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Price, quality and trade costs in the food sector ☆

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ABSTRACT

Recent developments in international trade theory have placed considerable and growing emphasis on the quality of the exported products, showing that it affects both the direction of trade and the countries' export performances. However, as quality is unobservable, a measurement problem clearly emerges. In this paper we review and apply some of the most recent methods developed in the international trade literature to estimate quality of traded products. We focus on the food sector, where the growing attention on quality and safety issues is leading to an increase in the demand for high quality products. In the first part of our empirical analysis, we investigate the properties of the estimated qualities, drawing some interesting results. In particular we find that, in contrast with what is often assumed in the literature, quality and prices are imperfectly correlated. The second empirical section is dedicated to the study of the relationship between price vs. quality and trade costs. What emerges is that, interestingly, the price and the quality of food exports are influenced differently by *ad valorem* and specific trade costs. Moreover, the magnitude of this relationship changes according to the level of product differentiation.

Introduction

In recent years, the food sector has seen a growing importance of quality as a fundamental feature of products. This is particularly true for developed countries, where consumers are increasingly concerned about the quality of the food products they buy, and aware of nutrition and health issues (Caswell and Mojduszka, 1996; Grunert, 2005; Bontemps et al., 2012).

This attention toward quality has been exacerbated by the recent significant increase in trade of agri-food products. Due to the progressive fall in trade barriers, worldwide consumers have had access to a wider choice of differentiated products coming from various origins. Since exporting countries often have different institutions and regulatory framework with respect to the importers, consumers at home perceive a higher risk of dealing with unsafe products. As a consequence, they become increasingly concerned about food safety and quality (Krissof et al., 2002).

In order to meet consumers' needs, national and international policies are laying down stringent quality requirements to guarantee the production of higher quality goods. The last years have been marked by the diffusion of many public and private food standards. These policies have been set with the aim of raising minimum quality requirements and giving consumers further information on what they are actually eating.

Other policies have been developed with similar objectives. This is the case, for example, of the European Union (EU) quality schemes, which identify geographical indications and traditional specialties with the purpose of promoting and protecting names of quality foodstuffs. In a broader context, FAO has recently launched a program concerning origin-linked quality and geographical indication, with the aim of valuing domestic food products in developing countries.

In this framework, the enhancement of food quality represents an important driver for countries' development, as well as a fundamental step toward raising products competitiveness in the international market. It also presents new challenges, especially for developing countries aiming at exporting to rich countries, as they have to make their products meet the high quality requirements (Maertens and Swinnen, 2009; Henson et al., 2011; Minten et al., 2013; Olper et al., 2014).

The importance of quality has been stressed by several authors in the international trade literature. Indeed, quality is often recognized for its essential role in driving the direction of trade and viewed as a pre-condition for export success (Grossman and Helpman, 1991; Amiti and Khandelwal, 2013).[1] According to the quality ladder models of Grossman and Helpman (1991) and

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[1] Product quality enters the international trade models with the seminal contributions of Linder (1961), Flam and Helpman (1987) and Falvey and Kierzkowski (1987). The first empirical evidence about the role of quality in determining the international trade patterns can be found in Schott (2004) and Hallak (2010). At firm level, recent theoretical and empirical contributions allow quality to be heterogeneous across firms (Baldwin and Harrigan, 2011; Verhoogen, 2008; Crozet et al., 2012; Fajgelbaum et al., 2011; Crinò and Epifani, 2012; Curzi and Olper, 2012).

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Aghion and Howitt (1992), the ability of a country to upgrade the quality of exports can positively affect economic growth and development (see Hausmann et al., 2007).[2]

In this context, it is important for countries, as well as international organizations and policy makers, to be able to have access to as "objective" information as possible on the quality of traded foods. This helps, on one side, to identify the pattern of product quality, which can be useful, for example, to assess the effectiveness of quality oriented policies. On the other side, identifying product quality rankings could be valuable for the allocation of the resources aimed at enforcing food control strategies and for supporting products' compliance with national and international standards.

However, the study of product quality is hindered by the difficulty to measure it, as quality is unobservable. Indeed, quality depends more on consumers' perception than on objective features of products. Researchers have tried to deal with this problem by using proxies for quality, in most cases assuming a direct relationship between price and quality. This assumption, albeit convenient, may lead to an inaccurate measure of quality. Indeed, prices usually reflect several other elements that are not attributable to quality. Moreover, consumers do not always associate higher prices with better quality when buying a food product, but they look instead at other characteristics, such as the advertisement for the product and/or its nutritional and dietary characteristics.

To address this issue, some studies have recently developed alternative methods to infer products quality, with the aim of obtaining more reliable measures (see, e.g., Khandelwal, 2010; Hallak and Schott, 2011; Khandelwal et al., 2013; Feenstra and Romalis, 2014). These methods have the advantage of disentangling quality from trade unit value, leading thus to the estimation of a quality measure separate from price.

In this paper we apply the models by Khandelwal (2010) and Khandelwal et al. (2013) to estimate product quality from trade data in the food industry. These approaches are based on the intuition that, conditional on price, traded products with higher market shares are assigned higher quality. Once we obtain the quality estimates we propose two different empirical exercises, which share the objective of assessing whether the quality measure gives additional information with respect to the use of price. Moreover, the first application is aimed at investigating countries' competition strategies, while the second one has the objective of testing how trade costs affect quality and price of exported food products.

In the first empirical section, we use the method by Khandelwal (2010) to estimate the quality of EU-15 food imports from worldwide partners, using data covering the period 1995–2007.[3] We aim at analyzing the evolution of quality over time, in comparison with unit values growth. This allows us to assess whether the two indicators go in the same direction and, moreover, to identify countries' (industries') competition strategies in international markets. In particular, two main strategies are often identified by the literature: price and quality competition. However, previous works aimed at identifying which of the two strategies prevails (e.g. Baldwin and Harrigan, 2011; Baldwin and Ito, 2011; Crozet et al., 2011) made use of unit value as proxy for quality. Our paper adds value to this line of research by considering quality separately from the price of traded goods.

In the second empirical section, we explore the relationship between export prices vs. quality and trade costs. This topic is considered of relevant importance in the literature, particularly due to the progressive trade liberalization and the associated fall in trade barriers. The issue of how trade costs condition countries'/industries' exports has been widely studied by previous works, but only few studies made use of direct quality measures (see Amiti and Khandelwal, 2013; Curzi et al., 2015). Our analysis, compared to previous literature, allows splitting export prices into a quality and a *pure* price components, and then investigating the relationship between trade costs and these two measures. To do this, we make use of the quality measure obtained with the method by Khandelwal et al. (2013), as it allows separating the quality component of export prices (expressed as unit values) from the *pure* price (quality-adjusted price). The effect of trade costs on price and quality is investigated taking into account both *ad valorem* and specific tariffs.

The main results can be summarized as follows. The first empirical section shows that there is poor correlation between the evolution of our quality estimates and unit values over time. This result is in line with what was found by Hallak and Schott (2011), who showed that price and quality often move in two opposite directions. This finding suggests being careful when using price as a proxy for quality in empirical analyses, since this could lead to a misleading interpretation of the results. From the second empirical section, it turns out that trade costs cause different effects on price and quality of exports. This is another piece of evidence showing that quality and price capture different attributes of food products. This analysis also allows having a more complete picture of the effect of trade barriers on consumers' welfare. In particular, our results show that *ad valorem* tariffs have a negative impact on the quality of exported products, while specific tariffs lead countries to export higher priced products but tend to have no significant effect on quality.

The remainder of the paper is organized as follows. In Section 'Estimating quality from trade data', we review the main methods to estimate quality, focusing on the approaches proposed by Khandelwal (2010) and by Khandelwal et al. (2013). Section 'Data and estimations' presents the data and the quality estimation results. In Section 'Going inside our quality estimates' we analyze in-depth some properties of the obtained quality estimates, and we compare price growth with quality growth for different groups of countries. In Section 'Price, quality and trade costs', we use the quality estimates obtained with the Khandelwal et al. (2013) method to estimate the relationship between price vs. quality and trade costs. Section 'Conclusions' presents some concluding remarks.

Estimating quality from trade data

The growing importance assumed by the quality of exported products in explaining the international trade patterns leads to face a relevant issue, that is the measurement of the quality of traded products.

The most common proxy for quality used in the trade literature is unit value (price), defined as nominal value divided by physical quantity of a traded product. This indicator has been widely used in empirical studies relying on the conjecture that higher unit value means higher quality, like the important contributions of Schott (2004), Hummels and Klenow (2005) and Hallak (2006). These works provide the first formal evidence that export unit

[2] The necessity for developing countries to improve the quality of their food products when exporting to wealthier countries is pointed out by Asche et al. (2015), who analyze the case of fish. The authors show that developing countries tend to export high value fish to developed countries, while importing low value fish from other developing countries. This pattern of trade is due to an income effect, governed by the Bennet's Law, according to which as people become wealthier they substitute away from low-quality foods toward higher-quality foods.

[3] The food industry has been only marginally covered by the estimates in Khandelwal (2010), which focused on products imported to the US in other manufacturing industries. Food products were only marginally included among the analyzed sectors, since, according to the Rauch (1999) classification, they are largely considered as homogeneous goods, and thus do not exhibit substantial quality differentiation. Our work is instead focused on the European food market, estimating quality for food products exported from all the world countries to the EU.

values increase with both the per capita income of the foreign destinations and the skill and capital intensity of the exporter country.

Like any comprehensive indicator, unit value has advantages and disadvantages. Among the advantages, it is easily available for a wide range of products and countries even at a highly disaggregated level (up to ten-digit) and for bilateral trade flows (Aiginger, 2001). However, there is broad evidence in the literature showing that unit value is an imprecise measure of quality. One reason for this is that unit values could reflect not only quality, but also other products characteristics. For example, higher unit value could reflect higher production costs (Aiginger, 1997) or higher margins created by market power (Knetter, 1997).

To overcome these problems, some recent papers have tried to obtain a more reliable proxy for quality. The methods proposed by these works share the same intuition: countries selling larger quantities of physical output, being the price equal, are classified as higher quality producers. Based on this assumption, Hallak and Schott (2011) developed a method which allows decomposing export prices into two different components, one measuring quality and the other representing the *pure* price, defined as quality-adjusted price. The authors infer countries' exported products quality by combining data on their prices with information about global demand for them. The method by Hallak and Schott (2011), being based on global trade, is suitable for inferring quality at country or industry level, but does not allow going into products' level detail.

The method developed by Khandelwal (2010) overcomes this limitation measuring quality based on the nested logit demand system of Berry (1994), which embeds preferences for both horizontal and vertical attributes. In this method, quality represents the vertical component of the estimated model and captures the main valuation that consumers attach to an imported product. The procedure requires information on both import data (unit value and volume) and production quantity, and is based on a straightforward intuition: "conditional on price, imports with higher market shares are assigned higher quality". The main advantage of the Khandelwal (2010) approach is the possibility to obtain quality estimates at the very detailed product–country level and over time.

More recently, Khandelwal et al. (2013) developed a method to infer quality from a CES demand function, which is conceptually similar to the model in Khandelwal (2010). This method allows decomposing the unit value of traded goods into quality and quality-adjusted price, thus obtaining two different and complementary components.

All the methods explained above are based on the demand side, assuming that product quality is associated with higher utility for the (representative) consumer. In this view, quality products are not only aimed at satisfying consumers in the domestic markets, but also traded in order to meet the demand of consumers abroad (Chi-Hung, 2011).

This demand-side approach has been complemented by Feenstra and Romalis (2014), who developed a method to estimate quality considering also the supply side. Basing on the Melitz (2003) model with heterogeneous firms, this new approach allows for the optimal quality choice by firms. The use of a firm heterogeneity model with export cutoff implies a negative relationship between quality and bilateral trade: as foreign demand rises, less efficient firms start to export, leading to a decrease in products' quality. In richer and bigger countries, this effect acts as an opposing force with respect to the demand-side intuition, according to which consumers in higher income countries have a preference for high quality.

Among the methods recently proposed in the literature, we choose to implement the models in Khandelwal (2010) and in Khandelwal et al. (2013). These approaches are chosen among all the methods available, since they allow inferring quality at the maximum level of product–country disaggregation and over time. In the first empirical section of the paper we implement the method by Khandelwal (2010), which is our preferred model because, by using a nested logit demand approach, it makes use of a more reliable substitution pattern.[4] The empirical analysis developed in the last section of the paper requires instead the use of the method by Khandelwal et al. (2013) to measure product quality.

In what follows, we summarize the Khandelwal (2010) and Khandelwal et al. (2013) approaches, that we applied to the food sectors in the empirical analysis.

The Khandelwal (2010) method

The method in Khandelwal (2010) is based on the discrete choice model by Berry (1994) and in particular on the nested logit case. This approach has the advantage of allowing consumers' preferences to be correlated across products with similar characteristics. The original model by Berry (1994), summarized in Appendix A, has been extended by Khandelwal (2010) in order to infer quality from trade data. The main equation of the model, which allows estimating the quality of a product *j*, exported by a country *c* to country *i* at time *t* is the following:

$$\ln(s_{jcit}) - \ln(s_{0it}) = \xi_{1,jci} + \xi_{2,t} + \alpha p_{jcit} + \sigma \ln(ns_{jcit}) + \gamma \ln pop_{ct} + \xi_{3,jcit} \quad (1)$$

Here, s_{jcit} represents the inside variety's overall market share and is defined as $s_{jcit} = q_{jcit}/MKT_{it}$, where q_{jcit} is the imported quantity of this variety, and $MKT_{it} = \sum_{cj\neq 0} q_{jcit}/(1 - s_{0it})$ is the industry size. The outside variety s_{0it} represents the domestic alternative to the imported variety, and is computed as one minus the industry's import penetration.[5] $\xi_{1,jci}$ indicates the exporter–product fixed effects representing the time invariant component of quality, while $\xi_{2,t}$ accounts for the year fixed effects capturing the common quality component. Finally, $\xi_{3,jcit}$ is a variety-time specific deviation (residual). The term pop_{ct} represents the population of country *c*, and accounts for the so called hidden varieties.[6] The quality of product *j* exported by country *c* to country *i* at time *t*, ξ_{jcit}, is then inferred using the estimated parameters from (1) as follows:

$$\xi_{jcit} = \hat{\xi}_{1,jci} + \hat{\xi}_{2,t} + \hat{\xi}_{3,jcit}. \quad (2)$$

Quality is thus obtained as the sum of two fixed effects and a residual. The equation above relies on the intuitive idea that the quality of an imported variety is given by its relative market share, after controlling for exporter size and price.

The Khandelwal et al. (2013) method

Khandelwal et al. (2013) developed a method to infer product quality, conceptually similar to the one of Khandelwal (2010),

[4] The Khandelwal et al. (2013) approach needs an estimate of the elasticities of substitution to be implemented. Yet, these elasticities, normally taken from Broda et al. (2006), are only available for each country at the 3-digit level of the Harmonized System classification and, thus, produce a less appropriate pattern of substitution than in Khandelwal (2010). Moreover, several authors have shown empirically the limits of the use of a Constant Elasticity of Substitution (CES) utility function when analyzing trade in food products (see Gohin and Féménia, 2009; Liu and Yue, 2012). For a deeper discussion about the limits of the CES approach in the context of new trade theory, see Neary (2009); by contrast, for a more optimistic view, see Bertoletti and Epifani (2014).

[5] Import Penetration is defined as the ratio of imports over the sum of imports and production, and computed for each country, NACE 4-digit industry and year.

[6] The importance of this term is due to the fact that larger countries may have a greater market share just because they export more unobserved or hidden varieties within a product. In this framework, population is a proxy for hidden varieties, and it is assumed to be proportional to the number of firms.

but based on a different underlying utility function. Indeed, this method exploits the property of the CES demand function and defines, for a given importing country, consumers preferences for a variety v (product j, exported by country c), produced by industry i as:

$$U = \left[\int_{v \in V} [\lambda(v)q(v)]^{(\sigma-1)/\sigma} dv \right]^{\sigma/(\sigma-1)} \quad (3)$$

where $q(v)$ represents the consumed quantity of variety v, $\lambda(v)$ identifies quality, and $\sigma > 1$ is the elasticity of substitution. Then, the consumers' demand for a product j, exported by a country c to a country i in year t is given by the maximization of the relation (3), under the usual budget constraint, obtaining:

$$q_{jcit} = (\lambda_{jcit})^{\sigma-1} (p_{jcit})^{-\sigma} P_{ct}^{-\sigma} Y_{ct} \quad (4)$$

where p_{jcit} is the price of the exported variety, while λ_{jcit} represents the relative quality attributed by the consumer. P_{ct} and Y_{ct} are, respectively, the ideal price index associated with (4) and the total amount spent for industry i's varieties. After taking the logs of (4), the following OLS regression can be estimated:

$$\ln q_{jcit} + \sigma \ln p_{jcit} = \alpha_j + \alpha_{ct} + e_{jcit} \quad (5)$$

where q_{jcit} and p_{jcit} are, respectively, the quantity and the price (unit value) of product h, exported by country c to country i at time t. α_j and α_{ct} account for product and exporter–year fixed effects, respectively. e_{jcit} is an error term. Quality is then estimated taking the residual from (5), and dividing it by the country–industry specific elasticity of substitution minus 1. Thus, *quality* $= \hat{\xi}_{jcit} \equiv \hat{e}_{jcit}/(\sigma - 1)$.

Moreover, once quality has been estimated, this method allows us to obtain the quality-adjusted-price component, $\hat{\delta}_{jcit}$, as follows: $\hat{\delta}_{jcit} \equiv \ln p_{jcit} - \hat{\xi}_{jcit}$.

Data and estimations

Regarding the Khandelwal (2010) method, we estimate Eq. (1) considering each member of the European Union with 15 countries (EU-15) separately (except Luxembourg, which has been excluded due to the lack of production data), to measure the quality of the food products imported from all trading partners in the world with data (including intra-EU trade). As we consider more than one importing country, we mitigate the potential bias due to specific country preferences toward certain products, which may occur when working on a single destination market.

We exploit the information on yearly trade value and volume from the EUROSTAT Comext database at the maximum level of disaggregation, namely the Combined Nomenclature (hereafter CN) 8-digit level. We collect data over the period 1995–2007, considering 2007 as the final year because extending the analysis to subsequent years may introduce noise in our quality estimates due to the 2008 and 2010 price spikes and 2009 financial crisis.

Data on the volume of the domestic production for each of the considered EU-15 countries are drawn from the EUROSTAT PRODCOM (*PRODuction COMmunautaire*) database. Production data are available at 8-digit level according to the PRODCOM classification, which is directly connected to the Statistical Classification of Economic Activities in the European Community (*Nomenclature statistique des Activités économiques dans la Communauté Européenne* – hereafter NACE) at the 4-digit level, as the first four digits of the PRODCOM code correspond to the 4-digit NACE industry.

The final database has more than 1,000,000 observations and contains information on the quality of more than 2200 CN 8-digit food products exported by 150 countries in the EU-15. The CN 8-digit food products are mapped into 21 industries according to the NACE 4-digit Revision 1.1 classification, through appropriate corresponding tables provided by EUROSTAT. We estimate Eq. (1) using both ordinary least square (OLS) and Two-Stage least squares (2SLS) regression (our preferred one). The instrumental variable approach is required because, looking at the right-hand side of Eq. (1), a potential endogeneity problem emerges, due to the correlation of the error term, $\xi_{3,jcit}$ with both the nest share and the j-variety's price. Indeed, both variables are clearly endogenous to the market share. To this end, as proposed by Khandelwal (2010) and, especially, by Colantone and Crinò (2014), the following variables are used as instruments for the price and the nest share: the interaction between unit transportation costs and the distance from c, and the interaction between the oil price and the distance from c[7]; the number of varieties within each product j, and the number of varieties exported by each trading partner.

Concerning the method by Khandelwal et al. (2013), data on the value and the volume of the exported food products are taken from the BACI (*Base pour l'Analyse du Commerce International*) database of CEPII (*Centre d' Etudes Prospectives et d'Informations Internationales*). The main advantage of these data is that they have been obtained through a procedure that corrects discrepancies between the import values, generally reported as CIF (cost, insurance and freight), and export values, reported as FOB (free on board) (for further details see Gaulier and Zignago, 2010).

We run Eq. (5) separately for each country in the sample and NACE 4-digit industry. Country–industry specific elasticities of substitution are taken from Broda et al. (2006). Since these elasticities are just available at the Harmonized System (hereafter HS) 3-digit level of disaggregation, following Colantone and Crinò (2014), we take the median values of all the corresponding HS 3-digit products, and we aggregate them at the NACE 4-digit level of disaggregation.

The use of the Khandelwal et al. (2013) method, with respect to the model in Khandelwal (2010), allows estimating quality for a larger sample of countries. Indeed, it does not require information on production (which is available just for few countries), and it is easier to implement, since an instrumental variable approach is not needed. For this reason, it allows considering not only EU-15 importers, but all importing and exporting countries worldwide. Using the method mentioned above, we measure product quality at the HS 6-digit level of disaggregation for the years 1995–2007.

In our second empirical application, we study whether trade costs affect price and quality of the exported food products across different destinations. We use FOB instead of CIF prices because they do not take into account freight costs. The use of CIF prices, which include freight costs, might in fact lead to a predetermined result. Data on trade costs come from the Market Access Map (MAcMap) database, which has been developed jointly by ITC (UNCTAD-WTO, Geneva) and CEPII. MAcMap provides data on bilateral duties at the HS 6-digit level of disaggregation for 189 importing countries, applied to 220 exporting partners for three specific years: 2001, 2004 and 2007. Duties are comprehensive of their *ad valorem* and specific (per unit) components, being the former expressed as a percentage, while the latter in current dollars per ton and then converted into *ad valorem* equivalent.

[7] Oil prices come from Brent. Bilateral distance is measured as the population-weighted kilometers between the two countries' largest cities, provided by CEPII. Since data on unit transportation costs are not available from Eurostat, following Colantone and Crinò (2014) we compute product-level transportation costs starting from variety-specific unit transportation costs for the United States (US) provided by Feenstra et al. (2002). Then, these transportation costs are regressed on partner fixed effects, in order to remove the influence of the US. From this regression we take the average of the residual across all partners within each 6-digit product code.

Table 1
Summary statistics of quality estimates.

	Khandelwal (2010)		Khandelwal et al. (2013)
	(1) OLS	(2) 2SLS	(3) OLS
Price *(mean)*	−0.260	−0.735	
Nest share *(mean)*	0.877	0.677	
Sargan test (*p*-value) *(mean)*		0.15	
R-squared	0.851	0.852	0.64
Observation per estimation *(mean)*	4378	4378	2313
Varieties per estimation *(mean)*	635	635	452
Total number of estimations	468	468	1849
Total observations across all estimations	1,138,022	1,138,022	4,310,988

Notes: This table reports estimation statistics for the quality estimates. Columns 1 and 2 report the results coming from running Eq. (1) separately for each of the EU-15 importing country–NACE 4-digit food industry in our sample using both OLS and 2SLS. The Sargan test has been computed in order to test whether the instruments are uncorrelated with the error term. Column 3 reports the results of running Eq. (5) separately for each of the exporting countries–NACE 4-digit industry in our sample.

Going inside our quality estimates

In this section we first present some statistics about the results of the quality estimates obtained with the methods of Khandelwal (2010) and Khandelwal et al. (2013). Then, considering the estimates coming from the Khandelwal (2010) approach, we show the quality rankings for two selected products, wine and beer. These two examples are aimed at explaining the mechanism behind the estimation method and interpreting the main results. Afterward, we move to testing the correlation between price and quality growth. This analysis has the objective of assessing whether the two measures have a similar evolution path or not, and, moreover, it allows us to draw some implications on countrie s'/industries' export competition strategies.

Quality estimations

Table 1 shows the summary statistics about our quality estimates. In order to estimate product quality with the method by Khandelwal (2010) we run Eq. (1) separately for each EU-15 imported country–NACE 4-digit industry. Columns 1 and 2 of Table 1 summarize the average parameters obtained by estimating Eq. (1). We run 468 different regressions (considering both OLS and 2SLS), with an average number of observations per estimation of 4378. Importantly, the pattern of estimated signs and the mean values of the price and nest share elasticities match the results in Khandelwal (2010) and especially the outcomes in Colantone and Crinò (2014), who estimated quality with the Khandelwal (2010) method in the EU market. In particular, note that the median IV price coefficient is about 3 times higher in absolute value than in the OLS model, suggesting that the 2SLS approach moved the price coefficient in the expected direction. Moreover, the mean *p*-value computed from the Sargan test suggests that the validity of the over-identifying restrictions cannot be rejected. Column 3 reports some summary statistics about the quality estimates obtained with the method by Khandelwal et al. (2013). We run Eq. (5) separately for each exporting country–NACE 4-digit industry, thus producing 1849 estimates.[8] The average *R*-squared is 0.64, while the average number of observations and varieties per estimation are 2313 and 452, respectively. Finally, the total number of exported food products for which we measure quality is 4,310,988.

Before using the estimated quality in our empirical applications, following Amiti and Khandelwal (2013), we apply some standard cleaning procedures. First, we drop varieties with unit values falling below the 5th or above the 95th percentile of the distribution within industries. Second, varieties with less than 4 observations detected at least twice are dropped. Third, we exclude varieties with an annual price growth falling below the 1st or above the 99th percentiles of the overall price growth distribution. Finally, as the quality estimates obtained can be noisy, the estimates falling below the 5th and above the 95th percentiles are dropped. After these cleaning procedures, the total number of observations changes from 1,138,022 to 846,063 for the Khandelwal (2010) estimation approach, and from 4,310,988 to 3,602,033 for the Khandelwal et al. (2013) methodology.

In order to give a better understanding of the pattern of quality estimates, Fig. 1 shows the NACE 4-digit food industries for which we measured product quality with the Khandelwal (2010) method, as well as the number of CN 8-digit products belonging to each sector (line graph). Moreover, Fig. 1 shows the average food industry quality ladder. Following the approach by Khandelwal (2010), quality ladder has been computed for each product category (CN 8-digit) as the difference between the maximum and the minimum value of quality for the first year of the considered period. Identifying the quality ladder of a specific product is interesting, since it gives information on products' market scope for quality differentiation.

By definition, in sectors characterized by a long quality ladder vertical product differentiation prevails, and thus, products are highly differentiated. By contrast, sectors showing a short quality ladder are the ones with lower quality differentiation, where horizontal product differentiation prevails. When two products are vertically differentiated, all consumers would prefer one to the other if they were sold at the same price (e.g. 30 years vs. 5 years old Whisky). By contrast, with horizontal differentiation, goods are different but at the same price some consumers will buy one and some will buy other, depending on their preferences (e.g. Pepsi and Coca Cola).

The results in Fig. 1 show that the food industries characterized by the highest quality differentiation are the meat products' sector (1511–1512–1513) and the production of alcoholic beverages, in particular distilled beverages (1591) and wines (1593).[9] Considering for example the wine sector, here the products are highly diversified, and often possess a strong identity and reputation which is related to the area of origin or to a particular brand. Food sectors where horizontal product differentiation prevails are instead the manufacture of bread (1581), beer (1596), fish products (1520) and mineral waters (1598). For these products, differently from the previous ones, diversification is not based on big quality differences between one variety and another, but more on horizontal attributes which allow distinguishing one product from the others.

To give a better idea of how the results from our quality estimation can be read, we present in Fig. 2 the estimated quality for a representative red wine category (CN 8-digit code 22042180). This measure is obtained as an average of the estimated qualities across importing countries in the first year of the period (1995). The upper panel ranks the average quality across the considered period.[10] As we have seen from the specification of the estimation

[8] Since the covariates in Eq. (5) are product and country–year fixed effects, we do not report any coefficient in Table 1.

[9] Due to the lack of production data for some importing countries we did the following aggregations: codes 1531, 1532, and 1533 are included in code 1530; codes 1541, 1542, and 1543 are included in the code 1540; codes 1551 and 1552 are included in code 1550; codes 1561 and 1562 are included in code 1560; codes 1583 and 1584 are included in code 1580; and finally codes 1592, 1594, and 1595 are included in the code 1590.

[10] The estimated quality from (1) has been normalized and then standardized (with mean 0 and variance 1) within each product category (nest) in order to control for the potential bias in the distribution of quality estimates, due to the different product structure of exports from various countries.

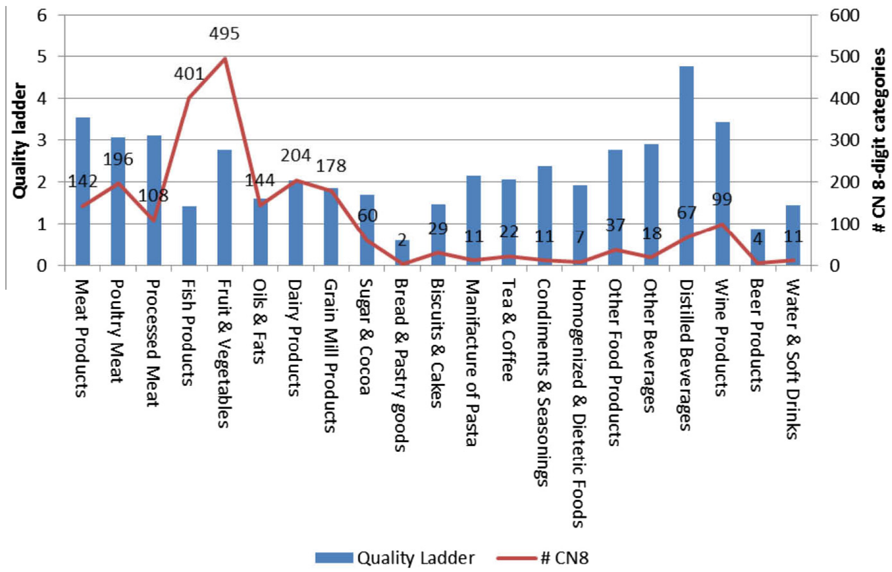

Fig. 1. Number of products and average quality ladder for the considered food sectors. *Notes*: This figure reports information on the NACE 4-digit food industries for which we estimated Eq. (1), considering separately each EU-15 country. The line graph shows data on the number of CN 8-digit products belonging to each NACE 4-digit industries. The histograms show the mean quality ladder level associated to each NACE 4-digit industry.

method by Khandelwal (2010), quality is comparable within each product category between the different exporters. Considering wine, the top quality exporters are France and Italy. The bottom panel shows the average price and the average market share within its 8-digit category. This is useful to understand the logic behind the implemented quality estimation: quality is in fact a measure of market share, obtained after controlling for price. We can see immediately that, within a category, the highest price products are not always the highest quality ones. For example, the wine from New Zealand, despite its very high price, is ranked fourth for quality because of its very low market share. By contrast French wine, which despite its high price is the one that consumers buy more on average, is first in the ranking.

The same information presented in Fig. 2 is replicated in Fig. 3 for beer. Here, the first two exporters for the quality of their products are Belgium and Denmark. Interestingly, when comparing the two products, wine and beer, the former displays a high variability across countries in terms of quality, while the latter shows a narrower quality range. This is in line with what emerges from the definition of quality ladders, suggesting that beer is a good whose differentiation is mainly based on horizontal attributes.

Price vs. quality growth

A central question related to the quality estimates is represented by their relationship with price, until now the most used proxy for quality. Thus, as a further step, we compare quality and price growth between 1995 and 2007. This analysis gives back a picture in sharp contrast with the common assumption that quality and price go hand in hand. When considering the whole sample, the correlation between the average quality and price growth, both normalized within each product category, is negative and close to zero (−0.01). This finding provides evidence that quality and price give different and complementary information when analyzing competition strategies of countries in the international trade market.[11] In order to make the results clearer and to identify the specificities of the considered countries, we present in Fig. 4 the correlation between price and quality growth in the period 1995–2007 for OECD and a sample of the major non-OECD (or emerging) countries, selected on the basis of the Financial Times Stock Exchange (FTSE) classification.[12] Quality growth is obtained here as the mean across all product codes available in the data. Considering the OECD sample, most of the countries show a positive quality growth in the considered period. However, in most cases, this is not linked to a corresponding growth of products' unit values but, quite surprisingly, to their reduction. This is even more evident when considering the sample of emerging countries. Here, by splitting the sample in advanced and secondary emerging countries according to the Financial Times Stock Exchange (FTSE) classification, we find that all the secondary emerging countries show a dynamic of price reduction. By contrast, some of the advanced emerging countries display a price increase pattern. However, all the countries which experienced a price reduction show a quality upgrading. Interestingly, all the Asiatic countries of this sample display such a pattern. This is in line with what pointed out by Lall and Albaladejo (2004), namely that China's competitive pressure is pushing its neighbors to raise their technological skills and thus the quality of their exports, while keeping competitive prices. By contrast, some countries whose price rose show a reduction in quality.

This dynamic is also evident when considering one single sector. In Fig. 5, we take as representative example the wine production. This sector has some interesting peculiarities, since it is characterized by three main producers and exporters (France, Italy and Spain). However, in the last decades some extra-EU countries have been becoming increasingly important in terms of production and exports. In Fig. 5 we compare quality and price growth between 1995 and 2007 in the overall wine sector (NACE 4-digit code 1593). The main results show that French and Italian wines, universally known as the highest quality ones, have increased in both quality and price. This means that, despite the price growth, consumers still show a preference toward these wines. By contrast, Spain and some extra-EU countries, whose

[11] Evidence of the fact that price and quality give different information has already been provided by Curzi et al. (2013), who tested the "collapse in quality" hypothesis during the 2008–2009 financial crisis.

[12] Countries have been classified as OECD and non-OECD according to the category they belong to in the first year of the analyzed period (1995).

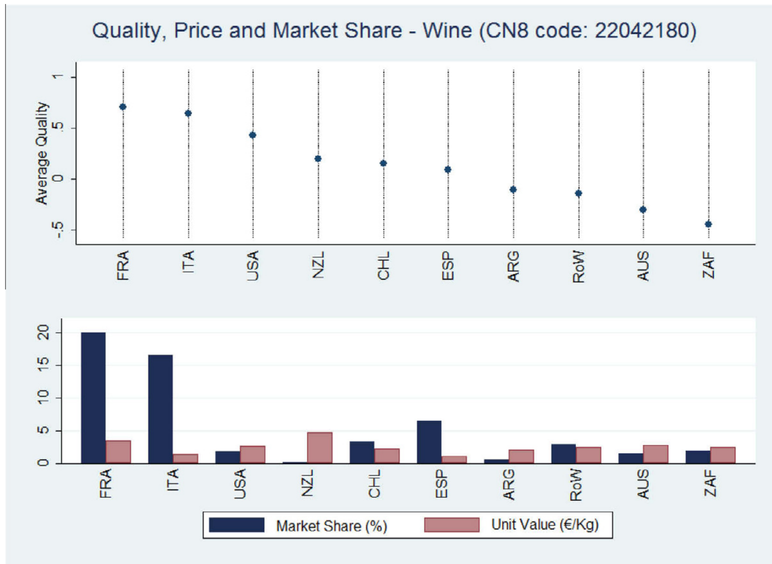

Fig. 2. Average quality, price and market share for red wine. *Notes*: Countries are ranked basing on their mean quality value in the year 1995 (see text for calculation details). Countries in the figure are presented with their ISO 3-digit code. The extended names of the countries are the following: FRA – France; ITA – Italy; USA – United States of America; NZL – New Zealand; CHL – Chile; ESP – Spain; ARG – Argentina; AUS – Australia; ZAF – South Africa; RoW – Rest of the World.

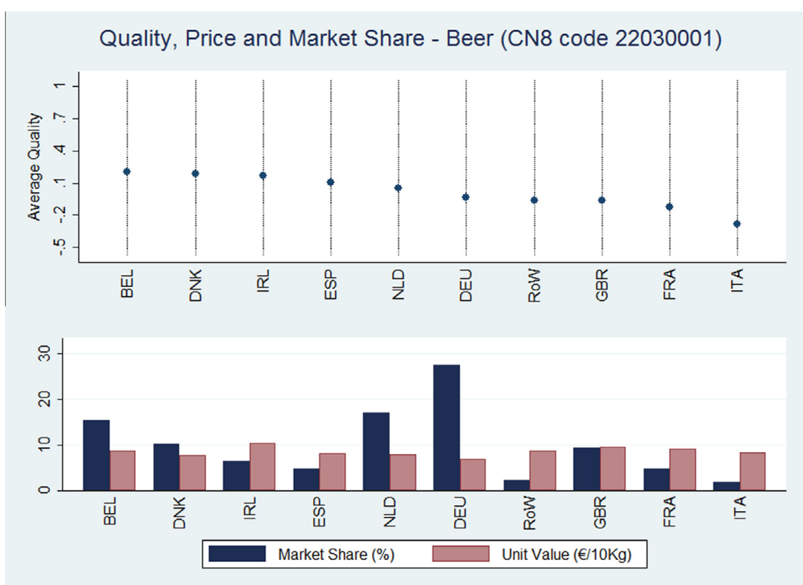

Fig. 3. Average quality, price and market share for beer. *Notes*: Countries are ranked based on their mean quality value in the year 1995 (see text for calculation details). Countries in the figure are presented with their ISO 3-digit code. The extended names of the countries are the following: BEL – Belgium; DNK – Denmark; IRL – Ireland; ESP – Spain; NLD – The Netherlands; DEU – Germany; GBR – Great Britain; FRA – France; ITA – Italy; RoW – Rest of the World.

wine sector is developing at a fast rate, show a decrease in prices joint with an increase in quality. This is in line with the recent dynamics of the wine sector, where French and Italian wines maintain their top positions in term of quality, while, at the same time, consumers start to know and appreciate wines coming from non-traditional producers. Indeed, Anderson et al. (2003) and Anderson (2010) point out that, in recent years, Italy and France have been facing growing competition from new producers such as Australia, New Zealand, California, Chile and Argentina, whose wines, characterized by a lower cost, are becoming more and more sophisticated. As an example, Argentinean and Chilean wines, whose exports were close to zero in the 80's, represent now the 5% and the 10% of global wine exports (Parcero and Villanueva, 2012).

Price, quality and trade costs

In this section of the paper we estimate the effect of two different trade costs, specific and *ad valorem* tariffs, on price and quality of exports. This issue is relevant and innovative, since no paper to date has included a specific quality measure in this kind of analysis. In the first paragraph we present the theoretical background of

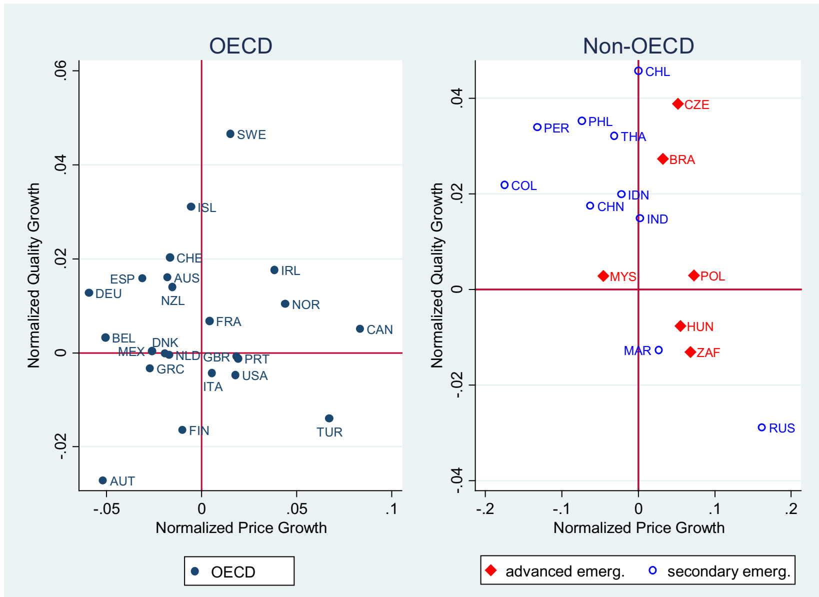

Fig. 4. Change in quality and price (1995–2007), OECD vs. non-OECD countries. *Notes*: This figure shows a comparison between normalized quality (*y*-axis) vs. normalized price (*x*-axis) growth in the period 1995–2007 for the sample of OECD and non-OECD countries. Non-OECD countries are classified into advanced and secondary emerging according to the Financial Times Stock Exchange (FTSE) classification. Countries in the figure are presented with their ISO 3-digit code.

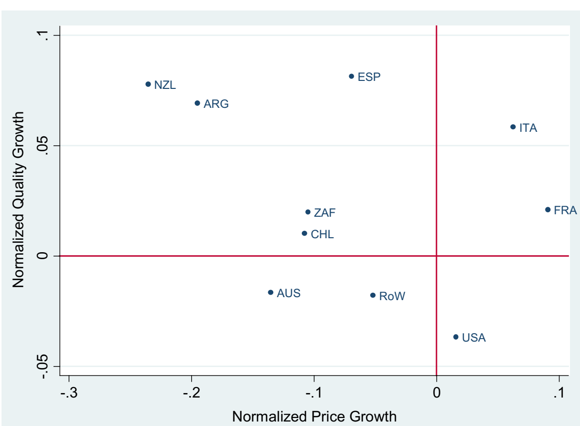

Fig. 5. Change in quality vs price – wine sector (1995–2007). *Notes:* This figure shows a comparison between normalized quality (*y*-axis) vs. normalized price (*x*-axis) growth in the period 1995–2007 for a representative sample of countries typical wine producers. Countries in the figure are presented with their ISO 3-digit code.

our study and the empirical strategy we implement. In the second one, the main results are displayed and commented.

Motivations and empirical strategy

In contrast with some important trade models, where exporters charge the same prices to all the destination markets (Krugman, 1980; Eaton and Kortum, 2002; Melitz, 2003), trade data on the export of food products show that free on board (FOB) prices considerably vary depending on the destination markets. Among the different reasons driving such variation, the fact that different destinations imply different trade costs (e.g. transportation costs and tariffs) could be relevant. The importance of trade costs in determining heterogeneity in export prices has been pointed out by several empirical studies, like the contributions of Hummels and Skiba (2004), Martin (2012) and Emlinger and Guimbard (2013).

In particular, we follow the work by Hummels and Skiba (2004), which studied the relationship between FOB prices and two different trade costs – specific and *ad valorem* costs – finding that the variation in prices of exports significantly depends on the level of trade costs that exporters have to face. Considering an import bundle and assuming that price is a proxy for quality, the shares of high-relative to low-quality goods are found to be increasing in per unit costs and decreasing in *ad valorem* costs. These results can be theoretically explained by two different mechanisms. On the one hand, the positive relationship between quality and per unit tariffs can be explained by the Alchian–Allen effect (Alchian and Allen, 1964), which states that higher priced (quality) products are exported to more distant countries in order to offset the higher transportation costs. On the other hand, the negative relationship between quality and *ad valorem* costs seems to be due to a pricing-to-market (PTM) behavior. This mechanism implies that *ad valorem* tariff shocks are partially absorbed by the exporter, which basically reduces its markup in order to be competitive, keeping quality unaffected.

These mechanisms – PTM and Alchian–Allen – offset each other and, according to Hummels and Skiba (2004), need to be considered together when estimating the relationship between trade costs and price. Hummels and Skiba (2004), in their empirical analysis, assume that price is a proxy for quality, thus interpreting the elasticity of prices as an elasticity of quality with respect to trade costs. However, with a more precise measure of quality in hand, an interesting question to answer is the following: how much of the variation in prices due to differences in trade costs is attributable to *pure* prices, and how much to quality?

Our contribution is aimed at answering this question. The main added value of our study as compared to previous ones is the possibility of estimating the effects of trade costs on *pure* price and quality separately. This is done by using the model proposed by Khandelwal et al. (2013), which allows decomposing FOB price into quality and quality-adjusted-price, as explained in Section 'The Khandelwal et al. (2013) method'. In our empirical approach, bilateral FOB prices and their two components are regressed on bilateral *ad valorem* and specific tariffs. Following Emlinger and Guimbard (2013), who provided support for the Alchian–Allen effect on the agricultural markets, we use specific tariffs –

expressed in amount of money per unit imported (usually Tons) – to test the effect of per unit trade costs on the prices of exported products. This is a difference between our analysis and previous studies, which made use of per unit freight costs (Hummels and Skiba, 2004) or, more extensively, per unit transportation costs proxied with bilateral distances (e.g. Hummels and Klenow, 2005; Baldwin and Harrigan, 2011; Martin, 2012). The use of specific tariffs has some important advantages. First, they are a precise measure of specific trade costs, while distance, as argued by Hummels and Skiba (2004), could be an imperfect proxy for unit transportation costs. Second, specific tariffs are particularly relevant in the agri-food trade, being often blamed for representing a protectionist measure set by developed countries to oppose the competition coming from low income countries. Finally, since specific tariffs are complementary to *ad valorem* ones, the use of the two protection instruments together allows having a more comprehensive picture of countries' trade barriers.

In our empirical approach, we aim at testing whether the variation in price and quality of exported food products across destinations is influenced by trade costs. In order to capture this variation, following Hummels and Skiba (2004), we take the difference between all variables and their means over a given exporter c and HS 6-digit product j. We employ a cross section relative to 2007, the latest available year in our dataset. The equation we test takes the following form:

$$\ln y_{jci} - \overline{\ln y_{jc}} = \beta(\ln adv_{jci} - \overline{\ln adv_{jc}}) + \gamma(\ln spc_{jci} - \overline{\ln spc_{jc}}) + \delta(\ln GDP_i - \overline{\ln GDP_{jc}}) + (\varepsilon_{jci} - \overline{\varepsilon_{jc}}) \quad (6)$$

where y_{jci} refers alternately to FOB price, quality and quality-adjusted-price of product j, exported from country c to country i, adv_{jci} while and spc_{jci} refer to the *ad valorem* and specific tariffs on product j exported from country c to country i, respectively.[13,14] Finally, GDP_i refers to the per capita income of the importing country i. This specification, conditioning on the exporter and commodity, allows examining variations across destinations i.

The use of OLS when estimating Eq. (6) may lead to biased results, due to the potential simultaneous determination of price (as well as its two components) and specific tariff. The relationship between price and specific tariffs may be subject to endogeneity, since countries tend to protect their domestic sectors more when they face competition from cheaper imports. Moreover, there are some variables which influence simultaneously price, quality and tariffs, like for example a country's preference toward high quality products. In order to overcome these problems, we rely on an Instrumental Variables (IV) approach. However, finding appropriate instruments, which are correlated with our endogenous variable but uncorrelated with the error term, is not straightforward. In order to deal with this issue, we follow a strand of existing papers in the international trade literature that instrument difference in tariffs with lagged level of tariffs (see Goldberg and Pavcnik, 2005; Hasan et al., 2012; Amiti and Cameron, 2012; Ahsan, 2013; Yanikkaya, 2003).[15] In our case, lagged values of specific tariffs are used as instruments for the difference between bilateral specific tariffs in the year of interest for a given product and the mean of tariffs across all destination countries for the same exporter–product pair. The use of these instruments is motivated by the particular structure and evolution of specific tariffs over time, as it clearly emerges from the data. Indeed, specific tariffs are equal to zero in most of the cases (about 90%), while they are positive in few cases (about 10%). Our data show that, when specific tariffs are positive in the first and second available years (i.e. 2001 and 2004), they are rarely removed in the latest year (i.e. 2007).[16] This persistency allows establishing a positive correlation between past specific tariffs and current ones. This translates into a positive correlation between lagged tariffs and the deviation of current bilateral specific tariffs from the mean of tariffs across all destination countries for a given product.[17]

Finally, we test whether the relationship between price, quality and trade costs is affected by the level of product differentiation by estimating Eq. (6) separately on the sample of horizontally and vertically differentiated products.

Results

Table 2 presents the results of estimating Eq. (6) with our IV approach.[18] The results in column 1 suggest that higher priced products are exported toward destinations where higher specific tariffs are implemented, while the opposite holds when *ad valorem* tariffs are considered. Moreover, we find a positive and significant coefficient for the importers' per capita GDP, which means that higher priced products are exported to richer countries.[19] Overall, these results are in line with previous findings in the literature (e.g. Hummels and Skiba, 2004; Martin, 2012; Emlinger and Guimbard, 2013). The innovative contribution of our analysis is presented in the next columns of Table 2. Here, the results shown in column 1 are decomposed to quantify separately the contributions of quality and quality-adjusted-price to the relationship between tariffs and FOB prices.[20] What clearly emerges from columns 2 and 3 is that the contribution of the two components is remarkably different when considering specific vs. *ad valorem* tariffs. Indeed, *ad valorem* tariffs prove to affect the quality component much more than the *pure* price, while the opposite holds for specific tariffs.

Looking in more detail at the results, column 1 shows that a 10% increase in the specific tariffs leads to a 0.78% increase of the FOB prices of the exported products. When considering the results in columns 2 and 3, where FOB prices are split into their two components, it emerges that a 10% increase in the specific tariffs leads to a

[13] For comparability with *ad valorem* tariffs, specific tariffs are converted in *ad valorem* equivalent (AVE) following Bouët et al. (2008) and Emlinger and Guimbard (2013). This is done by dividing specific tariffs expressed as per unit duties by the unit value of a reference group to which the exporter belongs, which represents the median unit value of worldwide exports of the same reference group. For detailed information on the reference groups' composition, see Bouët et al. (2008).

[14] Note that, following the international trade literature, in order to address the issue of the log transformation of zero tariff values, we computed the log of specific and *ad valorem* tariffs as follows: log(1 + tariff).

[15] Note that, as recently pointed out by Bellemare et al. (2015), the use of lagged explanatory variables as instruments in an Instrumental Variables approach may not be the ideal solution to address an endogeneity bias. Indeed, according to the authors, using lagged values could just move backwards the channel through which the endogeneity biases the estimates. This happens because using lags implies the assumption of "no dynamics among *unobservable*", which is very rarely defensible.

[16] Our data show that just 10% of the specific tariffs present in 2001 and 2004 have been removed in the 2007. In most cases, specific tariffs experienced a slight reduction in the considered period.

[17] Due to the high number of zeros, the mean of specific tariffs across all destination countries for a given product is in almost all cases lower as compared to the lowest positive specific tariff. Thus, where bilateral tariffs are positive, their difference from the mean across all destination countries for a given country–product pair will be in most cases positive too. As a consequence, lagged tariffs are positively related not only to current tariffs, but also to their difference from the mean. This makes it possible to use them as an instrument for our endogenous variable.

[18] The results of the first stage of the 2SLS are reported in Appendix Table A1.

[19] The Wu–Hausman test rejected the null hypothesis, suggesting that the 2SLS approach should be preferred to the OLS. Moreover, note that, as reported by the tests at the bottom of Table 2, our instruments comfortably pass the overidentification test, while the reported *F*-statistic computed on the first stage allows rejecting the null hypothesis of weak instruments.

[20] Note that, by construction, the sum of the coefficients obtained by regressing quality and quality-adjusted-price on each of the three covariates of our empirical equation will return the coefficient obtained by regressing the FOB price on the same variables. The reason behind this is that FOB prices are mathematically decomposed into their two complementary components, namely quality and quality-adjusted-price.

Table 2
Price, quality and trade costs.

	All sample			Short quality ladder			Long quality ladder		
	(1) Price	(2) Quality	(3) Quality-adj-price	(4) Price	(5) Quality	(6) Quality-adj-price	(7) Price	(8) Quality	(9) Quality-adj-price
(ln) Specific	0.078***	0.023***	0.055***	0.075***	0.006*	0.068***	0.080***	0.027***	0.052***
	(0.0016)	(0.0023)	(0.0022)	(0.0026)	(0.0032)	(0.0033)	(0.0021)	(0.0033)	(0.0031)
(ln) Ad valorem	−0.335***	−0.262***	−0.073***	−0.287***	−0.178***	−0.108***	−0.403***	−0.334***	−0.07*
	(0.0150)	(0.0222)	(0.0213)	(0.0183)	(0.0223)	(0.0230)	(0.0243)	(0.0392)	(0.0367)
(ln) per capita GDP (importer)	0.015***	0.011***	0.004***	0.012***	−0.003***	0.016***	0.019***	0.017***	0.002
	(0.0008)	(0.0012)	(0.0012)	(0.0011)	(0.0013)	(0.0013)	(0.0015)	(0.0024)	(0.0022)
Weak instruments (*F*-stat)	135,597	135,597	135,597	44,498	44,498	44,498	87,196	87,196	87,196
Overid Sargan statistic	2.39	2.73	0.40	0.008	0.011	0.03	2.32	1.4	0.068
p-value	0.12	0.10	0.52	0.92	0.92	0.86	0.13	0.23	0.79
N	143,223	143,223	143,223	71,132	71,132	71,132	72,091	72,091	72,091

Notes: This table shows the results of the IV estimation obtained by regressing FOB price, quality and quality-adjusted price on the (log) of import ad valorem and specific tariffs and the (log) of the importer per capita GDP. All these variables are expressed as their difference from the mean across all the destination countries for a given country–product pair. The instruments used for the specific tariff are the lagged specific tariff at time $T-3$ and $T-6$. The table reports the Stock and Yogo *F*-statistic to test the strength of the set of instruments, and the overidentification Sargan test. Significance levels: *0.10 **0.05 ***0.01.

0.23% increase in the quality of exported products and to a 0.55% increase in the quality-adjusted-price component. By contrast, a 10% increase in *ad valorem* tariffs leads to a 3.35% reduction in FOB prices. This corresponds to a 2.62% reduction in the quality component and to a 0.73% decrease in quality-adjusted-price.

To quantify the contribution of the quality component to the elasticity of FOB prices to tariffs, we compute the ratio between the coefficient on the quality component and the one on FOB prices (=0.023/0.078). This calculation reveals that quality accounts for about 29% of the overall FOB prices elasticity. Applying the same logic to *ad valorem* tariffs, we find that the contribution of the quality component to the result relative to FOB prices is about 78% (=0.262/0.335). The results in column 3 on the quality-adjusted-price component are complementary to those in column 2 in explaining the overall coefficients presented in column 1. Thus, the contribution of the *pure* price component to the overall elasticity of prices to tariffs is 71% (=0.055/0.078) for specific tariffs and 22% (=0.073/0.335) for *ad valorem* tariffs.

The positive relationship between specific tariffs and FOB prices is, thus, mostly captured by the pure price component, which means that, when high specific tariffs are implemented, countries tend to export higher priced products. A potential explanation of this result is that countries export higher priced products in order to offset high per unit costs. In this respect, the quality component of the exported good is less important, but, despite being weak, its contribution is a consequence of the fact that higher quality products tend to be more expensive. This result, thus, provides an empirical support of the Alchian–Allen effect.

By contrast, the implementation of high *ad valorem* tariffs leads to a considerably higher reduction in the quality of exported food products than in their prices. In this framework, the pricing-to-market mechanism seems to have a marginal role in explaining the negative relationship between FOB prices and *ad valorem* tariffs, since the quality-adjusted-price coefficient shown in column 3 accounts only for the 15% of the overall results. This finding suggests that pricing-to-market mechanism is not a sufficiently valid explanation for the relationship between *ad valorem* tariffs and FOB prices. Indeed, what seems to be really affected in this case is the quality composition of traded products. This could mean that exporters, when facing high *ad valorem* costs, often prefer to deliver lower quality products rather than reduce their markup.

In columns 4–9 of Table 2, we present the results of estimating our main specification by dividing the sample of the exported food products into two groups according to their quality ladder. The sample of short quality ladder is characterized by products where horizontal differentiation prevails, while the long quality ladder one consists of products with higher scope for vertical differentiation. The overall results hold in both samples, although some peculiarities emerge. Indeed, when considering the short quality ladder sample (column 4), the elasticity of FOB prices to both *ad valorem* and specific tariffs is lower than the one estimated for the overall sample, whereas the opposite holds for the long quality ladder sample (column 7). Moreover, when comparing the results on the short quality ladder sample (columns 5 and 6) to the ones on the overall sample, the former show a lower trade costs elasticity of quality and a higher trade costs elasticity of quality-adjusted-price. By contrast, the results in columns 8 and 9 show an opposite pattern for the long quality ladder sample, being the trade cost elasticity higher for the quality component and lower for the quality-adjusted-price component as compared to the overall sample.

These final results are in line with our expectations. The lower elasticity of quality to specific and *ad valorem* tariffs in the short quality ladder sample could be explained by the lower quality differentiation of the food products belonging to this group. This makes the range of choices rather narrow when countries have to select the quality of the goods they want to export to different destination markets. Exporters can instead adjust the price of exports across different destinations, following a pricing-to-market mechanism. By contrast, food products belonging to the long quality ladder sample seem to have higher scope for quality differentiation, as suggested by the higher elasticity of quality to specific and *ad valorem* tariffs.

These results suggest, again, the importance of considering quality separately from price. Although we show that the relationship with trade costs goes in the same direction for the two variables, there exists a remarkable difference in their relevance and role.

Conclusions

This paper reviews and applies some recent methods developed in the literature to estimate product quality from trade data. In particular, we use the models in Khandelwal (2010) and Khandelwal et al. (2013) to estimate the quality of the exported products in the food sector. The methods we use, in contrast with a vast literature that relies on unit values as a proxy for quality, account for both price and market share information to obtain quality estimates, taking into account a dimension related to consumers' preferences. The general objective of our paper is to implement these new methods to estimate quality in the food market at a high level of disaggregation, and to use them in two main empirical applications. The first application is aimed at comparing the evolution of our quality measures over time and across countries with the one of exported products' price. The results show that quality upgrading is often poorly correlated with price variation. Indeed, an increase in quality does not necessarily correspond to a growth in prices. On the contrary, in several cases, lower prices are accompanied by higher quality.

The second empirical application consists in implementing the method by Khandelwal et al. (2013), which allows decomposing FOB price into a 'pure price' and a quality component, and then testing the relationship between the obtained estimates and trade costs. The results prove to be different for *ad valorem* and specific trade costs, suggesting that the former lead exporters to sell abroad higher priced products, while the latter lead countries to lower the quality of exports. Interestingly, the role played by quality is much more important for *ad valorem* tariffs than for specific ones.

Overall, the results of this paper can be considered of relevant importance for the food sector. Here, more than elsewhere, the quality dimension plays an important role in determining countries' export success, due to the increasing consumers' requirements in terms of food safety and nutrition. Since improving the quality of food products is a fundamental objective for both developed and developing countries, having a more precise measure of quality as compared to the proxies used until now represents an important achievement. This is stressed by the results obtained in our empirical applications, which suggest that we should be careful when using price as a proxy for quality. Indeed, by assuming that higher price corresponds to higher quality when comparing traded food products, we risk incurring an imperfect identification, since the gap in prices may be also due to other reasons, such as different export strategies or different production costs.

The role of the quality measures can be particularly important when assessing the impact of trade policies on the exported products' quality. Our second empirical application shows that trade costs have a different impact on price and quality of products. This suggests that including quality is fundamental if we want to get a complete picture of how barriers to import influence countries' trade patterns. More specifically, when considering tariffs, it is interesting to estimate whether or not they lead countries to import higher quality goods. Our results suggest that *ad valorem* tariffs are a disincentive for quality upgrading, while specific tariffs leave the quality of products almost unchanged. These results, which are fundamental to assess the real effect of tariffs on consumers' welfare, would not have emerged by using prices as a proxy for quality. This kind of analysis can have important policy implications, since assessing the effect that tariffs have on products quality could give an idea about the effectiveness of such measures and the policy lines that governments should adopt in the future.

Appendix A

The method by Khandelwal (2010) explained above is based on the discrete choice model by Berry (1994), which is aimed at estimating the demand function in differentiated product markets. In this model, firms are price-setting in oligopolistic competition and the utility of the consumer depends both on the consumer i preferences and on the product j characteristics:

$$U(x_j, \xi_j, p_j, \upsilon_i, \theta)$$

where observed and unobserved (by the econometrician) product characteristics are represented by x_j and, ξ_j, respectively, while p_j is product's price. The term υ_i captures the individual characteristics that are not observed by the econometrician. Finally, θ represents a demand parameter.

In the method by Khandelwal, product quality accounts for the unobservable product characteristics, ξ_j, and represents the mean valuation that consumers attach to an imported good.

The utility of consumer i is modeled as a function of product and consumer characteristics:

$$u_{ij} = x_j\tilde{\beta}_i - \alpha p_j + \xi_j + \varepsilon_{ij} \tag{7}$$

where $\tilde{\beta}_i$ represents the consumer-specific taste parameter, while ε_{ij} represents the distribution of consumers' preferences around the mean of products valuation. The taste parameter $\tilde{\beta}_{ik}$ for a product characteristic k can be decomposed as $\tilde{\beta}_{ik} = \tilde{\beta}_k + \sigma_k\zeta_{ik}$, where β_k is the mean taste parameter for product k, and the mean-zero ζ_{ik} has an identically and independently distributed standard normal distribution across individuals and characteristics.

$$u_{ij} = x_j\beta_i - \alpha p_j + \xi_j + \sum_k \sigma_k\zeta_{ik} + \varepsilon_{ij} \tag{8}$$

From (8), the mean utility level of product j is defined as $\delta_j = x_j\beta_i - \alpha p_j + \xi_j$.

In the specific case of the nested logit model, the above general formula is modified by the inclusion of different sets of products, denoted as $g = 0, 1, \ldots, G$. This feature of the model allows consumer tastes to be correlated across products $j = 1, \ldots, N$, thus making the substitution pattern more reliable.

Using this approach, the utility of consumer i will be given by:

$$u_{ij} = \delta_j + \sum[d_{jg}\zeta_{ig}] + (1 - \sigma)\varepsilon_{ij} \tag{9}$$

where d_j is defined as above, and d_{jg} is a dummy variable equal to 1 if j is part of the set of products included in group g, and equal to zero otherwise. Using this framework, we are able to model the correlation between groups of similar products in a simple way (see Table A1).

As a next step, the model requires the estimation of the market share depending only on the mean utility level δ:

$$s_j = \mathscr{s}_j(\delta)(j = 1, \ldots, N), \tag{10}$$

where s_j is the observed market share and $\mathscr{s}_j$ is the predicted one.

Assuming that ε_{ij} follows an extreme value distribution, s_j is then obtained using a classical logit model and represents the probability of purchasing product j. We then define $s_{j/g}$, which represents the market share of product j as a fraction of total group share. Going through some passages, we get to a simple analytical expression for δ_j:

Table A1
First stage results 2SLS – price, quality and trade costs.

	All sample (1)	Short quality ladder (2)	Long quality ladder (3)
(ln) Ad valorem	−0.139***	−0.230***	−0.048*
	(0.0180)	(0.0233)	(0.0277)
(ln) per capita GDP (Importer)	−0.001	−0.0124***	0.009***
	(0.0010)	(0.0014)	(0.0017)
(ln) Specific ($t-3$)	0.453***	0.367***	0.490***
	(0.0030)	(0.0049)	(0.0039)
(ln) Specific ($t-6$)	0.326***	0.351***	0.316***
	(0.0031)	(0.0048)	(0.0041)
N	143,223	71,132	72,091

Notes: This table shows the results of the first stage of the 2SLS relative to the estimation of Eq. (6), whose results are reported in Table 2. In these regressions the endogenous variable, that is the difference of specific tariff from the mean across all the destination countries for a given country–product pair, is regressed on two selected instruments, namely the lagged specific tariff at time $T-3$ and $T-6$, as well as the other covariates in the model. Significance levels: *0.10 **0.05 ***0.01.

$$\delta_j(s,\sigma) = \ln(s_j) - \sigma\ln(\bar{s}_{j/g}) - \ln(s_0), \quad (11)$$

where s_0 represents the outside alternative. Its inclusion is relevant, since it gives to the consumer the possibility to purchase good zero instead of the competing inside products $j = 1,\ldots,N$.

The above formula, combined with the definition of δ_j, will become:

$$\ln(s_j) - \ln(s_0) = x_j\beta - \alpha p_j + \sigma\ln(\bar{s}_{j/g}) + \xi_j, \quad (12)$$

So that the estimates of β, α and σ can be obtained by regressing the difference (in logarithm) of market shares on product characteristics, prices, and the log of the within-group share.

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