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Innovative capacity and export perfor mance: Exploring heterogeneity along the export intensity distribution

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Innovative capacity and export perfor mance: Exploring heterogeneity along the export intensity distribution

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Abstract

This paper sheds additional light on the relationship between firm level innovative capacity and export intensity. By drawing from the recent literature on exporters' heterogeneity, we apply quantile regression techniques to a sample of Italian firms in order to verify whether the effect of innovative capacity – measured by R&D expenditures – varies along the conditional distribution of the export intensity, after controlling for censoring and potential endogeneity of the innovation variable. We confirm that R&D expenditures positively affect export intensity and we find that such effect has a bell shaped pattern along its conditional distribution: firms characterized by export intensity of about 60% can take highest advantage from investing in R&D activity. Overall results prove to be robust to several specification checks and suggest not only that firms innovative capacity helps to explain heterogeneity in export intensity performance, but also that its positive effect differs across the export to sales ratio distribution.

JEL classification: F14, O32, D22, C31, C36.

Keywords: Exports, R&D, quantile regression, endogeneity, distance to the frontier.

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1. Introduction

During the last two decades a host of empirical works have analyzed the relationship between firms characteristics and their exporting activity. The different approaches followed by the empirical literature reflect the evolution of the theoretical models which have gradually improved the explanation of the complex interactions between firms heterogeneity and participation to international markets.

One of the issues which have been analyzed is the role of firms innovative activity in favoring the exporting activity. Earlier models focused on the role played by new or cheaper products in enhancing exports, whereas more recent contributions often jointly model technology choices and export decisions, so that firm performance depends on different simultaneous choices which include trade participation. On the basis of such literature it is now widely recognized that the analysis of the export-innovation relationship cannot avoid to tackle possible endogeneity issues (Melitz and Redding 2013). In fact, investments in innovation might induce productivity improvements which allow firms to afford costs associated to the exporting activity and might enable firms to achieve greater ability to meet international markets demand, thus making exporting more profitable. On the other hand, the exporting experience might stimulate innovative activity through learning effects and better access to best practice technologies.

The applied literature has analyzed the link between innovation and exporting on the basis of different empirical approaches and has provided robust evidence in favor of the self-selection hypothesis, whereby most innovative firms display higher probability to start exporting or to perform better on international markets, whereas the evidence in favor of a positive impact of exports on innovation is scant. It is worth noting that – despite the alleged two ways relationship between innovation and exporting – the endogeneity issue has not always been appropriately tackled.

The aim of this paper is to shed additional light on the effects of firms' innovative capacity on their export intensity, by taking into account endogeneity issues and controlling for other firms characteristics which might favor the exporting activity. The main novelty of this study is that it investigates how the relationship between innovation and export varies along the conditional distribution of the export intensity. This research question has been addressed only by Wagner (2006) who applies quantile regressions techniques to a panel of German plants. However, the author does not tackle the endogeneity of firms innovative activity and restricts its sample to exporting firms, thereby disregarding censoring issues. We instead address the above issues by applying the recently developed Conditional Quantile Instrumental Variable estimator (CQIV) suggested by Chernozhukov et al. (2011) to a sample of Italian manufacturing firms[1].

All estimated models provide evidence in favor of a positive impact of R&D expenditures on export intensity and suggest that such effect has a bell shaped pattern along the export intensity conditional distribution, reaching its maximum impact around the central part of the distribution and being higher in the right tail of the distribution. Such results imply that firms characterized by export intensity of about 60% can take highest advantages, in term on further expansion of their sales in international markets, from investing in R&D activity.

This paper contributes to the literature which analyses the heterogeneity across exporters. Unlike the vast majority of the applied literature which focuses on heterogeneity in firms' observed characteristics, it highlights another dimension of heterogeneity, namely the one in the effect of some covariates. If some differentials are observed, we believe that such information might be useful for the design of policy interventions aimed at favoring exporting activity and productivity-enhancing policies at the micro level.

[1] A few authors in the international trade literature have used quantile techniques to evaluate the impact of the exporting activity along firms productivity distribution (Arnold and Hussinger (2010), Haller (2012) among others).

The rest of the paper unfolds as follows: the next Section synthesizes the theoretical background and the evolution of the empirical literature which has analyzed the relationship between innovation and exports. Section three describes the data and Section four illustrates our empirical strategy. In Section five we discuss empirical results and Section six concludes.

2. Theoretical framework and empirical literature.

Macroeconomic theory has analyzed the relationship between innovation and the exporting activity within the framework of trade theory and growth theory. Trade models focus on firm's capacity to develop product and process innovations as one of the main factors explaining internationalization choices and exporting performance. Neo-endowment trade models (e.g. Davis, 1995) explain trade on the basis of specialization and competitive advantage associated to factor endowments, which include knowledge accumulation and innovative capacity together with labor and capital. Trade and foreign direct investment (FDI) are associated to different stages of the product life-cycle in models based on product life cycle theory (e.g. Krugman (1979)) which predict that new innovative products are more likely to be produced and exported by developed countries, but will be produced (through FDI or imitation) and exported by less developed countries as products mature[2].

Within the framework of growth theory, endogenous growth models (e.g. Romer (1990) and Grossman and Helpman (1991)) suggest that the exporting activity might spur innovation through of different transmission channels: stronger competition induced by the enlargement of relevant markets which requires productivity improvements, the need to satisfy international technical standards, technological transfer from external markets (learning-by-exporting), better exploitation of scale economies which allow firms to cover the large fixed costs related to R&D and innovative activities.

Not surprisingly, these insights have been incorporated by the recent trade literature that moved away from analyzing industry level determinants of export to highlight the heterogeneity of exporters within industries[3]. Theoretical models developed at the beginning of 2000 years have tried to explain the link between firms decision to export and their productivity after assuming that productivity is a random, exogenous draw from a casual distribution (Bernard et. al. (2003) and Melitz (2003)), while more recent models have sought to endogenize firm-level productivity, by allowing firms to invest in productivity enhancing activity, like R&D expenditures. In such a theoretical framework firm-level productivity is often the outcome of a number of endogenous decisions which are jointly taken with trade participation. Yeaple (2005) focuses on a general equilibrium trade model with homogeneous firms. His model shows that, in the presence of fixed costs associated with both technology adoption and exporting, only those firms adopting a more advanced technology are able to start exporting. Similarly, Bustos (2011) suggests a model of trade with heterogeneous firms where the technology choice is jointly modeled with production and export decisions and shows that trade liberalization can stimulate the adoption of upgraded technology: "this modeling framework implies that (a) the most productive firms will choose to both innovate and export, (b) firms of lower productivity only export, (c) firms of still lower productivity choose to do neither, and (d) the least productive firms exit" (Melitz and Redding (2013)). Dynamic models of trade and innovation predicting that exporters will choose a higher innovation intensity with respect to non-exporters have been recently suggested. For example Aw et al. (2011) develop and estimate a dynamic, structural model of exporting and R&D that allows the self-selection of more productive firms into both exporting activity and R&D investments and

[2] Similarly, technology-gap trade models (e.g. Posner (1961) predict that a country which introduces a new product will export until other countries start producing the same product by imitation: when the imitation lag is over new innovations need to be generated in order to support the exporting activity.

[3] Melitz and Redding (2013) provide an exhaustive overview of the theoretical framework of the "heterogeneous firms and trade" literature. See also Bernard et al.(2012) for a survey of the empirical evidence on the field.

recognizes a direct effect of R&D and exporting on future productivity. In particular, authors suggest that the joint evolution of productivity and export decisions observed in a panel of Taiwanese firms can be explained by endogenous productivity changes induced by R&D efforts.

At the empirical level, firms' innovative ability has been included among those variables (others being productivity, size, age among others) that explain observed heterogeneity in firms' participation in international markets and provide support of "self selection hypothesis". The international evidence supports the hypothesis of a positive relationship between firms innovative capacity and exporting activity. Most studies employ R&D (generally measured by R&D expenditures or R&D employees) as a proxy for firm innovative ability and find that it is an important determinant of both exporting probability and export intensity (Harris and Li (2009) and Wagner (2006) among others). Other authors identify a positive effects of other innovation input indicators, like the share of workers with technical and scientific backgrounds or the presence of joint R&D projects with external partners (e.g. Lefebvre et al. (1998)). Furthermore, innovation output indicators, as product and/or process innovations or patents, are found to positively affect export intensity and/or the probability to become exporters (Caldera (2010), Ganotakis and Love (2011), Cassiman and Golovko (2011) among others).

Similar results are provided by studies conducted on Italian data which confirm the positive impact of input and output innovation indicators on exporting activity (e.g Basile (2001), Benfratello and Razzolini (2008), Morone et al. (2013), Castellani (2002), D'Angelo (2012), Nassimbeni (2001), Frazzoni et al. (2011), Sterlacchini (2001))[4]. In particular, among the most recent studies, D'Angelo (2012) shows that export intensity is positively affected by the share of R&D employees, the collaboration with universities for the R&D activity, the introduction of product and process innovations and the turnover from innovative activity[5]. Frazzoni et al. (2011) analyze the role of lending relationship and innovative capacity as main determinants of both exporting probability and export intensity on a sample of manufacturing firms. By applying Full Information Maximum Likelihood Probit and Tobit models, authors find that the introduction of product innovations exerts a positive impact on the exporting activity, while the introduction of process innovations does not seem to have any explanatory power. Morone et al. (2013) investigate the effect of alternative forms of innovation on the decision whether to export or not using data from the Indagine Tagliacarne 2004. By estimating the average treatment effect (ATE), where the type of innovation undertaken by firms (technological innovations, i.e. product and process innovations, non-technological innovations, i.e. organizational am market innovations or both) is considered as treatment, authors find that firms performing non-technical innovations are more likely to look for new markets, or to start exporting in the future, with respect to firms adopting technical innovations: indeed, switching from non-export to export status requires deep changes in management of firm involving new business practices as well as new marketing strategies; moreover, firms performing both types of innovation exhibit a higher probability to enter foreign markets.

Another branch of the empirical literature investigates the impact of the exporting activity on innovative capacity: this link might be explained within the framework of the so called "learning-by-exporting hypothesis" which predicts that firms might improve their performance by participating in international markets. In particular, a few studies identify a positive effect of the exporting activity on the introduction of product innovations (e.g. Damijan et al. (2010), Van Beveren and Vandenbussche (2010)), while others show that firms increase their R&D activity and upgrade their technologies as a result of exporting activity (e.g. Criscuolo et al. (2010) and Wagner (2012b)). Using Italian firm level data, Bratti and Felice (2012) test whether export activity improves firms innovativeness on a sample of about 1.500 firms. Authors estimate the probability of introducing product innovations and find that firms internationalization seems to boost the introduction of new product, even controlling for other

[4] For an exhaustive survey on the Italian empirical literature, see Bottasso and Piccardo (2013).

[5] The author estimates Tobit models on a sample of small and medium firms operating in high tech industries.

observable factors that may influence firm's innovativeness[6]. Similar results are obtained by applying both control function approach and instrumental variables techniques which account for endogeneity issues stemming from the possibility that firms innovativeness might in turn affect the exporting activity.

Wrapping up, a nowadays large literature has highlighted how firms innovative capacity is closely related to firms' penetration in foreign market. A dimension which still remains almost unexplored is whether the impact of innovative activity on export intensity changes for different quantiles of the export intensity distribution, being Wagner (2006) the only exception.

3. Data

The empirical analysis is based on a dataset of Italian manufacturing firms obtained by merging the VI, VII, VIII and IX waves of the "*Indagine sulle imprese manifatturiere italiane*" (Survey on Italian Manufacturing Firms) run every three years by the Unicredit-Capitalia Observatory of Medium and Small firms[7]. The sample is stratified according to size class, geographical area and industry (according to the Pavitt taxonomy) in order to significantly represent the population of Italian manufacturing firms[8].

These waves cover the periods 1992-1994, 1995-1997, 1998-2000 and 2001-2003 respectively, and provide qualitative and quantitative information concerning several firms characteristics such as ownership structure, workforce composition, internationalization and innovation activities, among others . Some variables have annual frequency, others refer to the last year of each wave and others cover the three-years time span. Survey data have been integrated with balance sheet information derived from the AIDA repository, a database elaborated by Bureau Van Dijk.

Unfortunately, the panel is strongly unbalanced, since only a very small fraction of firms is observed in all waves and a major change in the sample occurred between the VII and VIII wave. Therefore, we decided to apply cross sectional techniques on a sample of 1,165 firms obtained after pooling the four waves. Given the aforementioned break in the set of firms and given the use of lagged variables, we decided to keep in the sample firms observed in both the VI and VII waves and those observed in both the VIII and IX. In turn, current variables are observed in years 1997 or 2003, while three years lagged variables are observed in years 1994 or 2000 or over the periods 1992-94 or 1998-00[9].

Table 1 shows the distribution of the sample in terms of Pavitt classification together with firms export status. Such classification which groups firms on the basis of their technological competence, has been often adopted in many empirical studies on innovation, trade and competitiveness both at macro and micro level.

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[6] Moreover a positive correlation is found between innovativeness and the share of graduated workers, FDI, group membership, some technological inputs, mergers and acquisitions. Conversely, a negative correlation is found between introducing innovative products and unit labor costs and physical capital intensity.

[7] The sample is composed by a random sample of manufacturing firms with 10-500 employees and all firms with more than 500 employees.

[8] Pavitt (1984) suggested a classification of industries based on innovation related characteristics (e.g. product and process innovation, sources of knowledge, appropriability regimes), firms size, and competitive factors. Pavitt identifies four groups of sectors: *i*) the *Supplier-Dominated sector* is composed of the most traditional manufacturing industries which rely on sources of innovation external to the firm; *ii*) the *Scale-Intensive* sector is mainly characterized by large firms producing basic materials and consumer durables for which sources of innovation may be both internal and external to the firm with a medium-level of appropriability; *iii*) *the Specialized Suppliers* is composed by small, more specialized firms producing technology to be sold into other firms for which the level of appropriability is high; *iv*) the *Science-based sector is composed of* high-tech firms which rely on R&D from both in-house sources and university research and which develop new products or processes with a high degree of appropriability.

[9] This choice is also dictated by the lack of information on one of our main variable of interest (the share of export on total sales) in the VIII wave, i.e. for year 2000.

By and large, *supplier dominated* industries include textiles, footwear, food and beverages, paper and printing and wood; the *scale intensive* group includes basic metals, motor-vehicles, trailers and semi-trailers; *specialized suppliers* include machinery and equipment, office, accounting and computing machinery, medical, precision, and optical instruments; *science based* industries consist of chemicals, pharmaceuticals and electronics.
Table 1 shows that firms operating in *science based* industries represent a small fraction of the sample (only about 6%) whereas the percentage of firms in the other three sectors are much higher. On average, 77% of firms are engaged in exporting activity but the stratification by sector reveals that the Italian exports are mostly based, on the extensive margin, on the *specialized suppliers* and *science based* industries.

Table 1. Number of observations

Pavitt Taxonomy	Number of firms	Share of exporting firms
Supply dominated	478	74%
Scale intensive	314	67%
Specialized supplier	306	90%
Science based	67	85%
Total	1165	77%

Table 2 shows some descriptive statistics for the whole sample, for sub-samples of exporting and non-exporting firms and for different ranges of the distribution of the export intensity.
The export intensity (*expint*), defined as the ratio of firm's export sales on total sales, is on average about 40% for exporters and displays a high level of dispersion around the mean. For almost half of exporters (about 40%) sales deriving from the exporting activity are below the 30% of total sales, while remaining firms are uniformly distributed across higher values of the export intensity. Therefore, the export intensity distribution appears to be rightly skewed and hence not normally distributed; this shape of the export intensity distribution is confirmed by both graphical methods and statistical tests[10].
Firms innovative capacity is measured by the expenditure in R&D activity (*R&D*): more than half of exporting firms (52%) performed R&D activity, against only about 20% of non-exporting ones; furthermore average expenditure in R&D activity is much higher for exporting than for non-exporting firms and significantly increases along the export intensity distribution[11].
The average size, as measured by the number of employees (*size*), is about 142; as expected, size distribution is very asymmetric, with half of firms classified as small (52%) and just a lower fraction (14%) defined as large[12]. Exporting firms are, on average, significantly larger than non-exporting ones (172.69 vs 41.53) and size is positively correlated with export intensity, so that larger firms are those exhibiting higher shares of sales deriving from the exporting activity.
Area dummies (*North, Centre, South*) show that most firms (75%) are located in the North of Italy, while 19% are located in the Centre[13]. When considering exporting firms, firms in the North appear to be

[10] The values of both the Skewness (0.61) and Kurtosis (2.09) measures confirm that the export intensity distribution is not normal and it is rightly skewed. Statistical tests (Skewness and Kurtosis test, Shapiro-Wilk and Shapiro-Francia tests for normality) formally support such evidence.
[11] As for the R&D expenditures over total sales ratio, exporting firms show an R&D intensity of about 0.87% while non exporting firms invest a much lower percentage (about 0.28%). Moreover, the R&D intensity increases along the export intensity distribution ranging from 0.33 for the class of 0-5% of export intensity to 1.18% for the class of export intensity higher than 50%.
[12] We define firms as small when *size* < 50 employees, as medium when $50 \leq size < 250$ and large when $size \geq 250$. Just 19 firms have more than 1,000 employees.
[13] *North* takes a value of one for firms located in Emilia-Romagna, Friuli-Venezia Giulia, Liguria, Lombardy, Piedmont, Trentino-Alto Adige, Valle D'Aosta and Veneto. *Centre* takes a value of one for firms located in Abruzzo, The Marches, Tuscany, Lazio and Umbria. *South* is a dummy variable equal to one for firms located in the remaining regions.

more export oriented than firms in the rest of the country, both on the intensive and the extensive margins.

Pavitt industries dummies suggest that firms operating in S*pecialized suppliers* and *Science based* industries show not only a higher export propensity but also a higher export intensity, the share of firms belonging to *Specialized suppliers and, Science based* (*Supply dominated* and *Scale intensive)* industries increasing (decreasing) along the export intensity distribution.

Table 2: Descriptive statistics for different ranges of export intensity

	Export. firms	Non-export firms	Whole sample	0q-30q *exp*≤5%	30q-50q 5%<*exp*≤22%	50q-70q 22%<*exp*≤50%	70q-100q *Exp*>50%
Expint	39.97	0.00	30.71	0.99	14.16	37.74	72.23
	(28.07)	(0.00)	(29.83)	(1.73)	(4.78)	(8.49)	(13.52)
Size	172.69	41.53	142.29	61.04	137.31	175.47	219.67
	(393.69)	(58.43)	(350.56)	(195.88)	(503.21)	(243.69)	(438.16)
R&D	310.24	16.41	242.14	31.59	138.63	327.30	497.77
	(1441.53)	(67.15)	(1269.81)	(178.33)	(616.13)	(1794.25)	(1690.65)
Supply	0.40	0.46	0.41	0.47	0.45	0.36	0.35
dominated	(0.49)	(0.5)	(0.49)	(0.5)	(0.5)	(0.48)	(0.48)
Scale intensive	0.23	0.39	0.27	0.37	0.27	0.26	0.14
	(0.42)	(0.49)	(0.44)	(0.48)	(0.45)	(0.44)	(0.35)
Specialized	0.31	0.12	0.26	0.12	0.24	0.31	0.42
suppl.	(0.46)	(0.32)	(0.44)	(0.32)	(0.43)	(0.46)	(0.49)
Science based	0.06	0.04	0.06	0.004	0.04	0.07	0.08
	(0.24)	(0.19)	(0.23)	(0.19)	(0.2)	(0.26)	(0.27)
North	0.79	0.61	0.75	0.64	0.74	0.82	0.84
	(0.41)	(0.49)	(0.43)	(0.48)	(0.44)	(0.39)	(0.37)
Centre	0.16	0.29	0.19	0.27	0.17	0.15	0.14
	(0.37)	(0.45)	(0.39)	(0.44)	(0.38)	(0.36)	(0.35)
South	0.05	0.10	0.06	0.09	0.09	0.03	0.02
	(0.21)	(0.29)	(0.23)	(0.29)	(0.28)	(0.18)	(0.14)

Notes: standard deviations in parenthesis.

4. Empirical strategy.

The aim of this work is to investigate whether innovative activities and other export intensity determinants differently affect export intensity at various point of its distribution by applying quantile regressions techniques[14].

As previously mentioned, such approach has been adopted by Wagner (2006) on a sample of German exporting plants. The author estimates a model where export intensity depends on size, its square, the subsidiary branch plant status of the establishment, a dummy variable which identifies whether a firm operates in a crafts sector, the workforce composition, three dummies for different classes of R&D intensity, and a binary indicator for patents registration. However, standard quantile regression techniques adopted by Wagner (2006) do not account neither for the censored nature of our dependent variable nor for the possible endogeneity of explicative variables. Therefore, we decided to adopt different estimating approaches.

In order to assess the relationship between firms innovative capacity and export intensity (firm's export sales on total sales, in percentage), alongside with the effects of other firms' characteristics on their export performance, we consider the following empirical model:

$$Expint_i=\beta_0+\beta_1\ Innov_i+\beta_2\ X_i+u_i \quad (1)$$

[14] In order to make inference for the whole population, we estimated all regressions by weighting observations with sample weights that accounts for the stratified nature of the sample.

where subscript *i* denotes firms.
Firms' innovative capacity is measured by the logarithmic transformation of firms R&D expenditure which captures the existence of a system of incentives towards intentional innovative activities and can be considered as a proxy for "the allocation of resources to research and other information generating activities in response to perceived profit opportunities" (Grossman and Helpman (1991)).
Although the Unicredit-Capitalia survey reports information on the introduction of process and product innovation we do not use these variables since the export activity is often associated to organizational and technical changes which might be erroneously considered as product or process innovation whereas they represent product differentiation activity or simple process reorganization. The OECD Oslo Manual (2005), which provides guidelines for collecting and interpreting innovation data, indeed defines product differentiation as "the introduction of minor technical (or aesthetic) modifications in order to reach a new segment of the market, to increase apparent product range or to reposition a product in relation to a competing one".
As for the control variables, X_i is a vector of covariates which includes firm size and its square, a set of Pavitt dummies to account for the omission of sector specific time invariant characteristics which might bias our parameter estimates, a year dummy accounting for common macroeconomic factors and three area dummies variables indicating if firms operate in the North, Centre or South of Italy to control for time invariant locational effects. Indeed, being located in an area closer to foreign markets, characterized by higher quality economic infrastructures, lower corrupted environment, higher human capital, etc. might favor exporting performance and failing to account for such characteristics might bias parameters estimates.
Size is expected to have a positive effect on export intensity: given the existence of relevant sunk costs necessary to enter into foreign markets, larger firms might be able to take advantage of economies of scale in production, might show higher capacity of taking risks and obtain credit at lower costs (Wagner (1995)). Such prediction stems from several theoretical models suggested by different trade theory models (see Melitz and Redding (2013)). As the relationship between size and export intensity might be nonlinear, we also include the square of the size variable: Wakelin (1998) suggests that an inverted U-shape relationship may be associated to the existence of very large firms with monopolistic power, which may show less motivation to export.
Our empirical strategy consists in estimating a basic specification of equation (1) which includes the R&D variable alongside with size (and its square), industry, time, and geographical dummies and then assess its robustness by augmenting the basic specification with additional regressors[15].
Some explanatory variables might be endogenous to the model given the likely existence of reverse causality and simultaneity issues, as predicted by very recent theoretical models on trade. By assuming that the impact of our control variables on the export intensity needs time to take place, we include all explanatory variables in lagged form (three years) in order to weaken the reverse causality link[16]. However, given that the main focus of this study is to analyze the impact of R&D expenditure on firms exporting performance, we further tackle the endogeneity issue concerning R&D by applying instrumental variables estimation techniques. In particular, we assume that firms distance (lagged at t-3)

[15] We include some firms characteristics which have been found to affect export intensity in previous empirical literature, like the ownership structure (firms belonging to foreign owners might be more able to compete on international markets as they might have a larger international network) and a binary variable indicating if the firm has established, through either brownfield or greenfield, a foreign subsidiary in the previous three years period (FDI and exporting activity might be correlated since FDI might improve the knowledge of foreign markets and the knowledge of the markets obtained by exporting might favor FDI investments). We do not include productivity since the model includes the R&D variable which may be considered as one of its major driver, so that their explanatory power might overlap.
[16] Export intensity is observed either in 1997 or 2003, while lagged explanatory variables are observed either in 1994 or in 2000 (or over the periods 1992-94 and 1998-00).

from industry specific technological frontier might work as instrument for the R&D indicator. We derive instrument relevance from the recent literature (Aghion et al. (2004, 2005)) which argue that firms closer to the technological frontier have higher incentives to perform R&D activities in order to improve their innovation performance and expand their market shares. As for instrument validity, we posit that firms' distance from industry specific frontier affects export intensity exclusively through stimulating firms' innovative capacity[17].

Indeed, Aghion et al. (2004, 2005) suggest that the impact of (foreign) competition on firms' incentives to innovate is related to their distance from the technological frontier: competition should stimulate innovation activity for firms close to the technological frontier. In Aghion (2004) firms that are closer to the frontier have a greater incentive to innovate in order to preserve their market share, while firms that are far from the frontier have lower expected benefits from innovation since they can hardly face tough competition. Aghion et al. (2005) further develop this insight and suggest that firms closer to the frontier are spurred to innovate because competition reduces their pre-innovation profits (rents obtained if the firms do not innovate); on the contrary competition discourages firms that are far from the frontier from innovating because it negatively affects their post-innovation rents.

In order to build firm level distance from industry specific frontier we first estimate firm level TFP and define industry frontiers on the basis of the highest TFP level observed in each sector classified on the basis of the 2-digit industry ATECO classification. We prefer to adopt a more disaggregate definition of industries with respect to the Pavitt taxonomy, in order to obtain a more accurate measure of the distance variable.

Although such approach might not provide an ideal measure of firm distance from the technological frontier, we do not have enough information on more suitable variables, like those on firms patent activity. Admittedly, our measure of distance based on TFP might be correlated with firms export activity, even if such correlation is not univocally confirmed by the empirical literature: "There are exporting firms which are located at the lower end of the productivity distribution and high-productive non-exporting firms. Powell and Wagner (2014) document that in Germany exporters and non-exporters are highly heterogeneous with regard to productivity. Neither low-productivity exporters nor high-productivity non-exporters are a rare species. Hallak and Sivadasan (2011) document similar evidence for India, the U.S., Chile, and Columbia" (Wagner 2012a). Indeed, a detailed analysis of previous empirical literature suggests that firms productivity does affect firms export propensity but rarely is found to explain firms export intensity, once the innovation effort is taken into account in the specification (e.g. Barrios et al. (2003)). On the other side, a possible concern is related to the possibility that the exporting activity might induce higher productivity, thereby casting some doubt on the validity of our instrument; however, as Wagner (2012a) suggests, the empirical evidence in favor of the learning by exporting hypothesis is weaker with respect to evidence supporting the self selection process and is often related to specific sub-samples of firms (e.g. Castellani (2002), Razzolini and Vannoni (2011), De Loecker (2007)) [18].

Another issue which we need to control for is the censored nature of our dependent variable: indeed export intensity has a non-negligible mass at 0 due to the large fraction of non exporting firms. In order to account for both endogeneity of R&D and censoring bias issues we apply the Conditional Quantile Instrumental Variables estimator recently proposed by Chernozhukov et al. (2011) and

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[17] We conduct an exogeneity test on instruments in the context of IV and Tobit IV regressions. See below the discussion in the Empirical Results Section.

[18] Singh (2010), after surveying some of the papers published between 2006 and 2008, concludes: "studies supporting the self-selection hypothesis numerically overwhelm the studies supporting the learning by-exporting hypothesis, and this implicitly provides a stronger support for the effects of productivity and growth on trade as compared to the effects of trade on productivity and growth".

labelled as CQIV[19]. This estimator uses a control function approach by estimating a first stage for the endogenous regressor and a second one where the first stage estimated residual is included as an additional regressor. Moreover, in the second stage the probability of censoring is estimated for all observations and standard quantile estimators for uncensored data are iteratively applied on the subset of observations for which the probability of censoring is sufficiently low (for technical details see Chernozhukov et al. (2011)).

For comparison purposes, we estimate different specifications of equation (1) with various estimation techniques. In particular, we also use Censored Quantile Regressions (CQR), the Instrumental Variable Quantile regressions (QIV) and the simple Quantile Regression techniques (QR). The CQR approach treats the censored nature of the data but does not account for endogeneity issues, whereas the QIV approach only controls for endogeneity; on the other hand standard quantile techniques do not account for neither endogeneity nor for censoring issues. Moreover, in order to verify whether the quantile approaches give a more exhaustive picture of the relationship between firms export intensity and their innovation potential, we estimate our models by means of Instrumental Variables TOBIT, TOBIT, IV and OLS techniques which provide estimates of the parameters evaluated at the conditional mean of the export intensity distribution.

5. Empirical results

Tables 3a and 3b report estimates of the basic specification of equation (1) obtained by applying the different econometric techniques just mentioned. As far as the quantile approaches is concerned, since 23% of observed firms do not export, we present results for percentiles above the 30*th*; in particular, estimates are performed at seven percentiles, namely 30, 40, 50, 60, 70, 80 and 90.

First step estimated coefficients for the instrument (labeled as $distance_{t-3}$) result to be always negative and statistically significant, thereby confirming the relevance of the instrument and suggesting that firms closer to the industry frontier have more incentives to invest in R&D in order to improve their innovative performance. Alongside with estimated coefficients of R&D and control variables, we also present the coefficient of the control function residual (labeled as *CF residual*) which is significant for most quantiles, thereby confirming the endogeneity concerns on the R&D variable.

Overall, R&D expenditures positively and significantly affect export intensity; however, the magnitude of the effect displays a significant variability associated to different estimation techniques. Figure 1 shows the pattern of the R&D coefficient estimated with the CQIV techniques for the different percentiles, alongside with the marginal effect of the Tobit IV estimates.

CQIV estimates suggest that an increase of 10% in R&D expenditures induces an increase in export intensity which ranges between about 0.04 and 0.53 percentage points. In particular R&D estimated coefficients show a bell shaped pattern with the highest impact observed at the 80*th* percentile (where export intensity is about 60%) and display higher values in the right tail of the export intensity distribution. Therefore, CQIV regressions suggest that firms characterized by export intensity between about 50% and 60% can obtain higher advantages from investing in R&D activity in term on expansion on international markets, while such effect is weaker, but still significant, for firms whose exports sales is lower. As expected, Tobit IV estimates lies in the ranges of the CQIV values and suggest that an increase of 10% in R&D expenditures induces an increase in export intensity of about 0.12 percentage points. As clearly shown in Figure 1, the coefficients for four percentiles lie outside the Tobit IV confidence interval, thereby supporting the conditional quantile modeling with respect to a traditional conditional mean approach.

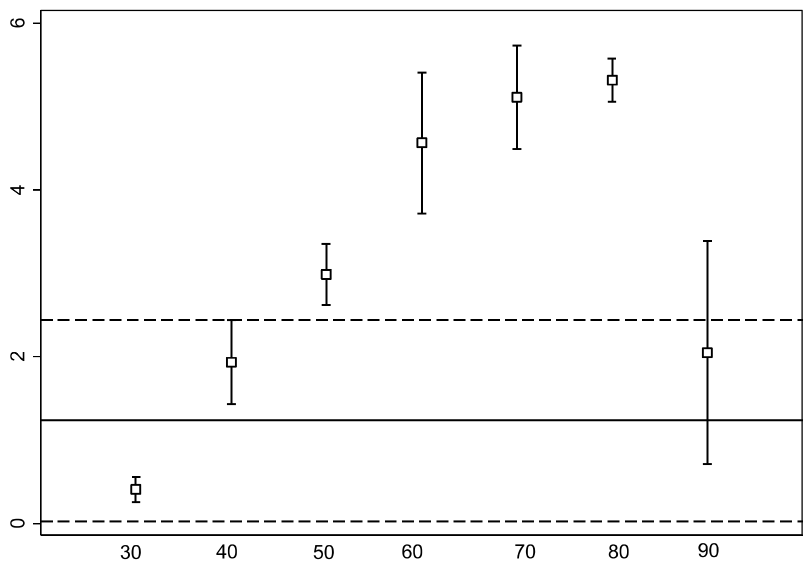
[19] Such estimator allows for the inclusion of just one continuous endogenous explanatory variable in the model.

A similar pattern of the R&D coefficients is observed when applying the QIV estimator, with marginal effects ranging between 0.01 and 0.31. Ignoring the censored nature of the dependent variable leads to a reduction of the impact of R&D on the export intensity also when evaluated at the conditional mean: linear IV coefficient is found to be about 0.17, which is close to the Tobit IV marginal effect (0.12).

The bell shaped relationship between firms innovative capacity and exporting activity is confirmed when we estimates equation (1) with CQR and QR approaches. In both cases the pattern of estimated coefficients for R&D appears to be shifted to the left of the export intensity distribution as they reach their maximum value in the central part of the distribution; furthermore, marginal effects are found to be lower with respect to CQIV and QIV values since they range between 0.034 and 0.07. Likewise, estimates obtained with Tobit and OLS methods are smaller than those computed with Instrumental Variables approaches (Tobit IV and IV). Hence, results obtained when both endogeneity issues and the censored nature of the dependent variable are neglected provide the lower bound of parameters values.

Consistently with previous international empirical literature, our findings suggest that investments in R&D activity has a positive effect on firms export intensity, either by generating a higher probability of introducing product/process innovations and/or by increasing firm absorptive capacity. Furthermore, by applying quantile regressions techniques we provide a more clear picture of such effect which results to vary at different point of the export intensity distribution, as previously found by Wagner (2006) [20]. However, we provide a more clear picture of the heterogeneity of the impact of R&D on the export intensity along its conditional distribution by properly taking into account the endogeneity of the R&D variable as well as the censored nature of the dependent variable.

Figure 1: censored quantile instrumental variable (CQIV) and Tobit IV estimates



Note: Figure 1 shows estimated R&D coefficients (squares) and their confidence interval (vertical lines) obtained by applying censored quantile instrumental variable estimator (CQIV) at 30th, 40th, 50th, 60th, 70th, 80th and 90th percentiles of the export intensity distribution. The horizontal continuous line indicates the R&D marginal effect estimated by applying instrumental variables Tobit (Tobit IV) model (evaluated at the mean of the regressors) and the horizontal dashed lines display the corresponding 95% confidence interval bounds.

[20] We cannot directly compare our point estimates with those of Wagner (2006) since his sample is very different as far as the way size, export intensity, and R&D intensity are measured.

Turning to discuss results concerning different control variables included in the basic specification of equation 1, the effect of firm size (evaluated at t-3) is not stable along the export intensity distribution and exhibits a significant variability associated to different estimation techniques. In particular, Tobit IV estimates does not show a significant role for the size variable, while coefficients from the CQIV regressions follow an bell shaped pattern up to the median while an U-shaped relationship between size and export intensity is observed in the right tail of the distribution.[21] Given that firms size in our sample increases along the export intensity distribution, these findings are broadly consistent with those obtained by Sterlacchini (2001), who finds an inverted U-shaped relationship for small firms, an U-relationship for large firms and no impact of size on export intensity for medium firms[22]. A similar pattern of the size coefficients is observed when applying the QIV estimator; while IV estimates do not show any impact of size on export intensity at the conditional mean of the export intensity distribution. A bell shaped relationship between firms size and exporting activity which persists along the export intensity distribution is shown by CQR and QR estimates as well as by Tobit and OLS regressions. As discussed above for the effect of R&D, the adoption of the most suited estimation technique helps to disentangle more nuanced evidence on the relationship between size and export intensity.

Looking at the coefficients of geographical location and Pavitt classification, heterogeneous results emerge according to different quantiles analyzed. On the one hand, CQIV estimates suggest that firms whose export intensity is higher than 35% and located in the South of Italy seem to enjoy a location advantage with respect to those located in the Centre, while the opposite is true for firms exporting a lower percentage of sales. However, this pattern is not confirmed when we apply other estimation techniques which do not provide conclusive evidence. Instead, being located in the North of Italy seems to positively affect export intensity in most of estimated models. Overall, regression techniques help us to detect some results otherwise hidden when using standard estimation techniques. Unlike most previous contributions, which document a negative effect on export performance of being located in the South (see Bugamelli *et al.* (2000) among others), our results suggest instead that, once we control for size and R&D, the disadvantage is suffered by firms located in the Centre, at least for percentiles above the 70^{th}. On the other hand, once we control for formal R&D activity, size, and location CQIV results suggest that industries in the *Supply dominated* sector (the omitted category) display an export advantage with respect to those of all three remaining sectors (except the lowest quantiles as for *Specialized Suppliers*), whereas the *Science based* sectors show the worst performance. These results are broadly confirmed by the estimates obtained with Tobit IV, QIV and IV, while the unconditional rankings of Tables 1 and 2 tend to emerge with the methods which do not take into account for the endogeneity of the innovation activity. [23]

In order to check the robustness of our results we estimated equation 1 after splitting the sample according to firms geographical location and size. Estimates conducted on firms belonging to the Northern part of the country confirm our main results on the relationship between R&D and export intensity, while results for the other sample (Centre and South) are not conclusive due to data

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[21] These results are supported by F-tests on joint significance of the size parameters.

[22] Some authors identify an inverted U-shape relationship between the two variables, while other authors do not investigate the non linearity of such relationship (e.g..Basile (2001, D'Angelo (2012), Castellani (2002) and Nassimbeni (2001)). Our results differ from those suggested by Wagner (2006), who finds a linear relation between size and export intensity only at the 0.25 quantile of the export intensity distribution.

[23] Most of results discussed so far are broadly confirmed by further empirical analyses when we alternatively include FDI and ownership structure indicators. A positive correlation between the export intensity and the FDI activity is observed outside the median and is stronger in the right tail of the export intensity distribution. Foreign ownership is found to positively affect export intensity for firms characterized by export intensity lower than 35%, while no conclusive results are found for other firms. Results are available upon request to the authors.

limitation. Furthermore, a bell shaped pattern of the coefficients of R&D is observed in both sub-samples based on size (small vs medium large firms), thereby confirming overall findings[24].

6. Concluding remarks

In this study we analyze firms export intensity determinants with a particular attention to the role of innovative capacity as one of the most important drivers of export performance. To this end, we apply different econometric techniques on a cross-sectional sample of Italian manufacturing firms.

In order to better understand the relationship between firms' innovative capacity and export intensity we study if such relationship varies along the export intensity distribution by applying quantiles regression techniques. We also deal with the censored nature of the export intensity variable and with the endogeneity of the innovation proxy by applying the CQIV estimator recently proposed by Chernozhukov et al. (2011).

Empirical results obtained by applying different estimation techniques confirm that R&D expenditures positively affect export intensity; furthermore, when the endogenous nature of the R&D variable is properly treated, such effect appears to have a bell shaped pattern along the export intensity conditional distribution, with firms whose export intensity is about 60% exhibiting higher returns from investing in R&D activity, while returns are found to be lower - but still significant - in the tails of the export intensity distribution. In particular, point estimates suggest that an increase of 10% in R&D expenditures induces an increase in export intensity that ranges between about 0.04 and 0.53 percentage points. These findings might be due to the indivisible nature of the innovative activity; in fact, firms exhibiting high export intensity are likely to operate in several foreign markets, so that they are able to benefit the most from the beneficial effects of innovative activity.

Be that as it may, overall results show the importance of taking into account the heterogeneous effects of covariates along the export intensity distribution, not only in order to better understand the relationship among export intensity and firms innovative effort, but also to provide useful insights for the design of policy instruments aimed at favoring export and productivity improvements. In particular, it has been recently argued that R&D incentives should take into account their impact on export performance (see Altomonte et al. 2013) and our results suggest that such policy measures are likely to have an heterogeneous effect, being stronger for firms characterized by a high level of export intensity.

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[24] Details are available upon request.

Tab. 3a Regression results

CQIV	*30*	*40*	*50*	*60*	*70*	*80*	*90*	***TOBITIV***
ln(R&D$_{t-3}$)	0.41***	1.93***	2.99***	4.57***	5.11***	5.32***	2.05***	1.23**
	(0.08)	(0.26)	(0.19)	(0.43)	(0.32)	(0.13)	(0.68)	(0.62)
size$_{t-3}$	77.67***	41.26***	37.50***	-37.56**	-67.94***	-79.85***	-23.60	4.82
	(2.56)	(9.04)	(7.08)	(15.69)	(12.43)	(4.22)	(23.06)	(30.63)
size$^2_{t-3}$	-25.97***	-25.68***	-50.14***	-1.36	9.90***	12.63***	5.44	-1.32
	(0.54)	(2.09)	(1.87)	(3.45)	(2.72)	(0.98)	(5.27)	(5.72)
North	19.31***	27.05***	26.35***	19.26***	12.93***	1.97	17.85**	7.49
	(0.47)	(1.98)	(1.48)	(2.89)	(1.60)	(1.28)	(6.93)	(5.72)
Centre	18.54***	11.14***	6.99***	3.70	-7.51***	-13.49***	2.44	2.85
	(0.60)	(2.44)	(1.81)	(3.40)	(2.09)	(1.48)	(8.43)	(5.99)
Scale intensive	-0.91**	-2.15	-4.83***	-17.24***	-17.38***	-19.68***	-23.28***	-6.76*
	(0.41)	(1.33)	(0.86)	(1.68)	(0.89)	(0.77)	(4.45)	(3.93)
Specialized suppliers	16.41***	7.34**	-5.59***	-24.58***	-24.30***	-28.06***	-4.49	-1.06
	(0.84)	(2.85)	(1.92)	(4.05)	(2.61)	(1.62)	(8.89)	(10.71)
Science based	-0.26	-9.50***	-22.91***	-38.59***	-47.43***	-44.08***	-22.23*	-9.06
	(0.95)	(3.25)	(2.28)	(5.08)	(3.64)	(2.04)	(11.45)	(9.91)
CF residual	-0.28***	-1.43***	-2.47***	-3.79***	-4.36***	-4.66***	-1.77***	--
	(0.07)	(0.24)	(0.18)	(0.40)	(0.30)	(0.13)	(0.67)	
_cons	-12.42***	12.88**	40.37***	89.15***	116.06***	146***	90.17***	--
	(1.59)	(5.46)	(3.92)	(9.23)	(6.80)	(3.15)	(17.16)	
distance$_{t-3}$	-18.41***	-18.41***	-18.41***	-18.41***	-18.41***	-18.41***	-18.41***	-18.41***
	(6.77)	(6.77)	(6.77)	(6.77)	(6.77)	(6.77)	(6.77)	(6.74)
CQR								***TOBIT***
ln(R&D$_{t-3}$)	0.04	0.16***	0.70***	0.67***	0.71***	0.55***	0.19**	0.31**
	(0.03)	(0.03)	(0.01)	(0.11)	(0.18)	(0.11)	(0.08)	(0.15)
size$_{t-3}$	90.22***	95.39***	135.94***	92.08***	84.98***	25.66*	24.22***	45.00***
	(2.19)	(2.91)	(2.10)	(16.34)	(20.56)	(14.81)	(6.79)	(10.89)
size$^2_{t-3}$	-33.94***	-33.93***	-96.44***	-27.11***	-23.01***	-5.33	-2.96**	-8.79***
	(0.71)	(0.95)	(1.09)	(5.29)	(6.20)	(4.44)	(1.31)	(2.52)
North	18.94***	26.71***	25.54***	25.77***	29.42***	20.08***	44.52***	12.93***
	(1.53)	(1.38)	(0.87)	(6.40)	(8.38)	(3.72)	(4.21)	(4.24)
Centre	18.42***	25.62***	3.90***	8.64	28.44***	18.72***	24.35***	8.48
	(1.76)	(1.72)	(1.01)	(6.99)	(9.27)	(4.20)	(4.86)	(5.45)
Scale intensive	-0.41	-0.72	-4.29***	-16.12***	-12.98***	-11.65***	-5.30	-6.62
	(0.91)	(0.89)	(0.41)	(3.46)	(4.08)	(3.02)	(4.27)	(4.27)
Specialized suppliers	18.13***	23.28***	18.36***	15.77***	22.35***	26.79***	28.90***	12.85***
	(0.84)	(0.94)	(0.53)	(5.04)	(6.75)	(4.67)	(2.29)	(4.45)
Science based	5.97***	2.78***	4.34***	2.95	4.85	7.80**	7.33	2.92
	(0.92)	(1.04)	(0.57)	(5.09)	(6.03)	(3.65)	(4.73)	(4.49)
_cons	-19.92***	-23.62***	-5.22***	6.79	6.82	29.66***	25.20***	--
	(1.68)	(1.55)	(0.94)	(6.59)	(8.11)	(3.94)	(4.42)	

*Note: standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. No. Observation 1165; CQIV: Censored Quantile Instrumental Variable, CQR: Censored Quantile Regression; CF residual: Control Function residual from first stage. Marginal effects evaluated at the mean of the regressors are reported for TOBITIV and TOBIT. Omitted categories are firms located in the South operating in the Supply Dominated sector.*
Estimates performed with Stata 12 Software.

Tab. 3b Regression results

QIV	*30*	*40*	*50*	*60*	*70*	*80*	*90*	***IV***
Ln(R&D$_{t-3}$)	0.18*	0.44***	1.54***	2.55***	2.79**	3.10***	2.73***	1.76
	(0.10)	(0.03)	(0.34)	(0.53)	(1.42)	(0.27)	(0.25)	(1.14)
size$_{t-3}$	77.33***	74.75***	53.24***	22.45	8.15	-47.60***	-52.66***	4.37
	(3.24)	(1.04)	(12.20)	(19.05)	(52.85)	(8.88)	(7.81)	(42.28)
size$^2_{t-3}$	-21.70***	-21.68***	-18.75***	-8.09**	-2.01	8.13***	9.67***	-1.64
	(0.60)	(0.19)	(2.26)	(3.55)	(9.85)	(1.66)	(1.45)	(7.81)
North	0.81	0.75***	-0.78	-4.23	1.05	3.43	25.59***	7.23
	(0.69)	(0.22)	(2.55)	(4.19)	(6.59)	(2.96)	(2.67)	(5.79)
Centre	0.02	-0.61***	-2.89	-4.67	-2.27	5.79*	13.64***	1.27
	(0.69)	(0.23)	(2.98)	(5.04)	(10.54)	(2.99)	(2.76)	(7.07)
Scale intensive	-0.67	-0.99***	-2.42	-6.80***	-14.34***	-18.86***	-8.78***	-7.17
	(0.48)	(0.14)	(1.55)	(2.37)	(5.47)	(2.23)	(2.84)	(5.46)
Specialized suppl.	16.95***	20.87***	14.24***	0.72	-1.81	-4.74	-8.91**	-0.63
	(1.15)	(0.36)	(3.96)	(5.37)	(13.79)	(3.68)	(3.43)	(14.5)
Science based	2.60**	3.05***	-5.85	-17.61***	-19.41	-27.36***	-22.29***	-12.79
	(1.20)	(0.38)	(4.37)	(6.60)	(17.50)	(4.38)	(4.67)	(15.66)
CF residual	-0.03	-0.14***	-1.01***	-1.96***	-2.10	-2.74***	-2.68***	--
	(0.09)	(0.03)	(0.33)	(0.50)	(1.34)	(0.27)	(0.24)	
_cons	3.05	9.55***	36.96***	67.47***	78.53**	96.35***	96.12***	48.19*
	(2.31)	(0.72)	(8.21)	(12.55)	(33.21)	(7.05)	(6.63)	(27.82)
distance$_{t-3}$	-18.41***	-18.41***	-18.41***	-18.41***	-18.41***	-18.41***	-18.41***	-18.41***
	(6.77)	(6.77)	(6.77)	(6.77)	(6.77)	(6.77)	(6.77)	(6.77)
QR								***OLS***
Ln(R&D$_{t-3}$)	0.04***	0.31***	0.62***	0.61***	0.72***	0.53***	0.23***	0.36**
	(0.01)	(0.005)	(0.06)	(0.04)	(0.24)	(0.10)	(0.03)	(0.16)
size$_{t-3}$	73.56***	78.56***	91.53***	95.26***	77.71***	28.44**	19.01***	51.59***
	(0.58)	(0.33)	(4.34)	(3.53)	(21.36)	(11.06)	(2.86)	(15.22)
size$^2_{t-3}$	-20.27***	-22.38***	-26.79***	-22.89***	-14.55***	-5.99***	-1.54***	-10.33***
	(0.11)	(0.07)	(0.87)	(0.72)	(4.44)	(2.08)	(0.56)	(3.32)
North	0.73***	0.93***	1.08	4.18***	8.88	22.74***	33.26***	12.05***
	(0.25)	(0.15)	(2.17)	(1.05)	(7.35)	(3.52)	(1.50)	(3.24)
Centre	0.29	-0.15	0.26	9.79***	6.12	21.01***	12.18***	7.40*
	(0.29)	(0.18)	(2.60)	(1.60)	(9.66)	(3.86)	(1.58)	(4.28)
Scale intensive	-0.36*	-0.77***	-1.27	-8.72***	-12.82**	-12.89***	-8.22***	-5.50
	(0.19)	(0.11)	(1.48)	(1.11)	(5.99)	(2.74)	(1.67)	(4.14)
Specialized suppl.	10.80***	22.64***	28.19***	20.38***	22.25**	26.48***	27.10***	16.25***
	(0.25)	(0.14)	(1.89)	(1.50)	(8.89)	(4.71)	(0.97)	(6.11)
Science based	5.86***	5.47***	4.72**	2.22	4.16	8.08**	3.91*	3.68
	(0.26)	(0.15)	(1.90)	(1.46)	(8.21)	(3.63)	(1.99)	(5.50)
_cons	-0.72**	6.60***	14.94***	19.33***	28.16***	27.37***	40.27***	14.78***
	(0.31)	(0.17)	(2.31)	(1.40)	(8.67)	(3.95)	(1.87)	(4.77)

*Note: standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. No. Observation 1165; QR: Quantile Regression; QIV: Quantile Instrumental Variable; CF residual: Control Function residual from first stage. Omitted categories are firms located in the South operating in the Supply Dominated sector. Estimates performed with Stata 12 Software.*

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