3) *RD*	(4) *RD*	(5) *DENIEDpred*	(6) *logTFP*
Estimation method	Probit	OLS	Probit	OLS	OLS	OLS
EXP			0.532***	0.193***	−0.007***	0.044***
			(0.042)	(0.015)	(0.003)	(0.013)
RD	0.532***	0.190***			0.000	0.040***
	(0.042)	(0.015)			(0.003)	(0.013)
DENIEDpred	−0.775***	−0.271***	0.053	0.005		−1.574***
	(0.262)	(0.091)	(0.264)	(0.092)		(0.088)
logTFP	0.177***	0.059***	0.160***	0.055***	−0.058***	
	(0.052)	(0.018)	(0.050)	(0.017)	(0.003)	
logSIZE	0.173***	0.057***	0.267***	0.093***	−0.010***	0.134***
	(0.025)	(0.008)	(0.024)	(0.008)	(0.001)	(0.008)
logAGE	0.092***	0.032***	0.029	0.010	−0.016***	−0.031***
	(0.025)	(0.009)	(0.025)	(0.009)	(0.002)	(0.008)
share_EXP	0.522***	0.182***	0.028	0.009	0.000	0.106***
	(0.125)	(0.044)	(0.123)	(0.042)	(0.007)	(0.035)
share_EXP_incent	0.053	0.015	−0.039	−0.015	0.009	0.021
	(0.130)	(0.045)	(0.129)	(0.043)	(0.008)	(0.038)
share_RD	−0.143	−0.052	−0.424***	−0.145***	0.004	0.188***
	(0.143)	(0.050)	(0.143)	(0.049)	(0.008)	(0.041)
share_RD_incent	−0.103	−0.036	0.164*	0.057*	−0.013**	−0.004
	(0.094)	(0.033)	(0.092)	(0.032)	(0.005)	(0.029)
ext_fin_dep	−0.007	−0.002	0.039	0.012	0.004	−0.046***
	(0.061)	(0.021)	(0.059)	(0.020)	(0.003)	(0.018)
Constant	−1.126***	0.114	−1.512***	−0.027	0.515***	0.083
	(0.249)	(0.086)	(0.251)	(0.086)	(0.012)	(0.080)
R^2		0.149		0.141	0.682	0.288

Notes: Dummy variables for sectors and countries included.
Robust standard errors in parenthesis.
*$p < .1$.
**$p < .05$.
***$p < .01$.

TFP. This finding can be explained by the presence of localized positive knowledge spillover effects concerning the expertise required to access foreign markets, or by the presence of some form of cooperative networking among peers, which fosters the creation of regional and sectorial exporting firm clusters. The share of firms benefitting from financial incentives on export is instead never significant (*share_EXP_incent*). The share of firms investing in R&D in the same region and sector (*share_RD*) is related to a lower propensity, for the focal firm *i*, to undertake the same investments, whereas it is positively related to its productivity. This may happen because of competitive effects arising from potential duplication in effort and because of the presence of localized knowledge spillovers. With imperfect appropriability, the focal firm can benefit from innovation realized by the peers through their R&D investments and this reduces its incentive to invest in innovation. The share of firms benefitting from incentives to invest in innovation (*share_RD_incent*) is positively associated with the decision to invest in R&D, while it correlates negatively with the probability to be credit constrained. Finally, the region-sector average dependence on external finance is negatively correlated with firm's productivity.

4.2. *Simultaneous equations system*

In order to take into account the simultaneous mutual relationships among exporting, R&D, financial constraints and TFP we estimate the following simultaneous equations model:

$$\begin{cases} \text{EXP}_i = \alpha_{11}\text{RD}_i + \alpha_{12}\text{DENIEDpred}_i + \alpha_{13}\text{logTFP}_i + \beta_1 X_i + \gamma_1 Z_{1i} + u_{1i}, & \text{(2a)} \\ \text{RD}_i = \alpha_{21}\text{EXP}_i + \alpha_{22}\text{DENIEDpred}_i + \alpha_{23}\text{logTFP}_i + \beta_2 X_i + \gamma_2 Z_{2i} + u_{2i}, & \text{(2b)} \end{cases}$$

$$\begin{cases} \text{DENIEDpred}_i = \alpha_{31}\text{EXP}_i + \alpha_{32}\text{RD}_i + \alpha_{33}\text{logTFP}_i + \beta_3 X_i + \gamma_3 Z_{3i} + u_{3i}, & \text{(2c)} \\ \text{logTFP}_i = \alpha_{41}\text{EXP}_i + \alpha_{42}\text{RD}_i + \alpha_{43}\text{DENIEDpred}_i + \beta_4 X_i + \gamma_4 Z_{4i} + u_{4i}, & \text{(2d)} \end{cases}$$

where X is the same set of control variables used in Section 4.1, and Z_1, Z_2, Z_3 and Z_4 are four different subset of the Z industry-region variables already used in the single equation regressions. Each subset of controls includes only the variables specific to each equation. In particular, Z_1 includes the two variables concerning export; Z_2 includes the two variables concerning innovation; Z_3 includes the share of firms benefitting from export incentives, the share of firms benefitting from R&D incentives and the average external finance dependence; Z_4 includes the share of firms involved in internationalization, the share of firms involved in innovation and the average external finance dependence. The incorporation of these Z variables with appropriate exclusion restrictions allows for the identification of the system.

The simultaneous equations are estimated using the SURs estimation procedure proposed by Zellner (1962, 1963) and Zellner and Huang (1962), assuming an unstructured variance–covariance matrix of the error terms. Results, reported in Table 10, confirm our preliminary findings and show a strong positive association between R&D, export and productivity. Exporting and productivity are negatively correlated with credit constraints, while, again, no significant direct relationship between the probability to be denied credit and R&D is found. The latter finding might suggest that banks are able to evaluate more accurately the quality of exporting activities than that of R&D investments. It may also suggest that firms do not rely on bank credit to fund their R&D activities. However, it does not necessarily imply the lack of any association between credit constraints and R&D, because of the presence of indirect links operating through export and productivity. Concerning the magnitude of the estimated coefficients, partial correlation coefficients between *EXP* and *RD* in

Table 10. Simultaneous regression equations (obs. 5340).

Dependent variable	(1) *EXP*	(2) *RD*	(3) *DENIEDpred*	(4) *logTFP*
Equation	(2a)	(2b)	(2c)	(2d)
EXP		0.368***	−0.011***	0.063***
		(0.013)	(0.002)	(0.012)
RD	0.364***		0.003	0.066***
	(0.013)		(0.002)	(0.012)
DENIEDpred	−0.419***	0.136		−2.860***
	(0.083)	(0.083)		(0.065)
logTFP	0.085***	0.091***	−0.105***	
	(0.016)	(0.016)	(0.002)	
logSIZE	0.028***	0.073***	−0.001	0.103***
	(0.008)	(0.008)	(0.001)	(0.007)
logAGE	0.028***	0.005	−0.015***	−0.052***
	(0.008)	(0.008)	(0.001)	(0.007)
share_EXP	0.147***			0.078**
	(0.037)			(0.033)
share_EXP_incent	0.008		0.008	
	(0.041)		(0.007)	
share_RD		−0.158***		0.162***
		(0.042)		(0.037)
share_RD_incent		0.051*	−0.010**	
		(0.030)	(0.005)	
ext_fin_dep			0.001	−0.035**
			(0.003)	(0.016)
Constant	0.214***	−0.020	0.484***	0.815***
	(0.063)	(0.065)	(0.011)	(0.067)
R^2	0.119	0.112	0.660	0.238

Notes: Industry and country dummies included.
Standard errors in parenthesis.
*$p < .1$.
**$p < .05$.
***$p < .01$.

Equation (2a) and (2b), between *EXP* and *logTFP* in Equation (2a) and (2d) and between *RD* and *logTFP* in Equation (2b) and (2d) are of similar size. Considerable differences are instead found when we compare the partial correlation coefficients between *DENIEDpred* and *EXP* or *logTFP* in Equation (2a) and (2d), respectively, vs. the correspondent partial correlation coefficients obtained when *DENIEDpred* is used as dependent variable (Equation (2c)). The latter coefficients turn out to be smaller in absolute terms. These differences in magnitude can be explained by the fact that *DENIEDpred* has a sample standard deviation (see Table 8) which is about three times smaller than the ones of *EXP* and *logTFP*. Thus, it is not surprising that the partial correlation coefficient estimated for a one-point increase of *DENIEDpred* is (in absolute terms) far larger than the ones estimated for one-point increase of *EXP* or *logTFP*.

Looking at the role played by our control variables we find that, on average, large firms are more likely to export and to do R&D and that size also positively correlates with productivity. Age is positively related to export, but shows no correlation with R&D. Indeed, firms will be able to start exporting after having reached an established position on the market, while R&D can be a core activity in young dynamic and entrepreneurial companies. Finally, age negatively correlates with both our credit constraints indicator and with productivity. As for the industry-region controls, again the focal firm's propensity to export is positively and significantly correlated with the share of exporting firms (*share_EXP*) located in the same region and operating in the same sector (the 'peers'), but not with public policies in the form of fiscal incentives to export (*share_EXP_incent*). By contrast, the focal firm's propensity to invest in R&D is positively correlated with the fiscal incentives aimed at supporting R&D investment (*share_RD_incent*) and negatively with the share of R&D investing firms located in the same region and operating in the same sector (*share_RD*). Again, the latter may be suggestive of prevailing competition effects in innovative efforts. The variable *share_RD_incent* is negatively correlated with the probability to be credit constrained, while the variables *share_EXP_incent* and *ext_fin_dep* are not significantly correlated with *DENIEDpred*. Finally, both the shares of exporting firms and that of innovating firms are positively related to firm's productivity: this seems to confirm that firms benefit from being active in an environment where peers are engaged in exporting and innovation. By contrast, being active in an environment highly dependent on external finance goes along with lower productivity.

4.3. *Robustness checks and intensive margins*

As a robustness check for the previous analysis, we use an alternative indirect measure of financing constraints proposed by Whited and Wu (2006),[18] henceforth WW. This is an index based on firm's characteristics and does not directly depend on bank's decision, but rather measures the firm's need of external finance. In the author's original article, the WW index is obtained as a solution to a constrained maximization problem of a structural investment model and it is defined as follows[19]:

$$\begin{aligned} WW = &-0.091 \times CF - 0.062 \times DIVPOS + 0.021 \times TLTD - 0.044 \times LNTA + 0.102 \times ISG \\ &- 0.035 \times SG\,, \end{aligned} \tag{3}$$

where *CF* is the ratio of cash flow to total assets; *DIVPOS* is a dummy variable that takes the value of one if the firm pays cash dividends[20]; *TLTD* is the ratio of the long-term debt to total assets; LNTA is the natural log of total assets; *ISG* is the firm's three-digit industry sales growth rate (measured, in our case, at the country level over all firms included in the AMADEUS database); and finally SG is the firm sales growth rate. Since we are interested in the financial situation of the firm in year 2008, the variables included in the index refer to that year.[21]

In order to improve the comparability across countries of this measure of financial constraints, we compute a modified version of the index (*WWdiff*) obtained by subtracting the country sample median from each firm's value of the original WW index. Descriptive statistics for both *WW* and

Table 11. FC indexes (reference year 2008).

Variable	Observations	Population	Mean	Std. dev.	Min	Max
WW	5573	120,388	−0.384	0.076	−0.764	−0.052
WWdiff	5573	120,388	−0.004	0.076	−0.374	0.338

WWdiff are reported in Table 11: firms having a negative value for *WWdiff* are less constrained than firms having a positive value.

Notice that *WWdiff* and *DENIEDpred* measure two different aspects of financial constraints: while *DENIEDpred* exploits a direct indicator measuring the probability to have a credit application denied by the main bank, *WWdiff* is an indirect indicator measuring the firm's shadow cost of external finance. Nevertheless, the two measures provide consistent information: the average value of *WWdiff* for firms with *DENIEDpred* below the sample median is lower than that of firms above the median value of *DENIEDpred* (−0.035 vs. 0.010). Thus, on average, firms with a lower probability to be denied credit by the bank (as measured by *DENIEDpred*) also show a lower need of external finance (as measured by the *WWdiff* indicator).

Table 12 presents the results from the estimation of the simultaneous Equation (2a)–(2d) this time using *WWdiff* to proxy for financing constraints instead of *DENIEDpred*. Most of the findings discussed in the previous sections are confirmed. In particular, although we now have a more general indicator of financing constraints (or needs), not necessarily tied to bank financing, the latter variable still displays no significant direct correlation with the probability to perform R&D.

As an additional robustness check, we take into account the fact that both export and R&D are characterized by high entry sunk costs, which have greater relevance in a firm's decision to

Table 12. Simultaneous regression equations (Obs. 5340). *WWdiff* proxy for financing constraints.

	(1)	(2)	(3)	(4)
Dependent variable	*EXP*	*RD*	*WWdiff*	*logTFP*
Equation	(2a)	(2b)	(2c)	(2d)
EXP		0.366***	−0.014***	0.033***
		(0.013)	(0.002)	(0.011)
RD	0.361***		0.000	0.056***
	(0.013)		(0.002)	(0.011)
WWdiff	−1.010***	0.044		−4.405***
	(0.115)	(0.116)		(0.086)
logTFP	0.046***	0.079***	−0.086***	
	(0.016)	(0.016)	(0.002)	
logSIZE	−0.007	0.074***	−0.034***	−0.058***
	(0.009)	(0.009)	(0.001)	(0.008)
logAGE	0.035***	0.003	0.001	−0.002
	(0.008)	(0.008)	(0.001)	(0.007)
share_EXP	0.147***			0.066**
	(0.037)			(0.032)
share_EXP_incent	0.009		0.004	
	(0.041)		(0.005)	
share_RD		−0.157***		0.153***
		(0.042)		(0.036)
share_RD_incent		0.052*	−0.002	
		(0.030)	(0.003)	
ext_fin_dep			−0.004*	−0.054***
			(0.002)	(0.016)
Constant	0.095**	0.041	0.091***	−0.100*
	(0.048)	(0.049)	(0.008)	(0.057)
R^2	0.121	0.113	0.438	0.254

Notes: Industry and country dummies included.
Standard errors in parenthesis.
*$p < .1$
**$p < .05$.
***$p < .01$.

Table 13. Simultaneous regression equations (Obs. 5106). Intensive margins.

Dependent variable	(1) *EXPint*	(2) *RDint*	(3) *DENIEDpred*	(4) *logTFP*
EXPint		0.083***	−0.0002***	0.0012***
		(0.004)	(0.0000)	(0.0002)
RDint	0.937***		0.0001	−0.0011
	(0.046)		(0.0002)	(0.0008)
DENIEDpred	−22.417***	0.668		−2.869***
	(4.241)	(1.269)		(0.066)
logTFP	4.081***	−0.360	−0.105***	
	(0.813)	(0.243)	(0.002)	
logSIZE	5.267***	−0.211*	−0.001	0.106***
	(0.418)	(0.127)	(0.001)	(0.007)
logAGE	1.011**	−0.243**	−0.015***	−0.049***
	(0.405)	(0.121)	(0.001)	(0.007)
share_EXP	10.193***			0.078**
	(1.913)			(0.034)
share_EXP_incent	4.831**		0.010	
	(2.091)		(0.007)	
share_RD		−1.490**		0.145***
		(0.638)		(0.038)
share_RD_incent		0.142	−0.011**	
		(0.458)	(0.005)	
ext_fin_dep			0.001	−0.040**
			(0.003)	(0.017)
Constant	−8.266**	2.772***	0.479***	0.858***
	(3.261)	(0.988)	(0.011)	(0.069)
R^2	0.178	0.039	0.657	0.230

Notes: Industry and country dummies included.
Standard errors in parenthesis.
*$p < .1$.
**$p < .05$.
***$p < .01$.

engage in these activities (the extensive margin). Hence, we further explore whether previous estimation results also hold when considering the intensive margins of export and R&D investment, that is, whether variable, rather than fixed, costs also play a significant role. Indeed, Table 13 presents the results obtained when considering the intensive margins of both export and R&D, measured as the 2007–2009 average percentage of export and R&D on total turnover (*RDint* and *EXPint*, respectively).[22] Results are again mostly consistent with our previous findings. The most notable change is that here TFP and R&D intensity are not significantly correlated: while more productive firms display a higher likelihood to engage in R&D activities, there is no correlation between the extent of R&D effort and the level of TFP. Also of interest is the now significant correlation between the share of firms benefiting from export incentives and the intensity of the focal firm's export.

4.4. *Causality*

In this section we analyze the plausible causal links going from productivity, financing constraints and R&D to export (Equation (2a)) and from productivity, financing constraints and export to R&D (Equation (2b)), by using a combination of lagged variables and IVs to address or at least reduce endogeneity concerns. In particular, our data allow us to lag by one year both TFP and the WW financing constraints index, which the previous sections showed to work analogously to our preferred *DENIEDpred* measure. We thus use *logTFP*$(t-1)$ instead of *logTFP*(t) and *WWdiff*$(t-1)$ instead of *DENIEDpred*(t) in Equation (2a) and (2b), where $(t-1)$ refers to 2007. Using lagged values for these regressors in Equation (2a) and (2b) help to reduce the endogeneity concerns arising from possible simultaneous feedbacks coming from current R&D and exporting activities.

As we cannot compute lagged values for both *RD* and *EXP*, we address the simultaneity between these two variables by using two stages least-square (2SLS) IV estimation methods. As instruments, we draw from the set of *Z* industry-region variables used in the previous sections plus two additional variables retrieved from the EFIGE survey in order to improve the overall instrument's relevance. The first additional IV is the industry-region average share of white collars (*share_whitecollars*) and is drawn from a question of the EFIGE survey asking information on the firm's workforce composition. This variable addresses the endogeneity of *RD* in the export Equation (2a). The rationale behind this choice is that engaging in R&D activities should be easier for firms localized in areas with a high concentration of labour-skilled human capital because of the lower search costs in hiring R&D personnel. A key assumption for the validity of the instrument is that these localized benefits should not affect the firm's propensity to export directly, but only indirectly through the increased probability of doing R&D, once controlling for other firm's characteristics (such as size, productivity and availability of external finance). The second additional instrument is a dummy variable which is equal to 1 if the firm occasionally

Table 14. Lagged and IVs regressions.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	*EXP*	*EXP*	*EXP*	*RD*	*RD*	*RD*
Estimation method	OLS	OLS	IV-2SLS	OLS	OLS	IV-2SLS
EXP				0.189***	0.188***	0.296***
				(0.0151)	(0.015)	(0.109)
RD	0.184***	0.182***	0.381**			
	(0.015)	(0.015)	(0.179)			
WWdiff	−0.579***			−0.141		
	(0.122)			(0.122)		
WWdiff(t − 1)		−0.729***	−0.678***		−0.085	−0.001
		(0.119)	(0.114)		(0.122)	(0.137)
logTFP(t − 1)	0.072***	0.047**	0.037*	0.039**	0.047**	0.040**
	(0.019)	(0.020)	(0.021)	(0.019)	(0.020)	(0.019)
logSIZE	0.037***	0.031***	0.011	0.090***	0.091***	0.086***
	(0.009)	(0.010)	(0.021)	(0.009)	(0.010)	(0.011)
logAGE	0.036***	0.040***	0.038***	0.006	0.004	−0.001
	(0.009)	(0.009)	(0.008)	(0.009)	(0.009)	(0.009)
share_EXP	0.181***	0.181***	0.166***	0.018	0.013	1st stage IV
	(0.044)	(0.045)	(0.039)	(0.043)	(0.043)	
share_EXP_incent	0.021	0.016	0.007	−0.005	−0.007	1st stage IV
	(0.044)	(0.044)	(0.042)	(0.043)	(0.043)	
share_RD	−0.044	−0.043	1st stage IV	−0.154***	−0.151***	−0.147***
	(0.050)	(0.051)		(0.049)	(0.050)	(0.043)
share_RD_incent	−0.039	−0.031	1st stage IV	0.067**	0.076**	0.077**
	(0.033)	(0.033)		(0.032)	(0.033)	(0.031)
share_whitecollars	0.142	0.146	1st stage IV	0.406***	0.351***	0.328***
	(0.108)	(0.114)		(0.104)	(0.106)	(0.099)
pastEXPocc	0.115***	0.118***	0.109***	0.016	0.016	1st stage IV
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	
Constant	−0.017	−0.023	−0.001	−0.098	−0.081	−0.078
	(0.060)	(0.061)	(0.051)	(0.063)	(0.064)	(0.058)
Under-ident test			28.783			79.146
(Anderson LM stat.)			[0.0001]			[0.0001]
Weak-ident test			9.601			26.66
(Cragg-Donald *F* stat.)			[0.0001]			[0.0001]
Over-ident test			2.689			0.100
(Sargan statistic)			[0.261]			[0.951]
Observations	5357	5222	5222	5357	5222	5222
R^2	0.162	0.168	0.132	0.144	0.143	0.133

Notes: Dummy variables for sectors and countries included.
Robust standard errors in parenthesis.
*$p < .1$, p-values in brackets.
**$p < .05$.
***$p < .01$.

exported before 2008 (*pastEXPocc*), and is again drawn from a question in the EFIGE survey. Specifically, the variable addresses the endogeneity of *EXP* in the R&D Equation (2b). The validity of this IV relies on the well-known persistency of the export activity due to the presence of fixed costs of exporting, with previous exporting experience increasing the current probability of exporting. At the same time, the idea is that previous occasional exporting activities should be weakly or un-related with the firm's current probability to invest in R&D, once controlling for other factors that drive past exports (such as lagged TFP and lagged credit constraints).

Table 14 reports the estimation results of the new set of single equation regressions augmented with the IV strategy. Columns (1) and (2) report the OLS estimation results when considering the probability to export (*EXP*) as dependent variable and using lagged values of *logTFP* and *WWdiff* as regressors. These results are quite close to the SUR estimates reported in column (1) of Table 12, although the magnitude of the coefficient associated with *RD* is now lower. A coefficient for R&D similar to the one reported in Table 12 is found again when we address the endogeneity of R&D through the IV-2SLS estimator (column 3). The comparison of the two coefficients suggests the presence of a downward bias when the simultaneity between *RD* and *EXP* is not taken into account. Similar conclusions can be drawn when comparing the estimates of columns (4)–(6) with the SUR estimates of column (2) in Table 12. The SUR estimate of the parameter associated to *EXP* is not too different from the IV-2SLS one for which we can infer a causal interpretation. Columns (1–6) also provide some evidence concerning the relevance and validity of our set of IVs. The relevance condition is supported by the rejection of the Anderson LM under-identification test and the Cragg-Donald weak-identification test in both columns (3) and (6), even when considering the 5% critical values reported by Stock and Yogo (2005). The exogeneity condition (although not formally testable) is supported by the non-rejection of the Sargan tests in both columns (3) and (6) and by the fact that none of the IVs are statistically significant when included in columns (1,2) and (4,5), respectively.

Clearly, the above empirical exercise can only provide a partial assessment concerning the mutual causal effects among R&D, export, TFP and financing constraints. Further research and richer data availability are needed in order to shed more light on the complex relationship involving these variables. However, we believe this evidence confirms the results of our previous analysis, suggesting a causal relationship pointing to a direct effect of financing constraints on export and an indirect effect on R&D.

5. Conclusions and policy implications

To the best of our knowledge, this is the first contribution providing joint empirical evidence on the mutual relationships among financing constraints, innovation, exporting activities and TFP in a simultaneous equation framework. Results confirm the well-known mutual correlation between exporting and R&D as well as the existence of a circular relationship between exporting and financial constraints: *ceteris paribus*, exporting firms are less likely to have their credit applications denied, and firms that are not credit constrained are also more likely to export. By contrast, we find that investing in R&D is not directly correlated with the probability to be credit constrained. However, this does not necessarily imply that financial frictions do not affect the ability of firms to pursue R&D, as indirect effects operating through export and productivity may still be in place. This is in line with recent findings (Caggese 2014) showing that indirect effects of financial frictions are much more important for innovation decisions than direct effects: financial constraints reduce innovation mostly by reducing incentives to innovate (because reduced entry and early exit of firms with financial difficulties reduce competition), rather than by reducing the ability to innovate (because of limited ability to borrow). The crucial role of firm's productivity in this framework is confirmed. In particular, productivity emerges as a key factor for explaining a firm's propensity to engage in exporting and R&D activities and in lowering firm's financial constraints. Our evidence thus shows how efficiency-improving strategies, mediated by the existence of credit constraints, are at the core of

firm's growth achieved through exporting and innovation. The latter calls for policy actions primarily aimed at alleviating credit constraints, together with the setup of an agenda of reforms of product and factor markets being able to foster an efficient allocation of resources (labor and capital) toward more productive firms.

Our results have relevant implications for the general debate on firms 'competitiveness'. While the policy community tends to agree that R&D activities, the presence in foreign markets, or the supply of cheap credit can all be associated with firms' competitiveness, these policies tend to be fragmented at the EU level both across countries, as well as across domains. Different countries run different policy schemes on internationalization, innovation or access to credit, and all these schemes do not necessarily address the correlations between policy areas that we have detected. In particular, our finding that credit is used mainly for the export activity, but not for financing R&D, calls for a consistent design of support policies. Innovation seems to be more reactive to the provision of specific incentives working directly at the firm level (e.g. R&D tax credit schemes), rather than access to credit; on the contrary, reforms of the banking system aimed at increasing the volume of loans to firms are more directly related to the support of internationalization activities.

Our results also show that, although credit constraints seem to directly affect exporting activities, but not R&D, the detected mutual correlation between exporting and R&D, robust to the presence of credit constraints, has a potential indirect impact on innovation and thus on long-term competitiveness. In particular, in those countries affected by an exogenous credit shock, firms could be forced to use internally generated cash flows to cover the fixed costs of their exports and thus maintain their market share, rather than financing R&D, thus trading-off investments in innovation. The latter would lead over time to an overall loss of competitiveness, unless appropriate support actions for innovation policies (in principle not obviously related to the initial credit shock) could be put in place.

This paper is just a first attempt in trying to disentangle these relationships. More work needs to be done in this area and our results call for further developments aiming at identifying causal effects through a wider set of IVs able to exploit also some time variation in the data. At the theoretical level, one potential avenue would be to integrate models of financial constraints and exporting à la Chaney (2013) or Manova (2013) with those of export and innovation à la Bustos (2011).

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No potential conflict of interest was reported by the authors.

Notes

1. The underlying research materials for this article can be accessed at http://bruegel.org/publications/datasets/efige/.
2. According to the pecking order theory (Myers and Majluf 1984), when asymmetric information increases the cost of financing (as in the case of R&D), firms prioritize their sources, first preferring internal financing, then debt, and lastly raising equity as a financing mean of 'last resort'.
3. Most of the literature summarized above is mainly focused on the link between financing constraints and innovation (input or output) and only recently has started to evaluate the consequent effects on productivity, of which innovation is a key determinant (Caggese 2014; Gorodnichenko and Schnitzer 2013).

4. The weight for firms in industry *k* and class size *s* is built as

$$\text{weight}_{ks} = \left[\frac{(\text{Pfirms}_{ks}/\text{Pfirms})}{(\text{Sfirms}_{ks}/\text{Sfirms})}\right] \times \left(\frac{\text{Pfirms}}{\text{Sfirms}}\right),$$

where $Pfirms_{ks}$ is the number of firms in industry *k* and class size *s* for the population in a given country (data have been retrieved from Eurostat – Structural Business Statistics for 2007); $Sfirms_{ks}$ is the number of firms in industry *k* and class size *s* in the EFIGE sample; *Pfirms* and *Sfirms* are, respectively, the total number of firms in the population and in the sample. The sum of these weights over firms is equal to the total number of firms in the reference population by country. Firms belonging to the same sector/size cell share the same weight.

5. See Barba Navaretti et al. (2011) for a more detailed description of the EFIGE survey and the sampling methodology.
6. In addition to these statistics, Altomonte, Aquilante, and Ottaviano (2012) also discuss in detail the characteristics and the representativeness of a restricted EFIGE sample for which firm's productivity was computable (a sample almost overlapping with our final sample), finding no major differences with respect to the original survey sample in terms of aggregate statistics.
7. Table A1 in the appendix provides the definitions of all the variables used in the analysis and a short description for each of them.
8. Similar shares of exporting firms are found at the national level from the elaboration of the OECD statistics database, table 'Trade by Enterprise Characteristics (TEC) by sector and size class (ISIC rev4)' (source: http://stats.oecd.org/Index.aspx?DataSetCode=TSEC1#). Note that the share of firms appears different from that reported in Barba Navaretti et al. (2011). This is because our sample only includes those firms for which, based on information available in Amadeus, we can calculate TFP. Such a sample selection is discussed in Altomonte, Aquilante, and Ottaviano (2012), where the characteristics of the firms resulting from the unconstrained sample (Table 2 in their paper) are compared with those resulting from the sample limited to those firms for which it is possible to retrieve TFP (Table 3 in their paper). They show how the restricted sample does not show any particular bias in terms of representation by category of firm.
9. Notice that Germany presents a high number of missing values for the CF variable. Therefore, these have been replaced by predicted values computed as the average CF value conditional on: fixed assets; intangible fixed assets; tangible fixed assets; total assets; shareholders funds; non-current liabilities (defined as the sum of long-term debt and other non-current liabilities); long-term debt; number of employees; sales and sector dummies.
10. In all the other models of the following sections the variable *logTFP* will refer to year 2008.
11. For all these variables, in order to winsorize outliers, the values smaller than the first percentile and larger the last percentile have been replaced by the values of those percentiles.
12. Notice that all firms in our final sample that were willing to increase their borrowing answered to the question about being denied credit (thus, DENIED presents no missing values for firms belonging to our final sample having MORECRED=1).
13. This result is in line with EUROSTAT statistics highlighting how, in 2007, the share of firms that were denied bank loan because of their too high level of debt ranged between 1.7 (for France) and 16.8 (for Spain) (source: table acf_d_lo1 'Reasons for partial success or lack of success in obtaining loan finance, by type of enterprise and NACE Rev. 2' of the EUROSTAT statistics database, available at: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=acf_d_lo1&lang=en).
14. Note that in calculating share_EXP and all the control variables described in this section, the focal firm *i* has been excluded from the computation of region-sector averages.
15. For export and R&D, the regressions are estimated using both OLS and probit methodologies, in order to provide an informal test on the robustness of our estimates to different estimation methods.
16. Results (available from the authors upon request) do not change in terms of sign and significance when bootstrap standard errors are used.
17. Notice that, since some region-industry clusters do not have enough observations, regressions are run on 5340 observations.
18. This index is an alternative to the often used Kaplan and Zingales (1997) index.
19. The objective function of the maximization problem is the expected present discounted value of future dividends subject to two constraints: one concerning the upper limit on the stock of debt and the other concerning a lower limit on dividends. The WW index represents the Lagrange multiplier associated with the second constraint and according to the authors it 'can be interpreted as the shadow cost associated with raising new equity, which implies that external (equity) financing is costly relative to internal finance' (see Whited and Wu 2006).
20. Since information concerning dividends is available in our sample only for a small fraction of listed firms, we will rely on a proxy for this variable. In particular, following Mancusi and Vezzulli (2014), we will attribute a value of 1 to the variable DIVPOS if the firm's net assets in 2008 were less than the sum of firm's net assets in 2007 plus the firm's profits (or losses) computed before tax, in formula: NET $\text{ASSETS}_t <$ NET ASSETS_{t-1} + PROFIT (or LOSS) BEFORE TAX_t.
21. Descriptive statistics for the variables included in the index are provided in Table A2 in the appendix.
22. Descriptive statistics for these variables are provided in Table A3 in the appendix.

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Appendix

Table A1. Definition of the variables.

Variable	Definition
MORECRED	Dummy variable = 1 if in 2008 the firm was willing to increase its borrowing at the same interest rate of its current credit line; =0 if the firm was not
DENIED	Direct indicator of credit rationing by the firm's main bank. It is a dummy variable = 1 if in 2009 the firm applied for more credit and was denied it; =0 if the firm did not apply for it or applied for it and was successful
DENIEDpred	Marginal predicted probability to be denied credit (value predicted starting from the probit model with sample selection (1a) and (1b)
CF	Cash flow on total assets for the year 2008
LTDEBT	Long-term debt on total assets for the year 2008
HIRINGS	Net hirings on total employees for the year 2008
CLIABILITIES	Current liabilities (Loans + Creditors + Other current liabilities) on total assets for the year 2008
logSALES	Logarithm of Firm' s sales for the year 2008

(*Continued*)

Table A1. Continued.

Variable	Definition
SG	Firm's sales growth rate for the year 2008. It is computed as: (sales in 2008 / sales in 2007) −1
WW	Whited and Wu (2006) index measured for the year 2008
WWdiff	WW index centered around the median value of the firm's country
logSIZE	Logarithm of the number of employees for the year 2008
logAGE	Logarithm of the age of the firm in years computed in 2008
logTFP	Logarithm of the total factor productivity estimated using the Levinsohn and Petrin (2003) semi-parametric production function algorithm, computed in 2007 and 2008
RD	Dummy variable = 1 if: • in the period 2007–2009 the firm undertook any R&D activity AND • in 2008 had a positive number of employees involved in R&D activities; =0 otherwise.
EXP	Dummy variable = 1 if the firm sold abroad directly from the home country some or all of its own products/services in 2008; =0 otherwise
RDint	Percentage of R&D expenditures on total turnover for the year 2008
EXPint	Percentage of exports on total turnover for the year 2008
share_EXP	The share of exporting firms located in the same region (defined at the NUTS 2 level) and operating in the same industry (defined at the NACE 2 digit level) of the focal firm *i*
share_EXP_incent	Share of firms located in the same region (defined at the NUTS 2 level) and operating in the same industry (defined at the NACE 2 digit level) of the focal firm *i* and answering 'yes' to the following question: 'Has the firm benefited from any kind of tax allowances and financial incentives on export?'
share_RD	Region-industry share of firms investing in R&D
share_RD_incent	Region-industry share of firms answering 'yes' to the following question: 'Did the firm benefit from tax allowances and financial incentives for R&D activities?'
ext_fin_dep	Average score that firms located in the same region and operating in the same industry of the focal one (*i*) gave when answering the following question: 'In the industry your firm works, how dependent are companies on external financing? To give your answer please use a score from 1 (not dependent all) to 5 (Extremely dependent).'

Table A2. Descriptive statistics for the variables composing the WW index (reference year 2008).

Variable	Observations	Mean	Std. dev.	Min	Max
CF	5573	0.057	0.164	−0.764	0.530
DIVPOS	5573	0.510	0.500	0.000	1.000
TLTD	5573	0.230	0.210	0.000	1.007
LNTA	5573	8.136	1.275	3.787	16.095
ISG	5573	0.067	0.267	−0.783	1.744
SG	5573	0.022	0.214	−0.508	1.041

Table A3. Descriptive statistics for the intensive margin variables of export and R&D.

Variable	Observations	Mean	Std. Dev.	Min	Max
EXPint	5326	17.828	25.534	0	100
RDint	5572	3.439	6.935	0	100