OVER THE ROC: PRODUCTIVITY, ECONOMIC SIZE AND FIRMS EXPORT THRESHOLDS[1]

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Abstract

Making use of a firm-level dataset for the universe of Italian exporting firms collected by Istat, we identify the minimum combinations of "economic size" (here defined in broad sense, summarising a set of size-related variables) and productivity that Italian manufacturing firms need to achieve in order to access international markets. These "export thresholds" are estimated by applying for the first time in economics the ROC (Receiver Operating Characteristics) methodology, already used in disciplines such as medicine, machine learning, natural science. By this way, we are able to detect a model-based, rather than subjectively-determined, cut-off observation allowing to identify exporters from non-exporters. This result allows us to obtain, for each industry: (1) a map of the firms above and below the export threshold, according to the economic size-productivity combination of exporting and non-exporting units; (2) the relative weight of productivity and size in determining the export threshold in a given industry; 3) the best lever of policy to be used in order to stimulate the internationalization of Italian firms.

The methodology proposed in this paper also paves the way for further important developments. In particular, our empirical model could be augmented to investigate other determinants of the thresholds such as those related to the industry structure or regulation, so helping design more effective policy interventions to reduce barriers to trade.

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Keywords ROC analysis, export threshold, intensive and extensive margin of exports

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1. Introduction

The recovery of international trade after the sharp fall in 2009 largely benefited those countries most ready to exploit opportunities provided by the external demand, in a framework where domestic demand was sluggish or decreasing, and export activity stood out as a key factor for firm survival. This was particularly relevant for Italy. Especially during the “second dip” of the crisis (2011-2014), Italian firms’ ability to operate in foreign markets was crucial to the evolution of the business cycle (see, among others, Accetturo *et al*., 2013; ISTAT, 2017).

Italy, in fact, is characterized by a high number of exporting firms (more than 177,000 in 2014; in EU only Germany had more); however, their share on total number of firms is very small (less than 6%). Moreover, the share of firms’ exported turnover is particularly low (5.1% in median), so that even exporting firms largely depend on domestic demand (Istat, 2017).

These peculiarities of the Italian industrial system have fueled the debate about the identification of the most appropriate policy measures to support and increase firms’ internationalization: is it more effective to aim at boosting the export-to-turnover ratio (intensive margin) or at increasing the number of exporters (extensive margin)? To answer such question, we need to know something more about what the necessary and sufficient conditions to export are.

In this vein, the purpose of this work is to estimate for each business sector an “export threshold”, identified by the combination of productivity and “economic size” corresponding to the transition from non-exporter to exporter status, where economic size is defined over a set of firm-level size-related variables.

To do so we apply, for the first time in economics, the Receiver Operating Curve (ROC) methodology, an approach already used in other disciplines, such as medicine (Kumar and Indrayan, 2011), machine learning (Majnik and Bosnic, 2013), and natural science (Warnock and Peck, 2010). The main advantage of applying ROC analysis is represented by the possibility to obtain a model-based, rather than a subjectively-determined, cut-off observation, on whose basis to discriminate between exporters and non exporters and to measure every firm's distance from the threshold. This is a novelty in comparison to standard models that estimate the probability to export (see e.g., Bernard and Jensen, 2004) or regression-based methods to identify average exporter premia. Furthermore, we deem that this approach could eventually provide a helpful knowledge tool for evidence-based policies aimed at promoting the internationalization of firms.

A large strand of literature developed with the purpose of overcoming the limits of the "representative firm" hypothesis, highlighting the role of firms' heterogeneity, in terms of structural characteristics (size, location, business sector exporting status), strategies (e.g. different forms of innovation, inter-firms relationships) and performance (e.g., revenues, profitability, productivity, innovation). Since the seminal work by Melitz (2003), the role of productivity emerged, largely prevailing over other factors. Differences in productivity are at the heart of several subsequent models (see Melitz and Ottaviano, 2008; Chaney, 2008; Bernard *et al*., 2011), according to which only more productive firms can cover the trade costs (sunk or entry costs) required to profitably operate in international markets (see Redding, 2010 for a survey on theoretical literature). There are two different kinds of trade costs: variable costs (e.g. tariffs) and fixed-entry (e.g. investment related to regulation compliance, running distribution chain, etc.). A fall in variable costs induces an endogenous shift in the productivity cut-off for exporting. A reduction in the fixed export costs has the same qualitative effect on the cut-off. This implies that following reductions of both fixed and variable trade costs will lead to new firms – which would not have exported under higher cost conditions – to enter foreign markets.

In Melitz (2003), exporting from country *j* to a foreign market *i* involves a fixed cost for market entry and variable iceberg trading costs. With *CES* preferences, the fixed cost explains the well-known empirical finding that only productive firms export, generating enough variable profits to cover the fixed exporting costs[2]. A fall in variable costs induces an adjustment of the value of exports by firms which are already

[2] Otherwise, in the presence of only variable trade costs, all firms would export, since CES preferences imply that the marginal utility of consuming any given variety approaches infinity as consumption of that variety approaches zero.

exporting (intensive margin) and a rise in the number of exporters (extensive margin), while a fixed cost reduction only determines an adjustment of the extensive margin[3].

In the Melitz world only firms above the export productivity level (a sort of "export threshold") sell both domestically and abroad. However, data also show that in many countries firms' productivity distributions between exporters and non-exporters overlap (see Castellani and Zanfei 2007 for Italy; see Schroder and Sørensen 2012 for a survey), implying that there are firms that do not export even though their productivity is above the threshold.

Schroder and Sørensen (2012) have shown that the irreconcilability between the Melitz theoretical results and the empirical evidence is only apparent and it is linked to the definition of productivity, theoretical (or marginal as in Melitz 2003), or empirical. Empirical works are forced to use average cost-based productivity measures, while the theory ranks firms according to marginal productivity. Considering productivity as proxied by value added per employee, Schroder and Sørensen (2012) show that models of trade-with-heterogeneous-firms predict that the productivity distributions of exporters and non-exporters can overlap and can generate a positive or a negative exporter productivity premium (defined as the outperformance of exporters with respect to non exporters).

Geishecker et al. (2017) further develop Melitz's approach, extending it to the possibility of having export premia in terms of firm size and sales (turnover), showing that these latter are fully in line with theory.

Therefore, there are other factors, beside firm productivity, that may determine export activity. An interpretation of this stylized fact is that sector- or firm- specific foreign market entry costs, exist[4]. Such costs (or barriers) may be internal or external to firms, and prevent them from exporting, contributing to explain why some very productive firms do not export. These cutoff values are not homogeneous, but might differ according to markets and sectors.

[3] In contrast, Melitz and Ottaviano (2008) assume quadratic preferences, which give rise to variable mark-ups and thus to competition effects arising from trade cost reductions. Under this assumption, it follows that intensive margin can also be affected by a reduction in fixed entry costs.

[4] Geishecker et al (2017) show, both at theoretical and empirical level, that even with uniform trade costs there is scope for heterogeneity in export premia due to industry-specific characteristics.

Among such other factors, firm size, representing a proxy of the capacity to afford sunk costs of exporting, may be relevant. In Melitz, there is no direct relationship between productivity and firm size. The link is indirectly established via a selection process in which only more productive firms thrive and grow over time (Melitz, 2003). However, empirical studies did find a direct relationship between export and size: exporters tends to be larger than non-exporters (Bernard and Jensen, 1995; Wagner, 2007). This raises important questions about the sources of export premia and, more specifically, whether, and to what extent, such sources are size-related. Internal sources include managerial talent, quality of inputs, information technology, R&D, learning by doing, and innovation (Syverson, 2011): small and large firms could differ in terms of access to these sources (Leung *et al*., 2008). External factors such as regulations and access to financing could also be responsible for productivity differentials between small and large firms (Tybout, 2000).

In the empirical literature, causal relationship between productivity, size and export activity has been largely analyzed (see Wagner, 2012 and ISGEP 2008 for a detailed survey). Several works found evidence of self-selection hypothesis: firms able to export are more productive because foreign markets entry costs represent a barrier that less productive firms are not able to overcome. This hypothesis implies that a firm should reach a minimum level (a “threshold”) of productivity before starting to export. However, the learning-by-exporting hypothesis points out the role of international competition as a key element to improve firms productivity: knowledge flowing from international buyers and competitors help improve the post-entry performance of exporters. Empirical evidence of self-selection is clear and wide, while evidence regarding the learning-by-exporting hypothesis, even though found in many studies (see for example Girma *et al*., 2004), is somewhat less straightforward, because it depends also on the characteristics of destination country (see Wagner, 2007 and Singh, 2010 for surveys). But learning-by-exporting effect may also be related to firm’s size: focusing on Spanish manufacturing firms, Máñez-Castillejo *et al.* (2010) show the existence of a process of self-selection into exporting among small firms but not among large firms, while the learning-by-exporting effect is significant independently from firm size.

These two hypothesis are alternative but not mutually exclusive. To sum up, productivity and size can be identified as the main drivers of firm's ability to export.

However, to the best of our knowledge, no attempts have been made so far to calculate the minimum combination of these determinants, i.e. the threshold for a firm to shift from non-exporter to exporter status; in this paper we try to fill this gap. In doing so, our contribution to the (empirical) literature is threefold: 1) we develop an empirical model to define the "export threshold", using a methodology (ROC) that is new for economics; 2) rather than consider just sales or the number of employees as a proxy of firm size, we adopt a broader definition of size, i.e. "economic" size, which is based on four factors related to different facets of size: workforce, turn-over, age, and capital intensity. This is all the more relevant in the Italian business system, which is characterized by a pervasive presence of small- and medium-sized enterprises (SMEs), using only workforce to grasp firm's size can be misleading. c) to provide an instrument able to map the positioning of firms with respect to the export threshold, giving useful insights to design more appropriate policies for firms' internationalization.

The paper is organized as follows. Section 2 presents a description of the dataset and ROC methodology. Section 3 discusses the empirical strategy and reports the estimation results. Section 4 illustrates some important policy implications raised by our approach. Section 5 summarizes and concludes.

2. Data and methodological strategy: using ROC methodology in the "export threshold" identification

2.1 Data

The reference statistical source is the firm-level dataset "Frame-SBS" for 2014. Developed by Istat, it relies on administrative data to provide information on the structure (number of employees, business sector, location, age) and main Profit and Losses account variables (value of production, turnover, value added, labour cost) of all the about 4.4 million of Italian firms (Luzi and Monducci, 2014).

This database is firstly integrated with other firm-level information drawn from Custom Trade Statistics, which is a census-type dataset reporting imports, exports and trade balance values. For each firm operating in Italy, it reports the value of goods traded with both EU (intra-EU trade) and non-EU operators (extra-EU trade) by destination market.

Moreover, some restrictions are needed in order to clean the dataset. In particular, bearing in mind the peculiar structure of the Italian business system, characterised by an overwhelming presence of SMEs (enterprises with less than 10 persons employed account for over 95% of total firms, 47% of total employment and 12% of total value added), we choose to focus our analysis on firms with “economic relevance”. To do so, we imposed the following restrictions: 1) since manufacturing sector represents the vast majority of the Italian total export (about 85%), we focus on firms operating just in these industries (excluding Tobacco, Refined petroleum products, Maintenance and repair, Other manufacturing); 2) enterprises must have positive value added, no less than 1 employee, positive consumption of fixed capital; 3) In line with Geishecker et al (2019), we do not consider many of the extremely small and unproductive exporters, including the less relevant “one-off” exporters, avoiding that these latter can affect the export threshold estimates. To do so, we exclude firms with less than 1200 euros of exported turnover (corresponding to 5% of firms turnover distribution).

We build this dataset for 2014 because this is the only year for which all the data merged are available. Referring to 2014, we are left with an operative database covering 210.109 firms, which account for over 50% of all manufacturing firms, 80% of employees, 82% of value added, 87% of exports. Table 1 reports industry composition and main information about strata of analysis.

Concerning industry composition, dataset closely reflects the specialization model of the Italian economy with respect to its participation in international trade: Machinery, Automotive, Metals, and Food and beverage account for over half of the total manufacturing export.

Table 1: Italy: Industry classification and firms characteristics – 2014

Industry	Nace code included	Number of firms	Share of firms	share of value added	Share of empolyees	Share of exports
Food and beverage	10,11	37439	17.8	16.2	16.0	8.2
Textile	13	8705	4.1	4.1	4.2	2.9
Wearing apparel	14	12673	6.0	5.6	6.0	4.1
Leather	15	8931	4.3	4.2	4.7	4.8
Wood	16	16620	7.9	7.4	5.4	0.5
Paper and print	17,18	12777	6.1	6.1	5.4	2.4
Chemicals and pharmaceutics	20,21	3491	1.7	2.0	2.5	8.4
Rubber and plastic	22	7635	3.6	4.0	4.7	5.4
Non metalic minerals	23	12107	5.8	5.6	5.5	2.9
Metals	24,25	47580	22.6	23.4	22.0	14.7
Electronics	26,27	9315	4.4	4.8	5.3	8.8
Machinery	28	18251	8.7	9.9	11.4	21.7
Automotive	29,30	2880	1.4	1.5	2.0	12.7
Furniture	31	11705	5.6	5.4	5.1	2.6

Source: Authors' calculation on Istat data.

2.2 Methods

2.2.1 ROC analysis and the definition of the threshold

The definition of the "export threshold" is based on the joint application of the Receiver Operating Characteristics (hereinafter, ROC) analysis and Youden's (1950) J index, which permits to identify a cut-off point over an independent variable in a logit model, so as to efficiently cluster observations with respect to a dependent binomial variable. This methodology is widely used in different disciplines, principally medicine, where it summarizes the ability of a marker (or diagnostic test) to discriminate between two groups of individuals (i.e. healthy and diseased).

Following Fawcett (2005), classification models (or classifiers) can give four possible outcomes, which are shown in the following "confusion matrix" (Figure 1).

Figure 1 – Confusion matrix

		Estimated classification	
		1	0
True classification	1	**TP** *(a)*	**FN** *(b)*
	0	**FP** *(c)*	**TN** *(d)*

Source: Fawcett (2005)

where:

TP = True Positives (a): positive observations are correctly classified as positive by the model;

FN = False Negatives (b): positive observations are erroneously classified as negative by the model;

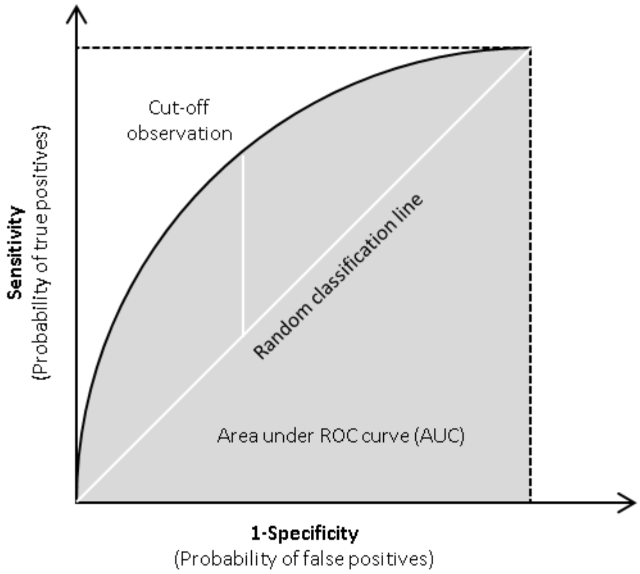
FP = False Positives (c): negative observations are erroneously classified as positive by the model;

TN = True Negatives (d): negative observations are correctly classified as negative by the model.

In this context, the validity of a classifier can be measured based on two main metrics. "Sensitivity", which represents the probability of detecting true positive cases (in terms of Figure 1: $\frac{a}{a+b}$); "Specificity", which reflexes the probability of detecting true negative cases (in terms of Figure 1: $\frac{d}{c+d}$). This latter is usually considered in its reciprocal expression (1-Specificity), which measures the probability of false positive cases.

The ROC curve (Figure 2) displays the position of each observation in the space of Sensitivity and 1-Specificity, showing the trade-off between the probability of detecting true positive or false positives across all possible cut-off points (Kumar and Indrayan, 2011).

Figure 2 – The ROC curve



The area under the ROC curve (AUC; the grey portion in Figure 2) provides a measure of the extent to which the clustering obtained by a model is more efficient than a pure random classification (represented by the 45° line). In this vein, AUC criterion is largely used to measure the goodness of fit of logit models, and to define the relative relevance of a set of variables in determining the overall logistic distribution of probability.

In order to single out along the ROC curve the observation that most efficiently discriminates between positives and negatives ($\widehat{Cut}$), the following equation is used:

$$\widehat{Cut} = h * sensitivity - (1 - h) * (1 - specificity) \qquad [1]$$

where h and $(1 - h)$ represent the relative weights to manage the trade-off between true positives and false positives. Setting-up $h < 0.5$ (i.e. finding true positives is less relevant than avoiding false positives) would correspond to a "conservative" selection, which assigns positive classifications only in presence of a strong evidence. Conversely, setting-up $h > 0.5$ (i.e. finding true positives is more relevant than avoiding false positives) would correspond to a "liberal" selection, which assigns positive classification also in presence of a weak evidence. Finally, setting-up $h = 0.5$ a "neutral" selection would be obtained.

Equation [1] can also be written as:

$$\widehat{Cut} = \frac{h}{1-h} * \left(\frac{a}{a+b} + \frac{d}{c+d} - 1\right) \qquad [2]$$

When $h = 0.5$, equation [2] turns out to be equal to Youden's (1950) J index

$$\left(\frac{a}{a+b} + \frac{d}{c+d} - 1\right). \qquad [3]$$

Youden's J, which maximizes the vertical distance between ROC curve and the 45° line (see Figure 2) and, consequently, the correct classification rate, it is the most commonly used (and advocate) criterion for detecting optimal cut-offs.[5] Moreover, the J index – implying a "neutral" choice between false positives and negatives – is all the more suitable for our purposes because we have no a-priori bias for the relevance of both types of false cases.[6]

2.2.2. Applying the ROC to define the "export threshold"

In this work, we apply ROC analysis to identify, for each industry, the export threshold for Italian firms.

Following the method presented in the previous paragraph, we estimate the probability to export in industry i based on the following logit model:

$$\mathrm{Prob}\ (\mathrm{Export} = 1|\mathrm{X})_i = \Lambda(\alpha\mathrm{X})_i \qquad [4]$$

where Λ is the cumulative distribution of the logistic function, α is the estimated parameter, and X is the covariate. Once estimates have been obtained, Youden's J permits to identify the cut-off observation in the i-th industry, thus also allowing to determine the value of the covariate representing the threshold:

$$\bar{X}_i = \mathrm{X}_{c,i} \qquad [5]$$

[5] Beside the J index, two other criteria are used to find optimal threshold point along a ROC curve: *a)* the minimization of the distance from the (0, 1) point; *b)* the cost minimization, which considers several types of costs, e.g. for correct and false classification, for further investigation etc., and it is rarely used due to its assessment difficulty.

[6] Actually, the "best" cut-off depends on whether one needs to maximize sensitivity at the expense of 1-specificity or vice versa. This often happens in medicine. The first case leads to a test that is maximal sensitive (i.e. one which correctly identifies diseased people at the expense of a lot of false positives). The second case generates a test that is better in "ruling-out" the disease. The Youden's J maximizes both.

where c is the cut-off firm. Using this cut-off, it is possible to classify firms as exporters or non-exporters according to their being over or under this threshold.

In this work, we test three models: (1) A pure sales model (S-model, where $X = Sales$), in which the export threshold is defined over the value of firms' turnover. (2) A pure productivity model (π-model, where $X = \pi$), in which the export threshold is defined over the value of labour productivity (value added-per-worker). (3) A composite model (Z-model, where $X = Z$), in which the export threshold is defined over a combination of productivity and an indicator of economic size (which in turn synthesises four size-related variables).

As pointed out in the introduction, pure sales and pure productivity models are fully consistent with Melitz's theory. Since sales is a common proxy for firm size, Z-model combines 1) and 2), also introducing a multi-dimensional definition of size ("economic size").

In pure sales and pure productivity models, ROC analysis can be directly carried out using the given variable (respectively, turnover and labour productivity) as covariate in the logit model, while for Z-model, the composite indicator Z has to be derived based on the following three steps procedure.

In the first step, for each industry, the "economic size" indicator is defined using Factor Analysis over a set of four variables: 1) number of workers; 2) turnover; 3) age (in terms of number of months from the date of inclusion in the Italian Business Register); 4) consumption of fixed capital. For each firm in the i-th industry, economic size is thus given by the linear combination of the four variables as resulting by retaining the first (rotated) auto-vector.

In the second step, the following logit model is estimated:

$$\mathrm{Prob\ (Export = 1|S, \pi, G, I) = \Lambda(\ \alpha_1 S + \ \alpha_2 \pi + \alpha_3 G + \alpha_4 I\ )} \qquad [6]$$

where Λ is the cumulative distribution of the logistic function, α_j are estimated parameters, S is firms' "economic size", π is firms' productivity (in terms of value added-per-worker), G is a set of dummy variables indicating the location of firms[7], and I is a set of dummy variables related to NACE 2-digit level of economic activity.

In the third step, the estimated coefficients of productivity and "economic size" from equation [6] are used to obtain the composite indicator $Z_{h,i}$ for each firm h in the i-th industry. In particular, estimated parameters are used as weights, while variables are taken at individual level[8].

$$Z_{h,i} = \widehat{\alpha}_{1,\mathrm{i}} S_h + \widehat{\alpha}_{2,\mathrm{i}} \pi_h \qquad [7]$$

$Z_{h,i}$ is the covariate in equation [4] for Z-model.

2.3.3. Fitting tests

Two main types of test have been carried out on the results obtained from the three models. Firstly, as shown in Table 2, we apply the usual AUC test to compare the models, which all show a high goodness of fit (almost always above 70% in each industry). Differences are quite small (even though all significant): S-model shows the best performance, π-model the lowest one, while Z-model lies in between.

Table 2 – Area under ROC curve (AUC): comparison among S-model, π −model and *Z*-model

Industry	AUCs			π -model - Z-model				S-model - Z-model			
	Z-model	P-model	S-model	Difference estimate	Lower bound	Upper bound	P-value	Difference estimate	Lower bound	Upper bound	P-value
Food and beverage	0.858	0.847	0.886	-0.012	-0.013	-0.010	<0.0001	0.028	0.024	0.032	<0.0001
Textile	0.843	0.750	0.874	-0.093	-0.100	-0.086	<0.0001	0.031	0.026	0.036	<0.0001
Wearing apparel	0.842	0.717	0.860	-0.125	-0.132	-0.119	<0.0001	0.018	0.015	0.021	<0.0001
Leather	0.809	0.673	0.797	-0.136	-0.146	-0.126	<0.0001	-0.012	-0.018	-0.007	<0.0001
Wood	0.795	0.725	0.824	-0.070	-0.076	-0.063	<0.0001	0.029	0.023	0.035	<0.0001
Paper and print	0.825	0.766	0.857	-0.060	-0.064	-0.055	<0.0001	0.032	0.027	0.037	<0.0001
Chemicals and pharmaceutics	0.803	0.761	0.837	-0.043	-0.051	-0.034	<0.0001	0.034	0.025	0.043	<0.0001
Rubber and plastic	0.836	0.746	0.848	-0.091	-0.098	-0.083	<0.0001	0.011	0.007	0.016	<0.0001
Non metalic minerals	0.737	0.706	0.764	-0.031	-0.035	-0.026	<0.0001	0.027	0.021	0.034	<0.0001
Metals	0.837	0.766	0.859	-0.072	-0.074	-0.069	<0.0001	0.022	0.020	0.024	<0.0001
Electronics	0.810	0.721	0.841	-0.089	-0.097	-0.082	<0.0001	0.031	0.026	0.036	<0.0001
Machinery	0.830	0.697	0.838	-0.133	-0.139	-0.127	<0.0001	0.008	0.007	0.009	<0.0001
Automotive	0.798	0.712	0.813	-0.087	-0.100	-0.074	0.0007	0.014	0.006	0.023	<0.0001
Furniture	0.833	0.720	0.848	-0.113	-0.120	-0.105	<0.0001	0.015	0.012	0.018	<0.0001

[7] We refer to five geographical areas: North-West, North-East, Centre, South, Islands.

[8] For the indicator Z other functional forms have been tested, including different combinations of our control variables. In all cases, the explicative power of the indicator (in terms of area under the ROC curve, precision and accuracy) worsens. Results are available on request.

Source: Authors' calculation on Istat data.

Secondly, we consider, for each model, the capability of the cut-offs identified by the J-index in classifying firms as exporters and non-exporters. Table 3 compares the models based on Precision and Accuracy. In particular, "Precision" measures the share of true positives over the total number of observations the model classifies as positives (i.e. firms correctly classified as exporters):

$$Precision = \frac{TP}{TP+FP} \qquad [8]$$

In turn, "Accuracy" measures the share of true positive and negative outcomes of the model (i.e. firms correctly classified as exporters and non-exporters) over the total number of observations:

$$Accuracy = \frac{TP+TN}{Total\ observations} \quad [9]$$

As Table 3 reports, considering Precision, Z-model outperforms both S- and π-model in all industries, while it shows a lower level of Accuracy in 9 out of 14 cases with respect to S-model, and in 5 out of 14 cases compared to π-model.

Table 3 – Fitting tests of the ROC estimates: comparison among S-model, π –model and *Z*-model

Industry	Z-model - S-model		Z-model - π-model	
	Precision	Accuracy	Precision	Accuracy
Food and beverage	0.7	0.2	3.9	1.9
Textile	7.2	-2.9	21.0	7.1
Wearing apparel	4.7	-3.6	13.9	4.3
Leather	1.7	-4.4	20.5	7.6
Wood	4.3	4.0	12.5	11.9
Paper and print	13.8	2.8	26.6	13.1
Chemicals and pharmaceutics	7.7	-22.5	14.4	-21.3
Rubber and plastic	9.9	-11.4	20.3	-4.4
Non metalic minerals	12.1	5.8	16.6	9.9
Metals	12.5	4.0	23.7	13.3
Electronics	13.5	-10.9	26.6	-3.1
Machinery	9.2	-16.9	20.7	-7.0
Automotive	14.4	-15.8	25.1	-8.3
Furniture	10.8	-0.8	26.9	9.9

Source: Authors' calculation on Istat data.

We decide to carry out the analysis using Z-model for two main reasons. First, this allows to express the export threshold in terms of a combination of productivity and economic size, thus permitting to consider possible balance between the two factors for a firm to become an exporter. Second, considering the results in table 3, Z-model guarantees an overall best performance in Precision with respect to both S- and π-model, even though it is only partially outperformed by S-model in terms of Accuracy.

Accordingly, Table 4 shows the level of Precision and Accuracy for Z-model, where the share of false positives and false negatives with respect to the whole set of observations is the "accuracy" complement.

Table 4 – Fitting tests of the ROC estimates: *Z*-model

Industry	Precision	Accuracy (Correct clustering)	Share of false positive	Share of false negatives	Share of export for true positives
Food and beverage	51.3	83.6	8.9	7.6	98.1
Textile	75.0	77.5	5.2	17.2	95.0
Wearing apparel	68.0	74.5	6.3	19.2	94.0
Leather	72.2	72.1	5.7	22.2	95.2
Wood	40.0	80.6	13.5	5.9	95.7
Paper and print	69.6	81.5	5.3	13.2	98.2
Chemicals and pharmaceutics	96.6	51.7	0.7	47.6	92.1
Rubber and plastic	93.2	65.4	1.5	33.0	94.3
Non metalic minerals	59.6	75.0	7.6	17.4	95.5
Metals	65.6	81.9	6.8	11.3	97.8
Electronics	93.9	65.0	1.1	34.0	93.9
Machinery	93.6	58.0	1.2	40.8	91.1
Automotive	96.5	58.2	0.4	41.4	94.9
Furniture	77.5	78.3	4.2	17.4	95.6

Source: Authors' calculation on Istat data.

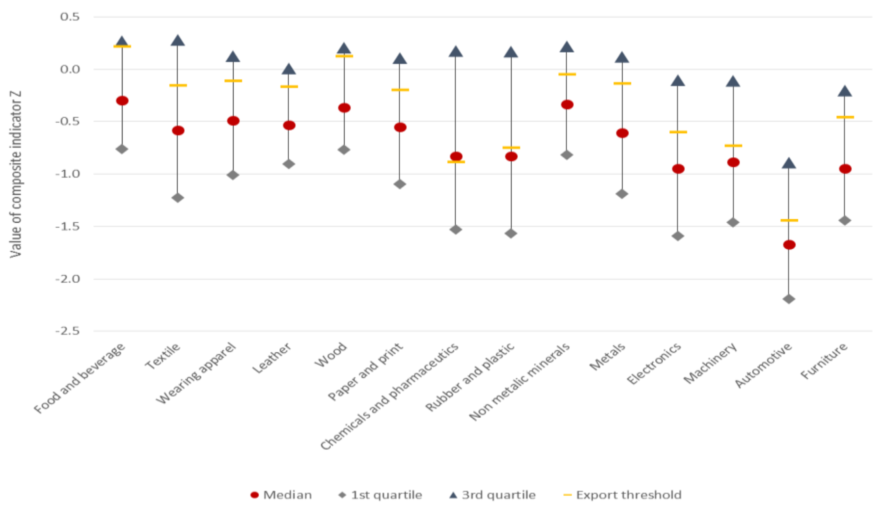
Z-model shows a high capability of correctly clustering exporters: in 8 out of 14 industries the Precision (column 2) is over 70%. Concerning correct and wrong classifications (columns 3 to 5), Z-model shows a better performance is detecting true positives (excluding Wood, in all industries the share of false positives is under 10%) while discharging clustering errors on false negatives. In order to assess to what extent this characteristic could result in a distorted selection, we calculated the weight of true positive observations in term of total exports. The last column confirms that our clustering method grasps a very large share of total exports in all industries (ranging from 91.2% in Machinery to 98.2% in Paper and print), suggesting that false negatives are basically negligible exporters (e.g. firms exporting just occasionally or with a low export-turnover ratio).

3. Results: A "map" of the firms over and below the export threshold

The procedure illustrated in section 2 allows to obtain a "map" of the distribution of Italian manufacturing firms across the export threshold in each industry, so giving useful insights on the linkages between economic size, productivity and access to export both from a positive and normative point of view.

Figure 3 shows, for each industry, firms' position with respect to the export threshold. It can be firstly noticed that in almost all industries just a quarter of firms lie above the threshold, with two notable exceptions: Food and beverage and Chemicals and pharmaceutics. As for the former, export threshold is higher than the third quartile of the distribution, so confirming the very limited participation of these firms in international markets. In quite an opposite way, in Chemicals and pharmaceutics the threshold lies below the median, reflecting the more "export friendliness" of this industry.

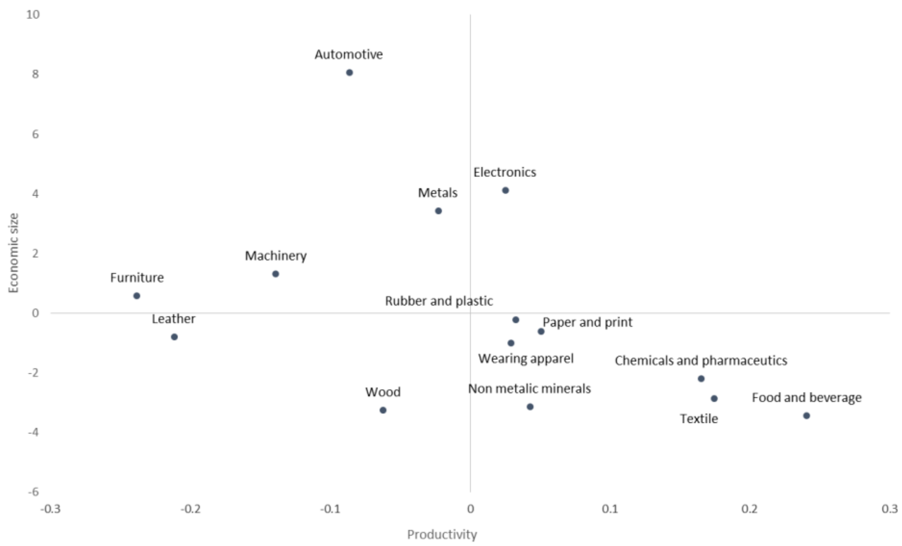
Figure 3 – Distribution of firms across export thresholds, by manufacturing industry – 2014



Source: Authors' calculation on Istat data.

More importantly, our approach also allows to evaluate the role of economic size and productivity as possible policy targets aimed at increasing the degree of internationalization of the Italian business system. In this regard, Figure 4 plots industries according to the relative importance of economic size and productivity with respect to manufacturing average[9]. A clear trade-off comes out between these two variables: in much part of industry, either the former or the latter appears to be more relevant in helping firms reach the export threshold. We basically have industries where the possibility to reach the threshold is either "productivity-driven" (mostly Food and beverages, Non-metal minerals, Wood, Chemicals and pharmaceutics) or "economic size-driven" (especially Automotive, Electronics, Metals, Machinery).

Figure 4. Relative importance of productivity and economic size in determining the "export thresholds", by industries – 2014 (effect of productivity –economic size – for industry *i* minus effect of productivity – economic size – for whole manufacturing)



Source: Authors' calculation on Istat data.

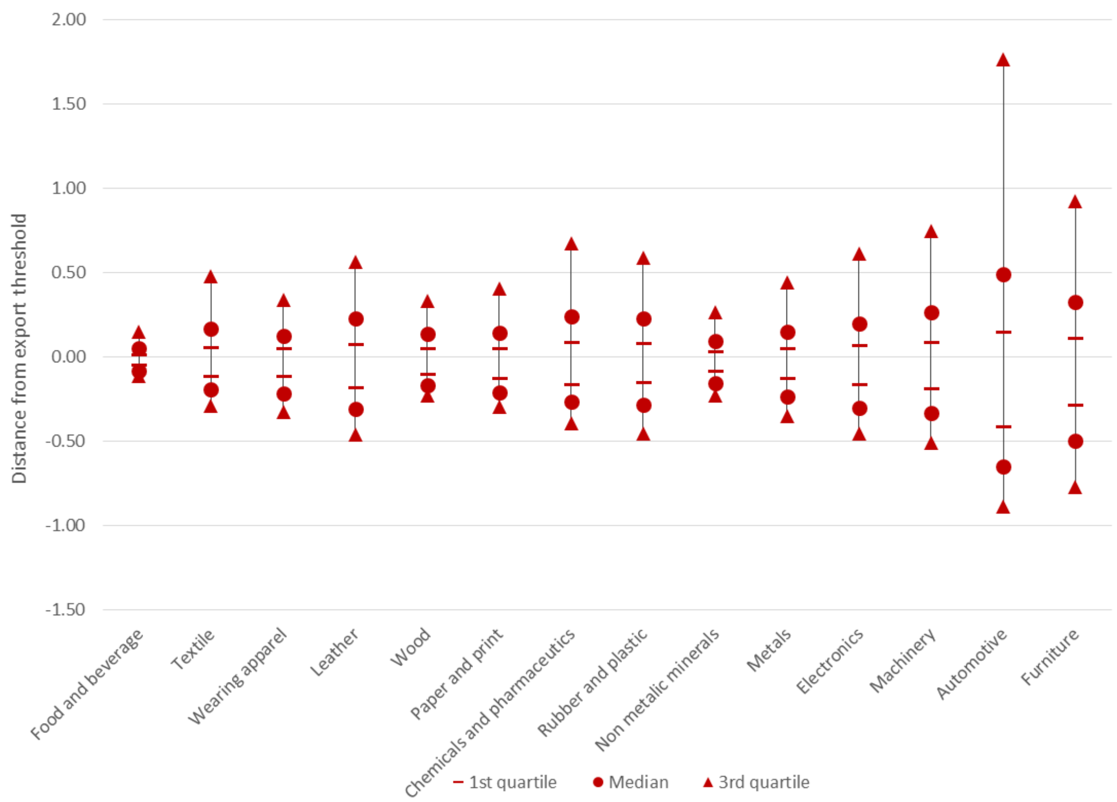
The possibility to map the distribution of firms across the export threshold in each sector, as well as the capability to identify the role of economic size and productivity in stimulating firms' participation to international markets, have important consequences also for a normative (i.e. policy-oriented) analysis,

[9] Following Geishecker *et al.* (2017), however, we have to take into consideration that different contribution of size and productivity can be the result of industry specific distortions that generate a wedge between the theoretical productivity concept and the empirical one. Furthermore another factor that can be affect these contributions are related to Industry differences in markups.

because it helps clarify the “requirements” to participate in international trade, (e.g. pointing out in what industries the capacity to successfully sell abroad -needs a “jump” in productivity, in economic size, some form of compensation between size and productivity and so on). What is more, our framework also offers a measure of the extent to which, for each industry, the incidence of exporting firms would be increased if the export threshold could be somehow reduced by some type of policy intervention.

On such bases, the “map” of the industries’ position across the thresholds is reported in Figure 5.

Figure 5. Firms distribution above and below the export threshold – 2014 (quartiles of distance, in terms of differences between firm’s values of $\mathrm{Z_i}$ and $\hat{\mathrm{Z}}$)



Source: Authors’ calculation on Istat data.

In all sectors values of the composite indicator Z related to the “above-threshold” units are more dispersed than the ones for “below-threshold” firms. In other words, firms crossing the export threshold tend to be more heterogeneous, in terms of the combination of economic size and productivity, with respect to the "below-threshold" (i.e. non exporting) ones. This happens to a larger extent in industries where the international competition, for Italian firms, is particularly strong, such as Textiles, Automotive, and Furniture.

This picture of exporting and non-exporting firms also helps highlight other significant heterogeneities between industries. On the one hand, comparing the distance between the quartiles of the Z indicator of firms above and below the threshold makes it possible to evaluate the differences in the economic size-productivity profiles between exporting and non-exporting firms. In this vein, for example, in some industries where competition is stronger (such as Food and beverages, Non-metallic minerals, and Wood and Papers and print), firms lying below the export threshold appear quite similar to the exporting ones. On the contrary, in industries characterized by high entry barriers and intense inter-firm relationships (such as Automotive, Machinery, Metals, and Leather), the combinations of size and productivity of exporting firms are very different (with higher values of Z indicator) from the ones of units below the threshold. In such industries, moreover, also the distance between exporting and non exporting firms that are closer to the thresholds (i.e. first quartiles of the two distributions) is larger, suggesting that the "threshold step", in such cases, might be quite high.[10]

As Table 4 shows, among the below-threshold firms, in every industry the units farthest from the threshold (4th quartile) are characterized by very poor levels of productivity, incidentally revealing conditions of inefficiency for (at least) one quarter of Italian domestic firms. As far the above-threshold units are concerned, it is worth noticing that firms most distant from the threshold account by far for the lion's share of total export (83.5% for whole manufacturing, with percentages ranging from 74,2% in Chemical and pharmaceutics to 92.8% in Paper and print). Such a substantial gap between exporters laying in 4th quartile

[10] It has to be borne in mind that, at this stage of the analysis, the possible closeness of domestic firms to the threshold, in itself, does not imply that the access to international markets is within easy reach. In principle, actually, thresholds cannot be properly compared with each other, because they strictly depend on the size-productivity conditions prevailing in their own sectors. Moreover, a number of other factors, other than a firm's economic size-productivity combination, might affect the capacity to venture into exporting: the level of the international demand for its goods, entry barriers, domestic relations of sub-contracting and so on. In other terms, also the business structural and demand characteristics are to be taken into account in order to adequately detect where a possible policy incentive to firm's growth in terms of size and/or productivity would be more effective in increasing Italian extensive margin of export.

and all other exporting firms also emerges with regard to firms' economic size: in every industry the average size of firms in the 4th quartile above the threshold is a multiple of that of 3rd quartile (ranging from 2.9 in Wood to 5.9 in Electronics).

Table 4 – Characteristics of firms above and below the export threshold, by industry and distance from the thresholds – 2014 (quartiles of the values of Z composite indicator)

Food and beverage

Quartiles	Persons employed (mean)	Productivity (thousand euros; mean)	Share of value added (%)	Share of persons employed (%)	Share of export (%)
Above threshold					
q1	8.6	36.3	2.6	3.9	0.8
q2	11.6	45.2	4.2	5.3	1.8
q3	18.7	68.4	8.9	8.6	6.3
q4	104.9	86.2	69.8	48.0	91.1
Total	36.0	68.1	85.6	65.9	100.0
Below threshold					
q1	6.0	29.0	6.6	12.3	-
q2	4.4	24.8	4.0	9.1	-
q3	3.5	20.4	2.6	7.2	-
q4	2.7	12.4	1.2	5.5	-
Total	4.1	21.7	14.4	34.1	-

Textile

Quartiles	Persons employed (mean)	Productivity (thousand euros; mean)	Share of value added (%)	Share of persons employed (%)	Share of export (%)
Above threshold					
q1	13.0	47.7	4.9	5.4	2.6
q2	18.3	55.2	7.6	7.6	5.3
q3	30.1	60.2	13.8	12.5	12.6
q4	107.5	65.9	55.9	44.8	79.4
Total	42.2	57.2	82.2	70.4	100.0
Below threshold					
q1	7.7	39.1	9.0	12.1	-
q2	4.9	31.7	4.6	7.7	-
q3	3.7	27.8	3.0	5.7	-
q4	2.6	16.1	1.2	4.0	-
Total	4.7	28.7	17.8	29.6	-

Wearing apparel

Quartiles	Persons employed (mean)	Productivity (thousand euros; mean)	Share of value added (%)	Share of persons employed (%)	Share of export (%)
Above threshold					
q1	11.2	32.7	3.7	4.9	1.6
q2	15.4	34.7	5.4	6.7	2.4
q3	23.0	48.7	9.8	10.0	6.6
q4	100.5	56.4	60.7	43.7	89.3
Total	37.5	41.9	79.6	65.3	100.0
Below threshold					
q1	7.3	30.2	9.1	13.0	-
q2	5.2	29.2	5.8	9.2	-
q3	4.0	25.0	3.7	7.0	-
q4	3.1	14.0	1.7	5.4	-
Total	4.9	24.6	20.4	34.7	-

Leather

Quartiles	Persons employed (mean)	Productivity (thousand euros; mean)	Share of value added (%)	Share of persons employed (%)	Share of export (%)
Above threshold					
q1	16.2	41.2	4.6	6.4	1.9
q2	20.4	47.8	6.7	8.1	5.1
q3	29.1	54.5	11.0	11.5	8.7
q4	99.6	64.2	58.8	39.4	84.3
Total	41.3	51.9	81.0	65.4	100.0
Below threshold					
q1	10.1	35.9	9.9	15.5	-
q2	5.7	33.1	4.9	8.8	-
q3	4.0	28.3	2.9	6.1	-
q4	2.7	17.5	1.3	4.1	-
Total	5.6	28.7	19.0	34.6	-

Wood

Quartiles	Persons employed (mean)	Productivity (thousand euros; mean)	Share of value added (%)	Share of persons employed (%)	Share of export (%)
Above threshold					
q1	6.3	33.2	5.8	6.5	2.1
q2	8.5	33.6	8.3	8.8	2.9
q3	12.3	39.7	13.4	12.7	8.6
q4	36.0	48.2	49.8	37.1	86.4
Total	15.8	39.2	77.3	65.1	100.0
Below threshold					
q1	4.1	29.4	11.2	14.5	-
q2	2.4	26.0	5.8	8.7	-
q3	1.8	23.0	3.7	6.4	-
q4	1.5	15.4	2.1	5.3	-
Total	2.5	23.4	22.7	34.9	-

Paper and print

Quartiles	Persons employed (mean)	Productivity (thousand euros; mean)	Share of value added (%)	Share of persons employed (%)	Share of export (%)
Above threshold					
q1	12.5	46.7	4.1	5.1	0.9
q2	16.5	50.4	5.8	6.7	1.9
q3	25.3	58.7	10.4	10.2	4.4
q4	116.9	71.2	61.9	47.3	92.8
Total	42.8	56.7	82.2	69.3	100.0
Below threshold					
q1	7.3	39.1	9.7	14.0	-
q2	4.1	33.6	4.5	7.8	-
q3	2.2	28.7	2.5	5.3	-
q4	1.9	16.6	1.0	3.6	-
Total	4.0	29.5	17.8	30.7	-

Chemicals and pharmaceutics

Quartiles	Persons employed (mean)	Productivity (thousand euros; mean)	Share of value added (%)	Share of persons employed (%)	Share of export (%)
Above threshold					
q1	41.5	102.0	4.8	5.2	4.3
q2	68.6	101.7	8.2	8.5	8.6
q3	115.1	109.9	13.9	14.3	12.9
q4	418.1	138.3	58.9	51.2	74.2
Total	159.4	113.0	85.7	79.2	100.0
Below threshold					
q1	21.0	99.2	8.6	10.3	-
q2	10.8	62.7	3.5	5.3	-
q3	6.9	51.8	1.7	3.4	-
q4	3.7	27.7	0.5	1.8	-
Total	10.6	60.4	14.3	20.8	-

Rubber and plastic

Quartiles	Persons employed (mean)	Productivity (thousand euros; mean)	Share of value added (%)	Share of persons employed (%)	Share of export (%)
Above threshold					
q1	20.7	58.1	5.3	5.6	3.2
q2	30.8	64.8	8.4	8.3	6.3
q3	49.2	69.1	14.3	13.2	13.4
q4	173.3	71.1	52.7	46.6	77.1
Total	68.5	65.8	80.7	73.7	100.0
Below threshold					
q1	11.8	50.2	9.0	10.7	-
q2	7.9	45.6	5.4	7.2	-
q3	5.8	42.0	3.5	5.3	-
q4	3.5	26.8	1.4	3.2	-
Total	7.3	41.1	19.3	26.3	-

Non metallic minerals

Quartiles	Persons employed (mean)	Productivity (thousand euros; mean)	Share of value added (%)	Share of persons employed (%)	Share of export (%)
Above threshold					
q1	10.8	42.6	3.5	4.2	1.5
q2	15.0	46.9	5.3	5.8	2.5
q3	24.1	57.7	9.7	9.4	5.8
q4	131.0	65.7	64.0	51.0	90.2
Total	45.2	53.2	82.5	70.5	100.0
Below threshold					
q1	6.9	36.1	8.4	11.6	-
q2	4.8	31.6	5.1	8.1	-
q3	3.4	26.2	2.8	5.7	-
q4	2.5	15.5	1.2	4.1	-
Total	4.4	27.4	17.5	29.5	-

Metals

Quartiles	Persons employed (mean)	Productivity (thousand euros; mean)	Share of value added (%)	Share of persons employed (%)	Share of export (%)
Above threshold					
q1	12.1	48.8	4.7	5.2	0.9
q2	16.5	53.7	6.8	7.0	1.9
q3	26.3	61.0	12.0	11.2	5.7
q4	106.4	68.5	55.2	45.5	91.4
Total	40.3	58.0	78.8	68.9	100.0
Below threshold					
q1	7.6	42.9	10.6	13.1	-
q2	5.0	37.1	6.0	8.6	-
q3	3.3	32.6	3.3	5.7	-
q4	2.1	20.1	1.3	3.7	-
Total	4.5	33.2	21.2	31.1	-

Electronics

Quartiles	Persons employed (mean)	Productivity (thousand euros; mean)	Share of value added (%)	Share of persons employed (%)	Share of export (%)
Above threshold					
q1	22.7	60.8	3.8	3.9	2.2
q2	32.5	69.6	6.1	5.6	4.3
q3	56.4	67.4	10.4	9.7	10.4
q4	331.2	71.5	62.0	56.7	83.1
Total	110.6	67.3	82.3	75.8	100.0
Below threshold					
q1	12.4	49.6	8.6	10.3	-
q2	7.7	47.3	4.7	6.4	-
q3	5.6	42.3	3.0	4.6	-
q4	3.6	26.4	1.3	3.0	-
Total	7.3	41.4	17.7	24.2	-

Machinery

Quartiles	Persons employed (mean)	Productivity (thousand euros; mean)	Share of value added (%)	Share of persons employed (%)	Share of export (%)
Above threshold					
q1	23.8	69.3	4.7	4.9	3.2
q2	34.8	71.3	7.1	7.2	6.0
q3	58.1	73.9	12.5	12.1	13.0
q4	233.4	80.0	55.1	48.4	77.8
Total	87.5	73.6	79.5	72.6	100.0
Below threshold					
q1	13.9	59.2	10.2	12.0	-
q2	8.5	52.0	5.5	7.3	-
q3	6.0	49.1	3.5	5.2	-
q4	3.3	32.8	1.3	2.8	-
Total	7.9	48.3	20.5	27.4	-

Automotive

Quartiles	Persons employed (mean)	Productivity (thousand euros; mean)	Share of value added (%)	Share of persons employed (%)	Share of export (%)
Above threshold					
q1	65.2	76.0	3.7	3.4	3.2
q2	111.5	71.3	5.7	5.9	3.9
q3	204.1	70.2	10.3	10.8	10.0
q4	1163.6	65.4	66.2	60.7	82.9
Total	383.9	70.8	85.8	80.8	100.0
Below threshold					
q1	27.0	62.4	8.8	10.2	-
q2	11.5	45.9	3.0	4.3	-
q3	7.6	40.7	1.7	2.9	-
q4	4.5	22.6	0.6	1.7	-
Total	12.6	42.9	14.2	19.2	-

Furniture

Quartiles	Persons employed (mean)	Productivity (thousand euros; mean)	Share of value added (%)	Share of persons employed (%)	Share of export (%)
Above threshold					
q1	12.4	39.2	5.1	5.8	1.9
q2	15.7	42.8	7.3	7.4	4.2
q3	25.3	48.0	13.1	11.8	9.5
q4	90.7	54.6	52.6	42.4	84.4
Total	36.0	45.1	78.1	67.4	100.0
Below threshold					
q1	7.2	33.2	11.4	14.4	-
q2	4.1	28.0	5.5	8.3	-
q3	3.0	24.9	3.4	6.0	-
q4	2.0	17.3	1.6	4.0	-
Total	4.1	25.9	21.9	32.6	-

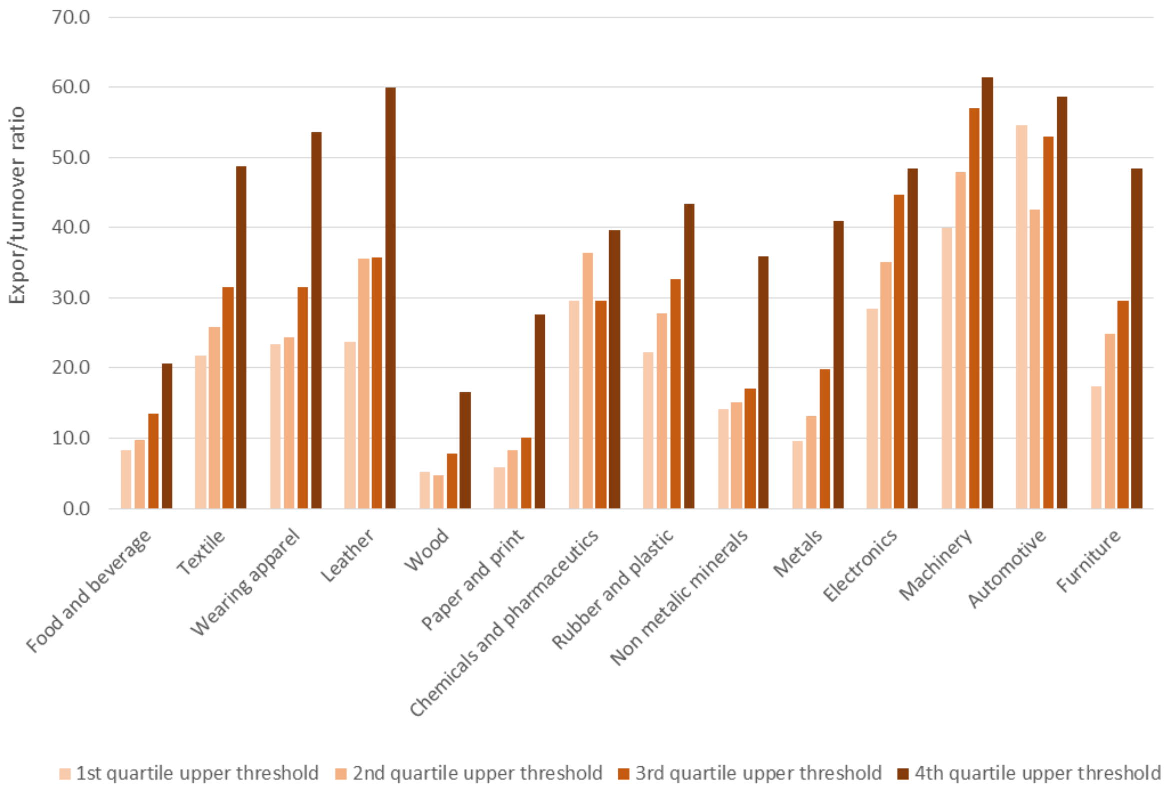
Total

Quartiles	Persons employed (mean)	Productivity (thousand euros; mean)	Share of value added (%)	Share of persons employed (%)	Share of export (%)
Above threshold					
q1	13.9	46.7	4.3	4.9	2.3
q2	19.5	51.8	6.5	6.8	4.4
q3	31.6	59.7	11.6	11.1	9.7
q4	137.1	70.3	59.2	48.0	83.5
Total	50.5	57.1	81.6	70.7	100.0
Below threshold					
q1	8.5	40.2	9.3	12.3	-
q2	5.3	34.7	4.9	7.7	-
q3	3.8	30.4	3.0	5.5	-
q4	2.5	18.9	1.2	3.7	-
Total	5.0	31.1	18.4	29.3	-

Source: Authors' calculation on Istat data.

The analysis of the export propensity of "above-threshold" firms offers some further insights. As Figure 6 shows, accordingly with the stylized fact that Italian business system is characterized by a relatively low intensive margin (see Istat, 2017), in most industries the export-to-turnover ratio is below 30% for half of firms (2nd quartile); actually, in all industries the most export-oriented firms are those more distant from the threshold (4th quartile). Moreover, in 10 sectors out of 14, the largest increase in such "intensive margin" occurs between the 3rd and 4th quartiles, independently from their distance from the threshold. This is particularly evident in some typical industries of the Italian specialization model (Textiles, Wearing apparel, Leather, Metals, Wood and Furniture).

Figure 6. Export propensity of firms above the threshold, by industry (average of export-to-turnover ratio by quartiles of distance from the threshold)



Source: Authors' calculation on Istat data.

4. Conclusions

In this paper, we determine the "export threshold" for Italian manufacturing industries by applying for the first time in economics a technique widely used in other disciplines such as medicine and natural sciences: the ROC curve. Export threshold is here defined as the firm-level minimum combination of (levels of) productivity and economic size (where the latter is defined on the basis of firm's turnover, persons employed, capital intensity and age) corresponding to the transition from the non-exporter to exporter status. We calculate export thresholds making use of a unique firm level dataset collecting information about the structural features of Italian firms, their profit and loss account and export performance. In a first step of the analysis, this allows to cluster Italian firms as exporters or non exporters depending on whether the value of their size-productivity combination lays above or below the export threshold, also giving a measure of their distance from the threshold itself. Fitting tests reveal a high ability of the model to classify exporters and non exporters, correctly identifying both exporting firms (true positive cases) and non-exporting firms (true negative cases): our "estimated exporters" account for almost 100% of the total value of export.

By applying this methodology, we are able to obtain a "map" of how Italian manufacturing firms are distributed across the export threshold in each industry, which may be helpful both from an analytical and normative point of view. There emerges a substantial gap between a quarter of exporters (firms with the highest combination of productivity and economic size) and the rest of Italian exporters. In particular, a large segment of Italian exporting firms is negligible in terms of share of value added and total export, even though they have productivity and size levels sufficient to export; it follows that the capacity of these firms to survive generally depends to a very large extent on the domestic demand.

However, especially in traditional industries (Food and beverage, Textiles, Leather, Wood), in which productive processes are more labour intensive, non-exporting firms account for a significant share of the overall manufacturing employment (ranging between 28% and 35%). Furthermore, among the "below-threshold” firms, the units closest to the threshold show the largest shares of value added and employment. It follows that in some important industries of the Italian specialization model, a policy aimed at increasing the extensive margin should be focused on this group of firms, with beneficial effect both on firms’ performance and total employment. In this vein, our “map” allows to find out which factor, among productivity and economic size, would be more effective for a firm to cross the export threshold. In other words, it would be possible to detect the best policy incentive to firm’s growth (in terms of size and/or productivity) acting through the more efficient factors to achieve this goal.

However, actually, thresholds cannot be properly compared among industries, because they strictly depend on specific characteristics, other than firm’s economic size-productivity combination, prevailing in their own sectors, like entry barriers, domestic relations of sub-contracting and so on.

This pave the way to develop the methodology proposed in this paper to take into account different kinds of trade costs highlighted by theoretical and empirical literature, both behind the border (such as transport costs, tariff and non-tariff regulatory measures, market access restrictions, trade finance availability) and crossing the border (such as documentation and customs compliance requirements, lengthy administrative procedures and other delays, transport infrastructure and logistics).

In particular, our indicator Z can be augmented taking into consideration “exogenous” barriers to firms’ internationalization that could be somehow reduced by some type of policy intervention. In this case, it would be possible to calculate how much a reduction in these trade barriers would increase the number of “new” exporting firms by lowering the export threshold.

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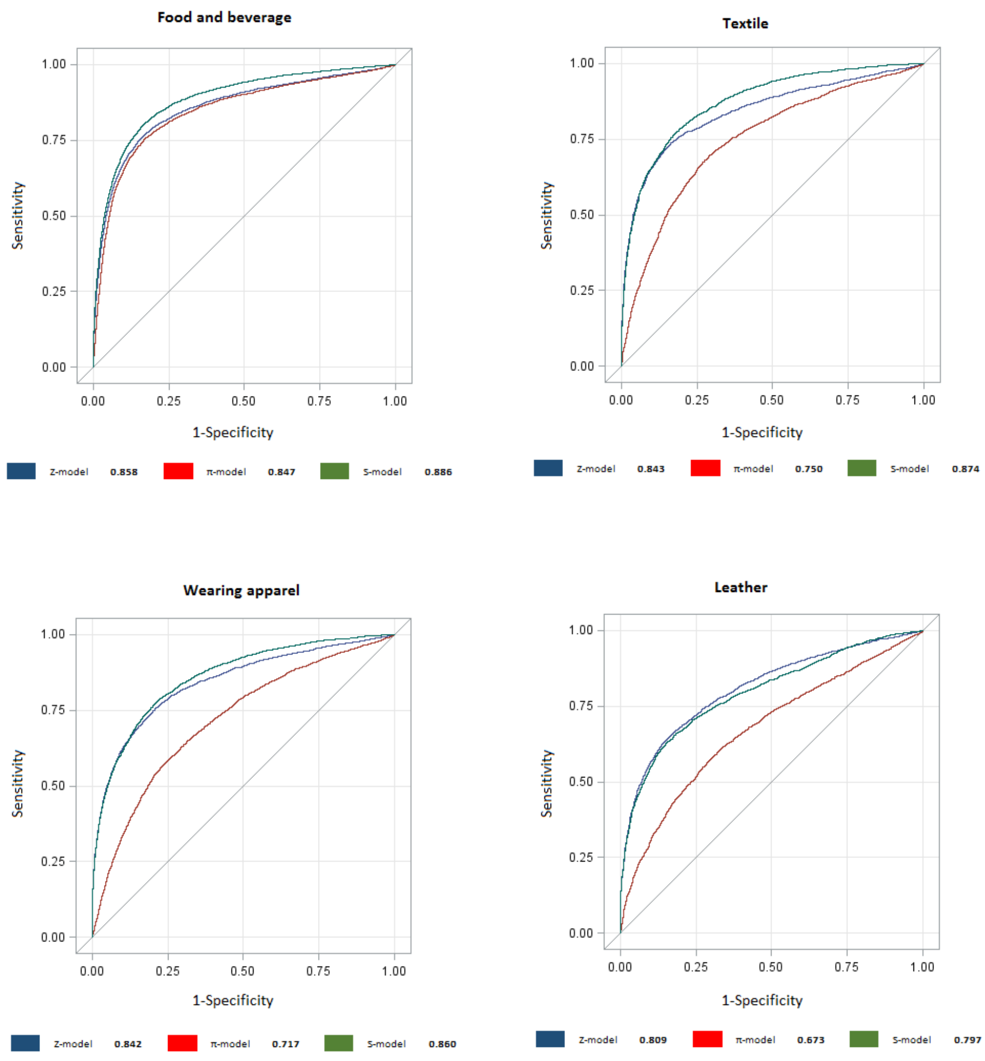
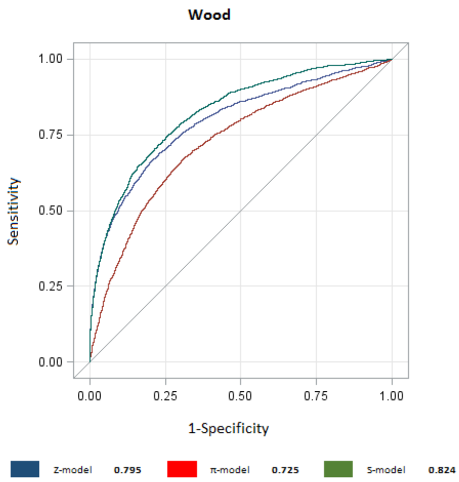
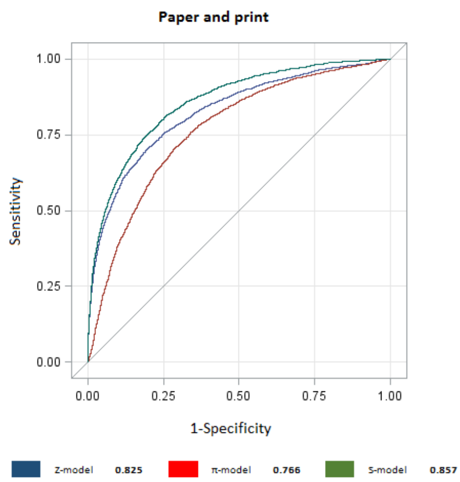
Appendix A

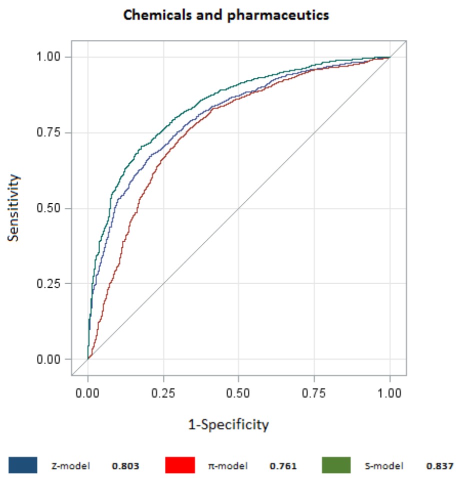
Following the results presented in Table 2, this appendix is devoted to show a graphical representation of the comparison between the AUCs of *Z*-model (productivity and economic size) and partial π-model (productivity) and S-model (sales) for all industries. Figure A confirms that in all industries, S-model shows a higher AUC with respect to Z-model, while the latter outperforms π-model.

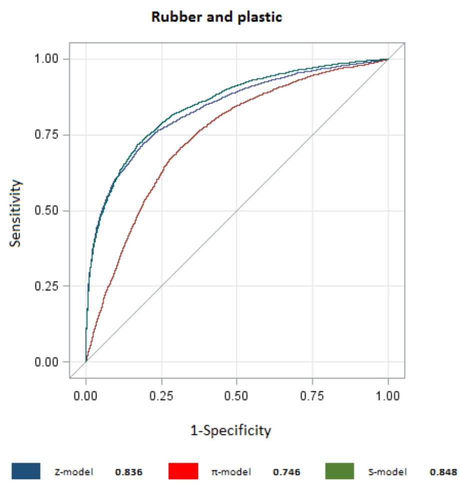
Figure A: ROC curves and AUCs for complete *Z* model and partial *π* model by industry

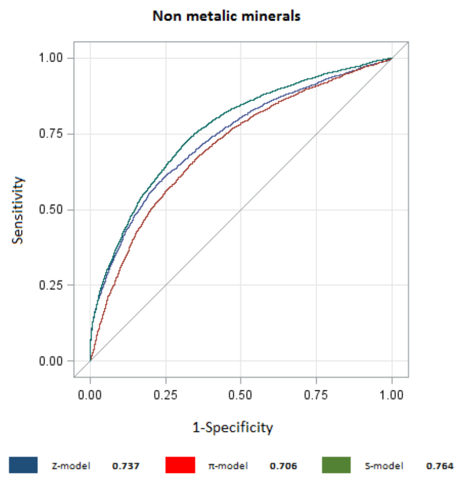


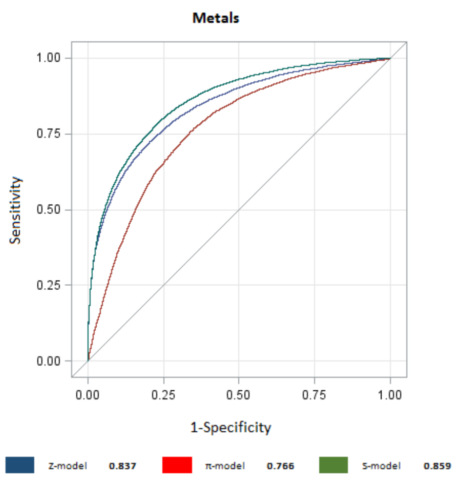

Wood
Sensitivity
1-Specificity
0.00
0.25
0.50
0.75
1.00
Z-model 0.795
π-model 0.725
S-model 0.824

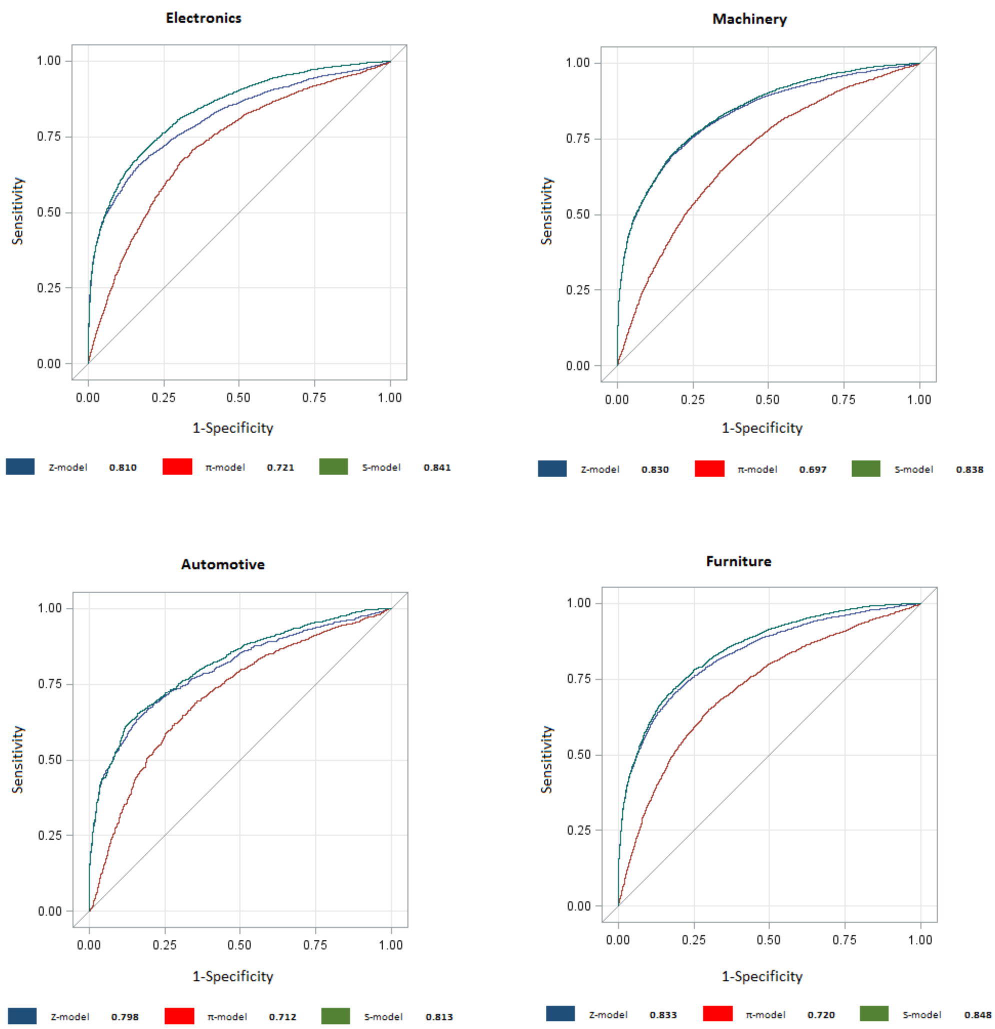

Paper and print
Sensitivity
1-Specificity
0.00
0.25
0.50
0.75
1.00
Z-model 0.825
π-model 0.766
S-model 0.857


Chemicals and pharmaceutics
Sensitivity
1-Specificity
0.00
0.25
0.50
0.75
1.00
Z-model 0.803
π-model 0.761
S-model 0.837


Rubber and plastic
Sensitivity
1-Specificity
0.00
0.25
0.50
0.75
1.00
Z-model 0.836
π-model 0.746
S-model 0.848


Non metalic minerals
Sensitivity
1-Specificity
0.00
0.25
0.50
0.75
1.00
Z-model 0.737
π-model 0.706
S-model 0.764


Metals
Sensitivity
1-Specificity
0.00
0.25
0.50
0.75
1.00
Z-model 0.837
π-model 0.766
S-model 0.859


Electronics
Sensitivity
1-Specificity
Z-model 0.810
π-model 0.721
S-model 0.841
Machinery
Sensitivity
1-Specificity
Z-model 0.830
π-model 0.697
S-model 0.838
Automotive
Sensitivity
1-Specificity
Z-model 0.798
π-model 0.712
S-model 0.813
Furniture
Sensitivity
1-Specificity
Z-model 0.833
π-model 0.720
S-model 0.848