Estimating Food Quality from Trade Data: An Empirical Assessment

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Summary

Recent developments in international trade theory give growing emphasis to 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 measure product quality relying on a nested logit demand structure developed by Berry (1994) and then applied to trade data by Khandelwal (2010). Our main goal is to investigate the reliability and the properties of the estimated qualities, focusing on the EU food sector, where the growing attention on quality and safety issues is leading to an increase in the demand for high quality products. Main results give credence to the accuracy of the quality estimates, which display some interesting properties. Indeed, the quality rankings we draw are in line with the expectations, and quality growth proves to be strongly correlated with TFP growth. Moreover, results reveal that the competitive strategy of countries (high-quality vs. low-price) tends to change when moving from OECDs to non-OECDs. Finally, we provide evidence that the quality and price components of export unit values behave differently when testing their relationship with trade costs.

Keywords: Quality estimates; Nested logit, Food products; International trade.

JEL classification: C23, F14, L15, Q17

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1. Introduction

Recent developments in the international trade theory have given increasing emphasis to the quality of traded products (Hallak and Schott, 2011; Fajgelbaum et al. 2013; Amiti and Khandelwal, 2013). Exports' quality seems to have a fundamental role both in driving the direction of trade, and in determining the countries' (firms) trade performances, as it is often viewed as a pre-condition for export success (Grossman and Helpman, 1991; Amiti and Khandelwal, 2013) [1].

Recent evidence shows that quality can be particularly important in the analysis of economic growth and development. Indeed, according to the quality ladder models of Grossman and Helpman (1991) and Aghion and Howitt (1992), the ability of a country to upgrade and export high quality products can positively affect economic growth (see Hausman et al., 2007).

In this paper we focus on the food sector, where the quality of products represents a fundamental element. This is due to the increasing attention of consumers towards the safety and quality of food products as a result of an income growth, and consequently to their purchases being more and more conditioned by health and dietary issues, as well as by other products attributes (Caswell and Mojduszka, 1996; Grunert, 2005; Bontemps et al., 2012). This growing attention to the quality attributes affects especially producers in developing countries who want to export to rich countries, as they have to make their products congruent with the high quality requirements. Indeed, international food supply chains are now largely governed by safety and quality (private) standards, and there is growing empirical evidence showing the tendency of many developing countries to upgrade the quality of their food exports to meet the stringency of these norms (Maertens and Swinnen, 2009; Henson et al. 2011; Minten et al. 2013; Olper et al. 2014).

The study of the role of product quality in trade and development is however hindered by the difficulty to measure it, as quality is unobservable. Researchers have tried to deal with this problem by using proxies for quality, in most cases unit values computed from trade data. Albeit convenient, the use of unit values leads to an imprecise measure of quality, as it captures several other elements that are not attributable to

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[1] Product quality enters the international trade models with the seminal contributions of Linder (1960), Flam and Helpman (1987) and Falvey and Kierzowski (1987). First empirical evidence on the role of quality in determining the international trade patterns can be found in Schott (2004) and Hallak (2010). At the 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).

quality. To address this issue, some studies have recently developed alternative methods to infer products quality, in order to have more reliable quality measures (see, e.g., Khandelwal, 2010; Hallak and Schott, 2011; Khandelwal, Schott and Wei, 2013).

After reviewing these new methods, this paper focuses on the application of the one of Khandelwal (2010), which allows to estimate quality at the finest level of disaggregation. This approach is based on the intuition that, conditional on price, imports with higher market shares are assigned higher quality. Our paper is firstly aimed at testing the reliability of the quality estimates for food imports from all the world partners to the EU-15, using data which cover the period 1995-2007. The food industry has been only marginally covered by the Khandelwal (2010) estimates, which focused on products imported to the US in other manufacturing industries.[2]

Secondly, we analyze the evolution of our quality measures over time, in comparison with the one of unit values. This allows us to assess whether the two indicators go in the same direction and, more importantly, to identify countries' (industries) competition strategies in the international markets. Indeed, according to a recent strand of literature (Baldwin and Harrigan, 2011; Baldwin and Ito, 2011; Crozet et al., 2011), two main countries (industries) competition strategies can be identified: price competition and quality competition. However, previous works are based on the use of the unit value as proxy for quality, while our paper, using two different variables (price and quality), gives value added to the analysis.

Finally, we explore the relationship between export prices, quality and trade costs. This topic is considered of relevant importance in the literature, in particular due to the progressive trade liberalization and the consequent fall in trade barriers. This topic has been widely studied in literature, but only few works made use of direct quality measures (see Amiti and Khandelwal, 2013; Curzi et al., 2014). In addition to previous works, our analysis allows to investigate the contribution of both the quality and the *pure* price component in the relationship between trade costs and export prices. To do this, we make use of the quality measure obtained with the method of Khandelwal, Schott and Wei (2013), as it allows to separate the quality component of export prices (expressed as unit values) by the pure price (price-adjusted-quality) one.

Some interesting results come out from our analysis. Our quality estimates, when ranked within some representative food sectors, prove to be in line with the common consumers' perception of quality, giving credence to the use of Khandelwal (2010) approach. Moreover, when used in a growth analysis, our quality measures display a poor correlation with unit values, and the use of the two indicators together reveals the existence of two different strategies: price competition on one hand (especially for developing countries), and quality competition on the other (in particular for developed countries). This result is line with the one of Hallak and Schott (2011), who found that price and quality often move in two opposite directions. Finally, when considering the relationship between export prices, quality and trade costs, we find that the quality and the *pure* price components of the export (fob) prices explain different trade costs. Indeed, from our analysis it emerges that the quality of the exported products seems to be responsible for the negative relationship

[2] Food products were only marginally included among the sectors analysed by Khandelwal (2010) as, according to the Rauch (1999) classification, they are largely considered as homogeneous goods, and thus do not exhibit substantial quality differentiation.

between fob prices and import tariffs, while the positive relationship between fob price and the distance of the destination market results to be mostly explained by the *pure* price component.

The remainder of this paper is organized as follows. In section 2, we review the main methods to estimate quality, focusing on the one of Khandelwal (2010). Section 3 presents the data and the quality estimation results. In section 4 we use our quality estimates firstly to draw some rankings, and secondly to carry out a growth and convergence analysis. In Section 5, some concluding remarks and the main implications of the results are discussed.

2. Estimating quality from trade data

The growing importance assumed by the quality of the exported products in explaining the international trade patterns leads to face an important issue, that is the measurement of the quality of the traded products.
The most common proxy used in the economic literature is unit value (price), defined as nominal value divided into physical volume of a traded product. This indicator has been widely used in empirical studies, which rely on the conjecture that higher unit value means higher quality, as in the important contributions of Schott (2004), Hummels and Klenow (2005) and Hallak (2006). These works provide the first formal evidence that export unit values increase with both the per capita income of the foreign destinations and the skill and capital intensity of the exporter country (Schott, 2004; Hummels and Klenow, 2005), as well as that higher quality products are disproportionally directed to higher income countries (Hallak, 2006).

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 very 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, because it also captures some aspects that are not attributable to quality. There are several reasons that lead to the conclusion that unit value does not represent a reliable proxy for quality. First, because product heterogeneity and classification errors are important sources of unit value noise (Lipsey, 1994). Second, because higher unit values could reflect higher quality but also higher costs (Aiginger, 1997). Finally, because higher unit values could also be the consequence of higher margins created by market power (Knetter, 1997).

To overcome these problems, some recent papers tried to purge all the elements above in order to obtain a more reliable proxy for quality. Basically, these methods share the same intuition, according to which countries selling large quantities of physical output, conditional on price, are classified as high quality producers. Based on this assumptions, Hallak and Schott (2011) develop a method that allows to decompose observed export prices into quality versus quality-adjusted-price components. They infer countries' exported products quality by combining data on their prices with information about global demand for them. The intuition behind this method is that two countries with the same export prices but different global trade balances must have products with different levels of quality. According to this method, price being equal, the country with the higher trade balance is revealed to possess higher product quality. However, a major shortcoming of the Hallak and Schott (2011) method is that, being based on global trade balance, it is suitable for inferring quality at the country or industry level, but not at the products line level.

To overcome this limitation, Khandelwal (2010) develops a method to infer 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 has this 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. Moreover, this method may be of particular interest in a trade analysis aimed to assess the role of product quality in influencing trade patterns. This is also the case of the trade model recently developed by Fajgelbaum et al. (2011), which, indeed, is based on a nested logit demand system and thus shares the same consumers preference structure. According to this model, heterogeneous consumers with non-homothetic preferences face a consumption choice over varieties of a horizontally and vertically differentiated goods and, as a result of an income rise, a higher fraction of consumers buys higher quality goods.

Finally, more recently, Khandelwal, Schott and Wei (2013) develop a method to infer quality from a CES demand system which is conceptually similar to the one of Khandelwal (2010), but it does not require the use of any instrument for the (endogenous) price component in the demand system (more on this below).

All the methods explained above share a common assumption, namely that product quality is associated with the higher utility for the (representative) consumer, and that this is fundamental in determining the direction of trade. Indeed, countries' (firms') high quality products are not only aimed at satisfying consumers in the domestic markets, but also at attracting consumers abroad (Chi-Hung Liao, 2011).

Among all the methods recently developed in the literature to infer quality, our preferred is Khandelwal (2010) as it allows to infer quality at the maximum level of product-country disaggregation and over time. Even if the method of Khandelwal, Schott and Wei (2013) would allow us to produce the same pattern of estimates, our choice fell on Khandelwal (2010) as in our view the nested logit demand approach allows for a more reliable substitution pattern, by placing varieties into appropriate nests.[3] However, in the last section of this paper, the empirical analysis proposed requires the use of the method by Khandelwal, Schott and Wei (2013) for measure product quality, as its implementation allows to use FOB prices instead of CIF, and, moreover, it allows to decompose FOB price in its quality and price-adjusted-quality components.

[3] The Khandelwal, Schott and Wei (2013) approach needs an estimate of the elasticity 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 Femenia 2009; Liu and Yue 2012). For an in-depth 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 (2012).

In what follows, we first review the nested logit demand system of Berry (1994), that is at the core of the Khandelwal (2010) approach, and then we propose an application of this method to food products in the EU-15 market.

2.1 A nested logit demand approach

Berry (1994) proposes a discrete choice model to estimate 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 preferences and on the product characteristics. In this setting, the product market share will be the result of the aggregate outcome of consumers' decision.

Consider a utility function of consumer i for a product j that depends both on individual and product characteristics:

$$U(x_j, \xi_j, p_j, v_i; \theta)$$

where the vector of product characteristics is represented by the observed (x_j) and unobserved (by the econometrician) (ξ_j) product characteristics and the price (p_j). v_i captures the individual characteristics that are not observed by the econometrician. Finally, θ represents a demand parameter. Consumers characterized by different v make different choices. Thus, in order to derive the integrated demand system, the choice function is integrated out over the distribution of v in the population. Throughout, v will be taken to have a known distribution. This distribution may be considered either as the empirical distribution of characteristics, or as a standardized distribution where standardization parameters are estimated. In this model, θ includes any parameter determining the distribution of consumer characteristics.

Denoting with δ_j the main utility that consumers receive from purchasing product j, then the utility function results to be exclusively dependent from the interaction between the product and the consumer characteristics

$$u_{ij} = \delta_j\left(x_j, \xi_j, p_j\right) + v_{ij} \qquad (1)$$

Assuming a linear specification for δ_j, it is possible to define the main utility level that consumer i obtains from product j as:

$$\delta_j = x_j\beta - \alpha p_j + \xi_j \qquad (2)$$

The discrete-choice market share function, s_j, is then derived from the consumer utility maximization, conditional on the product characteristics (x, p, ξ) and the consumer unobservable taste parameters v_i that lead consumer i to purchase product j. The market share of firm j is, in other words, the probability of purchasing product j, given the distribution of consumer preferences θ over the product characteristics.

The definition of the market size and the presence of an outside alternative completes the specification of the demand system. Consider now an outside good, $j = 0$, that the consumer i may choose to purchase instead of the competing differentiated products $j = 1, \ldots, N$, with a price not affected by the variation of the prices of the inside goods. The presence of an alternative good is important because, in a market without the option of the outside good, consumers are forced to choose among *N* inside goods, basing their decision only on differences in prices. Moreover, the possibility to choose an outside good avoids the unfortunate feature of some discrete models, where, due to the absence of an alternative, an increase in the price of the inside goods does not affect the aggregate output.

Different assumptions about the consumer preferences affect the utility function and, thus, the specification of the demand and the patterns of substitution. Assuming homogeneous preferences across consumers, the utility function takes the following form

$$u_{ij} = x_j\beta - \alpha p_j + \xi_j + \epsilon_{ij} \tag{3}$$

where ξ_j represents the mean valuation of an unobservable product characteristic that consumers attach to a product j and ϵ_{ij} represents the consumers' distribution around this mean, that is assumed to be mean zero and identically distributed across consumers and products. Assuming that ϵ_{ij} follows an extreme value distribution, the probability of purchasing product *j* is given by the following logit formula:

$$s_j(\delta) = \frac{e^{\delta_j}}{1+\sum_{j=1}^{n} e^{\delta_j}} \quad \text{for } j = 0, \ldots, N \tag{4}$$

Normalising the utility of the outside good to zero, it is possible to obtain the following linear model in price and product characteristics:

$$\ln(S_j) - \ln(S_0) = \delta = x_j\beta - \alpha p_j + \xi_j. \tag{5}$$

However, this simple logit specification has the limitation that it produces unreasonable substitution patterns, because products are differentiated just by their mean utility levels (δ_j), thus the substitution effects are the same independently of the degree of similarity between product characteristics.

To solve this problem, the obvious solution is to switch from homogeneous to heterogeneous preferences across consumer. The heterogeneous preferences across consumers are simply generated in a discrete-choice model just by the interaction between consumer and product characteristics. One possibility to do this is given by the nested logit models, that, in contrast to the simple logit model, allow consumer tastes to be correlated (albeit in a restricted way) across products.[4]

In the nested logit model the products are grouped in $G + 1$ exhaustive and mutually exclusive set of products $g = 0, 1, \ldots, G$. Products within the same set are assumed to be higher correlated than products belonging to different sets.

[4] The nested logit approach allows to model the correlation between groups, allowing correlation patterns to be dependent only on grouping of products which are pre-determined and not on the values of continuos variables (see Berry (1994) for more details)

Denote the set of products in group g as J. Regarding the outside good, $j = 0$ is assumed to be the only member of group 0. Thus, the utility that consumer i obtains from purchasing a product j, belonging to a group g will be:

$$u_{ij} = \delta_j + \zeta_{ig} + (1 - \sigma)\epsilon_{ij} \tag{6}$$

where, as in (2), $\delta_j = x_j\beta - \alpha p_j + \xi_j$ and ϵ_{ij}, as in the logit model, follows an extreme value distribution. The variable ζ, for all consumer i, is assumed to be common to all products in group g and has a distribution that depends on σ (with $0 \leq \sigma < 1$), that can be thought as a substitution parameter.

In the nested logit model, the market share of product j belonging to a group g, will be a fraction of the total group share

$$\bar{s}_{j/g}(\delta, \sigma) = \frac{e^{\frac{\delta_j}{1-\sigma}}}{D_g} \; for\, j \in g \tag{7}$$

where $D_g = \sum_{j \in J_g} e^{\frac{\delta_j}{(1-\sigma)}}$.

Taking the log of market share, it is possible to define the main utility level that consumer i obtains from product j as:

$$\delta_j(s, \sigma) = \ln(s_j) - \sigma \ln\, (\bar{s}_{j/g}) - \ln(s_0)\;. \tag{8}$$

Setting $\delta_j = x_j\beta - \alpha p_j + \xi_j$ and substituting gives

$$\ln(S_j) - \ln(S_0) = x_j\beta - \alpha p_j + \sigma \ln\, (\bar{s}_{j/g}) + \xi_j. \tag{9}$$

The above expression relates the market share of product j to the observed and unobserved product characteristics, x_j and ξ_j respectively, the product price p_j, and the log of the nested share, $(\bar{s}_{j/g})$, multiplied by the substitution parameter, σ.

2.2 Applying the nested logit demand approach to trade data

Khandelwal (2010) implements the method explained above to infer product quality from trade data, using price and quantity information, with the aim of relaxing the strong quality-equals-price assumption. In this method, product quality accounts for the Berry (1994) model's unobservable product characteristics, ξ_j, and represents the mean valuation that consumers attach to an imported product. Such method allows to consider consumers' preferences for both horizontal and vertical attributes and has the following straightforward intuition: "*conditional on price, imports with higher market shares are assigned higher quality*".

The quality of a product j, exported by a country c to country i at time t is then inferred using the following estimable demand function:

$$\ln(s_{jcit}) - \ln(s_{0it}) = \xi_{1,jci} + \xi_{2,it} + \alpha p_{jcit} + \sigma \ln(ns_{jcit}) + \gamma \ln pop_{ct} + \xi_{3,jcit} \tag{10}$$

where s_{jcit} represents the inside variety overall market share and is defined as $s_{jcit} = q_{jcit}/MKT_{it}$, where q_{jcit} is the imported quantity of such variety, and $MKT_{it} = \sum_{cj\neq 0} q_{jcit}/(1 - s_{0it})$ is the industry size. The outside variety s_{0it} completes the model and represents the domestic alternative to the imported variety computed as one minus the industry's import penetration.[5] $\xi_{1,jci}$ represents the exporter-product fixed effects and represents the time invariant component of quality, while $\xi_{2,t}$ are the year fixed effects that account for the common quality component. Finally, $\xi_{3,jcit}$ is a variety-time specific deviation (residual). In the relation (10) derived from Berry (1994), Khandelwal (2010) adds the term pop_{ct}, which represents the population of the country c, and accounts for the so called hidden varieties.[6] The quality of a product j exported by the country *c* to country *i* at time *t*, ξ_{jcit}, is then inferred using the estimated parameters from (10) as follows:

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

Quality is the sum of the *cj*-fixed effect, the time effect, and the residual. Thus, for several reasons, the method is in the spirit of the TFP estimation, which is indeed obtained as the residual from a production function.

3. Estimating quality in the EU food markets

In what follows, we apply the method outlined above to infer the quality of the imported food products in the EU-15 countries (except Luxembourg, for which we do not have production data) from all trading partners in the World with data, and at the finest level of product aggregation. We estimate equation (10) considering separately each of the EU-15 countries and thus mitigating the potential bias due to specific country preferences towards certain products, which may occur when working on a single destination market.

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

Data on the volume of the domestic production for each of the considered EU-15 countries are drawn from the EUROSTAT Prodcom database. Production data are available at 8-digit level according to the Prodcom classification, which is directly connected to the NACE 4-digit classification, as the first four digits of the Prodcom code identify 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

[5] We define Import Penetration as the ratio of imports over imports plus production and we estimated it 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 case, population controls for country size.

appropriate corresponding tables provided by EUROSTAT. Table 2 shows the number of CN-8 products contained in each NACE 4-digit industry.

We estimate equation (10) using both OLS and 2SLS regression (our preferred one). The instrumental variable approach is required because, looking at the right-hand side of equation (10), it emerges a potential endogeneity problem 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 *p*, and the number of varieties exported by each trading partner.

In order to estimate product quality, we run equation (10) separately for each imported country – NACE 4-digit industry. Table 1 summarizes the median parameters obtained by estimating equation (10). We run 468 different regressions (considering both OLS and 2SLS), with an average number of observations per estimation of 4,378. Importantly, the pattern of estimated signs and the mean values of the price and nest share elasticities match the ones of Khandelwal (2010) and, especially of Colantone and Crinò (2014), who estimate 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 the OLS one, suggesting that the 2SLS approach moved the price coefficient to 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. Finally, the bottom of the panel shows that 67% and 93% of the estimations report a significant price and nest share coefficients, respectively.

Before and after the quality estimations we apply some standard cleaning procedures. First, we drop varieties with unit values that fall 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 of more than 200 percent and less than 66 percent. Finally, as the quality estimates obtained can be noisy, the estimates that fall below the 5^{th} and above the 95^{th} percentiles are dropped.

4. Going inside our quality estimates

In this section we first present some quality rankings for selected products, whose quality reputation for specific countries is well known. In this way, we can test whether our quality measures can be considered reasonably realistic. After verifying the reliability of our estimates, we move to testing the correlation

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

between price and quality growth in order to analyze the evolution of the two measures. Our results suggest some important policy implications in terms of development analysis, which will be discussed in the final section.

4.1 Quality rankings

Our quality estimates allow to easily rank the quality of a specific food product [8], considering, for each exporter, the mean quality that importers attribute to that product. We take as representative examples three specific product categories for which quality is particularly important, and the quality ranking is reasonably defined by the common perception: *white quality wine*, *beer*, and *fresh bovine meet*. To simplify the readability of the graphical representation, for each of the three considered products we select a sample of countries, considering the ones with the highest market shares. We also rank the median value, and the 25th and 75th percentiles values. We compare quality at the beginning (1995-1996) and at the end (2006-2007) of the considered period, to also track the variation in quality ranking over time.

Figure 1 shows the quality ranking and its evolution for *white quality wine* (CN code 22042111). Consistently with the expectations, from the ranking it emerges that, among the traditional wine producer countries, France, Italy and Spain are the top quality wine exporters in both periods. Moreover, the figure shows that, during the observed period, there has been a process of convergence in the mean value of the estimated quality between the considered countries, a result in line with the dynamic of growth experienced by these countries in the world wine sector. Moreover, if one looks at the range of wines' quality for each of the considered producers, it is possible to note some differences between them. Consider for example France and USA, which are in both the considered periods, respectively, first and last. While France shows a narrow range of quality, USA shows a wide range of quality, namely very low quality measures for both the 25th percentile and the median values and a very high value for the 75th percentile. This could mean that the whole basket of French exports is considered by the consumers of very high-quality. By contrast, the USA export basket is almost equally divided between some products considered of very low quality and some others of very high quality. As a result, the mean quality value of the USA white quality wine is almost aligned to the one of the other countries, even if in the two considered periods it results last in the rank.

Figure 2 shows the quality ranking for *beer* (CN code 22030001) in the two considered periods. In line with the expectations, the first five countries ranked – Ireland, Belgium, Netherlands, Germany and Denmark – are in fact among the biggest producers and exporters of beer in the world. Unlike wine, the quality of beer does not show substantial differences between these five top quality producers, a result confirmed by the short (mean) quality ladder that characterizes this sector (see Table 1). Thus, apparently, competition in the beer market seems to be largely based on a horizontal differentiation strategy, more than on a vertical differentiation one. This evidence appears consistent with the actual situation of the world beer market. Indeed, excluding the phenomena of special beer production as the microbrewery, which represents an

[8] The estimated quality from (10) 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.

important reality especially in Belgium and US, at the international level the market is still largely based on beers with similar intrinsic quality values. Their competition is largely based on differences in the flavor and, more importantly, in the advertising strategy.

As for the product category *fresh bovine meat*, (CN code 02011000), Figure 3 shows that, consistently with the expectations again, USA, Brazil, Germany and France are the top quality exporters. The estimates are quite similar between the two considered periods, except for Brazil, which increases the quality of its exported products, becoming first in the quality ranking. Interestingly, USA moves from the first to the fourth position of the ranking. In comparison with beer, fresh bovine meat displays a longer quality ladder, suggesting that its market is characterized by relevant vertical differentiation. Moreover, when we use price as a proxy for quality, even if countries are ranked differently, the last result is confirmed, namely the fresh bovine meat market is characterized by a higher vertical differentiation than the beer one (results are not shown but are available upon request). This suggests that the use of prices, as well as quality, may be useful when the aim is to assess whether a market is mainly characterized by vertical or horizontal differentiation.

4.2 Quality and TFP growth

Understanding the evolution of quality over time can have a key role in a growth analysis. Starting from the quality ladder models of Grossman and Helpman (1991) and Aghion and Howitt (1992), a strand of literature has evolved showing the existence of a positive link between quality and economic growth . Hausmann et al. (2007), followed by Minondo (2010), give support to the idea that countries that export higher quality goods tend to grow more rapidly.

Total Factor Productivity (TFP) is indeed at the heart of the growth process and can rise as result of innovation and technological change. The positive link between quality and TFP has been shown by the literature at both macro and micro level. At macro level, quality upgrading can be viewed as a specific component of TFP in a growth analysis (Amiti and Khandelwal, 2013). This is empirically confirmed both for the whole manufacturing sector (Khandelwal, 2010) and for the food sector (Curzi et al., 2014). At the micro level, the existence of a positive correlation between quality and TFP has been theoretically introduced by the firm heterogeneity model of Melitz (2003) and empirically proved by Verhoogen (2008) for the manufacturing sector and by Curzi and Olper (2012) for the food sector.

Our proxy for quality allows to test whether, as expected, quality and TFP are positively correlated. Note that we are simply interested in correlation and not in the causality relation, since we are aware of the potential problems of endogeneity that may affect such relation.

In Figure 4, we relate quality growth to TFP growth between 2000 and 2007.[9] The correlation between the two measures proves to be strongly positive, as most of the considered countries has experienced a

[9] TFP has been estimated using data from UNIDO for each country, year and food sector according to the ISIC Rev. 3 classification. To this aim, a value added function with variable returns to scale is used (see Harrigan, 1999; Ruan and Gopinath, 2008). Capital is estimated from gross fixed capital formation, through the perpetual inventory method (see Hall et al., 1988; Crego et al., 1998). The estimated TFP is then linked to the NACE 4-digit categories through

positive growth in productivity accompanied by an increase in the quality of their food products. This is consistent with the fact that quality upgrading has a key role in the technology improvement of countries and, consequently, in their growth and competitiveness in international markets. As pointed out by Helpman (2011), international trade can stimulate countries to upgrade the quality of their products and thus lead to a faster productivity improvement. Thus, quality can be considered as vehicle through which countries can grow and develop.

4.3 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 which is 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 very 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. In order to make the results clearer and to identify the specificities of the considered countries, we present two separate graphs for OECD and non-OECD (or emerging) countries. Considering the OECD sample (Figure 5), most of the countries show a positive quality growth in the considered period. However, in most of the cases this is not linked to a corresponding growth of their unit values but, quite surprisingly, to their reduction. This is even more evident when considering the sample of emerging countries (Figure 6). 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 an opposite pattern, namely an increase in price. 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. By contrast, some countries whose price rose show a reduction in quality.

This dynamic is also evident when considering one single sector. In Figure 7, we take as representative example the wine sector. 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 become increasingly important in terms of production and also exports. The figure shows that France and Italy, whose wines are universally known as the ones of the highest quality, increased both quality and price. This means that even if the price grew up, consumers still show a preference towards these wines. By

correspondence tables provided by the United Nations Statistical Division. We use 2000 as the initial year (instead of 1995) as starting from this year allows to have data on a higher number of countries for which it is possible to estimate TFP, contrast, Spain and some extra-EU countries, whose 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, whose reputation is increasing. Indeed, Anderson (2004 and 2013) underlines that, in recent years, Italy and France are facing a growing competition from new producers like 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 almost zero in the 80's, represent now the 5% and the 10% of the global wine exports (Parcero and Villanueva, 2012).

4.4 Price, Quality and Trade Costs

Another interesting application consists of testing the relationship between price and quality with some variables accounting for trade costs. This is a relevant topic because, due to the progressive trade liberalization, it is important to study the effect of the consequent reduction of trade duties on the quality and the price of the exported products. To do this we test the following specification:

$$lny_{jcit} = \alpha_0 + \beta \ln tariff_{jit} + \gamma \ln\ distance_{ci} + \delta_h + \delta_i + \delta_c + \delta_y + \varepsilon_{jict} \quad (11)$$

Where, lny_{hijt} is our dependent variable and accounts for (fob) price and quality, alternatively. $\ln tariff_{hjt}$ represents the import tariff for product h, in country j at time t. $ln\ distance_{ci}$ is the bilateral distance between countries *c* and *i*. Finally, product, importer, exporter and year fixed effects are included. [10]

Fob prices are taken from the BACI database from CEPII. Data have been obtained through a procedure allowing to correct discrepancies between the import values, which are generally reported CIF (cost, insurance and freight), and export values, reported FOB (for further details see Gaulier and Zignago, 2010).

We use FOB prices instead of CIF prices because they do not take into account trade costs. Indeed, the use of CIF prices would lead to a pre-determined result, because CIF price, with respect to FOB one, is augmented due to trade cost.

Using data from BACI, quality is estimated with the method by Khandelwal, Schott and Wei (2013), which allows to estimate 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. With respect to what previously done using the method of Khandelwal (2010), in this case product quality has been estimated considering all the world trading countries in the sample, and, thus, not only the exports of food products in the EU15. Using such method, we measure product quality at the HS 6-digit level of disaggregation, over the period 1995-2007.

Moreover, this method allows to decompose the FOB price into two different components, namely quality and price-adjusted-quality. The latter, which is included among our dependent variables in (11), is obtained

[10] Note that we are only interested in studying a simple correlation and not the causality relation. Indeed, in that case, due to the potential endogeneous relationship between our dependent variables and the import tariffs, we would have to use an instrumental variable approach.

just by subtracting the quality component from the price. Further information on this method are available in Appendix. Finally, tariff data at the HS 6-digit level and over time come from WITS (World Bank). All tariffs are expressed as ad valorem equivalent. Data on bilateral distance is taken from CEPII.

The results in column 1 show that import tariffs are negatively related to the fob price of the exported food products. Looking at the results in columns 2 and 3, where quality and price-adjusted-quality are our dependent variables, we can see that the negative effect of tariffs displayed in column 1 is almost entirely captured by the quality component. Indeed, the coefficient of the price-adjusted-quality component is very low and statistically insignificant. This may be due to the fact that, when tariffs are lowered, the final prices for the consumer get lower, leading to a gain in the market share of the affected products. Indeed, by construction, the main determinant of our quality measure is market share.

The coefficient of distance in column 1 is positively and significantly related to the fob price. This result is in line with the so called Alchian and Allen effect, according to which higher quality products are exported in more distant countries in order to offset the higher transportation costs. However, when decomposing price in its two components, it emerges that the positive effect holds for the price-adjusted-quality component, while turns very low and even negative for quality. This could mean that the price of products, and not their quality, allows to offset the high export costs.

5. Conclusions

This paper estimates the quality of food products exported to the EU market with the approach proposed by Khandelwal (2010). This method, in contrast with a vast literature which uses unit values as a proxy for quality, accounts for both price and market share information to obtain quality measures. The main objectives of our paper are, firstly, to test whether Khandelwal (2010) method is reliable, and, secondly, to use the quality estimates to analyze countries' competition strategies. This is important because, especially in the food sector, the quality of exported products is a fundamental element for countries' success in the international markets, and, consequently, for their economic growth.

Our analysis finds evidence for the reliability of the Khandelwal (2010) approach. Indeed, the quality rankings that we draw for some representative food products are in line with the quality perceived by the public. Moreover, quality growth displays a strong correlation with TFP growth, in line with recent literature which identifies quality as an important component of productivity.

When comparing the evolution of our quality measures with the one of unit values, we find that quality upgrading is often poorly correlated with price variation. This means that an increase in quality does not always correspond to a growth in prices, but, on the contrary, in several cases lower prices are accompanied by higher qualities. Interestingly, this trend is common to many developing and emerging countries, revealing that their competition strategy consists not only in lowering prices, but also in upgrading the quality of their foods.

Another interesting result comes from implementing the method of Khandelwal, Schott and Wei (2013), through which FOB price is decomposed into a 'pure price' and a quality components, and then testing the relationship between the obtained estimates and trade costs. What emerges is that the negative relation between tariffs and price is mainly explained by the quality component of fob price, while distance has a positive effect just on the pure price one. This finding, in line with the rest of the paper, suggests that we should be careful when using price as a proxy for quality, as quality represents just one component of price measures.

Appendix – Inferring quality with the Khandelwal, Schott and Wei (2013) method

Khandelwal, Schott and Wei (2013) developed a method to infer product quality, which is conceptually similar to the one of Khandelwal (2010) but easier to implement since it does not require the use of instrumental variables. This method is simply based on the following intuition: "*conditional on price, a variety with a higher quantity is assigned higher quality*". It derives that in our estimation, once controlled for price, product which are imported in higher quantity are assigned higher quality.
In order to infer product quality, only data on the value and the volume of trade are needed. Indeed, the quality of the exported products is obtained from the residual of the following OLS regression:

$$ln\, q_{cht} + \sigma\, ln\, p_{cht} = \alpha_h + \alpha_{ct} + e_{cht} \tag{12}$$

Where q_{cht} and p_{cht} are, respectively, the quantity and the price (unit value) of product h, exported by country c to country i at time t. α_h and α_{ct} account for, respectively, product and exporter-year fixed effects. e_{cht} is an error term. Quality is then estimated taking the residual from (12), and dividing it by the country-industry specific elasticity of substitution minus 1. Thus, $quality = \hat{\xi}_{cht} \equiv \hat{e}_{cht}/(\sigma - 1)$.
We run equation (12) separately for each of the countries in the sample and NACE 4-digit industry. Country-industry specific elasticities of substitution are taken from Broda, Greenfield and Weinstein (2006). Since these elasticities are available at the HS 3-digit level of disaggregation, following Colantone and Crinò (2014), we took the median value the median value across all the corresponding HS 3-digit products, and we aggregate them at the NACE 4-digit level of disaggregation.

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Table 1. Summary statistics of quality estimates

	OLS	2SLS
	(1)	(2)
Price *(mean)*	-0.260	-0.735
Nest Share *(mean)*	0.877	0.677
Sargan test (p -value) *(mean)*		0.15
Observation per estimation (*mean*)	4378	
Varieties per estimation *(mean)*	635	
Total number of estimations	468	
Total observations across all estimations	1,138,022	
Estimation with stat. sig. price coeff.	67%	
Estimation with stat. sig. nest share coeff.	93%	

Notes: Table 1 reports estimation statistics coming from running equation (10) separately for each of the food industries in our sample with both OLS and 2SLS. Sargan test has been computed in order to test whether the instruments are uncorrelated with the error term.

Table 2. Numbers of products and mean quality ladder for the food sectors considered

NACE 4	Short description	#CN8	Mean Ladder
(1)	(2)	(3)	(4)
1511	Production and preserving of meat	142	3.54
1512	Production and preserving of poultry meat	196	3.05
1513	Production of meat and poultry meat products	108	3.11
1520	Production and preserving of fish and fish products	401	1.42
1530	Production and preserving of fruit and vegetables	495	2.77
1540	Manifacture of vegetables and animal oils and fats	144	1.60
1550	Manifacture of diary products	204	2.02
1560	Manifacture of grain mill products, starches and starch products	178	1.85
1580	Sugar and cocoa	60	1.70
1581	Manifacture of bread; manifacture of fresh pastry goods and cakes	2	0.59
1582	Manifacture of rusked and biscuits	29	1.47
1585	Manifacture of maccaroni, noodles and couscous	11	2.15
1586	Processing of tea and coffee	22	2.05
1587	Manifacture of condiments and seasoning	11	2.37
1588	Manifacture of omogenized food preparaison and dietetic food	7	1.93
1589	Manifacture of other food products n.e.c.	37	2.76
1590	Production of ethyl alcohol, cider, malt and other non-distilled fermented beverages	18	2.90
1591	Manifacture of distilled potable alcoholic beverages	67	4.78
1593	Manifacture of wine	99	3.44
1596	Manifacture of beer	4	0.86
1598	Production of mineral water and soft drinks	11	1.45

Notes: Table 2 reports information on the NACE 4-digit food industries, for which we estimated equation (2), considering separately each EU15 country. 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 the code 1550; codes 1561 and 1562 are included in the code 1560; codes 1583 and1584 are included in the code 1580; and finally codes 1592, 1594, and 1595 are included in the code 1590. Column 3 reports data on the number of CN8 products belonging to each NACE 4-digit industries. Column 4 shows the mean quality ladder level associated to each NACE 4-digit industry. Following the approach of Khandelwal (2010) quality ladder has been computed for each product category (CN 8) as the difference between the maximum and the minimum value of quality for the first year of the considered period. From this measure we classify products in long quality ladder (if they are above the median value) and short quality ladder (if they are below the median value).

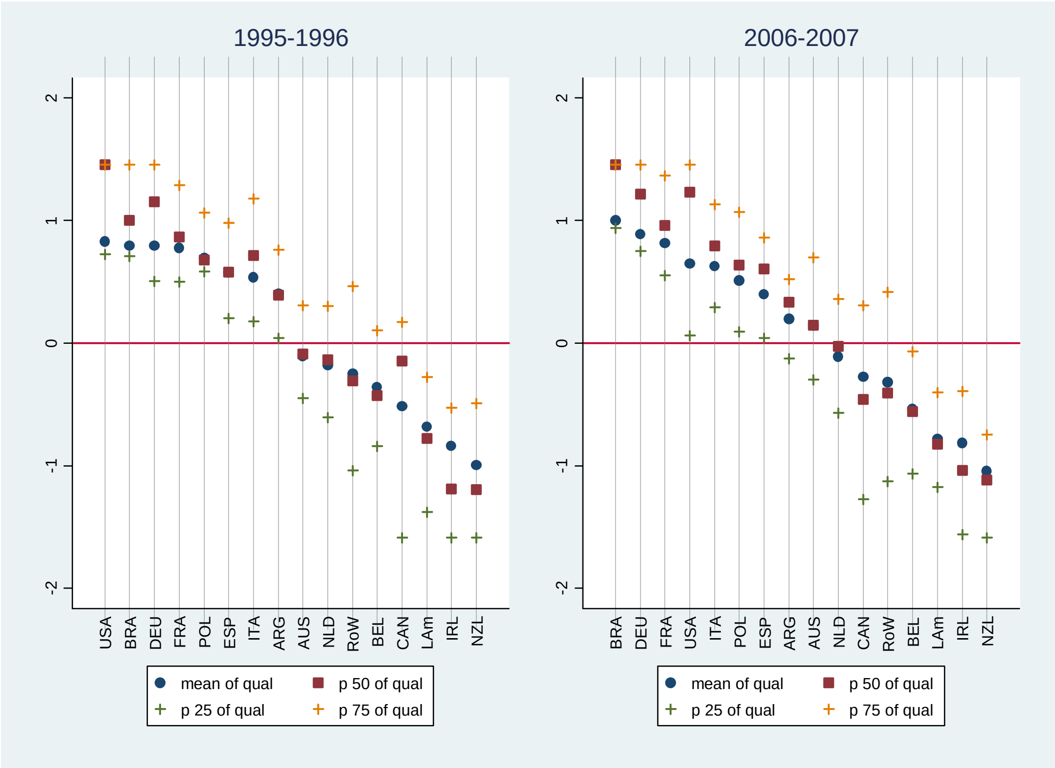
Figure 1. Quality ranking on "quality white wine" (CN8 code 22042111)

Notes: Countries rank are based on the their mean quality value in each of the two considered periods. See text for calculation details.

Figure 2. Quality ranking on beer (CN8 code 22030001)

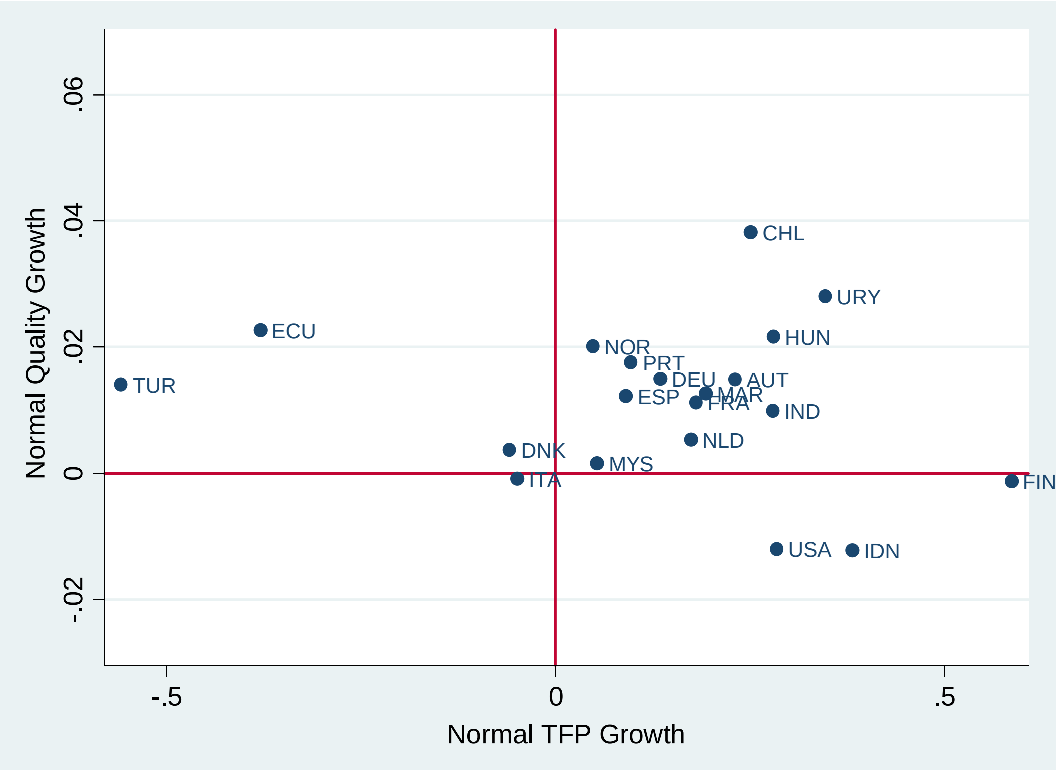
Notes: Countries rank are based on their mean quality value in each of the two considered periods. See text for calculation details.

Figure 3. Quality ranking on “fresh bovine meat” (CN-8 code 02011000)



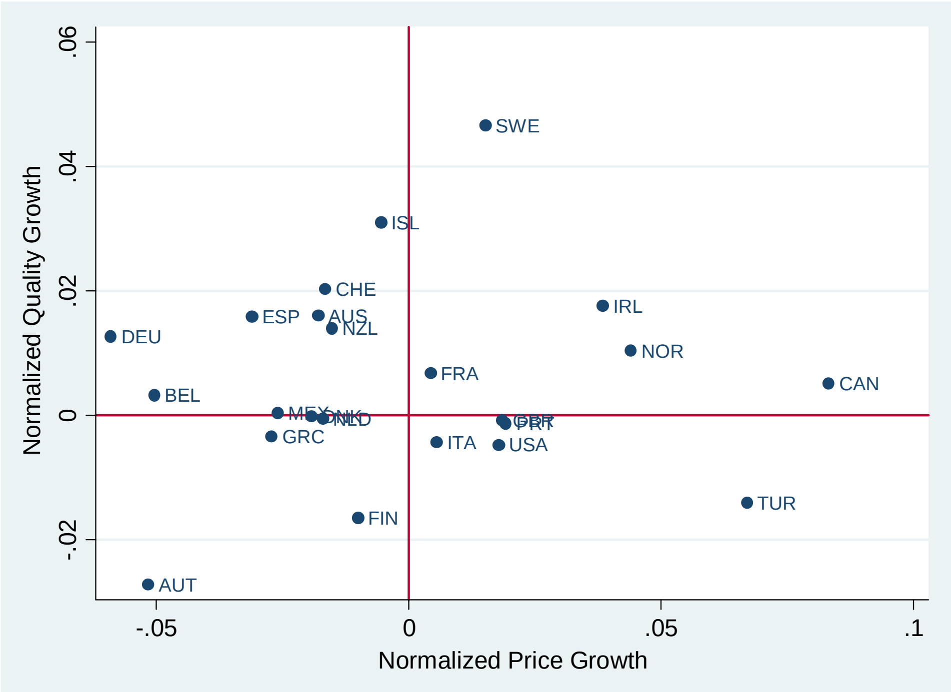
Notes: Countries rank are based on their mean quality value in each of the two considered periods. See text for calculation details.

Figure 4. Quality and TFP growth (2000-2007)



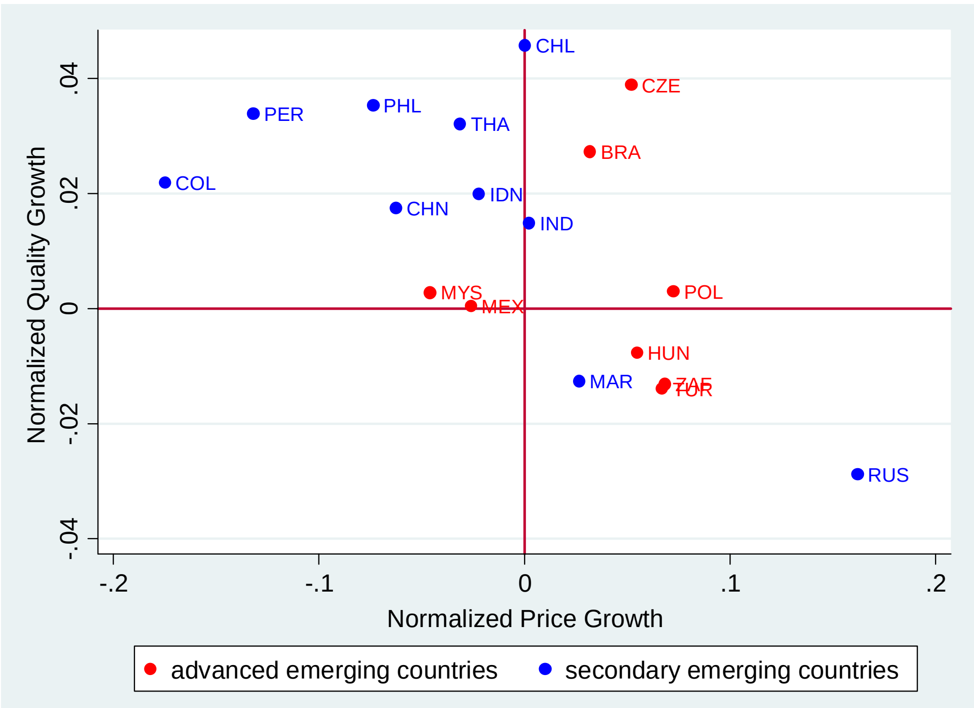
Notes: The figure shows a comparison between normalized quality (y-axis) vs. normalized TFP (x-axis) growth in the period 2000-2007 for all countries with data available for both Quality and TFP estimation. For more details about the TFP estimation, see the text.

Figure 5. Change in Quality vs. Price, OECD countries (1995-2007)



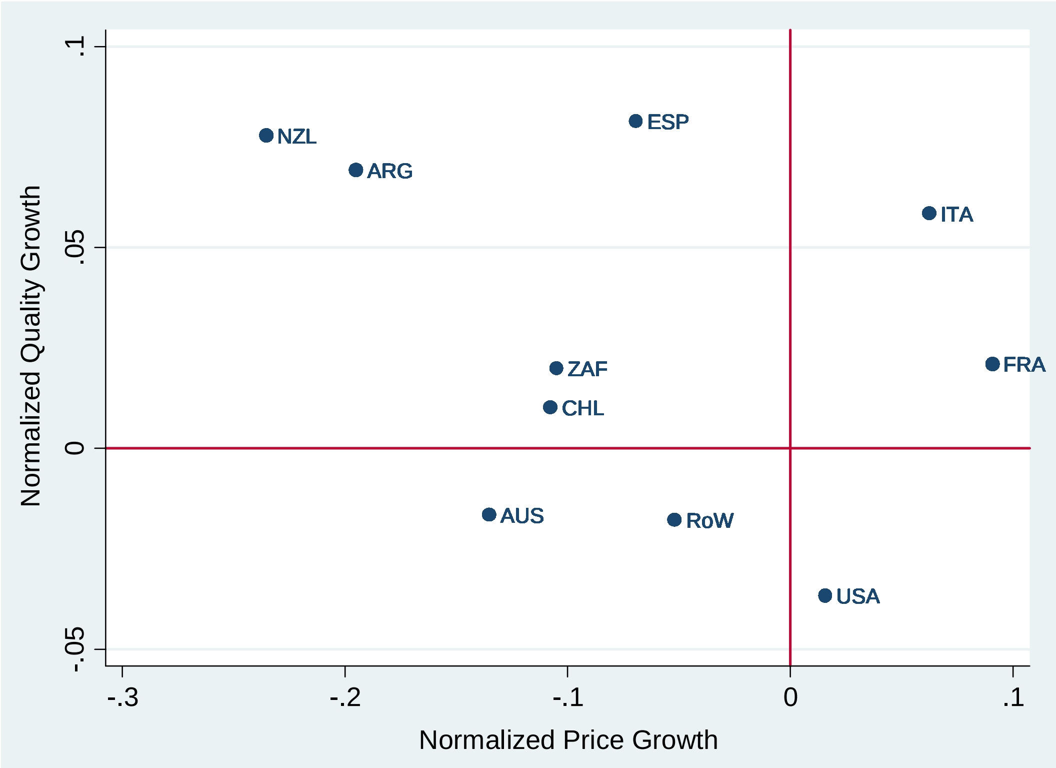
Notes: The figure shows a comparison between normalized quality (y-axis) vs. normalized price (x-axis) growth in the period 1995-2007 for the sample of OECD countries.

Figure 6. Change in Quality vs Price in non-OECD Countries (1995-2007)



Notes: the figure shows a comparison between normalized quality (y-axis) vs. normalized price (x-axis) growth in the period 1995-2007 for the sample of advanced and secondary emerging countries. Countries are classified in advanced and secondary emerging according to the Financial Times Stock Exchange (FTSE) classification.

Figure 7. Change in Quality vs Price – Wine Sector (1995-2007)



Notes: The figure 7 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.

Table 3. Price, quality and trade costs

	(1)	(2)	(3)
	(ln) Price	(ln) Quality	Price Adj. Quality
(ln) Tariff	-0.00297***	-0.00317***	0.000196
	(0.000752)	(0.000729)	(0.000878)
(ln) Distance	0.0692***	-0.00943***	0.0786***
	(0.000718)	(0.000676)	(0.000811)
Exporter FE	YES	YES	YES
Importer FE	YES	YES	YES
Product FE	YES	YES	YES
Year FE	YES	YES	YES
N	1,541,020	1,541,020	1,541,020

Notes: Table shows results of regressing the FOB price, Quality and Price-Adjusted Quality on the (log) import tariff and the (log) the bilateral distance. All regressions include exporter, importer, product (HS 6-digit) and year fixed effects. Significance levels: * 0.10 **0.05 *** 0.01.