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Variable export price elasticity, product quality, and credit constraints: Theory and evidence from Greek firms

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ABSTRACT

We propose a simple model with endogenous quality, additive non-homothetic preferences and credit constraints. A unique data set of Greek manufacturing firms with firm-level exports, credit scores and other financial variables supports the model's main predictions. Specifically, we establish that less credit-constrained Greek exporters with higher credit scores face export demand curves with lower price elasticity, charge higher export prices, and export higher-quality products.

1. Introduction

We propose a new tractable and testable model to analyze the effects of credit constraints on the behavior of exporters. The model combines additive non-homothetic preferences, endogenous product quality, and credit constraints. In the model, each firm produces a distinct variety, faces a variable price elasticity of demand, chooses the quality of its product, and finances an exogenous fraction of production costs by borrowing from a competitive banking sector. Credit constraints are modeled by assuming that each firm faces an exogenous probability that it will not be able to serve the export market as in Manova (2013) and Feenstra et al. (2014).

The model is employed to address several novel questions. What are the effects of credit constraints on price, quantity, and quality of exports? What are the effects of credit constraints (and other determinants) on the price elasticity of demand? Are the model's main predictions testable and empirically relevant? Specifically, do less credit-constrained Greek firms charge higher export prices, raise the quality of their exports, and reduce the price elasticity of demand for exports by selling more output?

Credit constraints affect the cost structure of exporters and thus influence the extensive margin (number of products) and intensive margin (quantity) of exports. When credit constraints operate primarily through external funding of fixed

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exporting costs, entry into foreign markets becomes more difficult (Chaney, 2016). When credit constraints affect marginal costs of production, export prices and markups are affected as well since less constrained exporters face lower marginal costs (Manova, 2013; Feenstra et al. 2014). Conventional reasoning suggests that lower marginal production costs lead to a lower export price and a higher export quantity especially when an exporter faces a negatively-sloped demand or marginal revenue curve. For instance, models of monopolistic competition with constant price elasticity of demand, as in Krugman (1980) or Melitz (2003), imply that less credit-constrained firms charge lower export prices, driven by lower marginal costs.

This implication does not enjoy empirical support. We document that less credit-constrained Greek firms charge *higher* export prices. This result echoes one of the main findings of Manova and Zhang (2012) who investigate empirically the pattern of Chinese export prices. Because higher quality translates into a higher price, these researchers argue strongly that empirically relevant trade models should feature endogenous product quality, although they do not develop a formal model with product quality.[1]

Building on the views of Manova and Zhang (2012), the present paper fills in part this gap by proposing a parsimonious yet flexible model featuring endogenous product quality, variable price elasticity of demand, and credit constraints. Higher product quality raises the demand for each variety and entails higher fixed and variable production costs. Variable price elasticity of demand allows firms to charge a higher price and a markup by operating on a less elastic segment of their demand curves. The typical firm finances an exogenous fraction of production costs by borrowing from a perfectly competitive banking sector as in Bandyopadhyay et al. (2018). The remaining fraction of production costs is financed through retained earnings. Each firm faces an exogenous probability that it will not be able to serve the export market (default rate) as in Manova (2013) and Feenstra et al. (2014). Credit constraints are captured by a higher default rate and firms maximize expected profits by choosing export quantity and quality.

One of the main theoretical predictions states that a less credit-constrained firm faces lower export price demand elasticity. Intuitively, an increase in firm survival rate raises expected marginal revenue inducing each firm to produce more output. Because the price elasticity of demand declines with firm output as in Krugman (1979) and Dinopoulos et al. (2011), output expansion reduces the price elasticity of demand.

The incorporation of demand curves with variable price elasticity constitutes a significant departure from constant elasticity of substitution (CES) preferences that have been used routinely in trade models.[2] Although CES preferences offer tractability, they are restrictive and carry several undesirable properties.[3] For example, in trade models with monopolistic competition and CES preferences firm output, prices, and markups are constant and thus cannot be affected by trade openness or trade policies. In addition, intraindustry trade does not have any effects on labor-market outcomes such as the skill premium (Dinopoulos et al., 2011) and unemployment (Firooz, 2019). As a result, there is a growing strand of literature analyzing the implications of trade models with variable price elasticities.[4]

The present model identifies several determinants of the price elasticity of demand for exports, which is inversely related to exported quantity as in Krugman (1979), Dinopoulos et al. (2011), and Simonovska (2015). According to the model, the price elasticity of demand declines with firm survival rate and consumer income; and increases with trade costs. The effects of market size, captured with the number of consumers, depend on the presence or absence of scale economies in marketing as in Arkolakis (2010).

The empirical analysis tests the model's predictions regarding the effects of credit availability, captured theoretically by the exogenous risk of default and measured empirically by each firm's credit score. In the case of Greek firms, this score is reported on a ten-grade scale and expresses the credit quality of a firm with respect to the probability of bankruptcy over a year. Thus, it constitutes an ideal measure of the firm's theoretical default risk. In practice, firm-specific credit scores are used routinely by banks to decide whether a Greek firm will receive a loan and the terms of the loan including the lending rate.

Our identification strategy is based on a semi-structural approach. We estimate variants of demand equations that capture the effect of variables of interest on export quantities conditional on prices. This approach allows us to obtain variable price elasticities by interacting prices with firm credit scores and destination-specific variables such as distance, consumer income and market size. We address the possible price-endogeneity problem of estimated demand equations by using the physical efficiency (productivity) of each firm, measured by physical output per worker, as an instrument following Foster et al. (2008). Variation in physical efficiency shifts the marginal cost of production and thus identifies the demand curve and its price elasticity.

We also deal with possible endogeneity in financial ratings by constructing an instrument for credit scores. The basic idea behind our identification strategy is to use variations in credit scores at the aggregate level as an instrument for a firm's credit score. This idea builds on the notion of network effects (Goolsbee and Klenow, 2002). The instrumentation assumption is that the firm's credit rating is correlated with the average credit score of other firms that export the same product, which is exogenous to unexpected shifts in export prices or quantities for the firm-product-destination pairs. As a result, our

[1] The online Appendix offers a number of regressions that are directly comparable to those reported by Manova and Zhang (2012) and illustrates that the main features of the dataset on Greek firms are similar to theirs.

[2] Non-homothetic preferences generate demand systems with variable price elasticity. However, demand systems with variable price elasticity can be constructed from homothetic preferences as well as Feenstra (2003) and Matsuyama and Ushchev (2017) demonstrate formally.

[3] Feenstra (2016, Chapter 6) offers an excellent discussion of these properties.

[4] See, for instance, Feenstra (2003), Melitz and Ottaviano (2008), Dinopoulos et al. (2011), Behrens and Murata (2012), Behrens et al. (2014), Simonovska (2015), Feenstra and Weinstein (2017), and Firooz (2019).

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instrument for a firm product-specific credit score is based on the previous-year average credit score of all firms that have exported the product in any destination, excluding the firm under consideration.

In addition to the effects of credit constraints, the model offers predictions on the effects of consumer income, trade costs and other market characteristics. The empirical analysis confirms these predictions by establishing that Greek exporters face less elastic demand functions for their products in richer and less distant markets. They also experience scale economies in marketing. The pattern of Greek export prices is consistent with the main findings of Manova and Zhang (2012) supporting their view that exporters choose optimally the quality of their products based on market characteristics in destination countries. Finally, the elasticity-related findings highlight the role of endogenous price demand elasticity as an essential element of empirically relevant trade models.

The proposed model generates a structural equation according to which the product-specific export revenue per consumer depends positively on product quality, per-capita income and the price elasticity of demand. Using the demand elasticities in our estimated demand equation and information on the other components of the structural equation, we obtain consistent estimates of exporter's quality at the destination level. The inferred product qualities are used to establish a significant positive correlation between higher product quality and greater credit scores. Indeed, less credit-constrained Greek firms export higher quality products in accordance to one of the model's predictions.

The rest of the paper is structured as follows. Section 2 presents an overview of related studies. In Section 3 we describe the dataset on Greek exporters and the main stylized facts about credit constraints. Section 4 presents a simple model with non-homothetic preferences, variable price elasticity of demand, endogenous quality and credit constraints. The model is used to derive several testable implications. Sections 5 and 6 present the econometric analysis and results respectively. Section 7 concludes.

2. Related literature

Our paper contributes to two main strands of trade literature. First, it belongs to the literature investigating empirically linkages between financial constraints and trade margins. Berman and Héricourt (2010) use a cross-country firm-level dataset of emerging and developing economies to establish that financial factors, measured by liquidity and leverage ratios, do not have a significant effect on export quantities or export participation suggesting that financial factors affect only the initial sunk cost of exporting. Greenaway et al. (2007) use a panel of UK manufacturing firms to establish that leverage and liquidity constraints influence negatively the likelihood of exporting (extensive trade margin). Feenstra et al. (2014) propose a Melitz-type model where asymmetric information between a lender and heterogeneous borrowers creates credit constraints. They provide empirical support for the model by reporting that Chinese exporters face more severe credit constraints than non-exporters primarily because exporters face a longer time lag to ship and sell their products abroad. Minetti and Zhu (2011) use a sample of Italian firms and report that credit rationing, based on survey responses, affects adversely the amount of foreign sales. Muûls (2015) finds that less financially-constrained firms in Belgium are more likely to export or import, export more products to more destinations, and also exhibit higher value of foreign sales per product-destination.

None of these studies analyzes the effects of credit constraints on the price elasticity of demand and none of them proposes a quality-based model of exporting. It should be mentioned that a positive correlation between less-credit constrained firms and higher export revenue is consistent with Melitz-type models. Since firms in these models face elastic demand curves, less financially-constrained firms that charge lower (as opposed to higher) export prices necessarily obtain higher export revenues. Our theoretical model shows that less credit-constrained firms charge *higher export prices* in addition to selling greater quantities indicating a demand-side effect. As said, this finding is inconsistent with Melitz-type models because they imply a negative correlation between less credit-constrained firms and export prices.

Second, our paper is related to the strand of trade literature investigating the role of quality in export pricing and its implications for the relationship between prices and market toughness, given by destination size and distance. Baldwin and Harrigan (2011) find that disaggregated export unit values are positively related to distance and negatively related to market size. The empirical findings are then explained as a composition effect within a quality-augmented Melitz-type model with CES preferences: since only the best firms sell in these markets charging high prices, average prices at the product level are higher in smaller and more distant markets. Moreover, several empirical studies such as Hummels and Skiba (2004), Johnson (2012), Martin (2012), and Hallak and Sivadasan (2013) find that exports have higher quality (measured by unit value) on average than domestic goods. Bastos and Silva (2010) and Harrigan et al. (2015) establish that unit values are higher in shipments to larger and richer nations.

We contribute to this body of literature by proposing a mechanism relating credit availability to export prices and quantities, which operates through changes in product quality. Specifically, our empirical findings confirm the predictions of a simple model featuring variable demand elasticity, endogenous quality, and credit constraints. Our theoretical model and empirical findings complement and extend existing results of studies on the 'quality sorting' of exporters, which have identified product quality through unit price, or quality-adjusted unit prices. To our knowledge, our study is the first to document the impact of credit constraints on prices and price elasticities of demand and relate them to destination-specific characteristics.

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The study by Arkolakis (2010) is closer in spirit to the present one. This study has put forward the idea that marketing expenditures affect trade at the firm-level based on the concept that additional advertising leads to additional revenues. The key assumptions are that the cost to reach a certain number of consumers in a market decreases with the number of potential customers; and that, within a given market, the marginal cost of marketing increases with the number of consumers reached. We adopt this idea in the present paper by assuming that effective market size depends on the number of consumers and the degree of scale economies in marketing. Although our empirical findings are consistent with scale economies in marketing, our paper differs from Arkolakis (2010) in scope, focus, and issues addressed.

Our paper is partially motivated by the empirical work of Manova and Zhang (2012) who establish that export prices are higher in richer, larger, and more distant destinations. These findings support the empirical relevance of trade models with endogenous product quality. However, their analysis does not include a formal model with endogenous quality. Our paper confirms the empirical findings of Manova and Zhang (2012) and focuses on the novel issue of the effect of financial restrictions on the behavior of exporters. We note that a salient feature of our approach is that we do not require product-quality information in the data to test the model's predictions. Our approach is also in line with Gervais (2015), who shows that demand factors are important in explaining firm-level exports even after controlling for productivity and, therefore, product quality plays an important role in explaining heterogeneity among exporters.

3. Greek exporters: Dataset and stylized facts

In this section we briefly describe the dataset on Greek exporters. We then present preliminary evidence suggesting that less financially constrained Greek firms charge higher export prices, export greater quantities and thus earn higher export revenues.

3.1. Data set

The dataset on Greek exporting manufacturing firms merges data from two sources:

i. Customs data on firm-level international trade transactions, which are collected separately for European Union (EU) partner countries (Intrastat) and non-EU partners (Extrastat) via Greek Statistical Agency (ELSTAT).[5]
ii. Financial sheet data supplied by ICAP, which is the largest Greek firm that supplies business information. ICAP provides information on balance sheet variables and other key data, such as the credit scores. In total, roughly 35,000 firms are included in the ICAP database. To maintain comparability with our data on exports we keep only those firms that belong (via the NACE classification system) to categories appearing at least once over the years of our sample in the exporting database [6]

Our estimations refer to year 2007. Our strategy to focus on a single year, also adopted by Manova and Zhang (2012), is motivated by the following considerations. First, the aim is to establish stylized facts based on a cross-section of firms and thus we abstract from concerns about nominal frictions, such as sticky wages and prices, and related firm or sectoral dynamics. Second, we avoid using data for subsequent years due to the world financial crisis that might have affected the nature of exporting in a small open economy like Greece (Behrens et al., 2013). Third, because data for only one year (denominated in Euros) are used, the analysis is not sensitive to possible adjustments in the quality of exports by Greek firms stemming from the adoption of Euro in 2001. In addition, credit scores are strongly persistent and the standard errors in empirical specifications could be misleadingly low in a panel setup because the number of observations would be effectively large without necessarily containing new information. Finally, outliers are likely to be of greater concern in a panel dataset extending over several years, as there is a lot of lumpiness because many firms do not export a given product to a given market in every year. Consequently, we estimate our model for 2007 and use data for 2006 only for the firm-specific credit scores in order to address possible endogeneity issues, as we will discuss below.

The literature on exporting and financial frictions has used a variety of measures capturing credit constraints. For instance, Greenaway et al. (2007), Bellone et al. (2010), Berman and Héricourt (2010) use liquidity (cash flows) and leverage (total debt over total assets) as measures of financially binding constraints. Yet, these balance sheet measures capture a single dimension of the firm's fundamentals and access to financial markets. Minetti and Zhu (2011) use survey responses from Italian firms on credit rationing based on a self-declared binary classification indicating whether or not a firm is credit constrained. However, in markets with strong asymmetries typically associated with financially constrained firms, survey measures tend to suffer from moral-hazard problems. For instance, firms have incentives to exaggerate their credit score in order to obtain lower-interest loans.

We measure the degree of credit constraints for individual firms using the ICAP Credit Rating score from the ICAP database. This score expresses a firm-specific multivariate estimate of credit quality with respect to the probability of default

[5] Our dataset consists of manufacturing products. The classification of all reported exported goods (approximately 2500 products) follows the Standard International Trade Classification (SITC) system.
[6] Sections A and B of the online Appendix offer more details on the construction of the dataset.

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and/or bankruptcy over a one–year time horizon. The credit score is a single indicator controlling for insolvency, excessive and/or bad debts, overdue accounts, and other typical commercial risks. The assessment is based on an analysis of commercial, financial and trading data derived from public sources and interviews with the rated firms, and it is measured on a ten-grade scale.

Importantly, the ICAP credit score is routinely used by Greek banks in their decisions to supply credit to firms. As a result, a low credit score does not only imply a higher probability of credit denial, but it is also associated with higher interest payments for any given loan, acting in a similar manner to credit constraints since it affects the size of the loans that can be afforded by these firms (Feenstra et al., 2014). The ICAP credit score is also used by firms in assessing the credibility of their clients and suppliers and thus provides a form of extra liquidity through short-term financing from suppliers. Section B of the online Appendix provides additional details on the construction and classification of ICAP credit scores.[7]

3.2. Stylized facts

We begin with a description of a few interesting patterns revealed by the Greek data which serve as stylized facts motivating our theoretical framework. The first column of Table 1 reports key statistics for our full sample of exporters. The sample consists of 2169 firms accounting for 1811 exported products. The average number of products per firm is 7.2 and the average number of destinations per firm is 5.8. Exporters are larger firms with greater sales and profits than the rest of the firms in the sample (not reported here), a finding that is typical in related empirical literature.[8] We find marked differences between more and less credit-constrained Greek exporters based on their credit ratings, as indicated in the second and third columns of Table 1. High-rated (less credit-constrained) exporters sell more products and serve more destinations compared to low-rated exporters.

Encouraged by the differences in main characteristics between more and less credit-constrained Greek firms, we next explore the nexus among credit scores, export prices, quantities, and revenues through OLS regressions. As Manova and Zhang (2012), we stress that the estimated coefficients reflect correlations, rather than causal effects. Table 2 reports OLS regressions of firm intensive margins on credit scores using firm-product-destination observations. Product fixed effects are included to control for systematic differences across goods in consumer appeal, comparative advantage, transportation costs, units of measurement (kilos versus physical units), and other product-specific characteristics. We also include destination fixed effects to account for destination-specific characteristics, such as consumer income, general demand conditions, transportation costs, as well as inflation and exchange rates. Finally, we include industry fixed effects in order to capture systematic differences across industries.

Panels A and B of Table 2 report the corresponding regressions with price and quantity as dependent variables respectively. Panel A indicates that firms with higher ratings charge higher prices with the coefficient becoming larger when we control for export revenues and quantities. Panel B indicates that higher ratings are associated with higher exports quantities, with the exception of column (4), where the coefficient of credit rating is negative when we control for firm revenues. These stylized facts indicate that less credit-constrained Greek exporters sell higher quantities at higher prices. These findings contradict the standard prediction of trade models with heterogeneous exporters and CES preferences, which predict that less credit-constrained firms that face lower marginal costs charge lower prices.

4. Theoretical framework

This section presents a simple model analyzing the impact of credit constraints on export prices, revenue and price elasticity of demand. Motivated by the aforementioned stylized facts on Greek exporters, we focus on the behavior of an exporter producing a differentiated product with endogenous quality and facing a demand curve with variable price elasticity. The firm treats quality as a choice variable raising the consumer willingness to pay and involving higher production costs.

We assume that each firm produces a single variety in two separate plants, or two distinct lines of production, with one devoted to exports and the other to domestic production, as in Verhoogen (2008).[9] Production, marketing and related activities occur before the product is sold abroad. Consequently, firms must finance an exogenous fraction of production and distribution costs, as in Feenstra et al. (2014). The remaining fraction is financed through retained earnings. The typical exporter faces an exogenous probability of default raising the costs of borrowing above the costs of funds. A competitive banking sector provides credit to each exporter. We also assume that each exporter faces iceberg-type trade costs.

4.1. Demand structure

The demand structure of the model borrows elements from Dinopoulos et al. (2011) and Simonovska (2015) by utilizing a translated additive Cobb-Douglas utility function leading to variable price elasticity of demand. However, unlike these two

[7] See also Muûls (2015) who uses a credit score measure for Belgian exporters that combines financial variables, firm-specific characteristics, as well as industry-specific and macro-economic variables.

[8] See also Arkolakis and Muendler (2013) for a survey on the empirical properties and regularities of various country datasets (including the Greek dataset).

[9] This choice is based on data availability. Extending the model to multi-product firms is feasible, but this would complicate the algebra without offering additional significant insights to the empirical analysis.

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Table 1
Greek exporting manufacturing firms, summary statistics (2007).

	All exporters	Credit scores of exporters	
		High	Low
A. exporting characteristics			
Number of exporting firms	2169	542	459
Value of exports	3279	8716	1217
Number of products	1811	1434	908
Number of destinations	173	144	119
Average number of products per firm	7.2	11.7	4.4
Average number of destinations per firm	5.8	8.2	4.1
Average number of destinations per product	9	6.6	3.6
Number of observations	33,106	14,793	4023
B. firm characteristics			
Employment	126	319	55
Age	17	22	13
Total sales	35,696	107,488	9923
Total assets	47,040	111,651	47,810
Fixed assets	27,113	64,397	36,560
Gross profits	7698	22,760	1737
Operating costs	6133	16,291	3069
Liquidity ratio	0.189	0.264	0.111
Leverage ratio	5.360	2.44	10.29
Cash flow	0.075	0.096	0.057

Notes: The classification of firm credit rating includes 10 categories from AA to H (see section B of the online Appendix). *High* rating firms are those in the top 2 categories (about 25% of the firms) and *Low* rating firms are firms rated 5 or below (about 20% of all firms). Liquidity ratio is defined as the firm's current assets less current liabilities over total assets. Value of exports, total assets, fixed assets, gross profits and operating costs are reported in thousand Euros. Leverage ratio is defined as the firm's ratio of total liabilities to equity. Cash flow is calculated as profits net of tax expenditures plus depreciation and is normalized by total assets (see also Minetti and Zhu, 2011).

Table 2
Export performance and credit constraints.

A. dependent variable: price			
Credit score	0.040*	0.052**	0.111***
	(1.87)	(2.43)	(5.79)
Revenues		−0.026***	
		(−10.45)	
Quantity			−0.171***
			(−84.26)
N	33,106	33,106	33,106
R^2	0.827	0.828	0.861
B. dependent variable: quantity			
Credit score	0.413***	−0.052**	0.459***
	(7.88)	(−2.43)	(9.71)
Revenues		1.026***	
		(408.08)	
Price			−1.141***
			(−84.23)
N	33,106	33,106	33,106
R^2	0.565	0.935	0.650

Notes: All variables are in logs. The regressions include a constant term and *t* statistics based on robust standard errors are in parentheses (* denotes p < .10, ** denotes p < .05, *** denotes p < .01). All regressions include product fixed effects, industry fixed effects and destination fixed effects.

studies, we augment the utility function by introducing endogenous product quality as in Feenstra and Romalis (2014) to capture the relationship between quality and credit availability. In order to maintain analytical tractability, we employ a partial-equilibrium framework and focus on the intensive (as opposed to the extensive) margin.

The foreign (export) market consists of N consumers and is served by n firms. Each firm produces a distinct variety. Following the standard approach to partial-equilibrium modeling, we assume that the utility of consumer j is given by:

$$U_j = \sum_{i=1}^{n} \beta_j \lambda_i \ln(z_{ij} + \theta) + z_{0j} \quad (1)$$

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where z_{ij} is the quantity of product i consumed by consumer j, λ_i denotes quality of product i, and z_{0j} is the quantity of a composite outside good consumed by consumer$j$. Parameter $\beta_j > 0$ captures the exogenous level of consumer j's willingness to pay. Parameter $\theta > 0$ introduces non-homothetic preferences, as in Simonovska (2015), and generates variable price elasticity of demand. Intuitively, parameter θ introduces the notion that a consumer gets utility from 'window shopping' or from having the option of consuming a variety.

Maximizing (1) subject to the standard budget constraint $I_j = \sum_{i=1}^{n} p_i z_{ij} + p_0 z_{0j}$ and setting the price of outside good equal to unity (p_0 = 1) yields the following inverse demand function for variety i

$$p_i = \frac{\beta_j \lambda_i}{z_{ij} + \theta} \tag{2}$$

Solving (2) for z_{ij} and aggregating over all consumers N yields $x_i = N\left[p_i^{-1}\lambda_i\beta - \theta\right]$, where $x_i = \sum_{j=1}^{N} z_{ij}$ is the aggregate quantity demanded for variety i and $\beta = \left(\sum_{j=1}^{N}\beta_j\right)/N$ is the average willingness to pay. Because consumer utility is symmetric across products, one can drop subscript i. For empirical purposes, we assume that the average consumer willingness to pay β increases with average consumer income $I = \left(\sum_{j=1}^{N} I_j\right)/N$, that is, $\beta = I^{\gamma}$, where $\gamma > 0$ is a parameter, as in Feenstra and Romalis (2014). These considerations lead to the following expression for the inverse demand for a typical variety

$$p = \frac{I^{\gamma}\lambda}{xN^{-1} + \theta} \tag{3}$$

Eq. (3) implies a finite reservation price $I\lambda/\theta$, that is products are non-essential. The reservation price increases with product quality λ and per-capita consumer income I; and decreases with parameter θ implying a flatter and thus more elastic inverse demand curve for higher values of θ. When $\theta = 0$ the inverse demand function becomes Cobb-Douglas with an infinite reservation price. Finally, observe that an increase in market size N shifts upward the inverse demand curve.

Eq. (3) generates the following *price* elasticity of demand

$$\varepsilon = -\frac{\partial x}{\partial p}\frac{p}{x} = 1 + \frac{\theta N}{x} > 1 \tag{4}$$

According to (4), the price elasticity exceeds unity, declines with quantity demanded x, and increases with the number of consumers N, as in Krugman (1979), Dinopoulos et al. (2011) and Simonovska (2015).

Export revenue is given by

$$R(x,\lambda) \equiv px = \frac{I^{\gamma}\lambda x}{xN^{-1} + \theta} \tag{5}$$

and generates the following marginal revenue functions

$$R_x \equiv \frac{\partial R(x,\lambda)}{\partial x} = p\left(1 - \frac{1}{\varepsilon}\right) = \frac{I^{\gamma}\theta\lambda}{\left(xN^{-1} + \theta\right)^2} > 0 \tag{6}$$

$$R_{\lambda} \equiv \frac{\partial R(x,\lambda)}{\partial \lambda} = \frac{I^{\gamma}x}{\left(xN^{-1} + \theta\right)} > 0 \tag{7}$$

4.2. Cost structure

We assume segmented domestic and export markets and focus only on the latter for expositional and empirical purposes. The representative firm faces fixed and variable production costs. The former increase with product quality λ and capture costs associated with establishing better product design, more effective distribution systems, better product-quality control, designing more effective advertising campaigns etc. For expositional convenience, we assume that fixed costs are quadratic in product quality and given by $\lambda^2/2$.

Variable costs depend on trade costs, marketing-based scale economies, and factor prices. We assume that the cost of delivering z_j units to consumer j in a market with N foreign consumers is given by $z\tau N^{1-\alpha}\mu\lambda$ where $z = x/N$ is the average (per-capita) consumption of a typical variety. Parameter τ > 1 captures iceberg type trade (transportation) costs: in order to deliver z units of output to a foreign consumer, the firm has to produce τz units of output. Parameter $N^{1-\alpha}$ captures, in a reduced form, marketing costs by transforming the actual number of consumers N into consumer "equivalents" $N^{1-\alpha}$ as in Arkolakis (2010). Thus the cost of serving N consumers depends on the number of consumer equivalents. This approach allows us to capture, albeit in a reduced form, income heterogeneity among consumers and the fact that not all consumers buy a particular variety.

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Parameter $\alpha < 1$ is associated with the degree of scale economies (or diseconomies) in marketing: if $\alpha = 0$ then marketing entails constant returns to scale; if $0 < \alpha < 1$ there are scale economies in marketing; and if $\alpha < 0$ there are scale diseconomies in marketing.[10] Parameter $\mu > 0$ captures the dependence of variable costs on factor prices and firm productivity. Finally, we assume that variable costs increase with product quality. The basic idea is that an exporter can use higher quality inputs (e.g. more skilled workers, better machines, higher quality raw materials or components) to upgrade product quality.

The above considerations are captured by the following cost function

$$C(x,\lambda) = \frac{\lambda^2}{2} + \left(\frac{\tau\mu}{N^{\alpha}}\right)x\lambda, \tag{8}$$

where $z = x/N$ was used.

4.3. Credit constraints

Following Bandyopadhyay et al. (2018) and especially Feenstra et al. (2014), we assume that an exogenous fraction of production costs $0 \leqslant \delta \leqslant 1$ is financed through a loan, whereas the remaining fraction $1-\delta$ is financed through retained earnings.[11] Each exporter receives a loan from a competitive banking sector and faces an exogenous probability of default, $0 < 1-\psi < 1$. If the firm defaults, it does not earn any revenue and the loan (principal plus interest payments) is not paid. If the firm does not default, it earns export revenue and pays back its loan. We abstract from issues associated with asymmetric information, incomplete insurance markets and the need for collateral payments. Consequently, the firm collects export revenue $R(x,\lambda)$ with probability ψ and pays back $(1+r)\delta C(x,\lambda)$, where r is the loan interest rate.

These assumptions lead to the following expression for expected profits from exporting

$$\pi = \psi R(x,\lambda) - (1-\delta)C(x,\lambda) - \psi(1+r)\delta C(x,\lambda) \tag{9}$$

where ψR is expected export revenue, $(1-\delta)C(x,\lambda)$ is the amount of production costs financed internally with certainty, and $\psi(1+r)\delta C(x,\lambda)$ is the expected cost of the loan. We assume that, at equilibrium, expected profits must be non-negative, that is, $\pi \geqslant 0$. This assumption ensures that the cash flow constraint holds: if the firm does not default, then revenue generated from foreign sales exceeds the loan value $R(x,\lambda) > (1+r)\delta C(x,\lambda)$.[12]

We assume that there is a perfectly competitive banking sector providing loans to exporters, as in Bandyopadhyay et al. (2018). Let $\rho > 0$ denote the exogenous cost of funds, that is, a loan of $\delta C(x,\lambda)$ costs the bank $(1+\rho)\delta C(x,\lambda)$ with certainty. By lending this amount to a firm the bank receives back $(1+r)\delta C(x,\lambda)$ from the firm with probability ψ. As a result, bank expected profit from a loan is $\Pi = \psi(1+r)\delta C(x,\lambda) - (1+\rho)\delta C(x,\lambda)$. Free entry into the banking sector implies $\Pi = 0$ and determines the lending interest rate charged to each firm

$$1 + r = \frac{1+\rho}{\psi}. \tag{10}$$

Eq. (10) states that the interest rate r increases with the cost of funds ρ and declines with survival probability ψ. In the empirical analysis, we assume that the latter is an increasing function of each firm's credit score.

4.4. Equilibrium

Each firm maximizes expected profit by choosing output and product quality and by taking the interest rate as given. Substituting equations (5), (8) and (10) in (9) leads to the following expression for expected export profit

$$\pi = \psi\frac{I^{\gamma}\lambda x}{xN^{-1}+\theta} - \phi\left(\tau\mu N^{-\alpha}\lambda x + \frac{\lambda^2}{2}\right) \tag{11}$$

where $\phi = 1 + \delta\rho > 1$. Setting $\tau = 1$ delivers the corresponding expression for expected domestic profit. Maximizing (11) with respect to output $\times$ and quality λ generates the following first-order conditions:

$$\frac{\psi I^{\gamma}\theta}{\left(xN^{-1}+\theta\right)^2} = \phi\tau\mu N^{-\alpha} \tag{12}$$

$$\frac{\psi I^{\gamma}x}{\left(xN^{-1}+\theta\right)} = \phi\left(\tau\mu x N^{-\alpha} + \lambda\right) \tag{13}$$

[10] This modeling of marketing costs follows the spirit of Arkolakis (2010) who uses a probabilistic framework leading to a more general specification of marketing costs within the context of a trade model with heterogeneous firms.

[11] All results hold for the case where the firm finances through external borrowing all production costs, i.e. $\delta = 1$.

[12] Manova (2013) provides an excellent discussion and exposition of the cash flow constraint in the context of a general-equilibrium model of trade with heterogeneous firms.

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In words, the firm maximizes expected profits from exporting by setting expected marginal revenue equal to expected marginal costs.[13]

Solving (12) for exported output yields

$$x = \left[\left(\frac{\psi N^{\alpha} I^{\gamma} \theta}{\tau \mu \phi}\right)^{1/2} - \theta\right] N, \tag{14}$$

and dividing the two first-order conditions generates the following positive relationship between output and product quality:

$$\lambda = \frac{\tau \mu x^2}{\theta N^{1+\alpha}} \tag{15}$$

Substituting export quantity x from equation (14) in (15) yields a closed-form solution to equilibrium quality,

$$\lambda = \tau \mu N^{1-\alpha} \left[\left(\frac{\psi I^{\gamma} N^{\alpha}}{\mu \phi \theta}\right)^{1/2} - 1\right]^2. \tag{16}$$

Eqs. (14) and (16) determine the equilibrium values of exported quantity and quality. By setting $\tau = 1$, these equations determine the corresponding domestic equilibrium with N and I denoting the number and per-capita income of domestic consumers.

4.5. Comparative statics

Data availability dictates the focus on empirically testable properties. Specifically, we consider the effects of measurable parameters on product price p, product quantity x, and price elasticity ε.

Substituting (14) and (16) into the inverse demand function (3) yields a closed-form solution to export price,

$$p = \frac{\lambda I^{\gamma}}{x N^{-1} + \theta} = N^{1-\alpha} \left[\left(\frac{\tau \psi N^{\alpha} I^{\gamma} \mu}{\theta \phi}\right)^{\frac{1}{4}} - \theta \left(\frac{\tau \psi N^{\alpha} I^{\gamma} \mu}{\theta \phi}\right)^{-\frac{1}{4}}\right]^2. \tag{17}$$

According to Eq. (17), firms exporting to countries with richer consumers and larger markets charge higher prices, especially in the presence of scale economies in marketing. At first sight, the effect of demand-based parameters on price seems plausible and straightforward. An increase in consumer willingness to pay measured by per-capita income I shifts the demand curve upwards resulting in higher output and price. Notice that an increase in output puts downward pressure on price and requires an increase in product quality to reverse the initial drop in price. This point is made clearer if one considers the effects of an increase in ψ, which reduces marginal and average costs, raises output and quality, and thus has a seemingly ambiguous effect on export price. It turns out that the quality-based effect on the export price dominates the output-triggered effect leading to a price increase. As expected, higher trade costs are reflected in higher export prices.

What are the effects on export quantity x, which is another observable variable of interest? Eq. (14) shows that a higher value of ψ implies a higher chance of earning export (and domestic) revenue and thus a higher probability of paying back the loan. It also implies a lower interest rate r, according to (10), meaning that a firm with higher ψ receives a higher credit score and thus is less credit constrained. As a result, a higher survival probability translates into lower marginal costs and higher export quantity. Similar considerations apply to the effects of per-capita income, which raises consumer willingness to pay leading to an outward shift in the inverse demand curve and a higher quantity. Larger markets translate directly to more output especially in the case of scale economies in marketing; and larger trade costs imply greater marginal costs and lower output.

Substituting (14) in (4) delivers a closed-form solution to the equilibrium price elasticity of demand

$$\varepsilon = 1 + \theta \left[\left(\frac{\psi N^{\alpha} I^{\gamma} \theta}{\tau \mu \phi}\right)^{\frac{1}{2}} - \theta\right]^{-1} \tag{18}$$

Eq. (18) indicates that virtually all model parameters affect the price elasticity of demand ε through export quantity$x$. Any parameter increasing export quantity leads to a less elastic demand. The following proposition summarizes these testable effects.

Proposition 1. *Export price elasticity of demand ε: declines with firm survival probability ψ; increases with trade costs τ; decreases with consumer income I; and decreases with market size measured by the number of consumers N if there are no scale diseconomies in marketing ($0 \leq \alpha \leq 1$).*

[13] The second-order conditions for profit maximization are satisfied in the neighborhood of equilibrium. Standard calculations deliver $\pi_{xx}=-2\psi I^{\gamma}\lambda\theta N^{-1}(xN^{-1}+\theta)^{-3}<0$; $\pi_{\lambda\lambda}=-\phi<0$; and $\pi_{\lambda x}=\psi I^{\gamma}\theta(xN^{-1}+\theta)^{-2}-\phi\tau\mu N^{-a}=\pi_x=0$, where π_{xx}, $\pi_{\lambda\lambda}$ and $\pi_{\lambda x}$ denote the second derivatives of (12) with respect to x and λ. Thus, $\pi_{xx}\pi_{\lambda\lambda}>(\pi_{\lambda x})^2=0$ ensuring that the solution to equations and corresponds to a maximum.

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The intuition behind Proposition 1 stems from additive non-homothetic preferences, captured by $\theta > 0$, which allow for variable price elasticity of demand; and in the present model imply that the demand elasticity declines with per-capita consumption $z = x/N$, as in Krugman (1979). As a result, any parameter raising export quantity leads to a lower price elasticity of demand for exports. Thus firms with higher credit scores, exporting in larger markets with richer consumers, or facing lower trade costs export higher quantities and face less elastic demand functions

Eq. (16) identifies the determinants of product quality and leads to the following proposition.

Proposition 2. *Export quality λ: increases with firm survival probability ψ, trade costs τ, and consumer income I; and increases with market size measured by the number of consumers N if there are no scale diseconomies in marketing ($0 \leq \alpha \leq 1$).*

As a choice variable, export quality governs the effects of model parameters on other endogenous variables such as export price and revenue. This point is made clearer by considering the effects of credit constraints in a model where quality is exogenous and the price elasticity of demand is constant. These are standard features of Melitz (2003) type models of trade with heterogeneous firms. In this class of models, the first-order condition yields equalization of expected marginal revenue to constant marginal cost and is given by $\psi p(1-1/\varepsilon) = \phi\tau\mu N^{-\alpha}\lambda$, where $R_x = \psi p(1-1/\varepsilon)$ in the left-hand-side is expected marginal revenue and quality λ is a constant parameter. It is obvious then that a rise in the firm credit rating, captured by higher ψ, leads to a lower export price p since the price elasticity of demand ε is constant in this case. In contrast, if product quality is endogenous, a higher ψ leads to a higher price as indicated in Eq. (17). Manova and Zhang (2012) argue persuasively that the structure of export prices is inconsistent with models that treat export quality as an exogenous variable.

5. Empirical strategy and results

5.1. Estimating credit-constrained demand elasticities

Taking the model to the data requires a strategy based on several considerations. We feel pretty confident assuming that the firm survival probability is an increasing function of each firm-specific credit score. As a result, the credit score reflects the degree of credit constraints. In addition, we are comfortable with our measures of export intensive margins, namely export revenue, export price (unit value) and quantity. We also feel confident with our assumption that consumer willingness to pay is an increasing function of per-capita consumer income ($\beta = I^{\gamma}$). This assumption naturally leads to use of per-capita GDP as a proxy of consumer income. Finally, we use population and distance as proxies for parameters N (market size), and τ (per-unit trade costs), respectively. The estimated effects of other variables of interest such as the degree of product differentiation should be interpreted as suggestive.

Keeping these considerations in mind, the comparative statics properties of the model summarized by Proposition 1 lead to the following reduced-form equation capturing the main determinants of price elasticity of demand for exports, ε,

$$\varepsilon = h\left(\overset{-}{\psi}, \overset{+}{\tau}, \overset{-}{I}, \overset{\pm}{N}\right) \tag{19}$$

where the sign over each parameter denotes its effect on the dependent variable. The probability of firm default ψ is measured by the firm credit score; consumer income I is measured by per-capita GDP of the destination country; the market size N is measured by population of the destination country and has a negative impact on the elasticity if there are scale economies in marketing; and trade costs τ is captured by the bilateral distance between origin and destination countries.

To examine the effects of credit constraints on export demand elasticities based on Proposition 1, we follow a semi-structural approach. Specifically, rather than relying on a reduced-form empirical strategy, we estimate variants of demand equations that assess the impact of the coefficients of interest on quantities conditional on prices. This approach is more robust on the choice of functional forms and allows us to obtain variable price elasticities by interacting prices with firm-specific (credit ratings) and destination-specific (distance, income, size) variables within the context of estimated demand equations.

Specifically, the factors that affect the price elasticity of demand according to (19) are estimated based on the following specification:

$$\ln x_{fd\omega} = \alpha_0 - \ln p_{fd\omega}\left[\alpha_1 + \beta_1 \ln \mathrm{fr}_f + \beta_2 \ln \mathrm{dist}_d + \beta_3 \ln \mathrm{gdp\_pc}_d + \beta_4 \ln \mathrm{pop}_d\right] + \sum \gamma_i Z_k^q + fe + \eta_{fd\omega} \tag{20}$$

where $x_{fd\omega}$ denotes the physical output (quantity) respectively of product ω by firm f shipped to destination d. Firm f's average export price for product ω in destination d, $p_{fd\omega}$ is constructed as $p_{fd\omega} = \frac{revenue_{fd\omega}}{quantity_{fd\omega}}$, with export revenues and quantities at product-firm level given by Intrastat/Extrastat database provided by the Greek Statistical Agency.

The following variables interact with prices and are dictated by model parameters: *firm f's credit score* fr_f described in Section 3.1 and taken from the ICAP database; *bilateral distance* dist_d from the CEPII database; *income* (measured by per-capita GDP), $\mathrm{gdp_pc}_d$; and *population* of destination d, pop_d, both from the World Bank's World Development Indicators.

The set of control variables for prices Z_k^q includes the *number of firms per product* ω, in order to control for product differentiation and industry variation. On average, each product is exported by 19 firms and this number varies from 1 to 393 exporting firms with a standard deviation of 29. We also control for the *number of firms per product* ω *in destination d* as a

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proxy for competition for products exported by Greece. Each product ω is exported in country d by 3.5 Greek firms on average and this number varies from 1 to 120 exporting firms (the maximum number corresponds to a subcategory of clothes exported to Cyprus) with a standard deviation of 5.8.

We also employ a set of *fixed effects fe*: *product* fixed effects to control for systematic differences across products that affect all manufacturers equally, such as units of measurement, transportation costs, and consumer appeal; *industry* fixed effects to control for different characteristics across industries that influence production of all products equally, such as industry level wage agreements etc.; and in some cases we use *destination* fixed effects to control for features of the target export market. Finally, $\eta_{fd\omega}$ is a firm-product-destination specific disturbance term.

We are interested whether the estimated export price elasticity of demand, derived from Eq. (20),

$$\hat{\varepsilon} \equiv -\frac{\partial \ln q_{fd\omega}}{\partial \ln p_{fd\omega}} = \alpha_1 + \beta_1 \ln fr_f + \beta_2 \ln dist_d + \beta_3 \ln gdp\_pc_d + \beta_4 \ln pop_d, \tag{21}$$

is sensitive to variations in parameters indicated by Proposition 1. This proposition states that: firms with higher credit ratings face less elastic demand ($\beta_1 < 0$); firms serving more distant destinations face more elastic demand ($\beta_2 > 0$); firms that export their products to richer destinations face less elastic demand ($\beta_3 < 0$); and firms serving larger export markets face less elastic demand ($\beta_4 < 0$) if there are scale economies in marketing.[14]

5.2. Price endogeneity

An obvious difficulty to estimate the export price elasticity at the firm level from Eq. (20) is that export quantities and prices adjust simultaneously, because producers optimally respond to demand shocks by changing prices. This creates a positive correlation between the export price and the residual, and leads to biased estimates of the price elasticity. To eliminate this well-known endogeneity bias in firms' idiosyncratic demand levels, we follow Foster et al. (2008) and exploit the micro structure of our dataset to estimate plants' idiosyncratic demand levels using supply-side (cost) influences on prices, which embody the firms' idiosyncratic technologies in the form of physical production costs. Specifically, we instrument prices using firm-specific physical productivity, which will be correlated with price variations, but uncorrelated with unobserved demand shocks and allows the identification of the price elasticity of exports. In contrast to expenditure-based measures of productivity, firm-specific physical productivity is determined by physical quantities of outputs. Its variation reflects dispersion in physical efficiency and possibly factor input prices, essentially reflecting the firm's average cost per unit. We expect a negative correlation between physical productivity and firm-level prices, which is consistent with equilibria where producers are price setters and more efficient businesses find it optimal to pass along their cost savings through lower prices.[15]

The firm's physical (labor) productivity (labeled *qtfp*) is based on quantities of physical output and is calculated as the ratio of output quantity to employment. We note that, given that most firms in our sample export more than one product, we impose the restriction that at least 50% of firm revenue is obtained from a single product. In our first-stage regressions, we confirm that *qtfp* is negatively correlated with firm-level prices. The Kleibergen-Paap LM statistic of underidentification rejects that any of the endogenous regressors is unidentified. Similarly, the Kleibergen-Paap Wald F statistic for weak identification rejects the null hypothesis of weak instruments for all relevant specifications (reported below in Tables 3 and 4).[16] These findings suggest that *qtfp*, is a strong instrument for price to overcome the typical simultaneity bias in demand estimation.

5.3. Endogeneity of financial ratings

A problem that is recognized in the literature on the assessment of the effects of financial constraints on firm performance is the potential endogeneity of the particular measure of financial constraints used.[17] The ICAP financial rating for Greek firms can be affected by firm profitability, productivity, and other idiosyncratic structural characteristics, and export status. However, it is not directly affected by our firm-specific intensive margins (export sales, prices and quantities), because they are

[14] An alternative estimation strategy could be based on using growth rates of export volumes and prices to identify export price elasticities (see Spearot, 2013). However, this method is not applicable in our context due to our focus on financial ratings that exhibit low variability across time.

[15] Two recent papers exploit time-varying information on firm-specific costs to identify the price elasticity of exports at the firm level. Fontagné et al. (2018) instrument export prices using firm-level electricity prices. They argue that firm level electricity cost shocks are related to time-varying factors exogenous to export performance at the firm level, such as regulation changes, year and length of beginning of contracts, national and local tax changes, location, changes in both market and regulated prices and local weather, and are likely to affect the firm's export performance only through the firm export price. Piveteau and Smagghue (2019) instrument export prices exploiting fluctuations in exchange rates interacted with firm-specific import shares, which shift a firm's costs of importing goods and generate firm-specific export price variations. Unfortunately, both methods require data that are not available for our sample of Greek exporters.

[16] The online Appendix presents the values of the first-stage regressions tests for underidentification and weak identification using the method of Sanderson and Windmeijer (2016). The full set of results from the first-stage regressions is available upon request.

[17] Regarding related literature, Manova et al. (2015) identify the role of financial constraints for Chinese exporters looking at foreign direct and portfolio investments, rather than balance sheet variables, and find that they have affected both fixed costs related to participation in exporting decisions and variable costs influencing the scale of foreign sales. Amiti and Weinstein (2011) use Japanese matched firm-bank data to identify a bank-firm trade finance channel and find that it accounts for roughly one third of the decline in exports during the Japanese crisis in the 1990s.

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Table 3
Export demand elasticities under credit constraints.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
					Dependent variable: export quantity				
Price	3.630***	3.761***	3.040**	5.529***	3.662***	6.207***	6.278***	6.889***	6.957***
	(12.84)	(11.24)	(9.88)	(11.11)	(16.94)	(11.54)	(11.26)	(12.18)	(11.85)
Price × credit score	−0.080***	−0.102***				−0.081***	−0.096***	−0.088***	−0.100***
	(−5.80)	(−3.74)				(−5.70)	(−3.49)	(−6.02)	(−3.57)
Price × distance			0.004			0.061***	0.062***	0.022	0.022
			(0.23)			(3.39)	(3.34)	(1.22)	(1.17)
Price × per- capita GDP				−0.251***		−0.245***	−0.244***	−0.256***	−0.255***
				(−7.41)		(−7.89)	(−7.79)	(−8.06)	(−7.98)
Price × population					−0.075***	−0.080***	−0.079***	−0.096***	−0.096***
					(−8.83)	(−9.23)	(−9.14)	(−10.78)	(−10.74)
Number of firms per product								−1.219***	−1.187***
								(−6.94)	(−6.48)
Number of firms per product-destination								0.020***	0.021***
								(8.70)	(8.60)
Destination FE	YES	YEΣ	NO	NO	NO	NO	NO	NO	NO
N	17,061	16,775	16,314	16,368	16,368	16,314	16,039	16,314	16,039
KP underid test	107.14	106.94	94.37	91.26	93.50	100.93	100.69	100.01	99.51
KP weak id test	50.11	9.93	44.13	42.71	43.27	18.49	18.56	18.31	18.31

Notes: All variables are in logs. The regressions include a constant term and *t* statistics based on robust standard errors clustered at firm level are in parentheses (our results are robust to alternative types of clustering, * denotes p < .10, ** denotes p < .05, *** denotes p < .01). The coefficients on (the negative of) *price* and its interaction terms yield the absolute value of the price elasticity of demand. All regressions include product fixed effects and industry fixed effects. *qtfp* has been used as instrument for prices. Given that *qtfp* is firm specific, firm fixed effects are not included. In columns (2), (7) and (9) *iv_fin* has been used as instrument for the credit score. In the last two rows *KP* denotes the Kleibergen-Paap rk LM statistic of underidentification and the Wald rk F statistic for weak identification.

Table 4
Export demand elasticities under credit constraints: sensitivity analysis.

	Dependent variable: export quantity								
	Consumption goods			Differentiated goods			One product per destination		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Price	3.236***	5.590***	6.251***	3.306***	5.586***	5.724***	3.852***	7.101***	7.208***
	(6.91)	(6.71)	(5.64)	(10.02)	(9.52)	(9.31)	(11.73)	(8.82)	(8.18)
Price × credit score	−0.068***	−0.068***	−0.143***	−0.061***	−0.067***	−0.109***	−0.124***	−0.139***	−0.153***
	(−3.64)	(−3.58)	(−2.77)	(−3.86)	(−4.06)	(−3.31)	(−5.51)	(−5.07)	(−2.93)
Price × distance		0.054***	0.047*		0.018	0.019		0.061**	0.061*
		(2.34)	(1.82)		(1.01)	(1.08)		(1.95)	(1.94)
Price × per- capita GDP		−0.224***	−0.220***		−0.180***	−0.173***		−0.241***	−0.243***
		(−5.27)	(−5.16)		(−5.92)	(−5.62)		(−5.72)	(−5.69)
Price × population		−0.068***	−0.068***		−0.074***	−0.073***		−0.098***	−0.099***
		(−5.74)	(−5.31)		(−8.12)	(−7.82)		(−6.35)	(−6.26)
Number of firms per product		−1.128***	−1.049***		−1.117***	−0.990***		0.197***	0.199***
		(−4.89)	(−4.41)		(−5.16)	(−4.57)		(2.97)	(2.97)
Number of firms per product-destination		0.020***	0.022***		0.018***	0.019***		0.026***	0.026***
		(5.79)	(5.08)		(7.31)	(7.38)		(5.77)	(5.57)
Destination FE	YES	NO	NO	YES	NO	NO	YES	NO	NO
N	3932	3782	3751	10,338	9898	9798	5264	4972	4912
KP underid test	32.09	28.83	17.31	70.63	69.86	67.93	81.49	63.56	46.55
KP weak id test	19.245	6.93	3.59	36.75	14.81	14.37	48.94	14.02	8.45

Notes: All variables are in logs. The regressions include a constant term and *t* statistics based on robust standard errors clustered at firm level are in parentheses (our results are robust to alternative types of clustering, * denotes p < .10, ** denotes p < .05, *** denotes p < .01). The coefficients on (the negative of) *price* and its interaction terms yield the absolute value of the price elasticity of demand. All regressions include product fixed effects and industry fixed effects. *qtfp* has been used as instrument for prices in all columns. Given that *qtfp* is firm specific, firm fixed effects are not included. In columns (3), (6) and (9) *iv_fin* has been used as instrument for the credit score. In the last two rows *KP* denotes the Kleibergen-Paap rk LM statistic of underidentification and the Wald rk F statistic for weak identification.

not publicly available. Since the credit score is based on information available at the end of each year, in our benchmark regressions we employ the lagged rating that is relevant for credit supply, and further use fixed effects to mitigate potential endogeneity.[18] Furthermore, because we examine the volume of exports at the firm-product-destination level, our empirical

[18] As a result all remaining regressions exclude firms with no rating observations for the previous year. This decreases our sample by almost 50%. The loss of observations would be much higher if higher-order lags of the rating were used.

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results are less sensitive to how much firms export across product-destination pairs depending on their access to credit. For example, even if credit scores are given to firms according to their unobserved productivity characteristics that affect their exporting performance, within-firm sales and price differentials per product-destination pair should not be seriously affected. Given that in our specification financial rating enters only in the interaction term with our instrumented endogenous variable (price), using the financial rating of the previous year is an appropriate way to cope with potential endogeneity problems.

Nevertheless, there can still be a potentially indirect problem of reverse causality. Suppose the volume of exports at the firm level is primarily driven by unobserved production costs, and lower credit scores are systematically given to firms with higher production costs. In this case, we might be attributing to the credit score what is actually driven by unobservable production characteristics. Our main identification strategy to address this potential caveat is to rely on considerations that drive credit suppliers to give credit to a firm other than those related to a firm's intensive export margins, and model the firm's credit rating based on firm-product characteristics. The key assumption is that the credit score of a single firm, which exports a particular product, is unlikely to drive the credit scores of other firms that export the same product.

In this vein, to form the instrument we employ the access to credit of firms that export a particular product using variations in credit scores at the aggregate level as an instrument for the credit score at the firm level. Specifically, our instrument for a firm-product pair is based on the previous-year average credit score of all firms that have exported the product in any destination, excluding the firm under consideration. Our claim here is not to explain fully the credit score but to extract some (hopefully exogenous) information from the supply of credit in the specific product market that would be reasonable for instrumentation.

The instrument builds on the well-known idea of network effects or externalities (see e.g. Goolsbee and Klenow, 2002), where the spatial composition of the economy at an initial period is used to predict exogenous changes for the individual unit (household or firm). This instrumental variable approach proxies the financial reasons for credit supply and, given that aggregate variations in credit access are not driven by firm specific characteristics, it is plausibly orthogonal to credit availability that relates to the underlying economic situation of the firm. The instrumentation assumptions are therefore that the firm's credit rating is correlated with the average credit score of other firms that export a product, which in turn is exogenous to unexpected shifts in export prices or quantities for the firm-product-destination pairs. Our instrument is not firm-specific since it applies to each firm-product pair and hence raises fewer questions in terms of satisfying the exclusion restriction.[19]

The first-stage regression is based on the following equation:

$$fr_{f\omega} = \delta_1 \frac{1}{(M-1)} \sum_{i=1;i\neq f}^{M} fr_{i\omega} + \bar{\delta}\,\bar{\mathbf{W}} + fe \tag{22}$$

where the dependent variable $fr_{f\omega}$ is the credit score of firm f exporting product ω. Variable $fr_{f\omega}$ is regressed on the firm-product specific instrument *iv*_fin defined as $\frac{1}{(M-1)} \sum_{i=1;i\neq f}^{M} fr_{i\omega}$, the average credit rating of all M firms other than firm f that export product ω; and the vector of exogenous variables included in the specification under consideration, $\bar{\mathbf{W}}$, with the vector of associated parameters denoted by $\bar{\delta}$.

Vector $\bar{\mathbf{W}}$ includes the interaction terms of *prices* with *bilateral distance*, with *income* and with *population* of destination d, the *number of firms per product* ω, and the *number of firms per product* ω *in destination d,* depending on the specification under consideration. Each first-stage regression includes a set of product fixed effects and industry fixed effects (denoted by *fe*). In this specification the parameter δ_1 captures the change in the firm's credit score which can be explained by the changes in the product market under consideration.

5.4. Empirical results

Table 3 presents the benchmarks results in the context of specification (20). Column (1) introduces the price-rating interaction term, which is found to be positive and statistically significant: a less financially constrained firm enjoys a higher credit score and faces a lower price elasticity of demand. Columns (3)–(5) explore sequentially the effects of destination distance, income per capita, and population on the price elasticity of demand using interactions terms. The coefficients on the interaction terms enter with the predicted signs and are statistically significant with the exception of distance. In column (6) all variables enter in a single specification, and are all statistically significant and take the predicted signs. Column (8), which controls partially for market structure proxied by the numbers of firms per product and firms per product-destination, shows a similar evidence. The general picture clearly implies that Greek exporters face binding credit constraints that affect the price elasticity of demand with less credit-constrained exporters facing less elastic demand. Columns (2), (7) and (9) report the same specifications using the average rating of all other firms that export the same product as an instrument for the firm's financial rating. The 2SLS estimates are similar to those of columns (1), (6) and (8), and are consistent with the hypothesis that there is no endogeneity problem between quantity demanded and financial ratings at the firm level.

[19] Since our regressions are cross-sectional, additional complications from the time persistence of credit scores are not introduced. It is possible that the association between a firm's credit score with the average credit score of firms that export a specific product does not apply equally to all firm-product pairs and might be affected, for instance, by the number of competitors in the product market or the number of products produced by the firm.

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We next investigate the robustness of our main findings to some plausible alternatives related to exporters and/or their products. For technological reasons innate to the nature of the manufacturing process, exporters in certain sectors incur higher up-front costs related to marketing and advertisement, and hence are relatively more financially dependent. Consequently, firms in these sectors are much more vulnerable to financial frictions. A relevant exercise is therefore to examine the elasticity responses for various firm groups, in which the elasticity is more likely to be differently affected based on their structural characteristics. As a first step, we distinguish between consumption and non-consumption goods. About 20% of the products that are exported by firms for which we have enough information in order to calculate firm-specific physical productivity (*qtfp*), are classified as consumption goods.[20] Overall we have 519 firms that produce 335 consumption goods. More than half of these firms (60%) have a high credit score and employ on average 173 employees compared to firms with low credit score that employ on average 34 employees. The results are reported in columns (1)–(3) of Table 4 and all hypothesized effects are again confirmed. To further shed some light on this finding, in columns (4)–(6) we test whether the elasticities are differently affected by credit constraints in sectors with greater scope for quality differentiation using Rauch's (1999) classification index. The price-rating coefficients take values similar to the ones reported for consumption goods.

We also test whether our results depend on the product mix of exporters. Several papers have analyzed the behavior of multi-product exporters and their implications for firm heterogeneity with emphasis placed on tougher competition (see e.g. Bernard et al., 2012; Arkolakis et al. (2016); Mayer et al., 2014). For simplicity of exposition, the theoretical model featured a single-product exporting firm; however, 89% of the firms used in the regressions are multiproduct firms. In the presence of financial constraints, a composition effect might arise on a firm's product mix that would then translate into differences in pricing: more financially constrained exporters might shift resources to the production of goods associated with lower perceived quality to counterbalance their comparative disadvantage. Thus, given input requirements, a less constrained firm producing a given set of products will export on average a larger share of higher-quality goods. This effect would skew the average firm price across products upwards and generate a spurious positive correlation between ratings and pricing at the firm level, which would in turn affect the elasticity estimates.

To address this potential caveat, we use only observations from firms that ship one product per destination. Our restricted sample consists of 814 firms about half (53%) of which have a high credit score and are on average larger (182 employees) compared to firms with low scores (37 employees). Columns (7)–(9) of Table 4 display the corresponding regressions, which show that the price-rating interaction term is negative as predicted but now takes a larger value compared to the previous specifications. This indicates that the reduction in the price elasticity for less constrained firms is substantially higher for single-product exporter establishing the robustness of our theoretical analysis and suggesting that multiproduct firms rely more on internal finance and/or are not affected by external finance as much due to product diversification.

Finally, comparing columns (2), (5) and (8) with columns (3), (6) and (9), in which *iv_fin* has been used as instrument for the credit score, we find that both the value and the statistical significance of all coefficients remain very similar.

6. Quality and credit constraints

The importance of export quality in analyzing the determinants of trade flows has sparked a vivid interest in the related empirical literature. The main challenge faced is that quality is unobserved and related empirical studies have used readily observable prices (unit values), as a proxy for export quality to study the relationship between quality and firm characteristics. However, unit values suffer from several shortcomings generated by differences in the composition of goods, their production costs, or pricing strategies within a given product category across exporters. In our context, for instance, if exporters that use lower-cost inputs are systematically less productive and hence are more financially constrained, compared to competitors they will sell more expensive varieties, by approximating quality with prices we may wrongly associate credit constraints with quality.

Indeed, recent papers developed strategies for quality estimation using explicit microeconomic foundations and established that observed unit values can be a poor approximation for export quality (Khandelwal, 2010; Hallak and Schott, 2011; Feenstra and Romalis, 2014; Henn et al., 2017).

Fortunately, our theoretical setup can be used in a straightforward way to deliver model-consistent estimates of exporters' quality. Following the spirit of Khandelwal's (2010) analysis, consider the demand equation (3), given by $p = I^{\gamma}\lambda\left[xN^{-1}+\theta\right]^{-1}$ where $\gamma > 0$ is a parameter to be estimated. Parameter θ is unknown, but we can use the expression for the price elasticity, given by Eq. (4), and express it as $\theta=(\varepsilon\text{-}1)x/N$. Substituting this expression in the demand equation (3) we obtain $px = \left(\lambda N I^{\gamma}\right)/\varepsilon$. This equation states that export revenue per variety px increases with product quality λ and effective aggregate consumer income $I^{\gamma}N$; and decreases with the price elasticity of demand ε. Taking logs yields:

$$\ln px - \ln N = \ln\lambda + \gamma \ln I - \ln\varepsilon$$

[20] We use the United Nations classification in Broad Economic Categories defined in terms of the Standard International Trade Classification (http://unstats.un.org/unsd/iiss/Classification-by-Broad-Economic-Categories-BEC.ashx).

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Table 5
Export quality and financial constraints.

	All firms				Score > 2	Diff. goods
	(1)	(2)	(3)	(4)	(5)	(6)
Credit score	0.769***	1.459***	0.217***	0.447***	0.611***	0.476*
	(8.79)	(10.40)	(2.72)	(3.42)	(4.05)	(3.21)
Employment			0.368***	0.481***	0.466***	0.478***
			(15.25)	(13.62)	(12.82)	(11.77)
N	15,854	31,747	15,658	31,384	31,188	20,283
R^2	0.530	0.649	0.547	0.669	0.670	0.683

Notes: All variables are in logs. The regressions include a constant term and *t* statistics based on robust standard errors clustered at firm level are in parentheses (our results are robust to alternative types of clustering of standard errors, * denotes p < .10, ** denotes p < .05, *** denotes p < .01). For regressions presented in columns (2), (4)–(6) the sample is disaggregated across products-firms-destinations. For regressions depicted in columns (1) and (3) the sample is aggregated across products for each firm-destination. All regressions include destination fixed effects and industry fixed effects. Regressions (2), (4)–(6) also include product fixed effects.

For our purposes, we aggregate our sample across products at the firm-destination level and run the following empirical specification with firm export revenues pooled at the destination level:

$$\ln(px)_{fd} - \ln N = \gamma \ln I + d_f + u_{fd} \tag{23}$$

where $d_f = \ln\lambda_{fd} - \ln\varepsilon - u_{fd}$ denotes the firm fixed effect and u_{fd} is the error term. We get an estimate of $\hat{\gamma} = 0.193$ that is statistically significant at the 1% level with the value of t-statistic 6.83.[21]. This implies that the 'elasticity-adjusted' quality is given by

$$\ln\lambda_{fd} = d_f + u_{fd} + \ln\varepsilon_d \tag{24}$$

and reflects the valuation for firm *f* exporting to destination *d* that is common across products (notice that these terms are not subscripted by ω).

Intuitively, conditional on destination per-capita income and the price elasticity of demand, higher export revenue per consumer (related to higher market share in the context of heterogeneous firms) increases with product quality. Eq. (24) provides an empirically useful decomposition of product quality consisting of three terms. The first term, given by fixed effect d_f, is the destination-invariant quality valuation that the market attaches to firm *f*. The second term, u_{fd}, is a firm-destination deviation from the fixed effect that is not observed by the econometrician. These two components of quality, d_f and u_{fd}, can be retrieved by our estimated specification (23). As for the final term, although the price elasticity of demand for exports, ε, is not directly observable, its determinants are summarized by Proposition 2 and consistently estimated by expression (21) for $\hat{\varepsilon}$. This implies that the price elasticity varies with destination characteristics and firm credit score. We therefore use our estimates reported in column 6 of Table 3 to retrieve $\ln\hat{\varepsilon}$ and obtain firm specific quality λ_{fd} at the destination level.

The inferred qualities are then used to verify the positive association between quality and credit constraints implied by Eq. (16) and Proposition 2. Column 1 in Table 5 reports that the coefficient on the credit score is positive and highly significant. Less credit-constrained firms export higher quality varieties within product categories. Next, in column 2 we use our disaggregated sample at firm-product-destination level and include product, destination and industry fixed effects, which indicate that the regressions consider the cross-sectional relationship between quality and credit constraints within products, destinations and industries.

Notice that by identifying quality through fixed effects in Eq (23) which is demand based and captures production-related scale effects only through the price elasticity of demand, one would conclude that larger and more productive exporters are more likely to be classified as high-quality producers. Within the context of our model, larger exporters produce more output and engage in quality upgrading. Therefore, in the remaining columns (3)–(6) we use employment to account for firm-size related scale effects. The coefficients on employment are positively related to quality, as the model predicts and are highly significant. The coefficient on the financial rating remains positive and statistically significant, but is considerably lower when we control for firm size since firms with higher output engage in quality upgrading.

Finally, columns (5) and (6) re-run the specification that controls for firm-size excluding some low-rated, highly constrained firms, and using differentiated goods, respectively. The coefficients on the credit score are positive and significant, although slightly lower in significance when only differentiated goods are considered since one would expect that the latter are correlated positively with product quality. Overall, although this exercise is clearly limited in scope, the positive relationship between the estimated quality of Greek exports and credit scores is consistent with the main prediction of the proposed model.

[21] The estimation of equation (23) is based on 15,928 observations and R-squared equals 0.284.

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7. Conclusions

This paper proposes a simple model featuring endogenous product quality, additive non-homothetic preferences, and credit constraints. We empirically test and confirm the main predictions of the model by using a unique data set with information on firm-specific credit scores and financial variables of Greek manufacturing exporters for the year 2007. Less credit-constrained Greek exporters generate lower price demand elasticities, charge higher prices, and engage in quality upgrading. In addition to the importance of financial constraints, these results highlight the empirical relevance of trade models with endogenous product quality and variable price elasticity of demand.

Our results bear several potentially important implications two of which are highlighted here. First, they strongly suggest that public policies leading to a reduction in the probability of default that might take the form of loan guarantees have substantial effects on exports. Our results also suggest that an increase in the probability of default, caused by the Greek financial crisis, which started in 2009, and the 2015 imposed capital controls can lead to a severe reduction in credit scores and export revenues.

8. Author statement

All authors contributed equally to the conceptualization of main ideas, the writing, review and editing. Elias Dinopoulos contributed primarily to the formal analysis. Sarantis Kalyvitis and Margarita Katsimi contributed primarily to data collection and empirical analysis.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jimonfin.2020.102135.

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