Essays on International Trade and Quality with Applications to Greek Firms

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Closing with a line dedicated to all of my friends overseas, inside, and outside Academia, and also to my family:
“I am afraid that even if I was offered a boat, I would choose the same raft once again”. [1]

[1] In Greek, «πολύ φοβάμαι πως και καράβι να μου προσφέρουν, εγώ τη σχεδία και πάλι θα διαλέξω», David Kait (2020).

Table of contents

List of tables

List of figures

Contributions of the Thesis

1. I estimate firm-level export price elasticities for Greek exporters, which can be used in policy reports or General Equilibrium model calibrations.
2. I develop a simple model that investigates the relationship between export product quality, innovation, and credit constraints at the firm level. The model predicts that the relationship between product quality and innovation depends on credit constraints.
3. I find empirically that the relationship between product quality and innovation is positive for less credit constrained exporters, but negative for highly credit constrained firms. These findings confirm the theoretical prediction of the model.

Introduction

Trade economists have identified product quality as an important determinant of exports at the country level (Schott, 2004; Hallak, 2006; Hallak and Schott, 2011; Feenstra and Romalis, 2014; Vandenbussche, 2014) and in shaping trade activity at the firm level (Crozet et al., 2012; Gervais, 2015; Manova and Zhang, 2012). However, as product quality is unobserved and expert assessments of quality are not widely available, the empirical literature related to product quality and exporting is not sufficiently developed. For example, Bernard and Jensen (2004), and Bernard et al. (2009) use US trade data at the firm level and find that during a crisis, or a boom, it is the intensive margin of trade that adjusts the most. Despite its apparent significance in shaping trade patterns, the adjustment of quality during periods of external adjustment remains an open question.

Strongly related to quality, innovation is considered to be one of the main factors underlying international competitiveness (Asheim and Isaksen, 1997; Michie, 1998). Firms consider innovation as a tool to enter new markets or maintain -and even reinforce- their competitive advantage (see, among others, Brown and Eisenhardt, 1995). However, little is known on innovation in the context of micro-exporting, mainly due to lack of detailed (or even aggregate) data. Not surprisingly, both innovation and product quality are therefore considered as important determinants of trade flows at the firm level. With the exception of Chen (2013), who investigates the influence of innovation on the extensive (number of products) and the intensive (value of each product) margins of exports, there is no research that investigates the relationship between estimated product quality and innovation at the firm level. The author shows that innovation has a major positive effect on the intensive margin in a way that suggests increasing quality of exports due to innovation.

An important factor of exporting activity involves access to finance as the cost needs of exporters are inherently different compared to those of firms that serve the domestic market. Manova et al. (2015), Minetti and Zhu (2011), and Feenstra et al. (2014) among others, find that credit constraints are an additional source of heterogeneity in export behavior across firms. According to Fan et al. (2015) and Dinopoulos et al. (2020), lower credit constraints increase both the price and the quality of the exported products. However, as the main challenge is how to identify product quality, none of these studies analyzes the effects of credit constraints on the quality of exports using a formal demand specification to derive export quality estimates at the firm-product-destination level. To the extent that investment is required to upgrade export product quality, credit constraints may affect an exporter's investment decisions on R&D activity (Brown et al., 2012; Crino and Ogliari, 2017; Jin et al., 2019). However, there is very little evidence on the relationship between export quality, innovation, and access to credit for exporters. As credit constraints may affect the costs and incentives to invest in quality-enhancing activities (see Long and Malitz, 1985; Maksimovic and Titman, 1991), it is important to investigate in what way such a prediction can be incorporated in international trade literature with heterogeneous firms.

In the present thesis I develop a simple framework to investigate the relationship among product quality, innovation, and credit constraints. Exporting firms choose their product quality considering their credit constraints and the level of their innovative activities. The current setup is suitable for an empirical analysis when detailed data on firms' innovative activities are not available, as it does not require a distinction between product and process innovation. The model predicts that the relationship between product quality and innovation at the firm level is positive when the firm's innovation expenditures are above a cut-off point that depends on the firm's level of credit constraints, but it is negative when its innovation expenditures are below this threshold.

To test the predictions of the theoretical framework, I use a unique combined dataset for Greek exporting firms. Following Hallak and Schott (2011), I define unobserved product quality as any intrinsic characteristic or taste preference that improves the consumer appeal of a product given its price. Hence, to identify product quality, the decomposition of observed export prices into quality and quality adjusted-price components is needed. Based on this definition and focusing on heterogeneous firms, I use the estimation strategy put forward by Piveteau and Smagghue (2019) to estimate time-varying product quality at the firm level for Greek exporters. This methodology estimates product quality based on a demand side approach, exploiting information from the importing activity of exporters. The main challenge when estimating demand functions is price endogeneity; as quality is costly to produce, prices are likely correlated with demand shocks. Piveteau and Smagghue (2019) present an instrument obtained by interacting real exchange rates with firm-specific importing shares, which is exogenous to any measurement errors in prices and also to the quality choices made by each firm.

With the firm-level product quality estimates at hand, I first present some stylized facts on the relationship between quality and credit constraints for Greek exporters, and also between Greek export quality and innovation. Following Bernini et al. (2015), I use leverage as a measure of financial constraints at the firm level and I show that more financially constrained Greek exporters export lower quality products. Using data on firm-level R&D expenditure and personnel, I find a positive relationship between product quality and innovation. I next focus on the relationship among export quality, innovation, and credit constraints. Consistent with the theoretical model, the empirical results confirm that the relationship between product quality and innovation is positive for low- and medium-credit constrained Greek exporters, but negative for the highly constrained ones.

The remainder of the dissertation is structured as follows. First, I analyze the importance of product quality on international trade, and I present the quality measures that exist in the related literature. Chapter 2 presents some characteristics of Greek exporters and explains the combined dataset used in the empirical parts of this dissertation. Next, the product quality estimation methodology developed by Piveteau and Smagghue (2019) is presented, as well as its application for the Greek exporters' case. Chapter 4 introduces to the relationship between quality and innovation, and chapter 5 establishes the relationship among product quality, innovation, and credit constraints. The last chapter presents the conclusions of the thesis.

Chapter 1. Product quality and exporting: A review of the literature

1.1. Quality and aggregate economic outcomes

The quality of products exported by firms has important aggregate economic outcomes. Linder (1961) first states the role of quality in determining the direction of trade. His hypothesis explains the effects of quality differences on the direction of trade. His main arguments are that richer countries spend a larger proportion of their income on high-quality goods, and that they have a comparative advantage on producing higher-quality goods. The conjecture is that countries that belong to the same income per capita category trade more to each other. Flam and Helpman (1987), Falvey and Kierzkowski (1987), Stokey (1991), and Murphy and Sheifler (1997) develop general equilibrium models based on Linder's hypothesis and formalize the relation of quality and trade patterns. Quality, besides its relationship with income, is also related to the direction of trade. According to Alchian and Allen (1964), the quality composition of exports increases with the distance between trading partners. Finally, the quality sorting hypothesis, is related to inputs' level of quality, in the context of heterogeneous firms, as in Melitz (2003). Firms employ higher-quality inputs in production so as to export higher-level versions of their products to the toughest markets, at higher prices.

1.1.1. Quality and income

Recent evidence supports the relationship between income per capita and quality noted by Linder (1961). Schott (2004) uses product-level data to investigate this relationship from the supply side, and reports evidence of specialization across products, as well as within product categories. The relationship between unit values, exporter endowments and exporter production techniques, supports the view that capital and skill-abundant countries take advantage of their endowments to produce vertically superior varieties within industries. This suggests that high-wage countries use their endowment advantage to add features or quality to their varieties, which are not present among the varieties emanating from low-wage countries. Hummels and Klenow (2005) use quantities and proxies for the number of varieties to analyze the extent to which larger economies export: (a) higher volumes of each good (intensive margin), (b) a wider set of goods (extensive margin), and (c) higher quality goods. They find that larger economies export more in absolute terms than smaller economies. Also, within categories, richer countries export higher amounts of products at higher prices to a given market, consistent with producing higher quality goods.

Hallak (2006) provides a testable framework to estimate the impact of quality on the direction of trade. He uses cross-sectional data for bilateral trade among 60 countries in 1995 and presents a product quality estimation strategy based on cross-country differences measured by variation in export unit values. His findings confirm the theoretical prediction that rich countries tend to import relatively more from countries that produce high quality goods. Sutton and Trefler (2016) adopt a supply-side Ricardian model to provide evidence that a country's income and the mix of products it exports are simultaneously determined by each country's capabilities (i.e., a country's productivity and quality levels for each good). According to their findings, the relationship between a country's export mix and its GDP per capita display an inverted-U general equilibrium relationship, both theoretically and empirically. Interestingly, they claim that a country may change its economic state without changing its product mix by improving the quality of goods that it already exports. Importantly, Hallak and Schott (2011)'s findings suggest that countries' income converges less rapidly than quality. In an attempt to explicitly estimate product quality by product, sector, and year, Hallak and Schott (2011) claim that consumers care about price relative to quality when choosing among products. In their model, two countries with similar export prices but different trade balances must have products with different levels of quality. They also find evidence of high- and low-quality variations on growth strategies applied by different countries.[2]

Khandelwal (2010) makes another direct attempt to infer product quality.[3] Using his own product quality estimates, he finds that developed countries export higher quality products relative to developing ones. In the same direction, Feenstra and Romalis (2014) show that developed countries tend to export more expensive goods that are estimated to be of higher-than-average product quality, and also import more expensive goods of higher product quality. Higher product quality explains most of the higher prices for these countries. Henn et al. (2020) confirm a greater preference for product quality in richer countries. They report that average product quality at the country level moves in parallel to the income per capita and conclude that product quality explains most of the higher export prices for developed countries. Interestingly, an empirical analysis conducted by Fontagné et al. (2008) indicates

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[2] Hausmann et al. (2007) claim that, ceteris paribus, countries that specialize in the types of goods that rich countries export are likely to grow faster.

[3] He proposes a procedure to infer product quality based on both unit value and quantity information.

that the products of developed countries are not directly competing with those of developing countries. Such findings broadly support models in which consumers value product quality, but quality is expensive to produce.

1.1.2. Quality and the direction of trade

Product quality is also a key factor in determining the direction of trade through the Alchian-Allen conjecture. Alchian and Allen (1964) have shown that in the presence of per unit transaction costs, the relative price of high-quality good decreases ("shipping the good apples out"). Hummels and Skiba (2004) provide an empirical confirmation of the Alchian-Allen conjecture showing that the quality composition of exports increases with the distance between trading partners. Additionally, they claim that international transportation costs within product categories increase with the income per worker in the importing country, which indicates that demand-side factors are a significant driver of export quality. Lugovskyy and Skiba (2015) emphasize the role of multilateral geographic factors in the quality of a country's exports, extending both the Alchian-Allen and Linder theories to a multilateral setting. In particular, in their model, proximity to richer export destinations increases quality due to a stronger preference for quality from these destinations[4], while a larger share of exports to more distant locations encourages the production of high quality goods[5], due to a smaller impact of the transportation costs on the delivery price of higher quality goods. Using trade data for the period 2000-2005 from the International Transport Database[6], they show that destination countries' characteristics affect product quality and exports of any given country, while the quality shipped to any destination depends on the demands from and the transportation costs to all destinations.

Empirical studies with firm-level data show that exporters set higher prices when selling to more distant and richer destinations. Such patterns of price discrimination across markets are consistent with firms shipping higher quality varieties to higher income and more distant markets, but also with firms charging variable markups across markets. Verhoogen (2008) links trade and wage inequality through quality-upgrading and focuses on shifts in the within-plant product mix between goods of different qualities sent to different markets by Mexican manufacturing plants. An increase in the incentive to export generates differential quality upgrading; initially more productive plants increase their exports, produce a greater

[4] The generalized Linder assumption.
[5] The Alchian-Allen supply side effect.
[6] This dataset decomposes transportation cost into ad valorem and specific components.

share of higher quality goods, and raise wages relative to initially less productive plants in the same industry. Similarly, Brambilla et al. (2012) analyze a panel of Argentinian manufacturing firms and conclude that firms exporting to high-income destinations hire more skilled workers and pay higher average wages. They suggest that hiring more skilled labor comes from the fact that Argentinian firms engage in quality upgrading due to the higher evaluation for quality of products in high-income countries. Flach (2016) presents an empirical assessment of the role of quality upgrading in explaining the price differences across destination countries. Using direct measures of quality upgrading for Brazilian manufacturing firms, she finds evidence of quality-based market segmentation, which drives firms to increase quality and prices on products destined to high-income countries.

In addition, and in contrast to the prediction of Melitz-type theoretical models with heterogeneous firms, there is evidence that more productive exporters set higher prices while as expected, higher quality is assigned to products with higher prices. More specifically, Bastos and Silva (2010) provide evidence that within product categories, higher productivity Portuguese firms tend to export greater quantities at a higher price to a given destination, which is evidence of product quality differentiation. Furthermore, firm productivity tends to magnify the positive effect of distance on within-product unit values, suggesting that higher productivity, higher quality firms serve more distant markets. In the same vein, Martin (2012) finds that prices within more differentiated industries are more responsive to changes in distance, which indicates that in these sectors, French firms can respond by adjusting their markups or their product quality across destinations.

In a detailed study on the behavior of Chinese exporting firms, Manova and Zhang (2012) show that within narrowly defined product categories, firms charge higher prices in richer, larger, bilaterally more distant, and less remote economies, a pattern that is more persistent for products with bigger potential for quality upgrading. Also, within each product, firms serving more destinations offer a wider range of export prices, especially for products with greater scope for quality differentiation. These findings indicate that different quality levels of inputs are used in the production of different quality levels of products shipped to different destinations. For the U.S. exporters, Harrigan et al. (2015) find that prices for narrowly defined categories differ substantially with the exporting firm and the destination market characteristics. Moreover, De Lucio et al. (2018) report that more productive exporters set higher prices and that export prices are higher in more distant and richer destinations. Their findings strongly support that quality competition is a major driving force of pricing within

Spanish exporters. Specifically, they show that differences in firm prices at the product-destination level are associated with the number of varieties covered by each product category, the volume of transactions and the vertical differentiation of products within firms. Whang (2014) develops a model of quality heterogeneity in which firms differ in their workers' skill level and higher-skilled workers are more productive in performing tasks that improve product quality. The model predicts that in relatively skill-abundant countries, firms with higher-skilled labor are more competitive and are able to export their varieties at higher prices to more difficult markets. These results confirm that the demand-side effects play an important role in shaping the variations in unit values across markets.

1.1.3. High-quality inputs

In the context of heterogeneous firms competing on both prices and product quality, the most profitable firms employ higher-quality inputs in production in order to export upgraded versions of their products to the toughest markets, at higher prices.[7] Johnson (2012) confirms that, prices in the majority of product sectors are increasing in the difficulty a firm faces when entering the destination market. However, Bastos et al. (2018) present a separate class of explanations focusing on quality choice. The varieties that a firm exports to a destination market may differ from those that the firm sells domestically, and may require different technologies, skills, and other inputs in production. This class encompasses two distinct mechanisms. First, per-unit transport costs may lead firms to export goods with higher value per unit, consistent with the "shipping the good apples out" effect. Second, if richer consumers are more willing to pay for product quality, firms may choose to sell varieties of higher quality in richer markets. These mechanisms suggest that destinations matter, but they emphasize different characteristics. In the first, what matters is distance from the home country -or more broadly, trade costs. In the second, what matters is the income level of consumers in the destination country.

Several studies indicate that demand for high-quality goods increases with income per capita. In addition to the "efficiency sorting" of heterogeneous exporters, there is a "quality sorting" of heterogeneous firms across markets. Eckel et al. (2015) examine the implications of cost-based versus quality-based competence for multi-product Mexican firms and find that firms in differentiated sectors exhibit quality competence, while firms in non-differentiated sectors exhibit cost competence. Manova and Yu (2017) use Chinese firm-level data to assess

[7] See for example, the model of Eckel and Neary (2010) which allows for the interaction of quality and cost differences between the varieties produced by a multiproduct firm.

empirically how “efficiency” and “quality sorting” interact with the product margin inside multi-product firms. They find that firms vary output quality across products by employing in production inputs of different quality levels, while their core competence is in varieties of superior product quality. Their results show that in markets where firms offer fewer products, they concentrate on their core varieties by dropping low-quality peripheral goods and by shifting sales towards top quality products, consistent with “quality sorting”.

1.1.4. Trade quality and the Great Trade Collapse

World trade experienced an unexpected and severe collapse between the third quarter of 2008 and the second quarter of 2009, as a consequence of the 2008 financial crisis, which started in the U.S. and then spread to the globe. According to Baldwin (2009), during the *Great Trade Collapse* trade flows fell for the great majority of product categories. According to Eichengreen (2010), and Kose and Prasad (2011) when foreign demand falls, a collapse of exports typically hits economies dependent to export activity, while Bems and di Giovanni (2016) document a flight from imports.

Given these developments, a strand of empirical trade literature examines quality during the trade collapse. Berthou and Emlinger (2010) find evidence of a lower demand for quality, as the trade collapse brought a fall of import prices at the product level. Esposito and Vicarelli (2011) document a positive relationship between product-level imports income elasticity and quality, where quality is proxied by unit values. However, again for imports, Levchenko et al. (2011) find no evidence of a relationship between product-level imports dynamics and quality. On the exports side, Chen and Juvenal (2018) use an observable measure of quality for Argentinian wine industry and document a flight from quality (compression of exporters’ margins especially for high-quality wines) leading to changes in consumption patterns due to aggregate shocks. During recessions, consumers switch to lower price products (see Coibion et al., 2015; Jaimovich et al., 2015; Nevo and Wong, 2019; Griffith et al., 2013), while the market shares of high-quality brands fall (Burstein et al., 2005). Furthermore, as the 2008 financial crisis has been characterized by volatile currency markets, the effects of real exchange rate changes may affect the export behavior of firms. Chen and Juvenal (2016) show evidence of decreasing export volumes, while export prices rise with quality due to changes in real exchange rates.

1.2. Quality measures in international trade

The main challenge in analyzing product quality is that it is unobserved at the macro and the micro level. A common feature in related studies is to employ price-based ad hoc proxies (observed export prices or unit values when the former is not available) to measure product quality. However, as Henn et al. (2020) point out, *high product prices do not necessarily suggest high product quality.* In general, export prices as a proxy for product quality may also reflect differences in production costs, shipping costs, market composition, firm composition, or the presence of an undervalued exchange rate, among others.

Khandelwal (2010), and Hallak and Schott (2011) rely on demand systems that exhibit sophisticated substitution patterns to develop more suitable proxies of product quality at the aggregate level. However, prices remain endogenous to product quality in the demand equation. As a consequence, they both follow instrumental variable approaches to identify product quality. Developing a nested logit demand framework based on Berry (1994), Khandelwal (2010) infers product quality at the country level. He estimates product-country level demand employing as an instrument for prices variety-specific transportation costs and isolates the unobserved quality component of the residuals. In his setting, quality is the vertical component of the estimated demand, while *higher quality is assigned to products with higher market shares conditional on prices*. His quality estimates reveal substantial heterogeneity in product markets' scope for quality differentiation. Hallak and Schott (2011) propose a different method for identifying countries' product quality over time allowing for both vertical and horizontal product differentiation. They claim that as consumers are assumed to care about price relative to quality in choosing among products, two countries with the same export prices but different trade balances must have products with different levels of quality. Their model is based on a Cobb-Douglas system across product groups at the upper-level with CES nests below it, to allow the elasticity of substitution for products supplied by a country to differ from the corresponding ones for products supplied by other countries. In this setting, *higher product quality is assigned to products possessed from a country with higher trade balance, among countries with identical export prices*.[8] Their method allows for price variation induced by factors other than quality.

Gervais (2015) also infers quality using instruments for prices. He estimates idiosyncratic demand from price and quantity data form the U.S. Census database, to obtain plant-level measures of product quality. In his model, the contributions of product quality and technical

[8] Product quality is varying across countries and sectors but is constant across products within a particular country and sector.

efficiency are separately quantified, while he instruments for prices with physical labor productivity.[9] He shows that product quality plays an important role in explaining plant outcomes in addition to plant efficiency and confirms that prices are increasing in product quality after controlling for productivity, which affects prices negatively. He concludes that the impact of changes in product quality and plant productivity are not equivalent. Product quality has a greater impact on selection into exporting than productivity changes.

Di Comitè, Thisse and Vandenbussche (2014) develop another quality measure at the country level. Their model incorporates both vertical and horizontal differentiation[10] allowing a separation of product quality from consumer taste effects. Instead of symmetric demand for all products, they incorporate varying consumer preferences across countries. Conditional on prices, a product may have a larger market share because (a) it appeals more to consumer taste, or (b) has a quality advantage (i.e., market share shifts due to quality or due to consumer taste). Vandenbussche (2014) follows the methodology proposed by Di Comitè, Thisse and Vandenbussche (2014) and develop a quality indicator to assess the position and the dynamics, of each Member State of EU in terms of market shares. The author studies the quality distributions constructed for each Member State and the corresponding quality ladders over time (2007-2011) and shows that products with the largest market shares may not have the highest quality.

Product quality has also been identified as a key factor in shaping trade activity at the firm level. According to Roberts et al. (2018), and Hottman et al. (2016), product quality seems to be one of the main sources of firm heterogeneity driving trade outcomes. Roberts et al. (2018) use micro data on export prices, quantities, and destinations of Chinese footwear products to estimate a structural model of demand pricing and export market participation (panel data 2002-2006). Their model incorporates firm-level heterogeneity across all firms' markets and relies on differences in firm export prices, controlling for firm costs and markups across destinations. They find that both firm-level demand and cost factors are important determinants of the entry decision into exporting. Specifically, firms with a high demand component export to more countries and the less popular destinations. The export price, quantity and destination patterns across firms indicate a potentially important role for unobserved firm components that persist across destinations. Firms that export to many destinations, also export to more difficult destinations, and have higher average export

[9] This instrument is only valid if product quality is constant over time within plants.
[10] See also Hallak and Schott (2011).

quantities in each one. These firms also have higher average export prices suggesting that demand differences are costly to produce and maintain. Finally, they find that across firm differences account for most of the micro-level price and quantity variation. On the other hand, differences in the type of product and to a small extent destinations account for this variation. In order to decompose the firm-size distribution into cost, quality, markups, and product scope contributions, Hottman et al. (2016) develop and estimate a model of heterogenous multi-product firms. Their model is based on a Cobb-Douglas system across product groups at the upper-level with CES nests below it, to allow the elasticity of substitution for products supplied by a firm to differ from the corresponding ones for products supplied by other firms. They use price and sales barcode-level data and show that variations in quality and product scope explain the major share of the variation of a firm's sales.

Khandelwal et al. (2013) use Broda and Weinstein's (2006) price-elasticity estimates to obtain quality measures at the firm level. The approach they follow to obtain quality estimates from the demand side, assuming a CES demand system, is based on the premise that conditional on price, higher quality is assigned to a variety with a higher quantity. They evaluate the productivity gains associated with the removal of quotas on Chinese textile and clothing exports. They find that quota license fees penalize low-quality firms, and as a result, quota removal induces entry by low-price, low-quality entrants.[11] However, according to Imbs and Mejean (2015), and Chetty (2012) price elasticity of demand may differ at the macro and the micro level, an artifact of aggregation, because estimates with aggregate-level data collapse disaggregate-level elasticities to homogeneity. As a result, utilizing price elasticities estimated by aggregate models and data, generates heterogeneity biases in the estimation of firm-level product quality. Adopting another ordinary measure for differentiation, Kugler and Verhoogen (2012), investigate the relationships between input prices, output prices, and plant size. They use a single-dimensional quality measure from Sutton (1998), based on R&D and advertising intensity information at the industry level. Both in Sutton's (1998) and Kugler and Verhoogen's (2012) contexts, there is a mapping between advertising and R&D intensity and the scope for quality differentiation in an industry, positing a role for fixed quality outlays. In this framework, more productive firms are likely to have a comparative advantage in using higher-quality inputs in sectors in which they pursue that it is possible to boost quality, and that firms will invest in advertising and R&D in such industries. However, advertising and R&D intensity may reflect both a scope for vertical differentiation and horizontal differentiation.

[11] Export growth is driven by the entrants rather than incumbents.

To address this concern, they adopt a measure of dissimilarity of input bundles used across firms within an industry put forward by Gollop and Monahan (1991), and the well-known measure of product differentiation developed by Rauch (1999), which reflects whether a product is differentiated or not, based on its pricing. Their empirical analysis reveals positive correlations between output prices and plant size, input prices, and plant size. Additionally, the output/input price-plant size elasticities are higher in sectors with greater scope for quality differentiation.

At the firm level, Crozet et al. (2012), Atkin et al. (2017), and Chen and Juvenal (2016; 2018; 2020) proxy product quality with expert assessments. Crozet et al. (2012) obtain direct measures of product quality for one exported product, the French champagne. Matching firm-level export data with expert assessments of the quality of champagne producers, they show empirically that firms with higher measured quality are more likely to export, export more and charge higher prices. Finally, they find that quality has the strongest influence on export success. Focusing on a different industry, Atkin et al. (2017) analyze expert assessments on rug quality produced by Egyptian firms to understand the impacts of exporting on firm performance and identify the mechanisms through which improvements occur. They observe large improvements in both quality and productivity in the context of learning-by-exporting, reporting a 16-26% increase on firm profits when exporting, relative to a non-exporting control group. Lately, Chen and Juvenal (2020) combine expert wine ratings as a measure of quality with Argentinian firm-level wine exports to show that although markups rise with destination distance from home and fall with tariffs, these effects are smaller in magnitude in the case of higher quality exports. The same observable measure of quality is also adopted by Chen and Juvenal (2016, 2018). The authors analyze the values, quantities, and unit values of firm-level exports in order to provide evidence of a flight from quality in traded goods. They show that the impact of changes in currency values on export prices increases with the quality of exported wines[12], while the response of export volumes to changes in real exchange rates decreases with quality.

Another proxy for product quality that has been used in trade literature is information coming from innovation surveys. Flach (2016) constructs a direct measure of quality upgrading for Brazilian manufacturing firms, suitable for her analysis, rather than quality levels. More specifically, this measure is an indicator variable based on questions form the PINTEC

[12] Exchange rate passthrough decreases with quality.

Industrial Innovation Survey, informative about quality upgrading over time.[13] She empirically assesses the role of quality upgrading in explaining the price differences across destination countries, and finds evidence of quality-based market segmentation, which drives firms to increase quality and prices on products destined to high-income countries. This is an important conclusion indicating that quality is an important margin of firm-level adjustment when segmenting destination markets. In the same vein, for the case of Mexico, the National Survey of Employment, Wages, Technology, and Training (ENESTyC), which offers information on whether a firm has acquired an ISO 9000 certification, has been exploited by Verhoogen (2008). In his seminal work, Verhoogen (2008) adopts this international production standard as a signal of high product quality and suggests that exporters adjust product quality and/or markups to high-income destinations.[14]

Finally, Piveteau and Smagghue (2019) provide a tool to estimate product quality at the firm level and study the link between product quality and export performance. They show that there is a mixed relationship between quality and exporters' scope when export prices are used as a proxy for quality, and they find that firms add varieties or destinations to their existing export portfolios when their product quality increases. Piveteau and Smagghue's (2019) methodology is the most integrated product quality inferring methodology at the firm level.[15] The authors exploit the information coming from the importing activity of exporters to estimate relative demand at the firm-product level. Using a CES demand system in which the quality of a product acts like a utility shifter, variations in the quality of exported goods over time and across firms will be revealed from variations in sales that cannot be explained by price movements. They instrument for prices using exchange rate variations interacted with firm-specific importing shares, allowing firms to pass importing cost variations to its consumers. As these variations are exogenous to prices, quality can be consistently identified at the firm, destination, product, year level.

[13] The measure of quality upgrading is based on two questions: (a) *whether firms undertook product innovation,* and (a) *whether product innovation was important to increase product quality*.

[14] This result also agrees with Brambilla et al. (2012) who use detailed data on Argentinean firms and exploits the variance of the export unit values at the industry level as an indication of high- medium- and low-vertical differentiation in each sector.

[15] Piveteau and Smagghue (2019) use the methodology put forward in Piveteau and Smagghue (2019) to examine the impact of Chinese competition faced by French exporters in their destination markets. Using firm-level trade data in the footwear industry, they find the growth of Chinese exports impacts substantially the export profits of French varieties, while the impact on expensive varieties is limited. Moreover, they establish that low-cost competition has heterogeneous impacts not only across, but also within industries, and that upgrading along the quality ladder does little to mitigate these impacts.

Chapter 2. Some stylized facts on Greek exporters

Prompted by the availability of large datasets at the micro level, an extensive empirical literature has emerged that attempts to map the characteristics and the behavior of exporting firms. This literature documents a number of robust facts about substantial and systematic heterogeneity of characteristics across firms. Iacovone and Javorcik (2010) claim that relying on firm-level data uncovers a lot of variation and patterns that are missed when more aggregated data are used. These include, among others, that more productive firms are larger and exhibit higher export earnings, enter more markets, pay higher wages, and are skill, and even capital intensive (see Redding, 2011; Melitz and Trefler, 2012, Melitz and Redding, 2014), that there is a strong link between exports and innovation at the firm level (Aw et al., 2011; Aghion et al., 2018; Chalioti et al., 2019), and that financial constraints are important to exporting firms (see, among others, Manova and Zhang, 2012; Feenstra et al., 2014; and also Anyfantaki et al., 2019, for Greek exporters). In this section, I present a description of some key characteristics of Greek exporting firms and compare them with those of exporters in other countries, as identified in empirical papers examining similar micro-exporting datasets. The analysis covers the years 2002-2014 with special emphasis given to the post-2009 years, as Greece was severely hit during by its debt crisis.

2.1. Data

This analysis uses firm-level data on Greek exports and imports from 2002 to 2014 from the Eurostat's Extra-EU trade statistics basis and Eurostat's Intra-EU trade statistics.[16] Export values in these data bases are free-on-board, while import values are cif (cost, insurance, and freight). The raw data are collected in a monthly basis and are aggregated to annual values and quantities traded by firm. The reason is that there is a lot of seasonality and lumpiness in the monthly data, and also that most firms do not export the same product to a specific market in every month. Only annual values that exceed a legal threshold are included in the dataset.[17]

[16] Extrastat is the system that produces statistics on trade in goods of European Union (EU) Member States with non-EU Member States and Intrastat produces statistics on trade in goods between countries of the European Union (EU).

[17] The Hellenic Statistical Authority sets this annual legal threshold applicable separately to arrivals and dispatches.

When goods are declared to the EU-statistics, they are classified according to the 8-digit Combined Nomenclature or CN8, which is the most detailed product classification system for keeping foreign trade statistics in the European Union.[18] The Nonmenclature, established to meet the requirements of both the External Trade and the Common Customs Tariff statistics of the EU, is based on the International Convention on the Harmonized Commodity Description and Coding System, the Harmonized System (HS), comprising the HS codes with further EU subdivision (see Table 2.1). Defining products at a highly disaggregated level minimizes the scope for product quality differences determining price variations within firms. In this analysis, the HS6 level is used in order to allow for international comparisons. [19]

Table 2.1: Product description at the HS6 and the CN8 level

HS6	CN8	Description
4503 10		- Corks and stoppers Detail
	4503 10 10	- Cylindrical Detail
	4503 10 90	- Other

Source: Europe RAMONE

Additional information at the firm level is obtained from the Annual Manufacturing Survey (AMS) conducted by the Hellenic Statistical Authority, which is available for the years 2002 to 2014. This survey contains data related to the economic activity of medium- and large-scale manufacturing firms. The AMS survey includes data for Greek manufacturers, such as the wage bill, number of employees, value added, operating costs, and investment.[20] More specifically, I use in my analysis operational costs, electricity costs, R&D expenditure and R&D personnel, and the detailed employment variables. Additional firm-level data on credit constraints faced by exporters are obtained from the ICAP database on Greek firms. Furthermore, a firm's total debt, total assets, age, real assets, and intangible assets provided by the same database are used. The mapping of the datasets was based on firm's tax identification numbers, which was first transformed to a random unique identifying key set

[18] The structure of the CN8 code is standardized. The first two digits of the CN8 code symbolize the sector where each product is classified; as CN8 digits ascend (until reaching the 8-digit level) we get a more detailed description of the recorded product.
[19] We have first checked that the HS6 product codes exported by Greek firms do not contain numerous CN8 product codes, maintaining the minimum scope for product quality differences.
[20] In order to exclude from our sample misreported variables of interest, we censor the extreme quantiles of each firm's total employment and total equity capital, below the 1st and above the 99th percentile.

by the Hellenic Statistical Authority.

Finally, I enrich the combined data set with various fundamental characteristics of the destination or the source country such as its distance from Greece (CEPII geographic distances), and its size, in GDP per capita and population terms, from the World Development Indicators of the World Bank.

2.1.1. Outliers

Trade data based on values and quantities contain a lot of noise due to rounding errors, misreporting on quantities and classification inconsistencies through time. This may lead to underlying product construction heterogeneity, and hence create unit value errors. Therefore, I trim the data using the following rules. First, following Van Beveren et al. (2012) and Piveteau and Smagghue (2019), I use the algorithm developed by Pierce and Schott (2012) to avoid product classification inconsistencies through time.[21] In order to deal with rounding errors and misreporting on quantities, as CN8 products may be measured in different units within HS6 categories, I use the supplementary unit provided by the Statistics division.[22] When at least the 80 percent of exporters in a specific product category are reporting this unit, I transform accordingly the measurement unit; otherwise, I drop the CN8 product that differ in measurement from the rest of its HS6 category. Finally, I clean the data dropping observations for which variations of prices are large from one year to another. “Large variations” refer to prices whose first differenced logarithm is either larger than unity or lower than minus one.

2.2. A glance at Greek exporters

Table 2 shows that a Greek exporting firm exports on average 7.8 products to 2.5 destination countries, with 40 percent being exported to richer destinations. Bastos and Silva (2010) find that these numbers for Portuguese firms are 9.9 and 3.4 respectively, while Brambilla et al. (2012) find that Argentinian wine exporters ship their products to 4.9 markets on average. Greek exporters also import on average 5.8 products from 9.5 source countries, with around 35 percent coming from richer countries. Bastos et al. (2018) examining Portuguese data find that exporters ship 8.5 different products to 3.8 different destination markets on average, exporting almost 60 percent of their value to rich destinations; while they import almost 17

[21] According to this algorithm, a new variable called synthetics is created for the product codes that change through time. We drop all HS6 codes that appear to be synthetic following the aforementioned process.

[22] Statistical authorities allow exporters to declare the quantities traded in two different units; either weight or a product specific supplementary unit.

products from 3.7 source countries, with 90 percent of their value imported from rich countries.

Table 2.2: Summary statistics – trade flows combined dataset

	mean	p50
Exports per firm	1,028	14.48
Share of exports to rich destinations (%)	40.32	32.22
Number of export destinations	2.53	1
Number of exported products	7.81	2
Imports per firm	902.32	115.54
Share of imports from richer countries (%)	35.34	25.41
Number of import source countries	9.52	7
Number of imported products	5.87	5
N (firms)	23,633	

Notes: Table reports averages across firms per year. All rows are conditional on a firm having both positive exports and positive imports. Values of exports and imports in ths of euro.

Next, I present a cross-country comparison of exporting firms' main statistics, available for Belgium, France, Hungary, Sweden (see Baldwin et al., 2008) and Portugal (see Bastos et al., 2018). As shown in Table 2.3, Greek exporters' main statistics are pretty similar to the Portuguese's ones, and also close to the range of average numbers of export destinations and exported products reported for Belgium, France, Hungary, and Sweden. However, in the cases of Belgium and Sweden the value of exports per firm is extremely high according to the data presented in Baldwin et al. (2008).

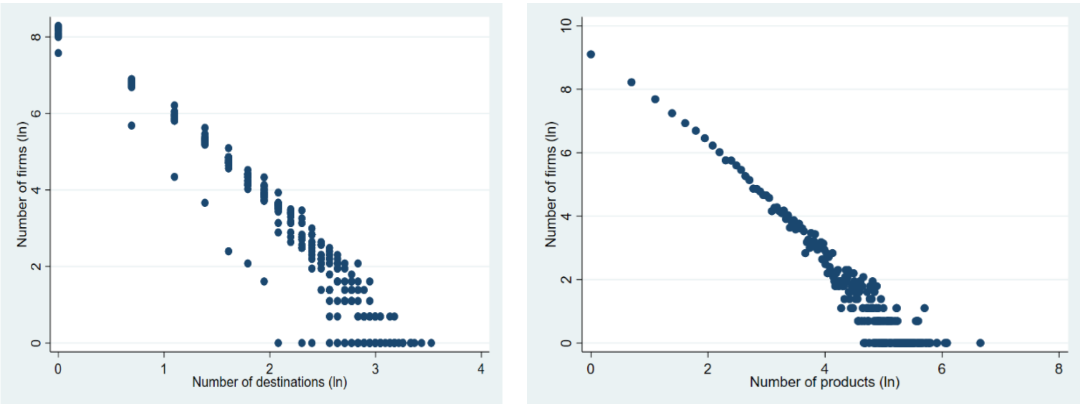
Table 2.3: Cross-country comparison

	Greece	Belgium	France	Hungary	Sweden	Portugal
Avg exports per firm (in mn euro)	1	6.2	0.4 - 2.6	0.3 - 1.4	9.2 - 60.6	1.3
Avg number of export destinations	2.5	-	1.3 - 2.2	1.1 - 1.3	1.4 - 3.2	3.8
Avg number of exported products	7.8	9.3	3.7 - 7.1	3.4 - 6.7	5.7 - 7.1	8.7

Notes: All figures reported refer to annual values. Author's own calculations for Greece calculated over the 2002-2014. Calculations for Belgium, France, Hungary, and Sweden are from Baldwin et al. (2008), while statistics for Portugal are from Bastos et al. (2018) for the year 1997. Statistics for France, Hungary and Sweden are calculated in ranges as they are based on calculations that depend on destination country groups, for the year 1999.

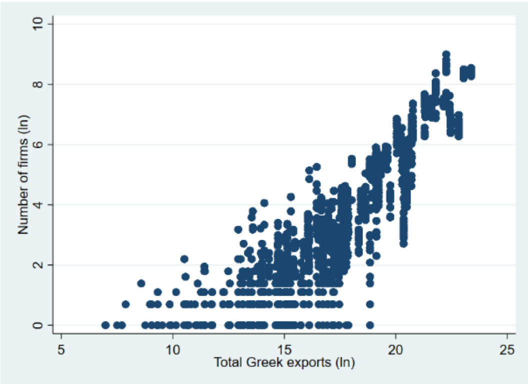
Figure 2.1 displays the frequency that Greek exporters serve numbers of markets and ship numbers of products, respectively. The number of firms serving a greater number of destinations and shipping a greater number of products falls in a smooth and monotonical way. In line with evidence from Portuguese exporters, Greek export flows are concentrated in a small number of exporters, in terms of destinations and products (see Bastos and Silva; 2010). This evidence is also in line with existing evidence for France, the U.S.A., Belgium, Brazil, and Chile (see Eaton et al., 2004; Bernard et al., 2007; Muûls and Pisu, 2007; Arkolakis and Muendler, 2013; and Álvarez et al., 2007); while Arkolakis and Muendler (2013) find that Danish and Norwegian exporters exhibit less pronounced declines in destination reach.

Figure 2.1: Greek exporters' frequency of destination markets and exported products

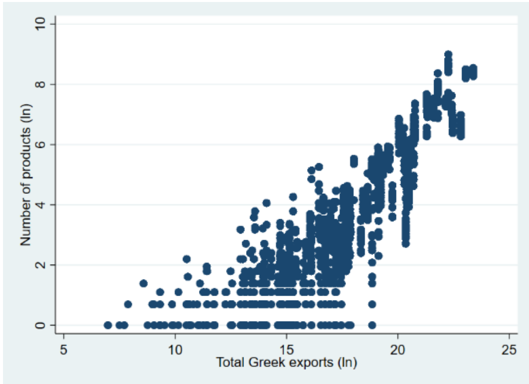


Focusing on gravity and the margins of trade, I next examine the aggregate value of Greek exports with respect to the number of exporting firms, the number of exported products, and the average value of exports per product per firm. The findings are similar to those of Bastos and Silva (2010) for Portuguese exporters. As shown in Figure 2.2, there is a strong positive association between aggregate exports, and both the number of exporting firms and the number of products exported. There is no clear direction on the relationship between the value of aggregate Greek exports to a given destination and the intensive margin accounted as the export value per product at the firm level.

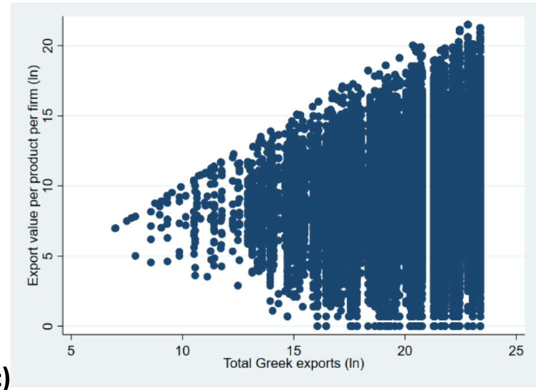
Figure 2.2: Aggregate exports and (a) number of firms, (b) number of products, and (c) export value per product



(a)



(b)



(c)

Shedding light on the behavior of exporting firms, we further examine their heterogeneous characteristics. As shown in the upper panel of Table 2.4, the average firm in this sample has 688,000 euro annual earnings, which decomposes to 13,380 euro annual earnings per worker, counts on average 26 years of operation, while almost twenty percent of its sales comes from its exporting activity. Accordingly, Bastos et al. (2018) report 10,010 euro per worker as a Portuguese firm's annual earnings, while an exporting firm's age is 25 years on average. Moreover, a Greek exporting firm in my sample is almost 30 percent leveraged, a finding close to related findings by Bernini et al. (2015). Now, looking closer at a Greek exporting firm's employment decomposition (see lower panel of Table 2.4) the average Greek exporter has around 80 employees, with this number being a bit higher for Argentinian exporting firms (almost 90 employees according to Brambilla et al., 2012), while quite higher for Portuguese exporters according to Bastos et al. (2018) (almost 110 employees). Around 40 percent of these employees are high-skilled (white-collar) employees with an average annual wage of 20,000 euro. According to Verhoogen (2008), the share of white-collar employees in Mexican exporting firms is 33 percent on average. Finally, the corresponding wage for the blue-collar category is 14,300 euro per year.

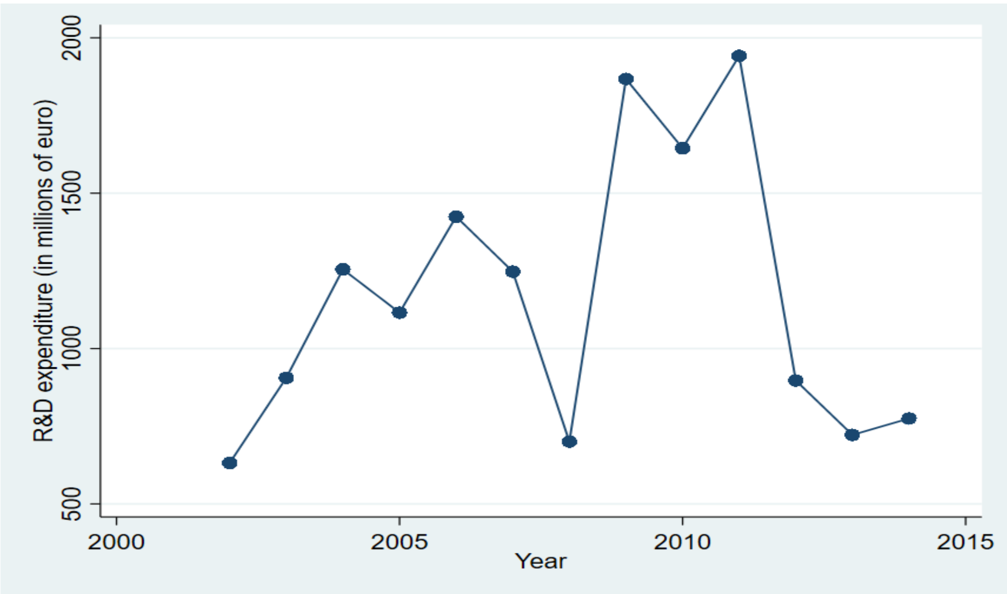
Table 2.4: Summary statistics – Greek exporters' merged dataset

	p5	p25	p50	p75	p95	mean
Earnings (in ths of euro)	-161.18	92.79	282.77	675.53	2,676.68	688.72
Annual earnings per worker (in ths of euro)	-6.47	4.31	10.22	18.97	42.48	13.39
Age of firms	6	14	23	34	56	26.11
Export share of sales (%)	.05	.57	3.06	13.28	66.44	19.04
Leverage	.03	.17	.34	.49	.68	.34
Employment	10.5	20	38.5	87.91	291	81.43
White collar employment share (%)	10	23.65	37.93	54.7	89.49	41.27
White collar annual wage (in ths of euro)	10.31	14.62	19.17	24.93	35.4	20.55
Blue collar annual wage (in ths of euro)	5.59	11.17	13.58	16.47	21.85	14.29

Notes: this sample consists of Greek exporters who also import their inputs. Data availability varies across variables.

Finally, in Figure 2.3, I present the R&D expenditure of Greek exporting firms in mn euro during the period 2002-2014. There is a substantial drop of R&D related expenditure made by Greek exporters in 2008, followed by a remarkable increase during the next three years and a sharp drop afterwards.

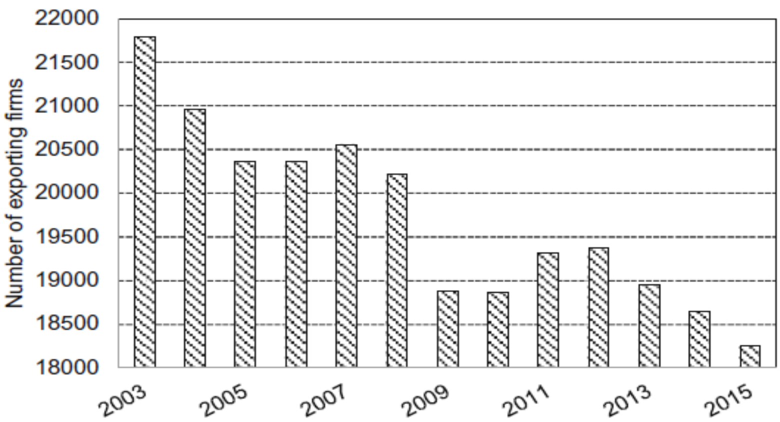
Figure 2.3: Total R&D expenditure of Greek exporting firms, 2002-2014



2.2.1. Greek exporters during the global financial crisis

Greece was severely hit by the global financial crisis of 2007-2009, which found Greece with twin deficits exceeding 15 percent of GDP. The recovery effort of the Greek economy focused mainly on the budget deficit. As a result, the country's trade deficit continued to raise worries about its sustainability. Its improvement was mainly due to a reduction in the country's imports. Between 2007 and 2012, the structural changes in the workplace (mainly a 13 percent drop in wages relative to the Eurozone average) were considered adequate to restore the competitiveness of Greek exports to pre-crisis levels, assuming a downward trend in domestic price levels. Instead, domestic prices followed an upward trend, which undermined efforts to boost competitiveness through lower labor costs as the other key operating and production costs of a firm, as well as the business-related uncertainty, increased. The entrance of new exporters was very difficult because of bureaucracy, lack of funding opportunities and lack of information. Active exporters faced the imposition of capital controls, and insufficient access to credit. Drivas and Katsimi (2019) find that the number of Greek exporting firms over the period 2009–2015 dropped substantially, indicating that the crisis led some firms either to stop their exporting activities or to declare bankruptcy.

Figure 2.4: the number of Greek exporting firms, 2003-2015



Source: Drivas and Katsimi (2019)

Next, I present Greek exporters' main characteristics with a special emphasis on the years after 2009. Table 2.5 shows that, during the years 2009-2014, a Greek exporting firm exports on average 7.6 products to 2.5 destination countries, with 40 percent of the exports destined to richer countries. Over the same period, Greek exporters import 5.3 products on average from 8.7 source countries, with around 37 percent of these imports coming from richer countries.

Table 2.5: Summary statistics – trade flows combined dataset, 2009-2014

	mean	p50
Exports per firm	1,317	16.24
Share of exports to rich destinations (%)	40.86	32.88
Number of export destinations	2.51	1
Number of exported products	7.63	2
Imports per firm	3,679.38	2,747.32
Share of imports from richer nations (%)	36.79	27.47
Number of import source countries	8.75	7
Number of imported products	5.34	4
N (firms)	14,433	

Notes: Table reports averages across firms per year. All rows are conditional on a firm having both positive exports and positive imports. Values of exports and imports in ths of euro.

Figure 2.5: Greek exporters' frequency of destination markets and products, 2009-2014

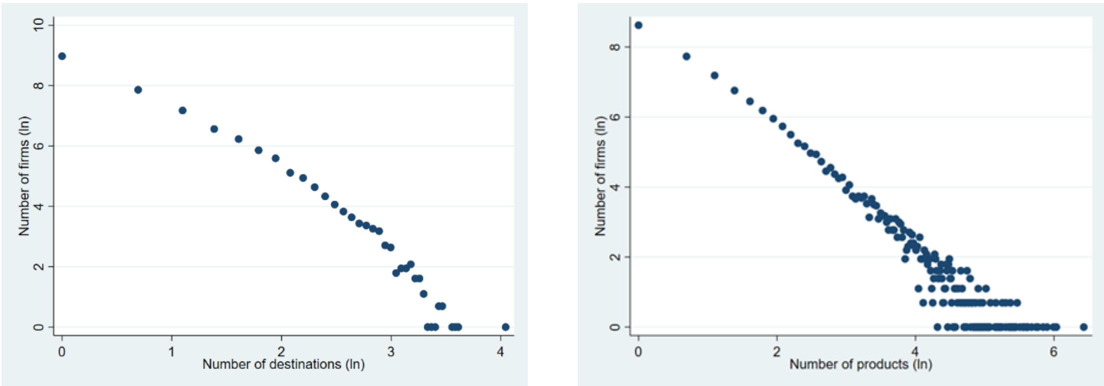


Figure 2.5 displays the frequency that Greek exporters serve numbers of markets and ship numbers of products after the global financial crisis, respectively. Clearly, the number of firms serving more numerous destinations and shipping a greater number of products falls in a smooth and monotonical way during this period as well.

Table 2.6: Summary statistics – Greek exporters' merged dataset, 2009-2014

	p5	p25	p50	p75	p95	mean
Earnings (in ths of euro)	-228.99	66.36	235.41	608.77	2,411.32	615.74
Annual earnings per worker (in ths of euro)	-8.38	3.5	9.52	17.96	40.21	12.07
Age of firms	9	17	26	37	59	28.85
Export share of sales (%)	.05	.07	3.87	16.41	72.25	20.82
Leverage	.02	.15	.33	.51	.72	.35
Employment	10	19	36	79	247	69.56

White collar employment share (%)	10	26.19	40.54	58.33	90.47	43.9
White collar annual wage (in ths of euro)	10.31	15.52	20.47	26.29	36.82	21.65
Blue collar annual wage (in ths of euro)	7.59	11.9	14.89	17.75	23.12	15.25

Notes: this sample consists of Greek exporters who also import their inputs. Data availability varies across variables.

The average firm has 615,000 euro annual earnings, which decomposes to 12,070 euro annual earnings per worker, counts on average 29 years of operation, while almost 21 percent of its sales comes from its exporting activity (see upper panel of Table 2.6). Moreover, a Greek exporting firm during this period is more leveraged in comparison to its leverage when examining the whole sample period. Also, a Greek exporter spends almost .10 percent of its expenses on R&D activities, presenting a substantial decrease on its R&D related expenditures.

Looking closer at the employment decomposition of Greek exporters during the crisis (see lower panel of Table 2.6), the average firm has around 70 employees, ten less than the average of the whole sample period. Only 20 percent of these employees are high-skilled (white-collar) employees; 50 percent less than the average of the whole sample period. Their average annual wage is around 20,000 euro, while the corresponding wage for the blue-collar category is 15,250 euro per year (which is slightly higher compared to the average wage of the whole sample period).

2.2.2. Greek innovative exporters

The final part of the analysis focuses on innovative exporting firms. According to Drivas and Katsimi (2019) Greek innovative exporters are a relatively small percentage of exporters, however, they account for 23.6 percent of total export sales. Table 2.7 shows that a Greek innovative exporting firm ships on average 16.4 different HS6 products to 5.5 destination countries, with 40 percent being exported to richer destinations. When examining the crisis period, I see a slight drop on these numbers. Greek innovative exporters also import their inputs on average from 16.7 different source countries (almost double with respect to the whole Greek exporters sample), importing 9.7 different products, with around 25 percent of these imports being sourced form richer countries. Again, these numbers are slightly reduced in the crisis period.

Table 2.7: Summary statistics – trade flows of innovative exporters combined dataset

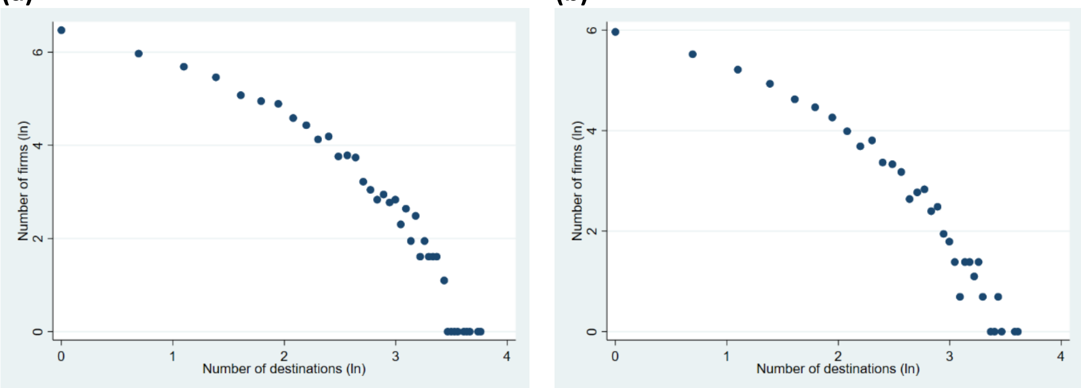
	mean	p50
Exports per firm	2,700.98 [2,181.5]	95.4 [147.85]
Share of exports to rich destinations (%)	39.29 [41.7]	30.81 [34.02]
Number of export destinations	5.49 [5.06]	3 [3]
Number of exported products	16.39 [12.66]	6 [5]
Imports per firm	1,137.68 [894.42]	269.3 [236.76]
Share of imports from richer nations (%)	25 [23.17]	13.48 [11.2]
Number of import source countries	16.67 [14.63]	15 [13]
Number of imported products	9.73 [8.36]	9 [8]
N (firms)	3,429 [2,090]	

Notes: Table reports averages across firms per year. All rows are conditional on a firm having both positive exports and positive imports. Values of exports and imports in ths of euros. Calculations focusing only on the crisis years in brackets.

Figure 2.6 displays the frequency that Greek innovative exporters serve numbers of markets and ship numbers of products (the right figure focuses on the financial crisis period), respectively.

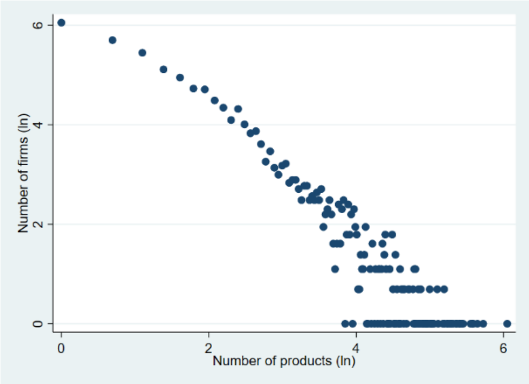
Figure 2.6: A. Greek innovative exporters' frequency of destination markets (a) 2002-2014 (b) during the years after the global financial crisis

(a) **(b)**

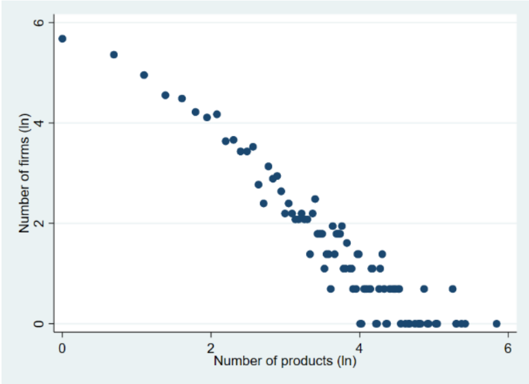


B. Greek innovative exporters' frequency of exported products (a) 2002-2014 (b) during the years after the global financial crisis

(a)



(b)



I find that the average firm has 697,000 euro annual earnings, which decomposes to 13,400 euro annual earnings per worker, counts on average 26 years of operation, while almost 19 percent of its sales comes from its exporting activity (see upper panel of Table 2.8). Also, a Greek exporter spends almost .12 percent of its expenses on R&D activities. Now, looking closer at a Greek innovative exporting firm's employment decomposition (see lower panel of Table 2.8), the average Greek innovative exporter has 82 employees (which falls to 72 during the crisis period). The 41 percent of these employees are white-collar employees, while the percentage of people employed in R&D related activities is .32. Their average annual wage remains around 20,000 euro, while the corresponding wage for the blue-collar category is 14,000 euro per year (which slightly increases in the crisis period).

Table 2.8: Summary statistics – Greek innovative exporters' merged dataset

	p5	p25	p50	p75	p95	mean
Earnings (in ths of euro)	-161.18 [-215.74]	93.65 [75.45]	286.55 [252.68]	683.93 [640.55]	2,702.49 [2,535.44]	697.86 [646.76]
Annual earnings per worker (in ths of euro)	-6.45 [-8.3]	4.31 [3.51]	10.22 [9.52]	18.97 [17.97]	42.48 [40.39]	13.4 [12.1]
Age of firms	6 [9]	14 [16]	23 [25]	34 [36]	56 [57]	26.21 [28.24]
Export share of sales (%)	.05 [.05]	.6 [.7]	3.18 [4.22]	13.58 [17.57]	66.99 [72.05]	19.37 [20.91]
Share of R&D expenses (%)	.0 [.0]	.0 [.0]	.0 [.0]	.0 [.0]	.29 [.18]	.12 [.10]
Employment	10.66 [10]	20.5 [19]	38.91 [36]	88 [79]	292.83 [251]	81.87 [70.08]
White collar employment share (%)	9.91 [11.11]	23.68 [26.31]	37.93 [40.74]	54.75 [58.49]	89.65 [90.52]	41.3 [44.02]
R&D personnel share (%)	.0 [.0]	.0 [.0]	.0 [.0]	.0 [.0]	1.68 [.96]	.32 [.29]

White collar annual wage (in ths of euro)	10.31 [10.29]	14.63 [15.52]	19.18 [20.48]	24.94 [26.31]	35.42 [36.77]	20.56 [21.64]
Blue collar annual wage (in ths of euro)	8.04 [7.58]	11.16 [11.89]	13.57 [14.88]	16.46 [17.74]	21.82 [23.07]	14.27 [15.23]

Notes: this sample consists of Greek exporters who also import their inputs. Data availability varies across variables. Calculations focusing only on the crisis years in brackets.

Chapter 3. Estimating trade quality: The case of Greek exporters

In this chapter, I present an application of the product quality estimation methodology developed by Piveteau and Smagghue (2019) for the case of Greek exporters. This empirical approach follows the spirit of Hallak and Schott (2011) and defines unobserved product quality as any intrinsic characteristic or taste preference that improves the consumer appeal of a product given its price. Thus, the identification of product quality requires the decomposition of observed export prices into quality and quality adjusted-price components.

In the international trade literature, it is common to rely on observed export prices (or trade unit values) as a proxy for product quality, based on the premise that a higher price is assigned to products of a higher quality. However, export prices and unit values may vary for reasons other than product quality. Prices reflect production costs and, hence, in a more homogeneous sector, where there is little scope for vertical differentiation, prices are less informative on quality, as they poorly capture differences in demand fundamentals.[23] Additionally, exchange rates are important in international trade; and an undervalued exchange rate could be mirrored into a lower export price for a given quality-level product. For example, Chinese skirts might be cheaper than Italian skirts in the U.S. market because of lower quality, but also, they might be cheaper either because of lower production costs - possibly related to lower quality of inputs employed in production-, or an undervalued exchange rate.

The industrial organization literature extensively assumes that consumers value price relative to quality when choosing among products. This is also the intuition behind Hallak and Schott (2011)'s identification strategy as two countries with different trade balances but identical export prices, have export products with different quality levels. Based on the same intuition but focusing my interest on heterogeneous firms, I use the estimation strategy put forward by Piveteau and Smagghue (2019) to estimate time-varying product quality at the firm level for the case of Greek exporters.

[23] There are also cases in which demand equations are estimated in contexts where vertical differentiation is limited or absent. For example, Foster et al. (2008) examine homogeneous products, while Broda and Weinstein (2010), and Handbury (2012) use barcode-level data that do not present any quality differentiation over time.

This strategy estimates product quality from the demand side, exploiting information coming from the importing activity of exporters to deal with demand estimation challenges. The main challenge when estimating demand functions is price endogeneity, and as quality is supposed to be costly to produce, one has to deal with the possibility of prices being correlated with demand shocks that may occur. To this end, Piveteau and Smagghue (2019) present an instrument obtained by interacting real exchange rates with firm-specific importing shares, which is exogenous to any measurement errors in prices and also to the quality choices made by each firm.

3.1. The empirical model with demand for quality

In this section I present the empirical model by Piveteau and Smagghue (2019), which estimates relative demand at the firm-product level. The authors first introduce a constant elasticity of substitution (CES) demand system in which the quality of a product acts like a utility shifter (i.e., a number of units of utility per physical unit of good). More conservative cases in the related literature are those of Roberts et al. (2018), who refer to the variety-specific utility shifter as a "demand index", and Foster et al. (2008) where this shifter is termed as "demand fundamental". In the present case, this variety-specific utility shifter stands for product quality, as a measure of the total appeal of a product variety to the representative consumer. In such a setting, variation in the quality of exported products across firms and destinations over time is identified from variation in sales that cannot be explained by price movements.

Consider a global economy of *d* destination markets, where in each market co-exist *i* symmetric consumers and *f* heterogeneous trading firms.[24] The representative consumer allocates his revenues over different varieties produced by the trading firms. A variety *j* is defined as a unique combination of a destination market *d*, a producing firm *f* and a product *g*. A representative consumer has two-tier preferences combining varieties through a nested CES aggregator. The lower level of the utility function aggregates consumption of varieties by product, while at the upper level the consumer connects consumption across products. Assuming a CES utility at the lower level (i.e., varieties are equally substitutable within products) and not imposing any functional form on the patterns of substitutability across products on the upper level, quality is identified as an index for each variety that contains any

[24] Every firm trades a differentiated good; each firm, within a market, produces a single variety and has a monopoly power on it. This translates to an elasticity of substitution set lower than unity to ensure the finiteness of mark-ups under monopolistic competition.

characteristic[25] which raises consumer's valuation of it.

At this point, it is important to explain the nested structure of the utility function; all product varieties are equally substitutable to the varieties of another product. Such a structure allows Toshiba laptops to be substitutes or complements to Levi's jeans, but supposing that they are indeed substitutes, then any combination of laptops and jeans varieties will also be substitutes. This structure is common in the related literature building on the random effect logit model of Berry et al. (1995)[26], as it allows for plausible correlation structures among consumer preferences. For example, assume that a consumer is about to choose between a leather jacket manufactured in Argentina and an English woolen jacket. If a leather jacket made in the United States of America enters the jacket market, a CES framework predicts that the market shares of all imported jackets will fall by the same percent. However, the Argentinian jacket's market share is expected to adjust more than the English jacket's share as the newly introduced jacket is also leather. This setting has the advantage that allows for such delicate substitution patterns as it places product varieties into appropriate nests.

The utility of the representative consumer in a destination market *d* at year *t* is

$$U_{dt} = U(C_{1dt}, \dots, C_{Gdt}),$$

$$C_{gdt} = \left[\sum_{f \in \Omega_{gdt}} \left(\lambda_{fgdt} q_{fgdt}\right)^{\frac{\sigma_j - 1}{\sigma_j}}\right]^{\frac{\sigma_j}{\sigma_j - 1}} \quad \text{for each product } g\text{=1…,G,} \tag{3.1}$$

where $U(.)$ is a utility function which is well-behaving, C_{gdt} the aggregate consumption of product *g* in destination market *d* at year *t*, Ω_{gdt} the set of varieties available to consumers, σ_j the constant elasticity of substitution[27] across varieties, while q_{fgdt} and λ_{fgdt} respectively, the aggregate consumption and the quality of each variety at year *t*. The representative consumer allocates his total expenditure across products and varieties, in order to maximize his utility. His behavior is expressed in the following form:

$$q_{fgdt} = p_{fgdt}^{*-\sigma_j} \lambda_{fgdt}^{\sigma_j - 1} P_{gdt}^{\sigma_j - 1} E_{gdt} \tag{3.2}$$

[25] Such characteristics may be tangible (see color, shape, size) or intangible (see brand name, customer service, advertisement, reputation).

[26] See Khandelwal (2010) where the elasticity of substitution is the same among varieties within a nest, no matter of their quality-level.

[27] Here a unique elasticity of substitution is assumed for presentation purposes. However, this assumption is relaxed across industries by making the natural assumption that within a nest, varieties are closer substitutes than across nests.

This is the aggregate residual demand function for a variety *fgd*, where E_{gdt} is the expenditure optimally allocated to a variety *fgd*. P^{*}_{fgdt} is the CIF (Cost Insurance Freight) price of the variety faced by consumers, in market *d*'s currency, while P_{gdt} is the price index of product *g* in market *d* at year *t*. The aggregate price index verifies:

$$P_{gdt}^{\sigma_j - 1} = \left[\sum_{f \in \Omega_{gdt}} \left(\frac{p^{*}_{fgdt}}{\lambda_{fgdt}} \right)^{1-\sigma_j} \right]^{\frac{1}{1-\sigma_j}}. \tag{3.3}$$

λ_{fgdt} is the quality of the variety *fgd*. It is important to note that σ_j is the own price elasticity of variety's *fgd* demand, when keeping constant the aggregate price index P_{gdt} and the aggregate expenditure E_{gdt}. In such a monopolistic competition framework, firms' individual decisions do not influence aggregate variables, as the firms are atomistic. In settings where firms are not atomistic, individual prices may have an aggregate impact, and as a result, the own price elasticity may differ across firms.

Piveteau and Smagghue further assume that exporting involves iceberg trade costs[28], common to all firms serving a destination market *d*. The CIF price expressed in destination d's currency and the FOB (Free on Board) price expressed in home currency are linked as follows:

$$p^{*}_{fgdt} = \frac{\tau_{gdt}}{e_{dt}} p_{fgdt} \tag{3.4}$$

In detail, e_{dt} is the direct nominal exchange rate from home currency to destination market *d*'s currency, and τ_{gdt} the corresponding to the trade flow iceberg costs. Plugging this expression into the aggregate residual demand function for the variety *fgd*, and log-linearizing, the resulting demand function taken to the data is

$$\log q_{fgdt} = -\sigma_j \log p_{fgdt} + \tilde{\lambda}_{fgdt} + \mu_{gdt} \text{ ,} \tag{3.5}$$

$$\text{with } \begin{cases} \tilde{\lambda}_{fgdt} \equiv (\sigma_j - 1)\left(\log \lambda_{fgdt} - \overline{\log \lambda}_{gdt}\right) \\ \mu_{gdt} \equiv - \ \sigma_j \log\left(\dfrac{\tau_{gdt}}{e_{gdt}}\right) + (1 - \ \sigma_j) \log P_{gdt} + \log E_{gdt} + (\sigma_j - 1)\, \overline{\log \lambda}_{gdt} \end{cases}$$

$$\text{and } \overline{\log \lambda}_{gdt} \equiv \frac{1}{H_{dgt}} \sum_{f \in H_{gdt}} log\, \lambda_{fgdt},$$

which is the average log-quality of product *g* exported by firms to a destination market *d* at year *t*. Once again, $-\sigma_j$ is the own price elasticity that varies across industries *j*, *q* stands for the

[28] A trading firm needs to ship $\tau_{gdt} \geq 1$ units of product *g* in order a whole unit to reach the consumer in market *d* at year *t*.

aggregate physical consumption while p for the price of variety *fgd*, and μ is a market specific term that conflates the average quality with other aggregate variables. This log-linearized form of the demand equation is the one brought to the data, where $log\ q_{fgdt}$ and $log\ p_{fgdt}$ are observable to the econometrician. The own price elasticity, σ_j, as well as the demand shifter, which consists of a variety-specific, λ_{fgdt}, and a nest-specific part, μ_{gdt}, are not observable and have to be estimated. To this end, the econometrician has to include a fixed effect at the destination×product×year level in the regression. It is important to highlight that the nest-specific term conflates the average quality of exports with other aggregate variables.

The methodology presented by Piveteau and Smagghue identifies product quality from the variety-specific term of the demand shifter. However, this procedure does not deliver an absolute measure of product quality, but a relative to the average quality exported by domestic firms to a destination market *d*. Although this measure is not suitable to analyze any variations present in the aggregate quality of the home country's exports, it is rather suited to analyze firm movements *relative to each other along the quality ladder across markets and over time*. So, **the term λ_{fgdt} captures the variety-specific quality identifier that delivers a measure of product quality relative to the average quality exported by domestic firms to a market.**

A closing comment on the demand structure of this methodology is that the estimation of product quality remains robust if the representative consumer assumption is relaxed, as e.g., in a nested-logit setup as in Khandelwal (2010). In such a setting, the parameter of interest, λ_{fgdt}, remains a measure of relative quality across firms and destination markets over time.

3.2. Price endogeneity

The main challenge of a demand estimation is that prices are endogenous to demand shocks. Hence, in this case, prices are endogenous to product quality (see e.g., Hallak and Sivadasan, 2013; Johnson, 2012; Kugler and Verhoogen, 2012) due to the presence of quality in the variety-specific demand shifter.

High quality is costly to produce and, as a result, correlation between prices and quality may occur from firms passing on this cost to consumers. Additionally, price endogeneity can also arise because more productive firms are likely to take advantage of their market power resulting in higher mark-ups. This endogeneity channel ("simultaneity problem") leads to an underestimated price-elasticity of demand when OLS estimation is used. In fact, a product's appeal to its consumers may increase to compensate the price effect on demand due to a quality upgrade.

Another source of possible endogeneity is the inherent construction of prices in international trade data. The standard technique to proxy for prices is to use unit values (export value over physical quantity). Such a proxy may contain a measurement error that in turn may trigger attenuation bias in the demand estimation. The bias generates a misconception on the magnitude of the variation of unit values in the case of an estimation using fixed effects.

Although previous literature has developed numerous empirical strategies to treat price endogeneity, they are not suitable for our analysis. In the I-O literature, many instruments for prices are presented in setups where either different varieties of a product and their characteristics are observed, or study only homogeneous products. However, these instruments are not suitable for analyses where unobserved vertical differentiation is present. In detail, Berry et al. (1995), in their seminal paper, instrument prices with competitors' product characteristics in the demand estimation. Hausman (1996), and Nevo (2000) treat a product's price on other markets as an instrument for prices, while Foster et al. (2008) use estimated physical productivities to eliminate endogeneity. Although these instruments are sufficient when price endogeneity is likely, trade data classification, even at the CN8 product-level, still allows for a wide scope for vertical differentiation within each category.

Instrumental variable approaches for demand estimation with trade data have been developed at the country level by Khandelwal (2010), and Hallak and Schott (2011). Khandelwal (2010) estimates product-country level demand employing as an instrument for prices variety-specific transportation costs, while Hallak and Schott (2011) propose a different method for estimating demand at the product-country level using as an instrument for prices the *Impure Price Index*, a country's net trade with the rest of the world.[29] Both the aforementioned instruments do not vary across firms within a market. This means that they cannot be applied to estimate firm-level demand and as a consequence, quality at the firm-product level. At the country level, Feenstra (1994) develops a demand estimation procedure which incorporates new product varieties into a CES unit-cost function using country-level trade data. This technique for estimating the elasticity of substitution allows correlation between unobserved taste parameters, prices, and quantities, exploiting the heteroskedasticity of supply and demand shocks. Broda and Weinstein (2006) supplement this approach to estimate the elasticities of substitution by allowing for a more general estimation

[29] This is a price index that aggregates a country's observed export prices at the product-level, up to the industry level.

technique and extend the treatment of measurement error. The estimation technique they adopt allows for random changes in the taste parameters of imports by country and is robust to measurement error from using unit values as they are not considered as proper price indices. Broda and Weinstein (2010) generalize Feenstra's (1994) simple intuition that one can use the market share of entering and disappearing goods to eliminate the quality parameters from the price index and write it only in terms of prices and market shares even when goods are constantly being replaced. They follow Broda and Weinstein's (2006) estimation procedure to define the difference between an exact price index with quality change. This procedure accounts for price changes of all products, including new and disappearing ones, and another price index, that only captures price changes of the constantly existing products. Although such demand estimation techniques can be applied to estimate firm-level demand from disaggregated trade data, they are not suitable when vertical differentiation is present. This is because the orthogonality assumption between demand and supply shocks made in these settings is likely to be violated if, for instance, product quality is costly to produce.

At the firm level, Gervais (2015) estimates idiosyncratic demand instrumenting prices with physical labor productivity[30], while Roberts et al. (2018) adopt firms' wages as an instrument in the demand estimation. These instruments are only appropriate if product quality is time-invariant. Khandelwal et al. (2013) calibrate a CES demand system using the price elasticities estimated by Broda and Weinstein (2006), inheriting the orthogonality assumption violation problem in the presence of vertical differentiation.[31] More recently, Fontagné et al. (2018) use electricity prices as an instrument in demand estimations. An advantage of this instrument is that the use of electricity cost shocks as instruments are more likely to affect exports only through their impact on export prices. Aghion et al. (2018) investigate the effect of export shocks on innovation and address the potential endogeneity by using firm-level export proxies, which respond to aggregate conditions in a destination country but still are exogenous to any firm-level decisions (see destination's import competition from the rest of the world). Finally, Piveteau and Smagghue (2019) take advantage of exogenous exchange rate variations interacted with firm-specific importing shares, which allow firms to pass importing cost variations to their consumers and are unlikely to be endogenous to the behavior of individual firms.[32] This instrument is appealing as it remains valid in the presence

[30] This instrument is only valid if product quality is constant over time within plants.
[31] Also, Broda and Weinstein's (2006) estimates are obtained at the product-country level. However, price elasticity may differ at the micro and the macro-level.
[32] Exchange rates as instrument for price endogeneity have also been used in studies that analyze the pass-through from exchange rates to export prices at the firm-level (Berman et al., 2012; Amiti et al.,

of quality which is time varying.

Any instrument at the firm level should be independent from non-price determinants of the individual demand faced by firms, but simultaneously, have an impact on individual production costs. The following subsection describes in detail how the endogeneity of prices is treated.

3.3. Instrumentation strategy

Piveteau and Smagghue (2019) use exogenous exchange rate variations interacted with firm-specific importing shares, which allow firms to pass importing cost variations to their consumers and are unlikely to be endogenous to the behavior of individual firms. The idea behind this choice is that *real exchange rate shocks on a firm's imports are cost shocks*, unrelated to relative demand shocks, which renders the instrument robust to time-varying product quality.[33] As the firm passes through these shocks to its export prices, firm sales adjust, and the demand function can be consistently identified.

These variations are arguably exogenous to unobserved demand shocks. For example, if a firm imports inputs from the U.S., while another imports from Europe, an appreciation of the dollar would induce an increase of the export price of the former, leaving unchanged the price of the latter. The response of the firms' relative sales to the change in their relative prices identifies the price elasticity of demand.

The import-weighted real exchange rate of a firm *f* at time *t* importing from country *s* is:

$$log\ (\overline{rer}_{ft_0t}) = \sum_{s} \omega_{fst_0} \times log(reer_{st}) \tag{3.6}$$

where ω_{fst_0} is the share of goods imported from the source country *s*, in the total imports of country *s* at time t_0.[34] In our analysis, real effective exchange rates are used, calculated as the

2014). Amiti et al. (2018) have also used exchange rates to obtain exogenous variations in the cost of imported inputs.

[33] Standard demand or supply shocks affect prices without necessarily affecting product quality. The exchange rate fluctuations based on macroeconomic conditions are unlikely to be correlated with demand shocks or quality decisions made by Greek exporters, which constitutes the structural error of the model.

[34] The formula of ω_{fst_0} is:

$$\omega_{fst_0} = \frac{m_{fst_0}}{\sum_{s=1}^{S} m_{fst_0}}$$

where m_{fst_0} is the share of imports that firm *f* imported from source country *s* at a reference time t_0 in the total imports of the firm *f* at the same time.

foreign currency over a basket of main currencies weighted for the trade flows of these currencies' countries.[35] A second source of variation at the firm level is also exploited; the share of total imports m_{ft} in the operating costs OC_{ft} of the firm at time *t* which accounts for the probability two firms experiencing in a different way the same real exchange rate shock depending on the role of imported inputs in their production process. Hence, the main instrument in our specification has the following form:

$$\overline{RER_{ft_0t}} = \ log\ (\overline{rer}_{ft_0t}) \times \frac{\sum_t m_{ft}}{\sum_t OC_{ft}} \tag{3.7}$$

This instrument is orthogonal to measurement errors on unit values, as information on exports is not involved in its construction (see attenuation bias).

Additionally, cost shocks on imports purchased in the year previous to *t* are expected to possibly generate an increase in the current price charged by an exporter *f*. Hence, a second instrument using the same set of weights as the main instrument, interacted with the real exchange rates at time *t-1*, is used. Both these instruments create exogenous firm-specific shifters that allow to identify price elasticities of demand. According to Piveteau and Smagghue (2019), although in a CES demand setting firms are atomistic and the pass-through on prices should equal unity, in the case of firms having a market power on the nest they are operating, this pass-through will be heterogeneous. To account for this possibility, they use an additional instrument constructed as the interaction of the main instrument with the market share of the exporting firm *f* in its HS6 operating category in destination country *d* on the initial year. In the case of Greece, there are no firms that have enough market power to affect the operating nest's price index, so as to include such an additional instrument. Finally, it is important to note that the idea of import-weighted exchange rates as an instrument for prices may be novel in the sense that it generates exogenous firm-specific cost shifters, however it is not new. Brambilla et al. (2012), and Bastos et al. (2018) use similar instruments, in the form of export-weighted exchange rates, to create exogenous changes in firms' destination markets selection.

Another potential bias of the price elasticity may stem from the correlation between the instrument used and product quality, as the quality of firm-level inputs adjusts when the real exchange rates fluctuate. To capture only the cost shifting effect while estimating the exchange rate pass-through on prices, one has to control for the possibility of the instrument

[35] We use REERs from the database developed by Darvas (2012).

is positively correlated to quality; thus, exporting-spell-specific fixed effects are added in the estimation.[36] In other words, to counteract the possibility that the price elasticity of demand is biased, as the instrument is constructed using import shares**,** variety-specific fixed effects are included in the specification. Intuitively, the instrument could be endogenous to quality, as it is very likely that higher-quality producing firms import higher-quality inputs from countries with stronger currencies, leading to a positive correlation of the instrument with quality in the cross-section of firms. Note that a firm's demand shifter may still be correlated with the instrument as a change in the exchange rate can both increase input prices and affect the competitiveness of the firm in a foreign market. The competitiveness effect is captured by product × destination × year fixed effects.

Moreover, following an exchange rate shock, the competitiveness of a firm is improved to an exporting destination; the firm may import higher quality inputs and export higher quality products to that destination. According to Bastos et al. (2018)[37], shipping to richer destinations leads an exporting firm to increase its average product quality and to use higher-quality intermediate inputs. Moreover, Bas and Strauss-Kahn (2015) find evidence that a firm may take advantage of an exchange rate or tariff change to upgrade its input quality in order to upgrade its export quality. To control for this type of unclear-shifting bias[38], two formulas that assume GDP per capita to be the proxy of input quality supplied by a given country are used. As changes occur at the level of the firm's trading partners, these instruments capture any quality adjustments. The import-weighted average GDP per capita of a firm *f* at year *t* is:

$$\overline{gdpc}_{ft}^{im} = \sum_{s} \omega_{fst}^{im} \times log(gdpc_{st}) \tag{3.8}$$

while the export-weighted average GDP per capita of a firm *f* at year *t* is:

$$\overline{gdpc}_{ft}^{ex} = \sum_{s} \omega_{fst}^{ex} \times log(gdpc_{st}) \tag{3.9}$$

where ω_{fst}^{im} and ω_{fst}^{ex} are shares of goods imported from and exported to country *s* by firm *f* at year *t*. Linder (1961) was the first to point out the stronger demand for high-quality products in richer countries, thus higher unit value goods are exported to rich destination

36 An exporting spell is defined as a sequence of consecutive years during which a firm-product-destination triplet is exported.

37 They use exchange rate movements interacted with indicators for initial exports to address endogeneity of average destination incomes.

38 Note that it is not possible to recognize whether such a result is due to competitiveness' state change of a poor or a rich source country.

countries; and the consequent demand-driven comparative advantage of richer countries in higher quality products, with the imports from rich countries being of a higher unit value as well (empirically confirmed by, among others, Hallak, 2006; Bastos and Silva, 2010; and Manova and Zhang, 2012).

Finally, a firm-entry dummy variable captures potential partial calendar years, $entry_{fst}$, that may affect the quality measures. As a firm is likely to enter a market at any time of the year, lower sales for that specific year are about to be documented in the calendar year (see Berthou and Vicard, 2015; Bernard et al., 2017).

3.4. Demand estimation

3.4.1. Econometric specification

The econometric specification proceeds in two stages. First, the exported price of the firms is regressed on the instruments, *firm* $\times$ *product* $\times$ *destination* and *competitiveness* fixed effects, the controls at the country level and the dummy variable that accounts for firms entering a market. The first stage takes the form:

$$log\, p_{fgdt} = \eta RER_{ft} + entry_{fgdt} + \beta \overline{gdpc}_{ft} + \delta_{fgds} + \delta_{gdt} + u_{fgdt} \qquad (3.10)$$

where p_{fgdt} is the price of variety *fgt* at time *t*, RER_{ft} the instrument vector, $gdpc_{ft}$ is a vector that contains our control variables, $entry_{fgdt}$ is our entry dummy, and δ's are the fixed effects included in the regression. Using the predicted values of exporting prices from the first stage, the structural equation of demand is estimated.

$$log\, q_{fgdt} = (1 - \sigma)\, \widehat{log\, p}_{fgdt} + entry_{fgdt} + \alpha \overline{gdpc}_{ft} + \gamma_{fgds} + \gamma_{gdt} + \varepsilon_{fgdt} \qquad (3.11)$$

The estimation of this equation is consistent if the structural error ε is orthogonal to our instruments. After estimating the second stage, we are able to calculate the measure of quality λ_{fgdt},

$$\lambda_{fgdt} = \hat{\alpha} \overline{gdpc}_{ft} + \hat{\gamma}_{fgds} + \hat{\varepsilon}_{fgdt} \qquad (3.12)$$

which equals the sum of the estimated coefficient of our GDP control variables, the *variety-specific* fixed effect, and the structural error of the second stage.

3.4.2. Estimation algorithm

Estimation of linear equations with two sets of high-dimensional fixed effects in an unbalanced panel is cumbersome. The usual approach to apply the within transformation method with respect to the fixed effect with more categories, and to add dummy variables for each category of the subsequent fixed effects (Wooldridge, 2010) is unfeasible both with large datasets, and in the case of more than one multi-level fixed effects. Moreover, because the panel is unbalanced along both dimensions, the two sets of fixed effects included in the econometric specifications are not orthogonal. Consequently, variables included in the regression need to be simultaneously projected on these two sets of fixed effects, as someone cannot rely on successive projections. To address these issues, following Piveteau and Smagghue (2019), I use the algorithm developed by Correia (2019), which first demeans the variables along the two sets of multi-dimensional fixed effects and then estimates the parameters of interest from the demeaned variables. Additionally, this algorithm automatically drops singleton groups in linear regressions where fixed effects are nested within clusters in order to eliminate any chances of incorrect inference stemming from overstating statistical significance.

In the details of this algorithm, Correia (2019) propose a feasible and computationally efficient method for solving linear models with an arbitrate number of multi-dimensional fixed effects. Numerous fixed effects with multiple dimensions help controlling for unobserved heterogeneity at the micro level, avoiding causal inference due to omitted variable bias. Few approaches have been developed mainly for applications in strongly balanced panels, or un-balanced ones, with a, however, either poor or slow convergence rates, recording arbitrarily large numbers of iterations when used in large datasets (see Baltagi, 2008; Abowd, Creecy, and Kramarz, 2002; Koutis, Miller, and Peng, 2012; Guimarães and Portugal, 2010; Gaure, 2015; among others). Correia (2019) builds on Guimarães and Portugal (2010), and Gaure (2015) replacing the projections of their multi-way fixed effects estimators with symmetric ones, in order to easily combine them with a conjugate gradient acceleration. Furthermore, Correia (2019) shows the equivalence between the solution of a two-way fixed effects model and the solution of a linear system on a graph Laplacian matrix, allowing for the application of combinatorial algorithms with an almost *linear running time*. Its relatively fast convergence is inherited by the use on the Laplacian solver, which computes in advance many of its results, setting as time-crucial only the first iteration. This methodology can be easily extended to other linear models (see two-stage least squares, or two-step linear GMMs), and also be used as the main structure for non-linear models such as two-way fixed-effects Poisson regressions, spillover models, or iterated and continuously updated GMMs.

3.4.3. Variation present in export flows database

The empirical models in international trade literature with heterogeneous firms require different levels of variations in data. In Table 3.1, I report the amount of variation present in export flows database combined with information on the importing activity of exporters. First, I report the number of source countries by exporting firm over the period 2002-2014. Note that a significant share of Greek exporters does not import the inputs they use in production. Next, the number of observations by exporting triplet is presented, where an exporting triplet is a combination of a firm *f* exporting to a specific destination country *d*, a product *g* at the HS6 disaggregation level. I also report the number of destinations that a firm serves. Finally, I report the number of varieties by export market, where an export market is a product *g*, destination country *d* and year *t,* triplet.

Table 3.1: Descriptive Statistics - Export Database

	p5	p25	p50	p75	p95	mean
full sample	N = 1,494,921					
#of source countries by firm	0	0	2	6	17	4.21
#observations by exporting spell	1	1	1	2	5	1.74
#of destination countries	1	1	2	4	19	5.30
#varieties by export market	1	1	1	2	8	2.63

The empirical approach described by Piveteau and Smagghue (2019) relies on large variations in the data. Table 3.2 shows the variation that exists in the sample used to replicate their methodology in order to get consistent estimates of product quality at the firm level. This methodology also requires information from the AMS survey, which is not available for the universe of Greek exporters. This reduces our sample to 69,809 observations. Due to the inclusion of two high-dimensional fixed effects in the demand estimation, the exporting triplets that only appear for one year will not be used in the estimation procedure. Additionally, as the dimensionality of the fixed effects used requires enough observations in order to identify variations across product varieties within destination markets, and also across time within varieties, only flows appearing for over 6 months are included in the analysis. Finally, the instrument adopted in this methodology, requires variations across firms in the set of countries they import from.

Hence, the final sample employed in the demand estimation consists of 58,863 observations. As shown in table 3.2, the variation of the instrument coming from the number of a firms' source countries is high enough, not affecting the extent to which variations in foreign exchange rates pass through to Greek exporters' export prices. The last two rows of the table show the extent to which the high-dimensional fixed effects included in the estimation specifications are identified.

Table 3.2: Descriptive Statistics - S&P application sample

	p5	p25	p50	p75	p95	mean
S&P methodology sample	N = 69,809					
#of source countries by firm	4	10	16	24	38	17.77
#of destination countries	1	1	3	7	28	7.41
#observations by exporting spell	1	1	2	4	13	3.92
#varieties by export market	1	1	2	3	11	3.27
Quality estimation sample	N = 58,863					
#of source countries by firm	3	12	19	26	41	20.19
#of destination countries	2	2	4	11	39	11.26
#observations by exporting spell	2	2	4	6	17	5.65
#varieties by export market	2	2	3	5	15	5.10

At the industry level, where the firm-level product quality estimates are obtained, the value of exports and the number of firms in the final sample vary as shown in Table 3.3. Finally, the Kernel density of export sales by industry is presented in Appendix A.1.

Table 3.3: Descriptive statistics by product category

	Average number of firms per year	Mean of exports (% of total shipments per year)
Animal Products	682	5.92
Vegetable Products	1,687	10.65
Foodstuffs	1,242	9.54
Mineral Products	536	27.15
Chemicals & Allied	1,574	9.95
Plastics, Rubbers	1,932	5.13
Raw Hides, Skins, Leather	1,237	2.00
Wood, Wood Products	1,650	1.50
Textiles	2,248	6.53
Footwear, Headwear	542	.16
Stone, Glass	1,169	1.17
Metals	1,991	11.04
Machinery, Electrical	3,826	6.42
Transportation	1,749	1.26
Miscellaneous	2,136	1.53

3.4.4. Price-elasticity estimation

Price-elasticities are estimated for fifteen product categories at the firm-industry level with a single first stage in order to circumvent any weaknesses of the first stage estimation at the industry level (see small number of clusters). Hence, the first stage is common across all industries, but the price elasticities are allowed to vary. The estimated specification includes RER_{ft_0t} and RER_{ft_0t-1} as instruments, the controls of section 3.4.1., an entry-in-the-market dummy, and the two sets of multidimensional fixed effects, while the standard errors are clustered at the firm level.[39] The estimated coefficients at the firm-industry level are statistically significant and range from -1.50 for the industry of *Chemicals & Allied* to -2.89 for *Footwear and Headwear* (see Table 3.4), which is close to the findings in the related literature.[40]

Table 3.4: Demand estimation by product category

	IV (single FS) coef.	st. errors	obs.
Animal Products	-1.050	1.215	626
Vegetable Products	-1.188	1.184	1,447
Foodstuffs	-.858	1.159	2,793
Mineral Products	.111	1.228	818
Chemicals & Allied	-1.508*	1.172	4,537
Plastics, Rubbers	-1.537*	1.166	4,740
Raw Hides, Skins, Leather	-2.755***	1.165	1,087
Wood, Wood Products	-1.757*	1.158	3,547
Textiles	-1.986**	1.150	12,945
Footwear, Headwear	-2.896***	1.162	186
Stone, Glass	-1.224	1.184	1,258
Metals	-1.372	1.168	5,154
Machinery, Electrical	-2.516**	1.166	7,490
Transportation	-2.775***	1.183	364
Miscellaneous	-2.520**	1.163	2,392

Notes: Industry level estimation including spell × firm × product × destination and product × destination × year fixed effects. Standard errors are clustered at the firm level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3.5: Aggregate demand estimation

	(1) OLS	(2) IV	(3) IV
Panel A (1st stage)	Dependent Variable : log price exports		
RER_{ft0t}		8.457*** (2.344)	8.352*** (2.262)
RER_{ft0t-1}			.165

[39] The error terms are clustered at the firm level to address potential correlation within each firm across different products over time.

[40] Piveteau and Smagghue (2019) report a range of -3.03 to -4.39; Fontagné et al. (2018) find an export price elasticity around -5; Erkel-Rousse and Mirza (2002) estimate trade elasticities between -4 and -15.

			(.539)
$GDPCex_{ft}$		.036	.036
		(.030)	(.030)
$GDPCim_{ft}$		-.003	-.003
		(.006)	(.006)
entry		-.042	-.042
		(.046)	(.046)
Panel B (2nd stage)	Dependent Variable: log export volume		
$\log(price_{fgdt})$	-.515	-2.252*	-2.221*
	(.102)	(1.160)	(1.175)
$GDPCex_{ft}$	.240	.297	.296***
	(.193)	(.189)	(.190)
$GDPCim_{ft}$	-.012	-.015	-.015
	(.023)	(.030)	(.030)
entry	-.932***	-.949***	-.948***
	(.246)	(.276)	(.275)
Kleibergen-Paap F-test		13.01	6.87
obs.	49,384	49,384	49,384

Notes: Pooled estimation including spell × firm × product × destination and product × destination × year fixed effects. Standard errors are clustered at the firm level. * p < 0.1, ** p < 0.05, *** p < 0.01.

At the aggregate level, when both instruments are included in the regression, the price elasticity of demand is -2.21. The export-weighted control variable and the entry-to-the-market dummy included in the regressions have the expected signs, while the import-weighted one is statistically insignificant. Importantly, this estimate is robust to control variables' inclusion, confirming that the reallocation of trade across differentially rich markets is not a source of endogeneity of the main instrument. Since there is no evidence of heterogeneous pass-through in the aggregate data, I can safely assume that the pass-through of import exchange rates to export prices is similar across industries.

In the econometric side details, the Kleibergen-Paap F-statistic for the identification of weak instruments is not rejected, indicating that the instruments used are suitable for the Greek exporters case.[41] Moreover, the Kleibergen-Paap Wald test for under-identification is rejected, so as the relevance condition of the instrument is satisfied (*uncorrelated with the endogenous regressors*). Finally, the Hansen test for over-identification is not rejected, verifying the validity of the set of instruments included in the regressions as it is uncorrelated with the error term ε.

In Appendix A.2, to assess the validity of the quality measure obtained by Piveteau and Smagghue (2019)'s structural demand estimation, I present various exercises applied on the

[41] In the case of a specification with two instruments, Stock and Yogo (2005) weak ID test critical values are at 20% maximal size, 8.75; while at 15% maximal size, 11.59.

quality estimates obtained for Greek exporters. Finally, I confirm that there is an imperfect relationship between prices and quality, as prices and quality are more correlated in markets with larger vertical differentiation.

3.4.4.A. Alternative instrument with electricity prices

To further examine whether the method of quality inferring I employ is suitable for Greek exporters, I replace Piveteau and Smagghues's (2019) price instrumentation strategy with the one presented in Fontagné et al. (2018) who use electricity prices to instrument for the endogeneity lying in demand estimations. An advantage of this instrument is that the use of electricity cost shocks as instruments rather than exchange rates is that they are more likely to affect exports only through their impact on export prices. However, it is important that the electricity price change in one year is plausibly uncorrelated with a quality change on the exported product in that year.

In detail, Fontagné et al. (2018) instrument export prices with firm-level electricity cost shocks which are related to factors exogenous to a firm's export performance as regulation changes take place, the year and length of beginning of contracts varies, and there are national and local tax changes and also changes in both market and regulated prices, likely to affect a firm's export performance only through its export price. In a different setting, Ganapati et al. (2016) also adopt energy cost shocks as instruments for marginal cost shocks, to estimate the pass-through of those shocks into domestic prices. In the Greek exporters case, I exploit data on firms' electricity spending from the Annual Manufacturing Survey, to construct a share of electricity over the total cost i.e., the ratio between the electricity bill and the total production costs.

The econometric specification proceeds in two stages. First, the exported price of the firms is regressed on the instrument, *competitiveness* fixed effects, the logarithm of firms' employment, and the dummy variable that accounts for firms entering a market. The first stage takes the form:

$$log\, p_{fgdt} = \eta El_{ft} + entry_{fgdt} + \beta lemp_{ft} + \delta_{gdt} + u_{fgdt} \qquad (3.13)$$

where p_{fgdt} is the price of variety *fgt* at time *t*, El_{ft} the electricity instrument, $lemp_{ft}$ is the logarithm of a firm's employment, $entry_{fgdt}$ is our entry dummy, and δ_{gdt} is the competitiveness fixed effect included in the regression. Using the predicted values of exporting prices from the first stage, the structural equation of demand is estimated,

$$log\ q_{fgdt} = (1-\sigma)\,\widehat{log\ p}_{fgdt} + entry_{fgdt} + \alpha lemp_{ft} + \gamma_{gdt} + \varepsilon_{fgdt.} \qquad (3.14)$$

The estimation of this equation is consistent if the structural error ε is orthogonal to our instruments.

At the aggregate level (see Table 3.6), the price elasticity of demand is -2.10, close to the one obtained by the main instrumentation method. The employment variable and the entry-to-the-market dummy included in the regressions both have the expected signs. Importantly, the estimates are robust to employment variable's inclusion, confirming that the size of a firm is not a source of endogeneity of the electricity instrument.

Table 3.6: Aggregate demand estimation, alternative instrument

	(1) OLS	(2) IV
$\log(\text{price}_{fgdt})$	-1.135*** (.037)	-2.105*** (.402)
log(employment)	.309*** (.035)	.311*** (.035)
entry	-1.252*** (.034)	-1.187*** (.042)
obs.	78,739	78,739
Kleibergen-Paap stat		33.42

Notes: Estimation includes product × destination × year fixed effects. Standard errors are clustered at the firm level. * p < 0.1, ** p < 0.05, *** p < 0.01.

Since there is no evidence of heterogeneous pass-through in the aggregate data, I may safely assume that the pass-through to export prices is similar across industries so as to procced to demand estimations at the industry level (see Table 3.7).

Table 3.7: Demand estimation by product category, alternative instrument

	IV (single FS) coef.	st. error	obs.
Animal Products	-1.589***	0.449	3,748
Vegetable Products	-1.648***	0.435	4,498
Foodstuffs	.310	0.466	21,155
Mineral Products	-2.345***	0.433	1,120
Chemicals & Allied	-2.565***	0.447	7,895
Plastics, Rubbers	-4.660***	0.526	7,776
Raw Hides, Skins, Leather	-3.094***	0.466	572
Wood, Wood Products	-3.329***	0.426	4,709
Textiles	-5.086***	0.794	5,244
Footwear, Headwear	-.357	0.486	126
Stone, Glass	-1.821***	0.441	2,420
Metals	-2.664***	0.501	5,673

Machinery, Electrical	-3.426***	0.622	3,615
Transportation	-3.498***	0.485	142
Miscellaneous	10.265***	0.612	1,823

Notes: Industry level estimation including product × destination × year fixed effects. Standard errors are clustered at the firm level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

In the econometric side details, the Kleibergen-Paap F-statistic for the identification of weak instruments is not rejected, indicating that the instruments used are suitable for the Greek exporters case.[42] Moreover, the Kleibergen-Paap Wald test for under-identification is rejected, so as the relevance condition of the instrument is satisfied (*uncorrelated with the endogenous regressors*).

[42] In the case of a specification with one instrument, Stock and Yogo (2005) weak ID test critical value is at 10% maximal size, 16.38.

Chapter 4. Product quality and innovation: A review of the literature

Innovation is the fundamental driver of economic development according to seminal work by Schumpeter (1934, 1942) and growth (see Romer, 1990). Still many decades later, there is an open discussion around innovation and its effects at the country, industry, and firm level. Recently, innovation got renewed attention with the emergence of heterogeneous firm models on trade, as one of the main factors underlying international competitiveness, productivity, output, and employment (Asheim and Isaksen, 1997; Michie, 1998). Firms in order to enter new markets or maintain -and even reinforce- their existing market share's competitive advantages consider innovation as a tool to achieve their goals (see among others Brown and Eisenhardt, 1995).

One major issue around innovation is the lack of available detailed (or even aggregate) data. In 1996, innovation gets a more exact definition, generally defined as the "implementation of new ideas that create value", referring to both main types of innovation, the product and process innovation (OECD, 1996). However, data on the two main types of innovation are not widely available. As a result, researchers study innovation mostly using patent data, or R&D investment data without particulars on whether they represent product and/or process innovation, and in the case of R&D investment, without any information on whether this investment is successful.

According to Linder et al. (2003), the attitude of managers with respect to innovation is not straightforward; they may consider primarily innovation as the entry of new products, as the process innovation to reduce cost of production, or even both. However, Martinez-Ros (1999) find that product and process innovation are closely linked, while Papadakis and Bourantas (1998), Gopalakrishnan et al. (1999), Sternberg and Arndt (2001), and Michie and Sheehan (2003), among others, show that product and process innovation do not necessarily have the same determinants and implementation purposes. For example, Michie and Sheehan (2003) show that the determinants of innovation and their effects differ according to whether the researcher examines only product innovation, process innovation, or both.

On the microeconomics literature, the concept of innovation is captured as well through two different mechanisms that can be projected to product and process innovation.[43] On the one hand, the process innovation comes through innovation investments targeting to production cost reduction through productivity enhancing activities (see Reinganum, 1981; Fudenberg and Tirole, 1985; Katz and Shapiro, 1987; Grossman and Helpman, 1991a, 1991b; Aghion and Howitt, 1992; Segerstrom et al., 1990; among others). On the other hand, innovation is considered to be the entry of new products in a market and/or vertical product differentiation (product innovation) both aiming at maintaining or further enlarging a firm's market share (see for instance, Carpenter and Nakamoto, 1990; Dutta et al., 1995).

More recently, the international trade literature has given renewed attention to innovation as trade can generate dynamic gains not only through higher exports, higher imports, relaxed technological constraints, technology spillovers, and higher employment for domestic firms, but also through innovative activities (see Pavcnik, 2002; Melitz, 2003; Bernard et al., 2003; Aw et al., 2007; Costantini and Melitz, 2008; Verhoogen, 2008; Lileeva and Trefler, 2010; and Bustos, 2011). Openness to international trade may affect firms' incentives to innovate, as it creates tougher market competition, but also offers growth opportunities. Importantly, innovators are more likely to be successful exporters and generate growth from the exporting activity than non-innovating firms (for an extensive survey see Love and Roper, 2015). Overall, the relationship between exporting activity and growth, and also between exporting and innovation activity, is strong (Golovko and Valentini, 2011).

4.1. International trade and innovation

Innovation is generally defined as the ''implementation of new ideas that create value'', referring to the two main types of innovation, the product and process innovation (OECD, 1996). Earlier, Schumpeter (1934) defines innovation as: ''The introduction of new goods, new methods of production, the opening of new markets, the conquest of new sources of supply, and the carrying out of a new organization of any industry''. Hence, innovative exporters are considered to undertake any of the aforementioned actions. The reason why attention is given on innovative exporters is because innovation is a fundamental driver of economic growth (Romer, 1990).[44]

[43] See for instance, Reinganum (1981), Fudenberg and Tirole (1985), Scherer and Ross (1990), and Lin and Saggi (2002) in the theoretical literature; while Scherer (1991), Rosenkranz (1996), and Cohen and Klepper (1996) in the empirical literature, among others.
[44] More recently, Jones (2005).

Lately, economists show growing interest in whether international trade can generate dynamic gains not only through higher exports, higher imports, relaxed technological constraints, technology spillovers, and higher employment for domestic firms, but also through innovative activities.[45] Traditional trade theories predict static gains from trade through reallocation of resources across sectors; however, recent literature emphasizes the idea that trade increases growth. As innovation is a driving force of growth, the relationship between exporting and innovative activities may be the key to success. A key idea in this literature, beginning with Rivera-Batiz and Romer (1991) and Grossman and Helpman (1991a), is that trade liberalization may affect firms' incentives to innovate, as it creates tougher market competition.

The key question is what encourages or hinders innovation, and how such impacts affect the exporting activity of firms. According to the related literature, trade-induced changes within a firm have an impact on its innovative activity; export opportunities, import competition, access to intermediate inputs, and credit constraints are the main answers to this question. Theoretical predictions on the impact of increased competition on innovation are ambiguous. According to Schumpeter (1943), there is negative relationship between innovation and competition. Grossman and Helpman (1991a), and Aghion and Howitt (1992) claim that innovation may be affected by negative effects on the market share of a firm due to increased competition. On the other hand, competition may increase innovation. Higher competition increases the threat to rents of incumbent firms close to the technology frontier; in order to preserve their rents, firms may increase innovative activities as in Aghion et al. (1997) and Aghion et al. (2001). These two effects are conflicting; with the final outcome being ambiguous as import and export competition may boost or dampen firm innovation.[46] Identifying such effects empirically is proven to be difficult as the information on firms' innovative activities is limited. However, such empirical questions have been extensively investigated and recently, have received renewed attention.

4.1.1. Import competition

To begin with, competition affects firms' incentives to innovate (recently, Gilbert, 2006; Cohen, 2010). In the I-O literature, the key mechanisms behind competition can help to understand the impact of import competition. According to Schumpeter (1942), competition

[45] Pavcnik (2002), Melitz (2003), Bernard et al. (2003), Aw et al. (2007), Costantini and Melitz (2008), Verhoogen (2008), Lileeva and Trefler (2010), Bustos (2011) among others.

[46] Schumpeter (1943), Coe and Helpman (1995), Aghion et al. (2001), Aghion et al. (2005), Lileeva and Trefler (2010), Aghion et al. (2018).

may reduce the potential rents that a firm could acquire through innovating; the so-called "Schumpeterian effect". In terms of import competition, this mechanism predicts that competition has a negative impact on firm innovation. On the contrary, Arrow (1962) claims that competition may also increase incentives to innovate through a reduction of the rents a firm can capture without innovating. This effect is called the "escape-competition effect" and implies that import competition has a positive impact on firm innovation; the opposite of the "Schumpeterian effect". Recently, Shu and Steinwender (2019) based on the agency literature, are focusing on what they call the "preference effect". This effect again predicts that import competition has a positive impact on firm innovation.

Aghion et al. (2001), Bombardini et al. (2017), and Chen and Steinwender (2017) find that although the "preference effect" and the "escape-competition effect" both drive firms to a positive innovation response to import competition, the former effect is decreasing, whereas the latter effect is increasing in a firm's initial productivity. Moreover, in Aghion et al. (2005), the "escape-competition effect" dominates when competing firms are very close in their levels of technological advancement. However, for firms who are far behind the leading firms at the technological frontier, the "Schumpeterian effect" dominates, giving them also a low chance of reaching it. Finally, with the Schumpeterian explanation focusing on changed incentives to innovate, Hombert and Matray (2017) claim that laggard firms innovate less in response to import competition as they become more constrained.

Early studies on developing countries find evidence on the "escape-competition effect". During the 1980s and the 1990s, Latin American countries underwent exogenous trade-liberalization episodes. In Chile, Pavnick (2002) finds that firms innovate more in industries facing more import competition. However, Bas and Ledezma (2010), covering 67 developing and developed countries, find that a fall of import barriers is positively related with productivity of plants in traded sectors, but not in the case of plants belonging to import-competing industries producing with increasing returns to scale. More recently, Fernandes and Paunov (2013) investigate whether trade stimulates quality upgrading. Their findings suggest that increased exposure to imports can be beneficial for incremental innovation outcomes. For Mexico, Iacovone (2012) develops a neo-Schumpeterian growth model predicting that the impact of liberalization on economic performance is positive on average, whereas more advanced firms benefit disproportionately more. Using Mexican plant-level survey data collected by INEGI that covers the entire period of NAFTA reforms (1993–2002), he confirms that the liberalization increased productivity growth on average. Focusing on the mechanisms that explain this result, he suggests that the liberalization under NAFTA generates two competing effects: it boosts more innovative efforts, because of a higher entry threat by foreign competitors; while on the other hand, the enhanced competition reduces expected profits and lowers the resources available for innovation. In Iacovone et al. (2011), the strong growth of Chinese exports resulting from China's entry into the World Trade Organization in 2001 is exploited, to study how trade liberalization that raises a country's import competition affects the innovative activity of Mexican firms. Their findings suggest that there is heterogeneity in the responses across firms, with the more productive plants be more likely to introduce innovation as a response to the unilateral competition from China than the less productive ones. Finally, Teshima (2010) advantages from a combination of Mexican plant-level datasets to examine the extent to which tariff changes lead to changes in total R&D expenditures through increased competition. The main finding is that the reduction of tariffs induced Mexican plants to increase their R&D expenses, suggesting that trade liberalization stimulates plants' innovative activities through increased competition. Furthermore, this study distinguishes between process R&D and product R&D and finds evidence that the effects of trade liberalization are primarily due to cost-cutting and technical efficiency improvements of plants rather than product innovation.

Using data for Brazilian manufacturing firms[47], Muendler (2004) finds a negative impact of tariffs on firm productivity, while Schor (2004) also confirms that the increased competition, the new access to inputs that embody better foreign technology, also contributes to productivity gains after trade liberalization. Furthermore, Fernandes (2003) based on similar data for Colombian firms[48], ends up to the same negative relationship between nominal tariffs and productivity, reinforcing the perception that trade liberalization has a positive impact on firm productivity. Amiti and Konings (2007) estimate the productivity gains from tariff reduction on final and intermediate goods in the case of Indonesia. They find that lower output tariffs can increase productivity through tougher import competition, whereas cheaper imported intermediate goods can raise productivity via learning, variety, and quality effects. For India, Topalova and Khandelwal (2011) examine the effects of the 1991's trade reform of India on firm-level productivity to conclude that lower tariffs on final goods, and lower input tariffs, both increased firm-level productivity, with input tariffs found to have a larger impact. At a cross-country setting, Gorodnichenko et al. (2010) show that globalization

[47] Pesquisa Industrial Anual (PIA) conducted by the Instituto Brasileiro de Geografia e Estatistica (IBGE), i.e. the Brazilian Census Bureau.

[48] The data are drawn from the Colombian Manufacturing census provided by DANE (National Statistical Institute).

brings opportunities and pressures for domestic firms in emerging markets to innovate and improve their competitive position. They show that the supply chain of multinational enterprises and international trade are important channels for domestic firms' innovation. Finally, Amiti and Khandelwal (2013) provide evidence on that countries' import tariffs affect the rate at which they upgrade their product quality. Using highly disaggregated data covering exports from 56 countries across 10,000 products to the United States[49], they find that lower tariffs are associated with quality upgrading for products close to the world quality frontier. Their findings support the "escape-competition effect" that induces a firm close to the frontier to invest in quality upgrading in order to survive competition from potential new entrants.

In the case of developed countries, there is empirical research for Northern America and Europe. Schmitz (2005), using U.S. and Canadian data on the iron industry for the period from 1970 to 1997, shows that increases in competition increases productivity. Furthermore, for the U.S., Bernard et al. (2006) examine the response of manufacturing industries and plants to changes in trade costs and they find that greater exposure to international trade via declining trade costs promotes productivity gains across industries within manufacturing, across plants within industries, and finally, within plants; potentially supporting the "Schumpeterian effect" channel. In Europe, De Loecker (2011) studying whether removing barriers to trade induces efficiency gains for producers, finds positive but insignificant effects for the Belgian textile market. Earlier, Blundell et al. (1999) who examine the relationship between innovation, market share, and competition using a panel of British firms, find that firms innovate more in industries more exposed to import competition. Moreover, they also find evidence that within each industry, conditional on the level of competition, the firms with a bigger market share innovate more, because the innovation preempts additional entry or the expansion of smaller firms and thus maintain their profits. Interestingly, Aghion et al. (2005) find an inverted-U shaped relationship between import competition and innovation at firms in UK. In this study, competition increases innovation in not very competitive industries, where firms are close in their levels of technological advancement, whereas in highly competitive industries, with large technological gaps, competition has the opposite effect on innovation.

Studies after 2013, focus mostly on import competition occurred from China's rise as the world's leading exporter. China, the largest developing country exporter, showed a rapid increase in patenting and a lowering of import barriers during the period 2000-2007, due to

[49]From the World Bank WITS database.

its accession to the WTO. As innovation is often viewed as an effective route to avoid low-cost foreign competition by allowing firms to climb the quality ladder and differentiate their products from low-wage countries' exports, the case of China became the ideal case study for more recent research on this filed. For twelve European countries, Bloom et al. (2016) examine the impact of Chinese import competition on broad measures of technical change, such as patenting, IT, and TFP. Their results suggest that increased import competition with China increases innovation within surviving firms, causing a significant technological upgrading in European firms in the affected industries. Additional evidence from European firms comes from Spain. Using data on Spanish firms[50], Chen and Steinwender (2017) provide support for the "preference effect" by showing that import competition has a positive effect only on initially unproductive family firms and not on professionally managed firms. For China, Bombardini et al. (2017) explore the impact of the change of the import competition environment, on firm innovation. Their findings are consistent with a model of step-by-step innovation a la Aghion et al. (2009) where import competition generally discourages innovation but encourages firms close to the technological frontier to increase their investments in R&D. More specifically, for a developing country like China, opening to international competition drives more productive firms to invest in research to improve products and processes, whereas less productive firms find it less attractive to innovate. The extent of technology spillover and the policy environment shape the aggregate effect as positive or negative under this setting. Similarly, Brandt et al. (2017) find a large and significant productivity-enhancing effect from output tariff reductions. Moreover, they also report a negative relationship between input tariffs and productivity suggesting that stronger import competition forces domestic firms to restructure (quality-upgrading). Studying the case of Korean manufacturing firms, Ahn et al. (2018) conclude that rising import and export with China lead to more patent applications by local manufacturing firms. However, they notice that some firms show the relationship of "Schumpeterian force" when they face competition, whereas other firms show "escaping competition" relationship. More specifically, "larger and better" firms are more likely to be facing the "escape competition" motive while "smaller and worst" firms are more likely to be facing "Schumpeterian force". Finally, their results suggest that Korean firms in the high-quality sector can escape from the import and export competition through innovation [51], while the low-quality sectors appear to have "Schumpeterian" relationship. The last developing country examined is Peru. Medina (2018),

[50] Encuesta Sobre Estrategias Empresariales, conducted by the Fundacion SEPI.
[51] "Escaping competition" relationship.

using the case of Peruvian apparel manufacturers' reaction to China's WTO accession, studies the quality upgrading route to escape competition from low-wage countries. She finds that import competition from China drove Peruvian apparel industry firms to upgrade their product quality and turn to exporting. In detail, using the information available on capital equipment from the Peruvian Economic Survey (EEA)[52], she shows that foreign competition decreases the return on a firm's fixed factor, driving the firm to reallocate capital and labor towards the production of high-quality varieties using high-quality inputs. As a result, more productive firms, already selling various products to various markets, intensify the production of their foreign high-quality products; while on the extensive margin, surviving less productive firms begin to produce and export high-quality products.

The evidence from firms in Northern America is mixed. Support is found for both the "Schumpeterian" and "escape-competition" effects. The former effect is present in the case of the initially weaker firms, while the latter is more pronounced at the initially more productive firms. Autor et al. (2016) and Xu and Gong (2017) claim that Chinese import competition has a negative effect on the R&D spending of U.S. firms; a result driven by initially less productive firms. In detail, Autor et al. (2016) study how import competition affects U.S. innovation by estimating the impact of greater exposure to trade on patenting by U.S. firms. Applying a novel internet-based matching algorithm to match all U.S. utility patents granted by 2013[53] to firm-level data[54] and trade data[55], they report a negative effect of rising Chinese competition on firm-level and patent production. They raise concerns about import competition causing firms to withhold their innovations from patenting in order to avoid releasing their intellectual property. They find that publicly listed firms operating in industries with higher import penetration from China have suffered larger reductions in patenting. Hence, they conclude that U.S. manufacturers manage to survive import competition not through innovation; a result well-explained by Dasgupta and Stiglitz (1980) who claim that greater competition in manufacturing could portend a more general decline in the profitability of an industry, thereby reducing incentives to invest in R&D. In the same direction, Xu and Gong (2017) report the same negative average effect of import competition on R&D. Additionally, they find evidence that import competition induces U.S. firms to reallocate R&D

[52] The EEA provides firm-level information on total revenue, wage bills, intermediate inputs, investment, and capital stock.
[53] They use the U.S. Patent and Inventor Database, which covers patents granted by the U.S. Patent and Trademark Office (USPTO) since 1975.
[54] Compustat contains information on firms' annual sales, employment, R&D expenditure, and industry.
[55] From the UN Comtrade Database.

expenditures towards more productive and profitable firms within each industry. However, they conclude that the positive reallocation effect offsets the negative average impact on R&D. Chinese import competition is found to also have a negative effect on the self-reported product and process innovations of Canadian firms. Kueng et al. (2021) examining how firms in high-income countries adjust to such an import penetration from emerging markets, show that on average, process innovation declines more than product innovation. At the same time, Chinese import competition seems to have a positive effect on the product differentiation of U.S. firms with large R&D stocks, according to Hombert and Matray (2017). Studying whether R&D-intensive firms are more resilient to trade shocks, they find that as a result of higher performance, R&D-intensive firms do not downsize and continue to invest in capital and labor despite being exposed to trade shocks, thanks to generous R&D tax credit policies. Importantly, the effect of R&D on firm performance arises through higher product differentiation, rather than through lower production cost. Finally, Chakravorty et al. (2017) report conflicting results from the impact of Chinese import competition on U.S. firms. More specifically, they find evidence that Chinese import competition has a positive impact on firm innovation; while they find this positive impact to be significant only for quality-adjusted patent counts, and not for the number of patent applications.

4.1.2. Export opportunities

Export demand shocks increase market size. As market size matters for innovation and productivity, improved access to foreign markets will raise firms' innovation incentives. This is the so-called "market-size effect" which prompts a firm to intentionally increase innovation in order to benefit from access to an enlarged market. Using the late-1994-peso crisis as a source of variation for plant productivity Verhoogen (2008) investigates the empirical implications of a quality-upgrading mechanism for Mexican manufacturing plants. Among others, he suggests that an increase in the incentive to export (for firms in a developing country) generates differential quality upgrading, a positive relationship between innovation and exports. Additionally, for China, Manova and Yu (2017) show that quality sorting governs multi-product firms' response to changes in economic conditions over time. Interestingly, they present evidence that export prices are positively correlated with worldwide exports across products within a firm-year; being stronger for R&D intensive industries with greater scope for quality upgrading. Examining the impact of trade integration on plant TFP, Bas and Ledezma (2010) report a positive relationship between a fall in export barriers and the productivity of plants in trading sectors, associated to productivity improvements in export-oriented sectors probably benefiting from knowledge spillovers. Moreover, Aw et al. (2011)

show that R&D investment and exporting decisions both have a positive effect on the Taiwanese plants' future productivity. Their empirical findings suggest that an expansion in export market size would increase the export and R&D participation rates of the plants involved. More recently, Coelli et al. (2018) using international firm-level patent data for over 60 countries focus on the effect of trade policy during the Great Liberalization of the 1990s. Their findings suggest that trade liberalization has significant positive effects on firm innovation. Decomposing their main finding, they show that both improved market access and tougher import competition have positive effects on innovation, both in terms of knowledge creation and protection of existing knowledge.

At the same time, export demand shocks increase competition as more firms enter the export market, reducing profits and thus innovation incentives. Overall, an export demand shock has a positive effect on innovation in high productivity firms, whereas it may have a negative impact on innovation in low productivity firms. Consistent with the market-size effect, initially more productive and more technologically advanced firms show a more positive response to increased access to export markets. Lileeva and Trefler (2010) study the case of the elimination of U.S. tariffs associated with the FTA for Canadian firms. They examine the response of Canadian firms that where induced to export to the United States as a result of U.S. tariff-cuts, interested in the impact of improved market access on firms' exports and investments. They find evidence that Canadian plants, that were induced to start exporting or export more due to tariff cuts, increased their labor productivity, engaged more in product innovation, and finally, presented higher adoption rates of advanced manufacturing technologies. These findings strongly reveal a positive relationship between improved export market access and innovation. However, their findings show that there is negative selection for less productive plants. In the same vein, Bustos (2011) studies the period of trade liberalization in Argentina and finds evidence that reductions in tariffs faced by exporting firms lead to increases in exports, innovative activities, or productivity enhancement. In his paper, the tariff reduction is the result of a regional free trade agreement, MERCOSUR, and the question is its impact on technology upgrading of Argentinian firms. More specifically, the empirical analysis attempts to evidence causality by linking exporting and technology adoption directly to the reduction in Brazil's tariffs for imports from Argentinian firms. Again, the main finding is that there is a positive link between the joint treatment of the export and technology investment decisions of firms driving to technology upgrading; with the results for the more productive firms having almost the double of the average impact.

Finally, there is also some evidence consistent with the Schumpeterian effect. The induced competition from the openness to export opportunities leads to a negative impact on innovation for non-exporters and initially less productive firms. Aghion et al. (2018) investigate the impact of export shocks on innovation for French firms and confirm the predictions of this discussion, showing that an export demand shock increases patenting of initially more productive French exporters, while it decreases innovation activities of low productivity firms. Ahn et al. (2018) study the case of Korean manufacturing firms and conclude that rising import and export with China lead to more patent applications by Korean manufacturing firms. Although, they notice that some firms show a "Schumpeterian" relationship when they face competition, other firms show an "escaping-competition" relationship. More specifically, larger, and "better" firms are more likely to be facing the "escape-competition effect"; while smaller, and "worse" firms are more likely to be facing a "Schumpeterian" force. Overall, their results suggest that Korean firms in the high-quality sector can escape from the import and export competition through innovation[56], while the same is not true for firms operating in low-quality sectors.

Another effect that has a positive impact on firm productivity and innovation is the learning-by-exporting. The conceptual difference here is that in learning-by-exporting, firms have access to extended knowledge without necessarily investing in innovation. Moreover, in this case, innovation occurs due to exporting, and not intentionally in order to export as in the previously examined effect. According to van Biesebroeck (2005), De Loecker (2007), and Atkin et al. (2017), learning-by-exporting happens mostly at firms that export to more developed countries. Van Biesebroeck (2005) finds that exporters in the sub-Saharan Africa countries are more productive and increase their productivity advantage after entry into a more developed foreign market. Similarly, De Locker (2007) concludes that export entrant firms become more productive once they enter foreign markets. Interestingly, his analysis shows that the productivity gains from exporting are higher for firms entering markets in relatively more developed countries. More recent evidence is provided by Atkin et al. (2017) partnered with Aid to Artisans (ATA)[57] through a randomized experiment for rug producers in Egypt. In their theoretical setting, learning-by-exporting can result from transfers of knowledge from buyers to producers, or from learning-by-doing. Using detailed survey information, they confirm that exporting improves technical efficiency. Importantly, their

[56] "Escaping-competition" relationship.

[57] ATA is a U.S.-based NGO with a mission to create economic opportunities for producers of handmade products in developing countries.

evidence confirms that learning-by-exporting occurs through information flows from knowledgeable buyers in high-income countries.

4.1.3. Access to imported intermediaries

Improved access to imports offers firms the opportunity to access increased variety and higher quality inputs. Furthermore, improved access to imports as a result of trade liberalization offers firms the opportunity to access most advanced technologies and know-how. Recent related literature investigates the effect of imported inputs on firm productivity and innovation. According to Halpern et al. (2015) and Bøler et al. (2015) access to imported intermediate goods may induce lower input costs, higher input quality, or even a more efficient production process. Hence, a firm may produce new and/or higher quality products as in Goldberg et al. (2010), Bas and Strauss-Kahn (2015), and Fieler et al. (2018). Additionally, a firm may innovate due to increased profit margins or more opportunities to learn about new product design, new production processes, new materials or technologies, and even new organizational methods through openness to new intermediate goods markets. At the same time, access to imported intermediates may decrease the overall innovation by reducing the need for process-improving technologies.

There is substantial empirical evidence reporting a positive impact of imported intermediaries to innovation, in a strand of the related literature where innovation is measured indirectly through TFP changes. Schor (2004) studies the effects of trade liberalization on the evolution of firm productivity and finds that the increased competition, the new access to inputs that embody better foreign technology, while it also contributes to productivity gains after trade liberalization. In the same direction, Kasahara and Rodrigue (2008) report a positive dynamic effect on productivity from the use of imported inputs. Additionally, Brandt et al. (2017) using annual data collected through surveys by the National Bureau of Statistics of China report a negative relationship between input tariffs and productivity suggesting that stronger import competition forces domestic firms to restructure (quality-upgrading). Fieler and Harrison (2018) use firm-level data for China's both state-owned (SOEs), regardless of size, and all non-state-owned manufacturing firms (non-SOEs) with annual sales of more than 5 million Yuan, for a period that includes the China's WTO accession in 2001, to provide evidence for a new source of gains from trade. Firms invest in product differentiation to escape import competition, while as firms differentiate, they impose their suppliers to also invest in differentiation, introduce new products and switch to skill-intensive sectors, thus, to innovate.

Two studies use tariff changes to compare the impact of import competition and that of access to imported intermediates, both finding that access to imported intermediates has a more positive effect than import competition. Amiti and Konings (2007) estimate the productivity gains from tariff reduction on final and intermediate goods in the case of Indonesia. They find that lower output tariffs can increase productivity through tougher import competition, whereas cheaper imported intermediate goods can raise productivity via learning, variety, and quality effects. Interestingly, they also find that non-importers can also gain from importers' access to imported intermediates, with the spillover effects however being weak. For India, Topalova and Khandelwal (2011) exploit firm-level information from the Prowess database to examine the effects of the 1991's trade reform of India on firm-level productivity. They evidence that lower tariffs on final goods, and lower input tariffs, both increased firm-level productivity, with input tariffs found to have a larger impact. Overall, the same tariff could affect the import competition faced by a firm or the access to imported inputs enjoyed by its downstream customers.

Furthermore, Goldberg et al. (2010), and Bøler et al. (2015) provide evidence of positive effects of access to imported intermediate goods on R&D.[58] Such evidence is present also for patenting by Bloom et al. (2016), product innovation by Goldberg et al. (2010), Bas and Paunov (2018), and finally for technology adoption by Bas and Berthou (2017), Juhász and Steinwender (2019), Bloom et al. (2016), Goldberg et al. (2010), and Halpern et al. (2015). In detail, Goldberg et al. (2010) report substantial gains from trade through access to new imported inputs. More specifically, they find that lower tariffs increase the availability of new imported input varieties resulting to an expansion of firms' product scope; an effect scaling based on the declines of input tariffs each industry experienced. Their further analysis shows that input tariff reduction contributed to a firm's product scope expansion by both making inputs cheaper, and by relaxing technological constraints via access to new imported input varieties. Now, in a work which may help explain why a number of studies find large firm-level productivity gains associated with input trade liberalization[59], Bøler et al. (2015) exploit the introduction of an R&D tax credit in Norway in 2002 to study the impact of an R&D cost shock on R&D investments, imported inputs, and their joint impact on firm performance. They find evidence that R&D lowers marginal costs both directly, through improved productivity, and indirectly, through cost savings on intermediate inputs due to outsourcing. Bas and Paunov

[58] However, there are two studies that find insignificant effects of intermediaries import competition on innovation (see Muendler, 2004; and Teshima, 2010).
[59] See Amiti and Konings, (2007), Goldberg et al. (2010), and Topalova and Khandelwal (2011).

(2018) use detailed and unique linked firm-product-level dataset for Ecuador, which includes the country's WTO accession year (1996) and show that access to high-quality inputs from abroad lead importers to expand their product scope, and also to their production upgrading. Relying on India's trade liberalization episode in the early 1990s Bas and Berthou (2017) investigate the link between input-trade liberalization and foreign technology adoption embodied in imports of capital goods. Their results show that the probability of importing capital goods is higher for firms producing in industries that experienced greater reductions on tariffs on intermediate goods, while only firms lying on the middle range of the initial productivity distribution were led to upgrade their technology. Using the roll-out of the global telegraph network on the 19th century cotton textile industry, Juhász and Steinwender (2019) study the impact of information and communication technology (ICT) improvements on trade. They provide evidence that ICT affected the diffusion of frontier technology through the complementary mechanisms of capital imports and knowledge transfer acquired through importing intermediates. Halpern et al. (2015) attribute one-quarter of Hungarian productivity growth during the 1993–2002 period to imported inputs; suggesting that imported inputs play a significant role in shaping firm performance in the Hungarian economy. Finally, for twelve European countries, Bloom et al. (2016) study the impact of Chinese import competition on broad measures of technical change, such as patenting, IT, and TFP. Their results suggest that increased import competition with China increases innovation within surviving firms, causing a significant technological upgrading in European firms in the affected industries.

Categorizing the empirical evidence by country, we can see that most of the studies focus on firms in developing countries. For these firms, the impact of access to imported intermediates may differ whether they have foreign ownership. Topalova and Khandelwal (2011) for India, find that foreign-owned firms experience lower positive impact than their Indian-owned counterparts. In the opposite direction, Halpern et al. (2015) report opposite results for the case of Hungary. Fewer research focuses on firms in developed countries. Here empirical evidence shows positive impact of access to imported intermediates to innovation; however, the underlying mechanism differs. According to Goldberg et al. (2010), firms in developing countries import high-quality inputs from firms in developed countries. Interestingly, firms in developed countries import low-quality inputs, according to Bloom et al. (2016).

4.1.4. Credit constraints

Within the literature focused on the effects of capital market imperfections on firms' activities, a general conclusion is that credit constraints affect firm investment, employment, and R&D decisions.[60] According to recent empirical evidence by Crino and Ogliari (2017), and Jin et al. (2019), credit constraints indeed affect a firm's investment decisions related to its R&D activity. Moreover, the business cycle plays an important role on firms' R&D investment behavior when credit constraints are present. According to Aghion et al. (2012), in more credit constrained firms, R&D investment falls during a recession but does not increase proportionally during upturns.

Beginning with seminal papers by Hall (1992) and Himmelberg and Petersen (1994), a growing body of empirical literature examines the link between innovation and financial constraints at the firm level. It is now widely believed that a transitory finance shock may hit a firm's innovative activities differently depending on factors such as size, age, and industry. In particular, small, young, and high-tech firms have been found to be more sensitive to economic volatility (Hall 2002). Over the last decade, a number of micro econometric studies (see Bellone et al., 2010; Minetti and Zhu, 2011; Egger and Kesina, 2013; Gorg and Spaliara, 2014a, 2014b, among others) have examined the relationship between exports and credit constraints. Summarizing this literature, Wagner (2014) reports that exporting firms are less financially constrained than non-exporting firms. Since exporting is associated with higher fixed costs than serving the domestic market only, a self-selected group of superior firms with higher productivity, larger size and more innovations are more likely to be exporters (Bernard and Jensen, 1999). Exporters may have greater possibilities to offset the consequences of financial shocks on innovation through various management strategies, including product and market diversification and greater amounts of customer-financed R&D (Shaver, 2011). However, exporters are proven to be heterogeneous; Shaver (2011) shows that the typical exporter is not a large innovative firm operating across many destinations with a broad portfolio of products. The median exporter is a small firm with 26 employees, 6 export products, and participates in 6 foreign markets.

Also, Lööf and Nabavi (2016) incorporate innovation into the literature on exports and credit constraints. They use data for Swedish exporting firms to study the relationship between innovation and financial factors in a regression that includes changes in cash holdings, cash flow and debt issues. Their main proxy for innovation is patent applications, which is related to the early phase in a firm's innovation process; while they also account new export products

[60] For a related survey, see Bond and Van Reenen (2007).

as a secondary proxy related to its final stage. They confirm that innovation is positively correlated with firm size, labor, and technology intensity, while they find no evidence on financial frictions among low- and medium-technology industries. However, they show that financially constrained innovative high-technology Swedish exporters tend to use financial management as a cyclical controller to reduce the effect of the business cycle fluctuations on their performance.

Not surprisingly, a firm's internal finance is an important determinant of its R&D expenditures. Egger and Keuschnigg (2015) investigate the mechanisms that link financial constraints on firms' R&D and possible expansion investments. They find that financial constraints are stronger for firms that cannot offer too much collateral, a finding that leads to an industry pattern dependent on the intensity of financial constraints. Hence, innovative firms with a low degree of asset tangibility and/or high risk are ceteris paribus more constrained than the rest of the firms. In the same vein, Himmelberg and Petersen (1994) examining data of small firms in a panel study of firms in high-tech industries find an economically significant relationship between a firm's R&D investment and its internal finance. Finally, according to Ughetto (2008) the source of innovation financing is internal cash flow. Using data on Italian manufacturing firms he finds that firms use no debt to finance R&D, and it seems that cash flow plays an important role in explaining capital investment, especially for small firms. However, while small innovative firms are facing subsequent financing constraints, large companies investing in innovation have disproportionate access to external financing.

4.2. Innovation measures in trade

A major issue when studying innovation is the lack of available data, a fact that makes empirical research on this topic cumbersome. Innovation is generally defined as the ''implementation of new ideas that create value'', referring to both main types of innovation, the product and process innovation (OECD, 1996). However, data on the two main types of innovation are not widely available. As a result, researchers study innovation by using patent data, or R&D investment data without particulars on whether they represent product and/or process innovation, and also in the case of R&D investment, without any information on whether this investment is successful. Here, I present the main measures of innovation available to researchers for analysis.

First, R&D expenditure and R&D personnel, stand as innovation investment measures. However, the fact that an investment occurs does not automatically means that it is successful. Hence, it is important to note that R&D investment does not necessarily lead to either new or improved products, and/or processes (Flor and Oltra, 2004; Kleinknecht et al., 2002). Moreover, according to Michie (1998) all innovations are not necessarily "born" through R&D procedures; innovations can emerge following a clever idea as in many cases occurs in small and medium enterprises (SME) where innovative efforts may be informal or occasional (Acs and Ardretsch, 1991; Kleinknecht et al., 2002; Michie, 1998).

In international trade literature, such information comes from Statistical Agencies' Datasets collected in formal, mostly annual, surveys, following standardized methods to collect such information endeavored by the OECD, Eurostat, or other international and regional Statistical Agencies. Indicatively, Canada's Workplace and Employment Survey (WES) is a representative survey which asks detailed questions about innovation outcomes and technology expenditures (Kueng et al., 2016); the National Survey on Innovation and Technological Behavior of Industrial Argentinian Firms conducted by the Argentinian government statistical agency (IndEC) that includes spending on computers and software; payments for technology transfers and patents; and spending on equipment, materials, and labor related to innovation activities performed within each firm (Bustos, 2011); Statistics Norway's R&D survey, which provides biennial information on firm-level R&D investment and R&D personnel (Bøler et al., 2015); and data from Compustat which contains information on firms' R&D expenditure (Hombert and Matray, 2017; Chakravorty et al., 2017; Xu and Gong, 2017). Finally, there is a dataset in Taiwanese electronics industry collected by the Ministry of Economic Affairs of Taiwan (MOEA) that reports data on R&D investment.

A specialized survey on innovative activities is conducted by the National Institute of Statistics and Geography of Mexico. The confidential Survey on Research and Development of Technology (ESIDE) covers three sectors: manufacturing, education, and government, and contains information on several aspects of innovative activities including information on expenditures for each type of R&D (product and process R&D). It also asks how much firms spend on (1) introduction of new products, (2) substantial quality upgrading of existing products, (3) routine quality upgrading existing products, (4) creation of new production process, (5) substantial improvement of existing production process, and (6) routine improvement of existing production process. Hence, there is a unique distinction between process R&D and product R&D, and also among other various measures of innovation, such as the introduction of Just in Time management system, job rotation schemes, quality controls, continuous controls, and production re-organizations (see Teshima, 2010; Iacovone, 2012). Another detailed survey at the firm level is the Encuesta Sobre Estrategias

Empresariales, conducted by the Fundacion SEPI in Spain. This survey provides detailed information firms' innovative activities, such as a number of innovation related outcome variables, information on product innovation, R&D spending, and the number of patents (see Chen and Steinwender, 2017). For example, there is response to the following question: "Indicate if during the year xxxx the firm introduced any important modification in the production process (process innovation). If so, indicate how this has been concretized: (a) introduction of new machinery, (b) new organizational methods in production, (c) both".

Alternatively, patent data are used as a proxy to firms' innovative activities. However, patent data measures invention rather than innovation (Coombs et al., 1996; Flor and Oltra, 2004; OECD, 1997); counting as innovation inventions that have not been transformed into marketable products or processes. Moreover, exactly as with R&D expenditure, not all innovations are patented. Patent filling data are available by Patent Offices worldwide; innovation data from the PATSTAT from the European Patent Office (EPO) used by Chalioti et al. (2020), Coelli et al. (2018), Aghion et al. (2017), and also by Bloom et al. (2016) in combination to another rich dataset on technical change including IT data collected by Harte Hanks on hardware and software information; the U.S. Patent and Inventor Database, which covers patents granted by the U.S. Patent and Trademark Office (USPTO) since 1975 (Blundell et al., 1999; Autor et al., 2017); the NBER patent file, the Harvard Business School patent database (see Hombert and Matray, 2017); patent data from the State Intellectual Property Office (SIPO) of China[61] (Bombardini et al., 2017); and finally, Korean patent data[62] from KIPRIS collected by the Korean Intellectual Property Rights Information Service (see Ahn et al., 2018).

4.3. Product quality and innovation

Now that the mechanisms that affect the relationship between innovation and international trade activity of firms have been established, my interest focuses on the relationship between product quality and innovation as the constant technological advancement at the firm level over the last decades mandates the investigation of the relationship between them.[63]

In a nearly axiomatic form, Villa et al. (1991), and Rossetto and Franceschini (1995) claim that the effect of innovation is the improvement of quality, while quality advancement becomes the aim of innovation. Indeed, both product and process innovation may improve product

[61] There are three categories of patents in the Chinese system: invention, utility, and industrial design.
[62] There are three types of patents in Korea: patents, utility patents, and design patents.
[63] According to Rosetto and Franceschini (1995) the Japanese manufacturing sector's success is based on the binomial quality and innovation.

quality at the firm level. Dubey and Wu (2002), and Fishman and Rob (2002) claim that firms which incorporate costly and risky product innovation mechanisms improve their product quality. Importantly, in their empirical analysis based on responses from 244 manufacturing firms, Koufteros et al. (2002) confirm the aforementioned claim, as their findings suggest that product innovation positively affects quality. Prajogo et al. (2008) claim that any enhancement in product quality may result in the development of new products, and at the same time product innovation, by exploiting new technologies, may aim at improving product quality. However, Dubey and Wu (2002) do not exclude the possibility of innovation being discouraged by too much or too little competition.

In the same vein, Prajogo and Sohal (2001) find common aspects between quality improvement and innovative activities, suggesting that the objectives of both quality and innovation may conform to each other. As a consequence, the factors that affect quality are expected to have an effect on innovation as well, and vice versa. First of all, the great increase in market competition accelerated by the liberalization of international trade has changed the environment a firm operates in. Many firms respond to increased market competition by using quality-based strategies (Foley et al., 1997) that can drive firms to make significant improvements in their profitability, productivity, and competitiveness, such as relying on quality upgrading mechanisms. According to Encaoua et al. (2000), and Brouwer et al. (2002), firms have also been urged to become more innovative. In the opposite direction, still on the evidence of a positive relationship between quality improvement and innovation activities, Prajogo and Sohal (2004), Abrunhosa and Moura E Sa (2008), and Prajogo and Hong (2008) conclude that firms focusing on quality also enhance their innovation activities. However, there is also evidence that innovation and product quality advancement are linked negatively. For example, Cole and Matsumiya (2008) claim that the pursuit of quality may inhibit radical innovation in the Japanese hi-tech sector, while Maxwell (1998) claim that the presence of minimum quality standards may reduce firms' incentives to innovate.

With a focus on micro-exporting literature, Teshima (2010) among others, investigating the idea that trade liberalization may affect a firm's innovative activities, takes advantage of a combination of Mexican plant-level datasets[64] to examine the extent to which tariff changes lead to changes in R&D through increased competition. His findings suggest that although trade liberalization may stimulate a plant's innovative activities, it affects a plant's capability

[64] This combined dataset is the unique that contains both the amount of R&D expenditure on product and on process innovation.

primary through increases in cost efficiency rather than through product innovation.[65] However, Amiti and Khandelwal (2013) claim that trade liberalization enhances quality upgrading, as low tariffs encourage quality upgrading for products close to the technology frontier. On a theoretical basis, an increase in competition may hinder innovation through negative effects on the market share of firms (see Aghion and Howitt, 1992), but at the same time, competition may increase innovation as in Amiti and Khandelwal (2013) where firms jump up the technology frontier (see Aghion et al.,1997; Aghion et al., 2001). Finally, according to Grossman and Helpman (1991a, 1995) the way for firms to climb up the quality ladder relative to competitors is to invest on innovation enhancing activities.[66] Recent empirical research on how import competition affects quality upgrading through innovative activities coming from Fernandes and Paunov (2013), and Flach (2016), present such evidence.

Although the relationship between innovation and quality has been widely examined on microeconomic, managerial, and even trade liberalization literature, very little empirical work has been done to explore the role of innovation on export product quality. Chen (2013) investigates the influence of innovation on the extensive (number of products) and the intensive (value of each product) margins of exports. Using disaggregate data on 105 countries' exports and data on patents granted by the US as a proxy for innovation, he finds that innovation has a major positive effect on the intensive margin. Further decomposing the intensive margin his findings suggest that innovation increase the quality of exports. Whereas, on my knowledge, there is no research, that investigates the relationship between estimated product quality and innovation at the firm level.

[65] Lawrence (2000) and Lawrence and Weinstein (2001) also stress the positive effects of increased competition on plants' incentive to be more cost efficient.
[66] See also Flam and Helpman (1987).

Chapter 5. Quality, innovation, and credit constraints in exporting

Upgrading output quality requires firms to increase investments directed to quality improvement. Furthermore, according to the literature on international trade, a firm's export behavior depends on financial factors. Hence, to the extent that investment is required to upgrade export product quality, financing constraints may affect an exporter's investment decisions on R&D activity (Brown et al., 2012; Crino and Ogliari, 2017; Jin et al., 2019). But how do these three, important for international trade, components interact? In this section, I first present a related literature review and stylized facts, evidence on the relationship between quality and credit constraints for Greek exporters, and also Greek export quality and innovation. I then investigate in a simple framework the relationship between product quality, innovation, and credit constraints. Finally, I present related empirical evidence for Greek exporters.

5.1. Literature review

5.1.1. Exporting firms and access to trade finance

Financial markets are crucial for firms' export activity.[67] The cost needs of exporters are inherently different compared to firms that serve the domestic market. Specifically, fixed, and variable costs[68] tend to be higher for exporters and need to be paid up front due to long time lags between production and sales due, for instance, to the need to build advertising and distributional networks, acquire specific legislative and regulatory information and requirements of the destination markets, and customize products. Also, the realization of revenues is uncertain and typically involves more complex, riskier, and less enforceable contracts between the lender and the borrower. As a result, potential exporters must have enough liquidity at hand and, not surprisingly, there is empirical evidence that financial constraints affect exporting decisions.[69]

Manova et al. (2015) provide evidence that credit constraints not only restrict international trade, but also affect the pattern of multinational activity for Chinese exporters. They use

[67] According to Auboin (2009), 80-90% of international trade involves some form of insurance, guarantee or credit.
[68] See Feenstra et al. (2014).
[69] Contessi and De Nicola (2012) review the role of finance on international trade.

foreign ownership status together with the variation in financial dependence across sectors as a source of identification and find that credit frictions hinder exports at the firm level, limit firms' entrance in new markets, and reduce the range of the products they export. Their findings also suggest that these effects are less strong for multinational subsidiaries as they easily access foreign capital markets or funding from their parent company. Additionally, Feenstra et al. (2014) suggest that Chinese firms face tighter credit constraints as their export share grows, as the shipping procedure lasts longer, and as the productivity of the firm presents greater dispersion.

Importantly, a higher degree of a country's financial development reduces financial constraints at the firm level and increases the probability of exporting. Manova (2013) embeds credit frictions in the Melitz (2003) model with fixed costs and firm heterogeneity and derives that larger and more productive firms are less likely to be financially constrained. Therefore, they are more likely to entry export markets. Furthermore, the author suggests that the effects of credit constraints at the firm level differ depending also on the financial vulnerability of the sector an exporter operates in. This finding is consistent with previous theoretical and empirical evidence suggesting that countries with higher-quality financial institutions show a comparative advantage in financially more vulnerable sectors.[70] In order to investigate the same effect, Alvarez and López (2013) use Chilean manufacturing plant-level data. Their analysis confirms both that an improvement in financial development increases the probability of exporting, and that the magnitude of the increase differs across industries depending on their degree of financial dependence. Additionally, focusing on the heterogeneous responses of plants with different characteristics, they find that size, capital intensity and foreign ownership positively affect the probability to export. According to Berman and Hericourt (2010), financial development positively affects both the intensive and the extensive margin of trade, as an increase in a country's financial development seems to act negatively both on the number of exporters and the exporting selection process. Furthermore, using a firm-level database from different investment climate surveys conducted by the World Bank, they find that financial development magnifies the impact of firms' productivity on exporting probability. However, productivity plays a key role in firms' export decisions only if there is sufficient access to external finance.

[70] For theoretical models see Beck (2002), Matsuyama (2005), Manova (2013), Chaney (2013), Ju and Wei (2005, 2010, 2011), and Becker et al. (2013). For empirical evidence see also Beck (2002, 2003), Svaleryd and Vlachos (2005), Hur, Raj, and Riyanto (2006), and Becker et al. (2013).

Accordingly, since firm heterogeneity is an important determinant of the terms of trade, it could significantly affect a firm's financial situation and shape the impact of credit constraints on both the intensive and the extensive margins of trade, in line with models of international trade based on firm heterogeneity and sunk entry costs. Eck et al. (2012) using BEEPS data on German firms in 2004 show that trade credit stimulates export activity at both the intensive and extensive margins of trade. More specifically, Eck et al. (2012) exploit data from the Business Environment and Enterprise Performance Survey (BEEPS) on German firms in 2004, jointly developed by the European Bank for Reconstruction and Development and the World Bank Group to analyze the business environment of firms in transition countries and to link it with firm performance. Their findings suggest that trade credit alleviates the effects caused by credit constraints faced by firms on both the intensive and extensive margins of exports, a finding that is not true for the import activities of the firms. Similarly, Muûls (2015) uses firm-level trade transaction data from Belgium, decomposes trade in extensive and intensive margins and provides evidence that firm trade behavior differs in the way the level and the growth of the trade margins are affected by credit constraints. Notably, she shows that at the firm level, the relationship between the country extensive margin of trade and the credit constraints differs with the direction of trade flows, while the intensive margin is positively associated with credit constraints only in the case of exports.

Additionally, similarly to Berman and Hericourt (2010), Minetti and Zhu (2011) assess the impact of credit rationing on firms' export decisions. They use detailed data for Italian manufacturing firms and find that strong rationing has negative effects on the export participation decision. Additionally, they look at the effect of rationing on foreign sales and find that less leveraged firms sell less abroad, especially in industries with high external financial dependence. Notably, the impact on the intensive margin is heterogeneous, as younger firms face a more pronounced negative effect. Forlani (2010) examines whether internal liquidity of Italian manufacturing firms determines their choices in their internationalization process. He finds that internal resources are an important determinant for the internationalization of firms: the level of cash-stock for credit-constrained firms determines their entry decisions. New entrants are ex ante relatively more leveraged, while there is no evidence of any post-entry financial health improvement.

Bellone et al. (2010) investigate whether limited access to external financial resources acts as a barrier on expanding their activities abroad and whether internationalization has only positive effects on financial health of firms. They use data on French manufacturing firms and find that less credit-constrained firms self-select into export markets. However, firms entering exporting markets do not present significant improvement in terms of financial health, at least in the short term. Close to this result, Greenaway et al. (2007) conclude that financial health should be seen as a result, and not as a selection-to-entry criterion in the export market. They suggest that such an improvement of the ex-post financial health of a firm might occur either due to the diversification of export associated risks and available sources of financing, or the yielding of a sufficient productivity perception which in turn creates the perception of an easiness of servicing external debt, and hence softens liquidity constraints. However, export status on its own does not seem to be enough. New UK manufacturing exporters are found to be in a similar to non-exporters' financial health position. Interestingly, the new exporters face more stringent financial constraints than non-exporters as they are expected to cover sunk entry costs. On the other hand, continuous exporters present an overall better financial health. Following the discussion on financial frictions and self-selection into exporting, Caggese and Cunat (2013) present a dynamic model, which shows that in equilibrium financing frictions reduce the aggregate productivity gains of trade liberalization by 25 percent, through the distortion of the incentives of the most productive firms to self-select into exporting. According to these findings, financing constraints affect firms both directly, when the constraints are binding, and indirectly through selection in exporting.

In the aftermath of the 2008-2009 financial crisis, scholars shift their attention towards the effect of financial frictions faced by firms, due to the global crisis, on their exports. Coulibaly et al. (2013) explore the extent to which financial conditions contributed to the decline in firms' sales. They use data from six emerging market economies[71] and find that export-intensive firms experienced sharper declines in sales during the crisis. In the same direction, Asmudson et al. (2011) investigate the role of the collapse in trade finance on the decline of trade during the same period. Combining data from four different surveys conducted by the IMF and BAFT-IFSA on commercial banks, they conclude that although shocks to trade finance[72] discouraged a volume of trade transactions, they are not the major factor driving the trade decline. Importantly, Bricogne et al. (2012) claim that most of the 2008-2009 trade collapse is attributed to the demand shock and the characteristics of the traded products. However, their findings indicate that tightened credit constraints during this period significantly worsened the export positions of French financially distressed exporters.[73]

[71] China, India, Indonesia, Malaysia, Taiwan, and Thailand.
[72] Measured through pricing margins of trade finance products and credit conditions.
[73] Accounting for almost 20% of the drop in exports of these firms.

5.1.2. Credit-constrained firms and quality

Since firm heterogeneity is an important determinant of firms' credit situation and shapes heavily both the intensive and the extensive margins of trade, credit constraints definitively affect firm-level decisions. According to Manova (2013), when financial constraints affect variable and especially marginal costs, export prices are affected as well, as more credit-constrained exporters face higher marginal costs. Credit constraints can therefore play a central role in export pricing decisions. In the same direction, Secchi et al. (2016) find that financial constraints affect price variation across exporters. They point out that Italian firms facing tighter credit conditions charge higher prices than unconstrained firms exporting the same product to the same destination. The price gap observed between financially distressed and unconstrained firms, emerges as a mix of two different effects; exporters pass higher production costs to their consumers through higher prices, and at the same time, lose their interest on maintaining their market share in the short run.

Eckel and Unger (2016) examine the effects of credit constraints on within-firm adjustments and selection into exporting when both cost-based productivity and product quality matter for the success of a producer. To analyze the effects of credit frictions, they propose a general equilibrium model of international trade that allows for both cost-based and quality-based sorting. They show that higher credit costs are associated with higher (lower) firm-level prices if the scope for vertical product differentiation is low (high). Accordingly, as product quality is considered as an additional intensive margin, apart from prices and quantities[74], credit frictions affect firm decisions on product quality as well. Bernini et al. (2015) examine whether the corporate financial structure matters for export quality of French exporting firms and find a negative causal relationship. Firms with high level of debt export lower quality products as they have fewer incentives to invest in quality upgrading. Also, when the strategic use of capital structure is not an option to either gain market shares or reduce the cost of production, they claim that this negative effect is stronger in more competitive industries.

Furthermore, there are a few studies that attempt to link export pricing with endogenous quality and financial constraints. Fan et al. (2015) introduce credit constraints and endogenous quality in a Melitz-type model and test the empirical relationship between credit constraints, quality and prices exploiting Chinese firm-level panel data. They find that lower credit constraints increase both the price and the quality of products, which confirms the

[74] see Bernard et al. (2012) who examine multi-product exporters.

"quality sorting" hypothesis, as also implied by the positive estimated association between prices and productivity. In a similar vein, Dinopoulos et al. (2020) document that less financially constrained Greek exporters charge higher prices and have higher export revenues. They propose a model with endogenous product quality and credit constraints, which features variable price elasticity of demand, and find that less credit-constrained exporters face less elastic demand and export higher-quality products.

5.2. Empirical measures of credit constraints

The literature on credit access of exporting firms employs a variety of credit constraint measures at the firm level, based on expert or firm self-assessment or on the financial sheets presented by the firms under consideration. Minetti and Zhu (2011) use detailed Capitalia Bank survey data for Italian manufacturing firms that provide a firm specific measure of credit rationing based directly on firms' responses to the survey.[75] They also construct measures of credit rationing based on firms' response to the survey, a measure of strong credit rationing, and one of weak credit rationing.[76] Additionally, the following measures of firms' financial conditions are treated as controls: (a) liquidity ratio, defined as the firm's current assets minus current liabilities over total assets, (b) leverage ratio, defined as the firm's ratio of total liabilities to equity, and (c) the ratio of cash flow to total assets, where the firm's cash flow is calculated as profits net of tax expenditures plus depreciation. Using the same data combined with two balanced-sheet data sets that provide a detailed statement of assets and liabilities, Forlani (2010) use short-and long-term debts, credit, assets, and equity to rank firms according to their level of credit constraints. Berman and Hericourt (2010) exploit information on exports and financial health at the firm level from different investment climate surveys conducted by the World Bank, to compute a Total-Debt-to-Total-Assets ratio (given by the sum of the short-term and long-term debt of a firm over its total assets) and a Cash-Flow-to-Assets ratio (given by the cash banks of a firm over its total assets). Greenaway et al. (2007) use a data set from profit and loss, and balance sheet data gathered by Bureau Van Dijk in the Financial Analysis Made Easy (FAME) database to construct a liquidity ratio, a current ratio, a leverage ratio, a Debt-to-Equity ratio and finally, an equity multiplier to account for the extent to which the firms under consideration are credit constrained. Specifically, the liquidity ratio is a financial ratio that indicates whether a company's current assets will be sufficient to meet

[75] Firms are asked directly whether they feel credit constrained or not.

[76] Questions asked included the following: (a)"In 2000, would the firm have liked to obtain more credit at the market interest rate?" and (b)"In 2000, did the firm demand more credit than it actually obtained?". Strongly rationed firms are those that gave positive answers to both questions, whereas rationed firms are those that gave a positive response to question (a), regardless of their answer to (b).

the company's obligations when they become due. The current ratio measures a firm's ability to pay off its current liabilities (payable within one year) with its current assets such as cash, accounts receivable and inventories. The higher the ratio, the better the company's liquidity position. The leverage ratio is a financial measurement that looks at how much capital comes in the form of debt (loans) and assesses the ability of a company to meet its financial obligations. The debt-to-equity ratio is the total shareholders' equity over the total liabilities of the firm. Finally, the equity multiplier is the ratio of the total equity over the total assets of a firm.

Coulibaly et al. (2013) study publicly traded manufacturing firms from six emerging countries (China, India, Indonesia, Malaysia, Taiwan, and Thailand) to analyze four financial variables obtained from the Worldscope database. Following Love et al. (2007) and Levchenko et al. (2010), they propose the use of two financial vulnerability variables measured as working capital (as an indicator of liquidity), or short-term-debt, over total assets. Moreover, external financing as the ratio of total external finance over total assets, and internal financing as the ratio of retained earnings over total assets, show the type of the financing dependence of each firm. Finally, in order to measure each firm's reliance on trade credit from its suppliers the ratio of payable accounts over the cost of goods sold is calculated. Exploiting data from annual surveys of Chinese manufacturing firms available from the National Bureau of Statistics of China (NBSC), Fan et al. (2015) propose a measure of financial access, and one of external financial dependence. The former measure uses data on total bank credits, long-term and short-term bank loans, to calculate the average bank loans accessed by each firm to provincial GDP ratio, whereas the latter uses a broad set of variables that reflect technologically adopted characteristics depending on each industry (e.g., external finance dependency, R&D intensity, inventory-to-sales ratio, asset tangibility).

Bellone et al. (2010) propose another measure of the degree of financial constraints and analyze data on French manufacturing firms from the Enquete Annuelle d' Entreprises (EAE), which is an annual survey that gathers balance sheet information, and the DIANE database published by Bureau van Dijk, which provides financial data on over one mn French firms. Following the methodology proposed by Musso and Schiavo (2008), they exploit information on total assets, return on total assets (which corresponds to firm profitability), liquidity (current assets over current liabilities), cash flow generating ability, solvency (own funds over total liabilities), trade credit over total assets, and finally repaying ability (financial debt over cash flow) and build two alternative indices of financial health ranging from 0 to 10. Alvarez and López (2013) use Chilean manufacturing plant-level data from the Annual National Industrial Survey (ENIA) conducted by the National Institute of Statistics of Chile (INE). As measures of financial development, they adopt the ratio of private credit by deposit money banks over GDP (Bank Credit), and the ratio of private credit by deposit money banks and other financial institutions over GDP (Domestic Credit), both coming from the data set compiled by Becket al. (2010). Muûls (2015) uses the Coface Services Belgium Global Score as a measure of credit constraints. The Coface Services Belgium Global Score is a credit worthiness score provided by the Coface Services Belgium, which is employed by firms and banks in the evaluation of their credit transactions. Recently, Belsey et al. (2020) study the implications of the probabilities of default for aggregate output and productivity using firm-level data. They combine data on repayment probabilities from Bureau Van Dijk's Orbis database with Standard and Poor's Probability of Default Model and CreditPro. They show that default risk is a useful, well-fitting, way of looking at credit market conditions at the firm level.

Eck et al. (2012) use data from the Business Environment and Enterprise Performance Survey (BEEPS) developed jointly by the European Bank for Reconstruction and Development and the World Bank Group based on firm self-assessment, to analyze the business environment of firms in transition countries and to link it with firm performance. This survey includes four measures of trade credit used by German firms: CIA given, CIA received, SC given, and SC received.[77] More specifically, firms are asked what percentage of their purchases of material inputs or services they pay before delivery (CIA given), what percentage of these purchases they pay late (SC received), what percentage of their own sales revenues they receive before delivery (CIA received), and what percentage of their own sales revenues they receive late (SC given). Secchi et al. (2016) exploit an independently estimated firm-specific credit rating issued by the Centrale dei Bilance (CB), an Italian Account Data Service company that collects annual administrative reports for all Italian limited liability firms. Financial analysts combine data from borrowers' annual reports and relevant soft information, based on a variety of qualitative and quantitative variables, to shape each firm's credit supply curve as perceived to be by the credit market.[78] In their recent work, Dinopoulos et al. (2020) use a solvency ratio estimated by an independent source, the ICAP Group. The ICAP Credit Rating expresses a

[77] In this survey, firms indicate whether access to financing is no obstacle, a minor obstacle, a moderate obstacle, or a major obstacle to their operations.
[78] Financial statement figures analyzed in the basis of industry- and region-specific risk components; indicators of market share positioning and future prospects; behavioral evaluation based on firm-specific credit events.

firm's credit quality with respect to the probability of default and/or bankruptcy within a one-year time horizon. It is a single indicator controlling for insolvency, excessive and/or bad debts, overdue accounts, and other typical commercial risks. Its estimation is based on an analysis of commercial, financial, and trading data derived from public sources and interviews with the rated firms.[79]

In this analysis, following Bernini et al. (2015), I adopt a leverage ratio as the measure of a firm's credit constraints using balance sheet data from the ICAP Database. In detail, Bernini et al. (2015), use balance sheet information from the Fichier Complet de Système Unifié de Statistique de Entreprises (FICUS), provided by the French National Statistical Office (INSEE), to construct two leverage measures: a firm's debt over its total assets, and over its total liabilities. Finally, using cash flows data, they construct dummy variables that indicate insufficient, normal, and abundant existence of internal resources form sales. In the Greek exporters' case, since the credit constraint measure is constructed with details available only at the end of each year, I use the lagged variable in our regressions. According to the literature studying the effect of financial frictions on firm performance, there is a potential endogeneity issue which stems from the choice of each particular credit constraint measure used. I address this potential endogeneity following Dinopoulos et al. (2020); since the leverage ratio is a financial measure that looks at how much capital comes in the form of debt (loans) and assesses the ability of a company to meet its financial obligations, available to us at the end of each year, we use the previous-year average leverage of all firms that have exported an HS6 product in any destination, excluding the firm under consideration, as an instrument. This average measure of credit rigidity is not directly affected by any of the firm-specific intensive margins (see quality, export sales, prices, and quantities) as they are not employed on its construction. The key assumption behind the use of the mean leverage within a product category is that the leverage of a single firm is not likely to be driven by the leverage of the

[79] The credit rating assignment process follows the completion of the quality control of the information collected by the ICAP Group. First, the financial accounts, the derogatory data and the relevant commercial characteristics of the firms are assessed by a standardized statistical algorithm. The qualitative assessment of the same firms from an Analyst follows; it corresponds to a proposal for the adaption of the evaluation of the statistical algorithm. Next, the Analyst evaluates specified criteria for the entities examined, which may lead to a final configuration of the previously proposed rating score. Additionally, a sensitivity analysis is conducted. According to the ICAP Group, the variables involved in the formulation of the proposed credit rating are re-examined and re-calculated, based on specific stress scenarios, resulting to the identification of those factors and benchmarks that may, and under certain conditions, lead to a differentiation of the credit rating during a future reassessment of the rated firms. Finally, the assessment procedure of the firms in question is considered by the Lead Analyst and in specific cases by the Rating Committee, to give the final approval of the credit rating assignment.

rest of the firms in a product category.

5.3. Quality and credit constraints: Some stylized facts

During Greece's economic downturn in the post-2009 period, Greek firms faced severe credit constraints. The main issue that Greek exporters encountered during this crisis was their poor ability to access credit markets to finance their trade costs, ending up moving in a vicious circle of liquidity shortage. Not surprisingly, when a firm confronts financial frictions, its ability to trade abroad is expected to be negatively affected due to either a decrease in the value of exports, or a decrease in the number of firms that enter an export market (Chaney, 2016; Bricongne et al., 2012). The latter effect is expected to be quantitatively less significant than the overall decline in exports, but exports may have a significant prolonged effect on a country's export performance (Görg and Spaliara, 2014a; 2014b; 2018; Jaud et al., 2017). Bernard and Jensen (2004), and Bernard et al. (2009) use US trade data at the firm level and find that during a crisis (or a boom), it is the intensive margin[80] of trade that adjusts the most. Yet, despite its apparent significance in shaping trade patterns, the adjustment of quality during periods of external adjustment with severe credit constraints remains an open question.

In this section, I estimate the relationship between quality and credit constraints for Greek exporters over the period 2002-2014, using data as described in Chapter 2. According to the related literature presented above, I expect this relationship to be negative. The econometric specification proceeds in two steps. In the first step, I regress the leverage measure of each firm *f* at year *t-1* on the mean leverage level of the industry *i* where the firm *f* is employed in exporting (instrument), and destination fixed effects. A crisis fixed effect is included to account for any unobserved effects that a crisis year may have on individual firm decisions.[81] The destination fixed effect aims to counteract the possibility of exporters shipping different quality levels of products to different destination countries (see Manova and Zhang, 2012; Flach, 2015), and also the possibility of a "frequent client" destination country that facilitates economic transactions, or a kind of learning-to-exporting to some destinations due to already known export protocols. Hence, the first stage of the regression is:

[80] The intensive margin of trade is the value and volume of trade, as well as the number of products and destinations. Note that, according to Bernard et al. (2012), quality is considered as an additional intensive margin.

[81] Bernard and Jensen (2004), and Bernard et al. (2009) find that during a crisis, or a boom, it is the intensive margin of trade that adjusts the most.

$$leverage_{ft-1} = a_1 \overline{leverage}^{i}_{t-1} + crisis + \delta_d + u_{ft-1} \tag{5.1}$$

Using the predicted values of this first stage, I estimate the relationship between quality and credit constrains at the firm-destination-product level:

$$q_{fgdt} = \beta_1 \widehat{leverage}_{ft-1} + crisis + \gamma_d + \varepsilon_{fgdt} \tag{5.2}$$

The leverage is expected to have a negative impact on product quality at the firm level, as more credit constrained firms are expected to export lower quality products.

5.3.1. Estimation results

In Table 5.1, I present results from the regression of firm-level quality estimates obtained in section 3.4.4. on the leverage measure defined as a firm's debt over its total assets. All estimations include destination fixed effects to control for different characteristics across destination countries, while standard errors reported are clustered at the firm × product level.

Table 5.1: Quality and leverage

	(1) OLS	(2) OLS	(3) IV	(4) IV
	Dependent Variable: $leverage_{fgt-1}$			
mean $leverage_{fgt-1}$			.127*** (.028)	.127*** (.028)
	Dependent Variable: $quality_{fgdt}$			
$leverage_{ft-1}$	.079 (.113)	.078 (.113)	-3.679** (1.640)	-3.678** (1.639)
country f.e.	Yes	Yes	Yes	Yes
crisis f.e.	No	Yes	No	Yes
obs.	76,668	76,668	64,826	64,826
Kleibergen-Paap F-test			19.44	19.43

Notes: All estimations include destination fixed effects. Standard errors are clustered at the firm × product level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Consistent with the quality sorting hypothesis, *more financially constrained Greek exporters exhibit lower product quality*. More specifically, a one-unit increase of a firm's leverage ratio decreases product quality by 3.6 points on the quality ladder.[82] In the econometric details, the Kleibergen-Paap F-statistic for the identification of weak instruments is not rejected,

[82] As product quality is identified at the firm, product, destination, year level and is relevant to the average quality of a product category to a specific destination market, we define the quality ladder as the difference between the 95th and the 5th percentile of the quality distribution of a product category in a destination market (normalized to have a mean of zero and a variance of 1). Its length reveals the degree of vertical differentiation.

indicating that the instruments used are suitable for the Greek exporters case.[83] Additionally, the Kleibergen-Paap Wald test for under-identification is rejected, so as the relevance condition of the instrument is satisfied (uncorrelated with the endogenous regressors). The issue of adding different fixed effect combinations is not straightforward as our panel has multiple dimensions that could affect both product quality and the credit constraints that a firm face. However, such an inclusion does not change our main result. I conclude that *financially healthier Greek exporters exhibit higher product quality.*

5.3.2. Robustness tests

5.3.2.A. Firm-specific crisis-related factors

In order to account for any firm-specific crisis-related factors that may influence the production, firm × crisis fixed effects are included in the quality and leverage regressions of Section 5.3.1. The main result is not affected. However, as presented below, the impact of leverage on product quality is larger when we account for firm-specific crisis-related factors that may influence the production.

Table 5.2: Alternative fixed effects scheme

	(1) OLS	(2) OLS
	Dependent Variable: $leverage_{fgt-1}$	
mean $leverage_{fgt-1}$		.029*** (.005)
	Dependent Variable: $quality_{fgdt}$	
$leverage_{ft-1}$	.056 (.111)	-18.806*** (6.436)
country f.e.	Yes	Yes
firm × crisis f.e.	Yes	Yes
obs.	76,475	64,623
Kleibergen-Paap F-test		28.45

Notes: All estimations include destination fixed effects and firm × crisis fixed effects. Standard errors are clustered at the firm × product level. * p < 0.1, ** p < 0.05, *** p < 0.01.

5.3.2.B. Firm maturity and size

In the corporate finance literature, the external finance dependence might vary by nature for young and mature firms. Therefore, in an alternative specification, firm age is included as a control variable. The ICAP Database reports the foundation year for every registered firm; exploiting this information I calculate the age of each firm. As shown in Table 5.3, the main

[83] In the case of a specification with one instrument, Stock and Yogo (2005) weak ID test critical values are at 15% maximal size, 8.96; while at 10% maximal size, 16.38.

result is robust to the inclusion of a firm's age. However, when someone accounts for the firm maturity the impact of credit constraints on product quality is by a unit higher.

In the same vein, according to Manjón-Antolín and Arauzo-Carod (2008), the size of a firm increases its surviving chances over a period of crisis, mainly because young firms often face greater difficulties in accessing financial markets than "established" firms (see Pérez et al., 2004). In Greece, during the recent economic crisis, larger SMEs proved to be more resilient and faced limited liquidity problems, in comparison to smaller SMEs experienced serious liquidity problems (Mylonas and Tzakou-Lambropoulou, 2014). Consequently, the inclusion of a firm's size in our estimation may have an impact on the relationship between quality and credit constraints. Hence, I use a firm's real assets form the ICAP Database to account for its size. As shown in Table 5.3, the result is robust to the inclusion of firm size in this estimation, as well as in addition to firm age.

Table 5.3: Quality, leverage, firm maturity, and size

	(1) OLS	(2)	(3)	(4) IV	(5)	(6)
Panel A (1st stage)	Dependent variable : $leverage_{ft-1}$					
mean $leverage_{it-1}$				.028*** (.005)	.027*** (.005)	.027*** (.005)
$\log(age_{ft})$				.042*** (.011)		.034*** (.011)
$\log(\text{real assets}_{ft-1})$					.013*** (.003)	.009** (.003)
Panel B (2nd stage)	Dependent Variable: $quality_{fgdt}$					
$leverage_{ft-1}$	.031 (.113)	.137 (.116)	.110 (.118)	-19.498*** (6.919)	-19.224*** (7.176)	-19.672*** (7.474)
$\log(age_{ft})$	.275*** (.076)		.298*** (.079)	1.095*** (.366)		.976*** (.346)
$\log(\text{real assets}_{ft-1})$		.033 (.032)	.003 (.033)		.296** (.123)	.188* (.108)
country f.e.	Yes	Yes	Yes	Yes	Yes	Yes
firm × crisis f.e.	Yes	Yes	Yes	Yes	Yes	Yes
Kleibergen-Paap F-test				24.97	24.24	22.48
obs.	74,473	73,385	71,771	62,937	61,955	60,609

Notes: All estimations include destination and firm × crisis fixed effects. Standard errors are clustered at the firm × product level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.3.2.C. Trade credit

As the demand for trade credit is positively related to credit constraints (see Bonte and Nielen, 2011), I alternatively examine the relationship between quality and trade credit to find out whether this specific type of credit promotes or hinders the quality of exported products. Trade credit can be categorized as an alternative financing option in periods of liquidity shortage for firms, while on the same time can be considered as a proxy for a firm's leverage condition. In this section, I use a firm's intangible assets as a proxy for trade credit (following Tsuruta, 2015) in order to alternatively measure credit constraints of exporting firms. Indeed, the relationship between quality and trade credit is negative as expected. However, the magnitude of trade credit's effect on quality is very limited compared to the credit constraints measure used in the main analysis (see Table 5.4).

Table 5.4: Quality and trade credit

	(1) OLS	(2) IV
Panel A (1st stage)	Dependent Variable : trade $credit_{ft-1}$	
mean trade $credit_{it-1}$		.021*** (.005)
Panel B (2nd stage)	Dependent Variable: $quality_{fgdt}$	
trade $credit_{ft-1}$	.010 (.011)	-1.796** (.820)
country f.e.	Yes	Yes
firm × crisis f.e.	Yes	Yes
Kleibergen-Paap F-test		13.90
obs.	69,095	57,190

Notes: All estimations include destination and firm × crisis fixed effects. Standard errors are clustered at the firm × product level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.4. The role of innovation in trade quality

Strongly related to quality, innovation is considered to be one of the main factors underlying international competitiveness (Asheim and Isaksen, 1997; Michie, 1998). Firms in order to enter new markets or maintain -and even reinforce- their competitive advantage consider innovation as a tool to achieve their goals (see among others Brown and Eisenhardt, 1995). However, little is known on innovation in the context of micro-exporting, mainly due to lack of detailed data. Not surprisingly, both innovation and product quality are therefore considered as important determinants of trade flows at the firm level. However, with the exception of Chen (2013) who investigates the influence of innovation on the extensive (number of products) and the intensive (value of each product) margins of exports and finds that innovation has a major positive effect on the intensive margin in a way that suggests increasing quality of exports due to innovation, there is no research that investigates the relationship between estimated product quality and innovation at the firm level. In the following section, I present an empirical investigation of the relationship between estimated product quality and innovation.

5.4.1. Quality and innovation: Some stylized facts

In this section, I estimate the relationship between export product quality and innovation for Greek firms over the period 2002-2014. On my knowledge, there is no research, that investigates the relationship between estimated product quality and innovation at the firm level. I expect this relationship to be positive as Chen's (2013) findings show that innovation has a major positive effect on the intensive margin of trade.

I regress the quality measure, obtained as described in Section 3.4.4., on two firm-level innovation measures constructed from data available in the AMS Database. The first innovation measure is based on the firm's expenditures related to R&D, defined as the share of a firm's total production costs related to Research and Development activities of the firm:

$$R\&Dexp = \frac{R\&D\ expenditure}{total\ production\ costs} \tag{5.3}$$

while the second is based on a firm's personnel working on R&D related positions, and is defined as the share of a firm's employees related to R&D over the firm's total employees,

$$R\&Dper = \frac{R\&D\ personnel}{total\ employees}. \tag{5.4}$$

A destination fixed effect is included in the regression to account for the possibility of a "frequent client" destination country to facilitate economic transactions, or a kind of learning-to-exporting to some destinations due to already known export protocols, or even to account for the possibility of firms exporting higher quality products to specific markets. The standard errors are clustered at the firm × product level. A crisis fixed effect is included in a second similar regression to account for the existence of any unobserved effects that a crisis year may have on individual firm decisions,

$$q_{fgdt} = \beta_1 \widehat{innovation}_{ft} + crisis + \gamma_d + \varepsilon_{fgdt}. \tag{5.5}$$

5.4.2. Estimation results

In Table 5.5, I present results from the regression of firm-level quality estimates obtained in Section 3.4.4. on both innovation measures previously discussed. Additional summary statistics on the sample of Greek innovative exporters is presented in Appendix B.1. All estimations include destination fixed effects to control for different characteristics across destination countries, or even to account for the possibility firms exporting higher quality products to specific markets. Standard errors reported are clustered at the firm × product level. Specifications (2) and (4) also include a crisis fixed effect.

Table 5.5: Quality and innovation

	(1)	(2)	(3)	(4)
	Dependent Variable: $quality_{fgdt}$			
$R\&Dexp_{ft}$	5.341***	5.415***		
	(1.441)	(1.428)		
$R\&Dper_{ft}$			2.048**	2.068**
			(.818)	(.810)
country f.e.	Yes	Yes	Yes	Yes
crisis f.e.	No	Yes	No	Yes
obs.	166,401	166,401	166,380	166,380

Notes: All estimations include destination fixed effects. Standard errors are clustered at the firm × product level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Consistent with the strand of the innovation literature that predicts a positive relationship between product quality and innovation, I find a *strong positive relationship between product quality and both innovation measures (R&D expenditure and R&D personnel)* employed in my analysis. Accounting for any unobserved effects that a crisis year may have on individual firm decisions, the estimated relationship between the variables of interest becomes stronger; consistent with empirical findings that during a crisis the intensive margin of trade that adjusts the most.[84]

5.4.3. Robustness tests

A strand of the innovation literature is trying to explain the heterogeneous innovative behavior of firms according to their age, the phenomenon of young innovative firms (see among others Schneider and Veugelers, 2010; Czarnitzki and Delanote, 2013), and the relationship between firm age and probability of innovation (see Huergo and Jaumandreu, 2004a; 2004b; and Cucculelli et al., 2014). Therefore, in an alternative specification, firm age is included as a control variable to capture age-related effects. The ICAP Database reports the foundation year for every registered firm; exploiting this information I calculate the age of each firm. As shown in Table 5.6, the main result is robust to the inclusion of a firm's age.

Morris (2018) explains that a firm's innovation efforts, its capital intensity and human capital are important for product and process innovation. Consequently, the inclusion of a firm's capital intensity may have an impact on the relationship between quality and innovation.

[84] See Bernard and Jensen (2004), and Bernard et al. (2009).

Hence, I use a firm's real assets form the ICAP Database to account for its capital intensity. As shown in Table 5.6, the result is robust to the inclusion of firm capital intensity in this estimation, as well as in addition to firm age.

Table 5.6: Quality, innovation, firm maturity, and capital intensity

	(1)	(2)	(3)	(4)	(5)	(6)
			Dependent Variable: $quality_{fgdt}$			
$R\&Dexp_{ft}$	7.392***	6.949***	7.120***			
	(1.928)	(1.990)	(2.011)			
$R\&Dper_{ft}$				3.392***	3.178***	3.186***
				(1.062)	(1.107)	(1.105)
$\log(age_{ft})$	.091**		.077*	.092**		.078*
	(.045)		(.047)	(.045)		(.046)
$\log(real\ assets_{ft-1})$		.039**	.035**		.040**	.036*
		(.018)	(.020)		(.018)	(.020)
country f.e.	Yes	Yes	Yes	Yes	Yes	Yes
crisis f.e.	Yes	Yes	Yes	Yes	Yes	Yes
obs.	43,419	44,642	43,149	43,343	44,566	43,073

Notes: All estimations include destination fixed effects and firm × crisis fixed effects. Standard errors are clustered at the firm × product level. * p < 0.1, ** p < 0.05, *** p < 0.01.

5.5. A theoretical model of endogenous quality, innovation, and credit constraints

To the extent that investment is required to upgrade export product quality, credit constraints may affect an exporter's investment decisions on R&D activity (Brown et al., 2012; Crino and Ogliari, 2017; Jin et al., 2019). However, there is very little evidence on the relationship among export quality, innovation, and access to credit for exporters. As credit constraints may affect the costs and incentives to invest in quality enhancing activities (see Long and Malitz, 1985; Maksimovic and Titman, 1991), it is important to investigate in what way such a prediction can be incorporated in a setup with heterogeneous exporting firms.

In this section, I develop a simple framework to investigate the relationship between product quality, innovation, and credit constraints. In this model, exporting firms choose their export quantity and quality, subject to the credit constraints they are facing and their level of innovative activities. The model does not require a distinction between product and process innovation and, hence, it is suitable for empirical investigation when detailed data on firms' innovative activities are not available.

5.5.1. Demand structure

The demand structure of the model follows Dinopoulos et al. (2020), who use a translated Cobb-Douglas utility function as in Simonovska (2015). The demand structure also follows

Feenstra and Romalis (2014) in introducing endogenous product quality, adapted on a partial-equilibrium framework to remain tractable.

The destination market consists of *N* consumers and is served by *n* firms. Each firm produces a distinct variety of a product *i* which enters symmetrically in the consumer's utility function. Assuming that the utility of consumer *j* is given by,

$$U_j = \sum_{i=1}^{n} \beta_j \lambda_i \ln(x_{ij} + \theta) + x_{0j} \tag{5.6}$$

where x_{ij} is the quantity of product variety *i* consumed by consumer *j*, x_{0j} denotes the consumed quantity of an outside good, and λ_i is the quality of product variety *i*. Consumer *j*'s willingness to pay is captured by β_j, which is an exogenous non-negative parameter. Parameter $\theta > 0$ introduces consumer's non-homothetic preferences i.e., his utility increases with the option of consuming a variety or even window-shopping for this variety.

Maximizing consumer *j*'s utility function (5.1) subject to a standard budget constraint,

$$I_j = \sum_{j=1}^{n} p_i x_{ij} + p_0 x_{0j} \tag{5.7}$$

where the price of the outside good is assumed to be equal to unity, I get the following expression for the inverse demand for a product variety *i*,

$$p_i = \frac{\beta_j \lambda_i}{x_{ij}+\theta}\,. \tag{5.8}$$

Solving for x_{ij} and aggregating over all consumers *N*, leads to the following expression for the aggregate quantity demanded for product variety *i* over all consumers *N,*

$$q_i = \textstyle\sum_{j=1}^{N} x_{ij}\,,$$

and the consumers' average willingness to pay for this product variety,

$$\beta = \left(\textstyle\sum_{j=1}^{N} \beta_j\right)/N.$$

Following Feenstra and Romalis (2014), the average willingness to pay increases with the average consumer income,

$I = \left(\sum_{j=1}^{N} I_j\right)/N$, so as $\beta = I^{\gamma}, \gamma > 0.$

This implies that there is a finite reservation price (i.e., products are non-essential) increasing in product quality and per capita consumer income, and decreasing with consumer's non-homothetic preferences, equal to $I\lambda/\theta$.[85] The latter implies a more elastic inverse demand curve for higher values of θ, while when $\theta = 0$ the reservation price is infinite. The inverse demand for the typical variety is then given by:

$$p = \frac{I^{\gamma}\lambda}{qN^{-1}+\theta}. \tag{5.9}$$

Hence, the export revenue of firm *j* is

$$R(q,\lambda) \equiv pq = \frac{I^{\gamma}\lambda q}{qN^{-1}+\theta}. \tag{5.10}$$

5.5.2. Cost structure

The representative firm faces both fixed and variable costs. I assume that fixed costs increase with product quality and innovation expenditure, as both quality and innovation require initial investment costs.[86] For instance, an exporting firm requires an investment to organize a R&D Department that hosts any related activity focused on new or enhanced products, or that is effective in generating and implementing innovative ideas or adopt creatively evolving consumer tastes into production. It also requires an investment on product quality or a quality enhancing production investment, such as purchase superior technology machines that produce a final product of better quality, organize a quality-control department, or acquire a patent or a related certification. For expositional convenience, these fixed costs enter in a quadratic form given by $(\lambda r)^2/2$, which also ensures the existence of a well-defined and positive optimum in the profit maximization problem (see also Dinopoulos et al., 2020).

In addition, the exporting firm faces variable costs of production. Assuming that product quality is costly to produce as firms may employ higher quality inputs in the production process, variable costs increase with product quality. In contrast, innovation expenditures reduce marginal production costs (see Melitz, 2003; or Hallak and Sivadasan, 2013). For example, a producer might develop or employ innovative packaging to maintain his products safe or fresh. Finally, a firm faces credit constraints δ, where $\delta > 0$. At the micro level, financing constraints are expected to have a negative influence on a firm's growth (see for

[85] As consumer utility is symmetric across products, I drop subscript *i*.
[86] See for instance, Kugler and Verhoogen (2012), and Eckel and Unger (2015).

instance Beck et al., and 2005; Ayyagari et al., 2008). Thus, I assume that higher credit constraints affect the size of production and hence affect the firm's variable costs.

Given all the above, I assume the following cost function:

$$C(q,\lambda) = \frac{(\lambda r)^2}{2} + \delta \frac{q\lambda}{r}. \tag{5.11}$$

5.5.3. Equilibrium

Each firm maximizes expected profit from exporting by choosing output and product quality and by taking the level of credit constraints, and innovation expenditures as given. Substituting the equations (5.5) and (5.6) leads to the following expression for export profits,

$$\pi(q,\lambda) = \frac{I^{\gamma}\lambda q}{qN^{-1}+\theta} - \frac{(\lambda r)^2}{2} - \delta \frac{q\lambda}{r} \tag{5.12}$$

Maximizing equation (5.7) with respect to output q and quality λ leads to the following first-order conditions:

$$\frac{I^{\gamma}\theta}{(qN^{-1}+\theta)^2} = \frac{\delta}{r}, \tag{5.13}$$

$$\frac{I^{\gamma}q}{(qN^{-1}+\theta)} = \lambda r^2 + \frac{\delta q}{r}. \tag{5.14}$$

Now solving for the exported output yields

$$q = \left[\left(\frac{rI^{\gamma}\theta}{\delta}\right)^{1/2} - \theta\right]N, \tag{5.15}$$

which determines the equilibrium value of exported quantity.

Dividing the two first-order conditions (5.8) and (5.9) generates the following positive relationship between output and product quality:

$$\lambda = \frac{\delta}{r^3\theta N}q^2. \tag{5.16}$$

Substituting the expression (5.11) for q, we get that

$$\lambda = \frac{\delta}{r^3\theta N}\left[\left(\frac{rI^{\gamma}\theta}{\delta}\right)^{1/2} - \theta\right]^2 N^2, \tag{5.17}$$

which determines the equilibrium value of exported quality. Substituting λ into the inverse demand function (5.4) yields a closed-form solution to export price,

$$p = \frac{I^{\gamma}\lambda}{qN^{-1} + \theta} = \frac{I^{\gamma}\frac{\delta}{r^{3}\theta}\left[\left(\frac{rI^{\gamma}\theta}{\delta}\right)^{1/2} - \theta\right]^{2} N}{\left[\left(\frac{rI^{\gamma}\theta}{\delta}\right)^{1/2} - \theta\right] + \theta} \tag{5.18}$$

In order to investigate the relationship between product quality and innovation we take the derivative of the former with respect to the latter using (5.12),

$$\frac{d\lambda}{dr} = \frac{\delta\mu}{N\theta}(-3)r^{-4}\left[\left(\frac{rI^{\gamma}\theta}{\delta}\right)^{1/2} - \theta\right]^{2} N^{2} + \frac{\delta}{N\theta}2r^{-3}\left[\left(\frac{rI^{\gamma}\theta}{\delta}\right)^{1/2} - \theta\right] N\frac{1}{2}\left(\frac{I^{\gamma}\theta}{\delta}\right)^{1/2} r^{-1/2}$$

A necessary and sufficient condition for the derivative to be positive is:

$$\left(\frac{rI^{\gamma}\theta}{\delta}\right)^{1/2} > 3\left(\frac{rI^{\gamma}\theta}{\delta}\right)^{1/2} - 3\theta.$$

The last inequality implies that for $r > \frac{\delta\theta}{I^{\gamma}}$ the relationship between product quality and innovation is positive, $\frac{d\lambda}{dr} > 0$. When $r < \frac{\delta\theta}{I^{\gamma}}$, this relationship is negative, $\frac{d\lambda}{dr} < 0$.

In other words, *the relationship between product quality and innovation at the firm level is positive when the firm's innovation expenditures are above* $\frac{\delta\theta}{I^{\gamma}}$*, but it is negative when its innovation expenditures are below this cut-off point*. Thus, when the level of innovation expenditures of firms is low (below the threshold level), an increase in the level of credit constraints δ, will drive more firms to experience the negative relationship between product quality and innovation, ceteris paribus (see Figure 5.1). In the same vein, an increase in the level of credit constraints, moves the threshold to the right leading also more firms with low levels of innovation to experience a negative relationship between their innovation activities and their product quality.

Figure 5.1: Innovation and product quality

$\frac{d\lambda}{dr} < 0$		$\frac{d\lambda}{dr} > 0$
low innovation	$r = \frac{\delta\theta}{I^{\gamma}}$	*high innovation*

It should be noted that as credit constraints affect both product quality and innovation at the firm level, they may affect a firm's choice related to both. In Appendix B.2., I present a tractable framework, in which firms also choose the level of their innovative activities. The prediction of the model on the relationship between product quality and innovation remains the same.

5.6. Empirical analysis

To test the prediction of the theoretical framework, I use data of Greek manufacturing exporting firms from the AMS Database that cover the period 2002-2014. I construct two alternative innovation measures, as described in Section 5.4.1. The first is based on a firm's expenditures related to R&D, and the second is based on a firm's personnel working on R&D related positions. Next, I split the sample of the Greek exporters, based on how leveraged a firm is, into low-, medium-, and high-leveraged firms, to consider the rigidity of each firm's situation with respect to its credit constraints. Following Bernini et al. (2015), I adopt a firm's debt over its total assets as the main measure of credit constraints. This leverage ratio is constructed using balance sheet data from the ICAP Database.

5.6.1. Econometric Specification

The econometric specification is simple; I regress the quality measure, obtained as described in Section 3.4.4., on the innovation measure constructed using data form the AMS Database at the firm level, by leverage category as defined above. As exporters tend to ship different quality levels of products to different destination countries (see Manova and Zhang, 2012; Flach, 2015), a destination fixed effect is included in the regression, while the standard errors are clustered at the firm × product level. The inclusion of a destination fixed effect also counteracts the possibility of a "frequent client" destination country that facilitates economic transactions, or a kind of learning-to-exporting to some destinations due to already known export protocols. A crisis fixed effect is also included to account for any unobserved effects that a crisis year may have on individual firm decisions,

$$q_{fgdt} = \beta_1 \widehat{innovation}_{ft} + crisis + \gamma_d + \varepsilon_{fgdt.} \tag{5.19}$$

5.6.2. Estimation Results

In Table 5.7, I present results from the regression of the firm-level quality estimates on both innovation measures previously discussed, by firms' level of credit constraints. All estimations include destination fixed effects to control for different characteristics across destination countries, while standard errors reported are clustered at the firm × product level. Specifications (2) and (4) include crisis fixed effects to account for any unobserved effects that a crisis year may have on individual firm decisions.

Table 5.7: Quality and innovation regressions by firms' level of credit constraints

	(1)	(2)	(3)	(4)
	Dependent Variable: $quality_{fgdt}$			
	Low credit constraints			
$R\&Dexp_{ft}$	7.343***	7.428***		
	(2.471)	(2.437)		
$R\&Dper_{ft}$			5.971***	6.068***
			(1.609)	(1.563)
obs.	18,720	18,720	18,658	18,658
	Medium credit constraints			
$R\&Dexp_{ft}$	8.817***	8.738***		
	(2.505)	(2.532)		
$R\&Dper_{ft}$			2.975***	2.917***
			(.967)	(.940)
obs.	14,640	14,640	14,640	14,640
	High credit constraints			
$R\&Dexp_{ft}$	-7.378**	-7.437**		
	(3.717)	(3.726)		
$R\&Dper_{ft}$			-5.745***	-5.837***
			(2.013)	(1.846)
obs.	11,758	11,758	11,744	11,744
country f.e.	Yes	Yes	Yes	Yes
crisis f.e.	No	Yes	No	Yes

Notes: All estimations include destination fixed effects and firm × crisis fixed effects. Standard errors are clustered at the firm × product level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Consistent with the theoretical model presented in Section 5.5., in which the firm chooses its product quality given its innovative activities and the level of credit constraints it faces, the empirical results confirm that the relationship between product quality and innovation is non-linear. It is positive for low- and medium-credit constrained Greek exporters but becomes negative for the highly credit constrained ones. Additionally, when considering the Greek crisis period, this relationship does not change drastically as there is only a minor change on the impact of the crisis fixed effect.

5.6.3. Robustness tests

A strand of the innovation literature is trying to explain the heterogeneous innovative behavior of firms according to their age, the phenomenon of young innovative firms (see among others Schneider and Veugelers, 2010; Czarnitzki and Delanote, 2013), and the relationship between firm age and probability of innovation (see Huergo and Jaumandreu, 2004a; 2004b; and Cucculelli, 2014). Also, in the corporate finance literature, the external finance dependence might vary by nature for young and mature firms. Therefore, in an alternative specification, firm age is included as a control variable. The ICAP Database reports the foundation year for every registered firm; exploiting this information I calculate the age of each firm. As shown in Table 5.8, the main result is robust to the inclusion of a firm's age.

Morris (2018) explains that a firm's innovation efforts, its capital intensity and human capital are important for innovation. Consequently, the inclusion of a firm's capital intensity in the estimation may have an impact on the relationship between quality and innovation. Hence, I use a firm's real assets from the ICAP Database to account for its capital intensity. As shown in Table 5.8, the main result is robust to the inclusion of firm capital intensity in this estimation, as well as in addition to firm age.

Table 5.8: Quality, innovation, firm maturity and capital intensity, regressions by firms' level of credit constraints

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent Variable: $quality_{fgdt}$					
Low credit constraints						
$R\&Dexp_{ft}$	7.385***	7.212***	7.201***			
	(2.460)	(2.549)	(2.559)			
$R\&Dper_{ft}$				6.059***	5.890***	5.907***
				(1.555)	(1.631)	(1.619)
$\log(age_{ft})$	.086		.073	.085		.073
	(.075)		(.076)	(.075)		(.077)
$\log(\text{real assets}_{ft-1})$		.039	.037		.036**	.033
		(.026)	(.028)		(.065)	(.028)
obs.	18,299	18,601	18,238	18,237	18,539	17,176
Medium credit constraints						
$R\&Dexp_{ft}$	8.750***	7.546***	7.607***			
	(2.546)	(2.642)	(2.642)			
$R\&Dper_{ft}$				2.707***	2.145**	2.034**
				(.937)	(.930)	(.938)
$\log(age_{ft})$	.202***		.162**	.208***		.165**
	(.064)		(.066)	(.064)		(.066)
$\log(\text{real assets}_{ft-1})$		.103***	.089***		.108***	.094***
		(.025)	(.027)		(.026)	(.027)
obs.	14,170	14,533	14,118	14,170	14,533	14,118
High credit constraints						
$R\&Dexp_{ft}$	-1.510	-3.035	-1.199			
	(4.512)	(4.374)	(4.535)			
$R\&Dper_{ft}$				-4.165*	-4.434**	-4.134*
				(2.295)	(2.260)	(2.315)
$\log(age_{ft})$	.008		.017	.017		.027
	(.060)		(.062)	(.060)		(.062)
$\log(\text{real assets}_{ft-1})$		-.035	-.033		-.033	-.032
		(.026)	(.028)		(.026)	(.028)
obs.	10,923	11,480	10,765	10,909	11,466	10,751
country f.e.	Yes	Yes	Yes	Yes	Yes	Yes

crisis f.e.	Yes	Yes	Yes	Yes	Yes	Yes

Notes: All estimations include destination fixed effects and firm × crisis fixed effects. Standard errors are clustered at the firm × product level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

All in all, the relationship between product quality and innovation is positive for low- and medium-credit constrained Greek exporters but negative for the highly credit constrained ones, with the Greek crisis period having a minor impact on it, as well as the firms' age and capital intensity.

Conclusion

This thesis sheds light on the complex relationship between product quality, innovation, and credit constraints at the firm level in the context of international trade. Since the emergence of heterogeneous-firm trade models, product quality, innovation, and credit constraints are found to be main drivers of a firm's exporting activity. Strongly related to quality, innovation is considered to be one of the main factors underlying international competitiveness (Asheim and Isaksen, 1997; Michie, 1998). Also, credit constraints are found to have an impact on the quality of exported products (see Fan et al., 2015; and Dinopoulos et al., 2020). To the extent that investment is required to upgrade export product quality, credit constraints may affect an exporter's investment decisions on R&D activity (Brown et al., 2012; Crino and Ogliari, 2017; Jin et al., 2019). However, there is very little evidence on the relationship among export quality, innovation, and access to credit for exporters.

Trying to map this relationship, I develop a simple model, where innovative exporting firms choose their product quality, subject to the credit constraints they are facing. Since this setup does not require the distinction between product and process innovation, it allows for international trade analysis when detailed data on firms' innovative activities are not available. The relationship between product quality and innovation is positive when the firm's innovative activities are above a threshold that depends on the firm's level of credit constraints, but it is negative below this cut-off point.

In order to test this theoretical prediction, I take advantage of a unique combined dataset for Greek exporting firms and estimate product quality based on the methodology put forward by Piveteau and Smagghue (2019). This methodology estimates relative demand at the firm-product level and identifies product quality from the variety-specific term of the demand shifter. To treat price endogeneity, Piveteau and Smagghue (2019) exploit exogenous exchange rate variations interacted with firm-specific importing shares. As real exchange rate shocks on a firm's imports are cost shocks, the firm passes them through to its export prices, firm sales adjust, and the demand function can be consistently identified. The estimated price elasticity of demand for Greek exporters is -2.2.

With the time-varying product quality at hand, I first present stylized facts; evidence on the relationship between quality and credit constraints for Greek exporters, and also Greek export quality and innovation. As expected, the impact of how leveraged a Greek exporter is on its product quality is negative, while the relationship between its product quality and its innovation efforts is positive. I next focus on the relationship among export quality, innovation, and credit constraints. Consistent with the theoretical model, the empirical results confirm that the relationship between product quality and innovation is complex and depends on the level of a firm's credit constraints. My empirical findings show that this relationship is positive for low- and medium-credit constrained Greek exporters, and negative for highly constrained firms.

This finding may have important implications for research on deeper determinants of aggregate productivity, and policies aiming at fostering competitiveness and export development. As exporting firms are heterogeneous in multiple aspects, in ways that affect trade margins, any trade policy changes should mirror their heterogeneous needs. For instance, a policy change directed to boost Greek firms' exporting profile through investment strategies targeting firms' innovative activities, should consider their heterogeneity in credit constraints in order for the competitiveness strategy to be efficiently implemented.

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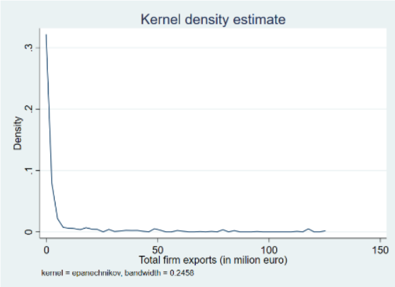
Appendix A: Quality estimation

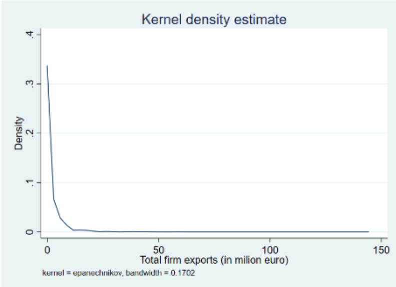
A.1. Kernel density by product category

Figure A.1: Kernel density of export value per year by product category

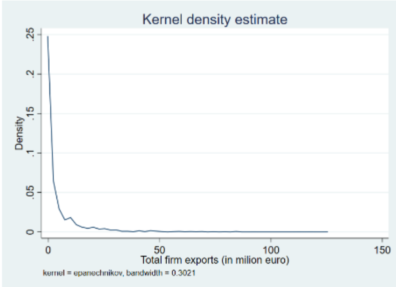
(1) Animal Products



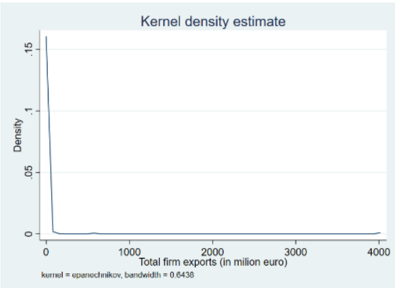
(2) Vegetable Products



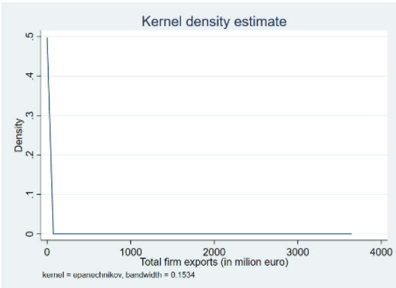
(3) Foodstuffs



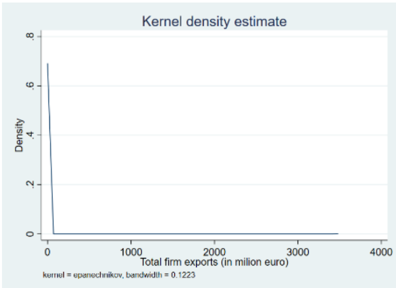
(4) Mineral Products



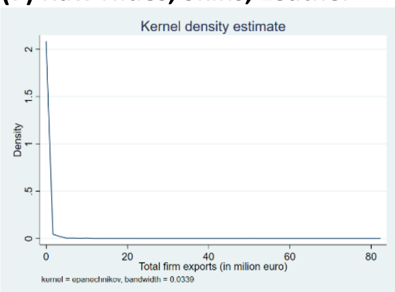
(5) Chemicals & Allied



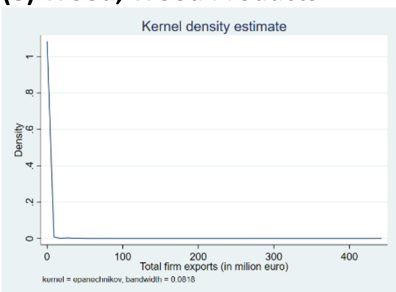
(6) Plastics, Rubbers



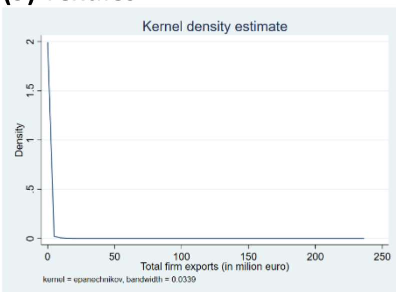
(7) Raw Hides, Skins, Leather



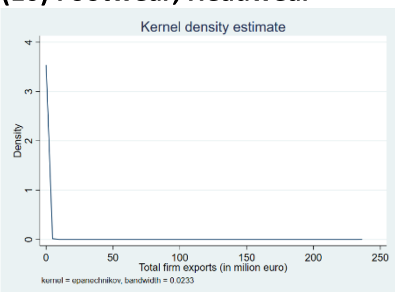
(8) Wood, Wood Products



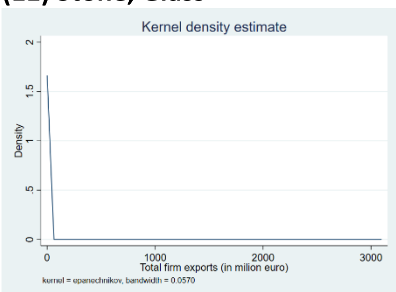
(9) Textiles



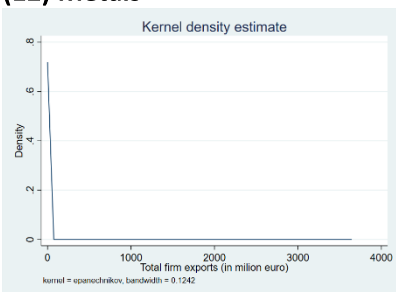
(10) Footwear, Headwear



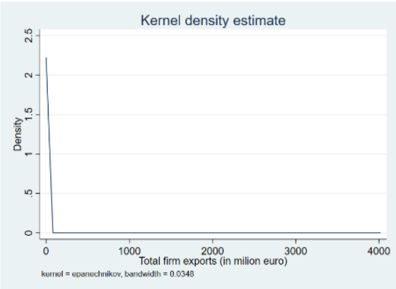
(11) Stone, Glass



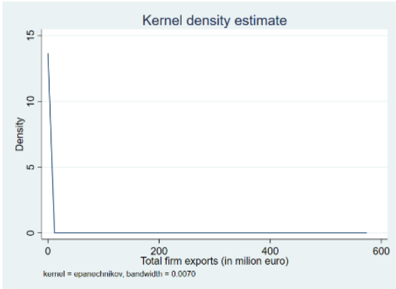
(12) Metals



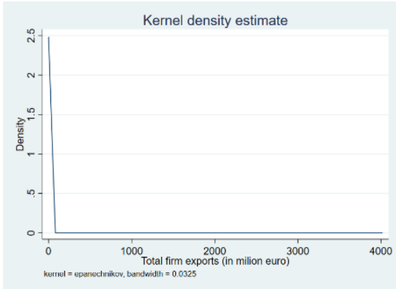
(13) Machinery, Electrical



(14) Transportation



(15) Miscellaneous



A.2. Quality consistency tests

In order to assess the validity of the quality measure obtained by their structural demand estimation, Piveteau and Smagghue (2019) apply various exercises on their quality estimates. In this section, I present such exercises applied on the quality estimates obtained for Greek exporters.

A.2.1. Correlation with firms' characteristics

First, the quality measure is related to firms' characteristics obtained from the AMS dataset. Given that this dataset does not cover the whole universe of Greek exporters, the observations of this correlation test drop in comparison to the quality estimation regressions.

Table A.1: Correlation with firms' characteristics

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable: $quality_{fgdt}$					
	no fixed effects		destination, product, and year fixed effects		dest × prod × year fixed effects	
log(wage)	.345***	.294***	.456***	.279***	.650***	.339***
	(.034)	(.063)	(.040)	(.071)	(.049)	(.113)
log(capital)		.063***		.094***		.210***
		(.014)		(.017)		(.030)
obs.	187,084	52,595	186,596	52,041	129,045	21,799
R^2	0.0024	0.0042	0.0573	0.1511	0.2284	0.3744

Notes: the variable log(wage) is obtained by taking the logarithm of the total wage bill divided by the number of employees. Specifications (1) and (2) have a non-reported constant. Standard errors in parentheses are clustered at the firm × year level. * p < 0.1, ** p < 0.05, *** p < 0.01.

As shown in Table A.1, the quality measure is correlated positively to the average wage paid by a firm, which generally proxies the qualitative of a firm's employees. In order to proxy for the size of the firm, the total stock of capital employed is used. Adding this size control does not affect the correlation between the quality measure and average wage. Moreover, this correlation becomes even stronger when we include destination, product, and year fixed effects, either individually or as a fixed effects triplet, indicating that firms with higher wages systematically produce higher quality, in comparison to other exporters in the same destination market. Such findings, reinforce the evidence that this quality measure captures heterogeneity across firms, related to product quality differences and vertical differentiation.

A.2.2. Prices as a proxy for quality

As mentioned previously, the absence of suitable product quality measures with big coverage in the product space has led economists to use prices as a proxy that indicates product quality. However, prices as a proxy may conflate many factors that are not related to product quality, while also ignore characteristics that enter the consumers' valuation of a product. As shown in Table A.2, there is an imperfect relationship between prices and quality, as prices and quality are more correlated in markets with larger vertical differentiation. In these markets, variations in prices are mostly driven by quality variations than by cost variations.

Table A.2: Correlation between prices and quality

	(1)	(2)	(3)
	Dependent variable: log($price_{fgdt}$)		
	All markets	>5	>20
$quality_{fgdt}$	.270*** (.001)	.107*** (.000)	.107*** (.000)
$quality_{fgdt}$ × qual. ladders	.085*** (.000)	.337*** (.002)	.338*** (.002)
obs.	1,107,341	171,954	169,633
R^2	0.8141	0.8890	0.8877

Notes: Quality ladder is the difference between the 95th and 5th percentiles of the quality distribution within a market, normalized to have a mean of zero and a variance of one. Quality measures and prices are also normalized to have zero mean and a standard deviation of one within markets. Each regression includes product × destination × year fixed effects. Standard errors in parentheses are clustered at the product × destination × year level. * p < 0.1, ** p < 0.05, *** p < 0.01.

In detail, to account for the degree of vertical differentiation in a market, I construct a market specific measure of the length of the quality ladder. Following Khandelwal (2010), for any product × destination × year triplet, I take the difference between the 95^{th} and the 5^{th} percentile of the quality distribution, so as the market specific length of the quality ladder is constructed. Moreover, in order to avoid the presence of an effect on the slope between prices and quality due to the dispersion of qualities, prices and quality are normalized such that, within markets, they are centered around zero and have a standard deviation of one. All regressions include destination $\times$ product $\times$ year fixed effects so as price and quality relationship is identified within a market.

Table A.2 shows that export prices and quality are positively correlated, justifying the use of prices as a proxy for quality. However, this correlation is stronger in markets with a larger degree of differentiation, i.e., markets with a long quality ladder. This finding indicates that in markets with little vertical differentiation, prices might contain little information about quality, and hence, prices are not a good proxy for quality in such a case.

Appendix B: Quality, innovation, and credit constraints in exporting

B.1. Additional summary statistics

Table B.1: Firm leverage by product category

	mean debt (in ths of euro)	mean leverage intensity
Animal Products	105.75	.015
Vegetable Products	115.86	.012
Foodstuffs	203.12	.029
Mineral Products	205.55	.022
Chemicals & Allied	140.92	.017
Plastics, Rubbers	171.57	.026
Raw Hides, Skins, Leather	18.25	.006
Wood, Wood Products	221.68	.025
Textiles	77.57	.013
Footwear, Headwear	28.50	.009
Stone, Glass	78.74	.015
Metals	154.82	.024
Machinery, Electrical	99.58	.016
Transportation	32.72	.005
Miscellaneous	74.69	.013

Table B.2: Firm R&D intensity by product category

	R&D expenditure intensity	R&D personnel intensity
Animal Products	.02	.070
Vegetable Products	.05	.213
Foodstuffs	.10	.362
Mineral Products	.06	.240
Chemicals & Allied	.70	1.62
Plastics, Rubbers	.41	1.20
Raw Hides, Skins, Leather	.11	.17
Wood, Wood Products	.37	.87
Textiles	.15	.41
Footwear, Headwear	.06	.10
Stone, Glass	.15	.40
Metals	.36	1.08
Machinery, Electrical	.65	1.80
Transportation	.06	.20
Miscellaneous	.44	.98

B.2. A theoretical model of endogenous quality, endogenous innovation, and credit constraints in exporting

To the extent that investment is required to upgrade export product quality, credit constraints may affect an exporter's investment decisions on R&D activity (Brown et al., 2012; Crino and Ogliari, 2017; Jin et al., 2019). However, there is very little evidence on the relationship among export quality, innovation, and access to credit for exporters. As credit constraints may affect the costs and incentives to invest in quality enhancing activities (see Long and Malitz, 1985; Maksimovic and Titman, 1991), it is important to investigate in what way such a prediction can be incorporated in a setup with heterogeneous exporting firms.

In this section, I develop a simple framework to investigate the relationship between product quality, innovation, and credit constraints. In this model, exporting firms choose their export quantity, innovative expenditure, and product quality, subject to the credit constraints they are facing. The model does not require a distinction between product and process innovation and, hence, it is suitable for empirical investigation when detailed data on firms' innovative activities are not available.

B.2.1. Demand structure

The demand structure of the model follows Dinopoulos et al. (2020), who use a translated Cobb-Douglas utility function as in Simonovska (2015). The demand structure also follows Feenstra and Romalis (2014) in introducing endogenous product quality, adapted on a partial-equilibrium framework to remain tractable.

The destination market consists of *N* consumers and is served by *n* firms. Each firm produces a distinct variety of a product *i* which enters symmetrically in the consumer's utility function. Assuming that the utility of consumer *j* is given by,

$$U_j = \sum_{i=1}^{n} \beta_j \lambda_i \ln\left(x_{ij} + \theta\right) + x_{0j} \tag{B.1}$$

where x_{ij} is the quantity of product variety *i* consumed by consumer *j*, x_{0j} denotes the consumed quantity of an outside good, and λ_i is the quality of product variety *i*. Consumer *j*'s willingness to pay is captured by β_j, which is an exogenous non-negative parameter. Parameter $\theta > 0$ introduces consumer's non-homothetic preferences i.e., his utility increases with the option of consuming a variety or even window-shopping for this variety.

Maximizing consumer *j*'s utility function (B.1) subject to a standard budget constraint,

$$I_j = \sum_{j=1}^{n} p_i x_{ij} + p_0 x_{0j} \tag{B.2}$$

where the price of the outside good is assumed to be equal to unity, I get the following expression for the inverse demand for a product variety *i*,

$$p_i = \frac{\beta_j \lambda_i}{x_{ij} + \theta} . \tag{B.3}$$

Solving for x_{ij} and aggregating over all consumers *N*, leads to the following expression for the aggregate quantity demanded for product variety *i* over all consumers *N,*

$$q_i = \sum_{j=1}^{N} x_{ij} ,$$

and the consumers' average willingness to pay for this product variety,

$$\beta = \left(\sum_{j=1}^{N} \beta_j\right)/N.$$

Following Feenstra and Romalis (2014), the average willingness to pay increases with the average consumer income,

$$I = \left(\sum_{j=1}^{N} I_j\right)/N, \text{ so as } \beta = I^{\gamma}, \gamma > 0.$$

This implies that there is a finite reservation price (i.e., products are non-essential) increasing in product quality and per capita consumer income, and decreasing with consumer's non-homothetic preferences, equal to $I\lambda/\theta$.[87] The latter implies a more elastic inverse demand curve for higher values of θ, while when $\theta = 0$ the reservation price is infinite. The inverse demand for the typical variety is then given by:

$$\mathrm{p} = \frac{I^{\gamma} \lambda}{q N^{-1} + \theta} . \tag{B.4}$$

Hence, the export revenue of firm *j* is

$$\mathrm{R}(q, \lambda) \equiv pq = \frac{I^{\gamma} \lambda q}{q N^{-1} + \theta} . \tag{B.5}$$

B.2.2. Cost structure

The representative firm faces both fixed and variable costs. I assume that fixed costs increase with product quality and innovation expenditure, as both quality and innovation require initial investment costs.[88] For instance, an exporting firm requires an investment to organize a R&D Department that hosts any related activity focused on new or enhanced products, or that is

[87] As consumer utility is symmetric across products, I drop subscript i.

[88] See for instance, Kugler and Verhoogen (2012), and Eckel and Unger (2015).

effective in generating and implementing innovative ideas or adopt creatively evolving consumer tastes into production. It also requires an investment on product quality or a quality enhancing production investment, such as purchase superior technology machines that produce a final product of better quality, organize a quality-control department, or acquire a patent or a related certification. For expositional convenience, these fixed costs enter in a quadratic form given by $(\lambda r)^2/2$, which also ensures the existence of a well-defined and positive optimum in the profit maximization problem (see also Dinopoulos et al., 2020).

In addition, the exporting firm faces variable costs of production. Assuming that product quality is costly to produce as firms may employ higher quality inputs in the production process, variable costs increase with product quality. In contrast, innovation expenditures reduce marginal production costs (see Melitz, 2003; or Hallak and Sivadasan, 2013). For example, a producer might develop or employ innovative packaging to maintain his products safe or fresh. Finally, a firm faces credit constraints δ, where $\delta > 0$. At the micro level, financing constraints are expected to have a negative influence on a firm's growth (see for instance Beck et al., and 2005; Ayyagari et al., 2008). Thus, I assume that higher credit constraints affect the size of production and hence affect the firm's variable costs.

Given all the above, I assume the following cost function:

$$\mathrm{C}(q,\lambda) = \frac{(\lambda r)^2}{2} + \delta\frac{q\lambda}{r}. \tag{B.6}$$

B.2.3. Equilibrium

Each firm maximizes expected profit from exporting by choosing output, product quality and innovation expenditures, and by taking the level of credit constraints, as given. Substituting in the equations above leads to the following expression for export profits,

$$\pi(q,\lambda) = \frac{I^{\gamma}\lambda q}{qN^{-1}+\theta} - \frac{(\lambda r)^2}{2} - \delta\frac{q\lambda}{r} \tag{B.7}$$

Maximizing equation (B.7) with respect to output q, innovation expenditures r, and quality λ leads to the following first-order conditions:

$$\frac{I^{\gamma}\theta}{(qN^{-1}+\theta)^2} = \frac{\delta}{r}, \tag{B.8}$$

$$\frac{I^{\gamma}q}{(qN^{-1}+\theta)} = \lambda r^2 + \frac{\delta q}{r}, \tag{B.9}$$

(B.10)

$$R\left[\left(\frac{RI^{\gamma}\theta}{\delta\mu}\right)^{1/2} - \theta\right] = \frac{1}{N\delta}.$$

Now solving for the exported output yields

$$q = \left[\left(\frac{rI^{\gamma}\theta}{\delta}\right)^{1/2} - \theta\right]N, \tag{B.11}$$

which determines the equilibrium value of exported quantity.

Dividing the two first-order conditions (B.8) and (B.9) generates the following positive relationship between output and product quality:

$$\lambda = \frac{\delta}{r^3\theta N}q^2. \tag{B.12}$$

Substituting the expression (B.11) for q, we get that

$$\lambda = \frac{\delta}{r^3\theta N}\left[\left(\frac{rI^{\gamma}\theta}{\delta}\right)^{1/2} - \theta\right]^2 N^2, \tag{B.13}$$

which determines the equilibrium value of exported quality. Finally, innovation has a real, non-negative root that equals $root(\delta N^2\theta I^{\gamma} - 1 - 2\delta N\theta - \delta^2 N^2\theta^2)$. Consequently, there is also a non-negative closed-form solution for export price.

In order to investigate the relationship between product quality and innovation we take the derivative of the former with respect to the latter using (B.12),

$$\frac{d\lambda}{dr} = \frac{\delta\mu}{N\theta}(-3)r^{-4}\left[\left(\frac{rI^{\gamma}\theta}{\delta}\right)^{1/2} - \theta\right]^2 N^2 + \frac{\delta}{N\theta}2r^{-3}\left[\left(\frac{rI^{\gamma}\theta}{\delta}\right)^{1/2} - \theta\right]N\frac{1}{2}\left(\frac{I^{\gamma}\theta}{\delta}\right)^{1/2} r^{-1/2}$$

A necessary and sufficient condition for the derivative to be positive is:

$$\left(\frac{rI^{\gamma}\theta}{\delta}\right)^{1/2} > 3\left(\frac{rI^{\gamma}\theta}{\delta}\right)^{1/2} - 3\theta.$$

The last inequality implies that for $\delta < \frac{RI^{\gamma}}{\theta\mu}$ the relationship between product quality and innovation is positive, $\frac{d\lambda}{dr} > 0$. When $\delta > \frac{RI^{\gamma}}{\theta\mu}$, this relationship is negative, $\frac{d\lambda}{dR} < 0$.

In other words, *the relationship between product quality and innovation at the firm level is positive when the firm's credit constraints are below* $\frac{RI^{\gamma}}{\theta\mu}$, *but becomes negative when credit constraints are above this cut-off point.* Thus, I expect that when credit constraints are low, an increase on innovation expenditure induces a drop in variable costs. As a result, the firm can afford to increase its product quality. On the other hand, when a firm's credit constraints are high, the rise in innovation not reducing enough the variable costs, renders the rise in quality harmful for the firm's profits. In other words, even if any innovative effort reduces the variable costs of production (see among others Melitz, 2003; Hallak and Sivadasan, 2013), when an exporting firm is highly credit constrained, spending more on innovation does not counteract the increase of production costs. As a result, the production of higher quality products is hindered.

Figure B.1: Credit constraints, innovation, and product quality

$\frac{d\lambda}{dr} > 0$		$\frac{d\lambda}{dr} < 0$
low credit constraints	$\delta = \frac{RI^{\gamma}}{\theta\mu}$	high credit constraints