Upgrading Food Product Quality:

The Impact of Tariffs and Standards

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Abstract

In this paper the effects of tariff reduction and enhanced standards on efforts to upgrade food product quality are analyzed. Compliance costs are introduced into a model of competition and innovation where the rate of food product quality upgrading is affected by both changes in tariffs and standards. Using disaggregated data for European food imports from 159 trading partners over the period 1995 to 2003 across 28 industries, it is found that the effect of lower tariffs and stricter standards on quality upgrading varies non-monotonically, whereby products that already have relatively higher quality are more likely to be upgraded but those having relatively lower quality are less likely to be upgraded.

Keywords: Competition, standards, product quality upgrading, distance-to-frontier

JEL classification: F13, F14, O13

Introduction

Food product quality matters in international trade (Curzi, Raimondi, and Olper, 2015). Food safety and other concerns have led many countries to adopt standards designed to improve the quality of traded food products. Based on data for the two-digit Harmonized System, six of the ten sectors with the highest intensity of standards cover food and agricultural products (Essaji, 2008). In 1995, the World Trade Organization (WTO) adopted the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) which establishes the basic trade rules for food safety and animal and plant health standards. It grants member countries the right to set their own standards if scientifically justified. Although the aim of the SPS Agreement is to share common regulations across WTO member countries, the measures have the potential to reduce trade flows, thereby generating negative economic outcomes.

The European Union (EU) has adopted food safety standards in line with the SPS Agreement, and over time, enforcement has become stricter. The number of standards applied to food products by the EU has also grown from about 150 in 1996 to almost 800 in 2003. Food safety standards generally refer to voluntary standards, yet these provide a legal basis for developing or initiating mandatory standards or regulations (see Article 2.4 of the WTO Agreement on Technical Barriers to Trade (TBT)). All member states and any exporters who seek market access should conform to the "essential requirements" of standards enforced by the European Committee for Standardization (CEN), a trans-national association established by national standard-setting bodies across Europe. Exporters also have an incentive to adopt the standards since consumers are generally well aware of the risks associated with food safety (Segerson, 1999). Therefore, standards affect exporter behavior even though adoption may not in fact be mandatory.

The increased use of food product standards is commonly rationalized as the response of policymakers to consumer demand for characteristics such as improved product safety, sustainable production methods, and greater product information (Wilson, 2007; Sexton, 2013). Key here is the role of standards in solving two market failures: provision of public goods in food production, and reduction of transactions costs associated with information asymmetries concerning product characteristics. In this context, standards are expected to generate aggregate welfare gains (increased utility to consumers exceeding the cost of implementing standards), although redistribution from consumers to producers may occur depending on the extent to which standards increase the price of food products (Swinnen, 2016).

The potential for redistribution through standards leads to the possibility that lobby groups seek to influence policymakers in the establishment and implementation of the standards. Importantly, in an open economy setting, there is a possibility that they may provide protection to domestic producers, and are, therefore, subject to "regulatory capture" (Fischer and Serra, 2000; Swinnen, 2016; 2017). In an environment where commitments were made in the Uruguay Round of GATT to bind/lower tariffs on agricultural and food products and improve market access, the growth in food product standards has led to a focus on evaluating whether standards are nontariff measures (NTMs) designed to generate protectionist outcomes.

While the distortionary effect of tariffs is well-understood, there is no straightforward welfare presumption about the trade impact of standards (Beghin, 2013). Standards may reduce trade due to their price effects, but at the same time increase domestic welfare due to resolution of a market failure. Alternatively, under appropriate supply and demand conditions, standards can act as a "catalyst" to trade, with benefits to both consumers, as well as domestic and foreign producers (Swinnen, 2016). In the case of food product standards, the bulk of the empirical evidence supports the "barrier to trade" hypothesis, e.g., Otsuki et al. (2001), Wilson and Otsuki (2004), Olper and Raimondi (2008), and Li and

Beghin (2012). While there is currently limited empirical support for the "catalysts to trade" hypothesis, there is evidence that developing countries that have taken advantage of high standards have been successful in accessing export markets (Maertens and Swinnen (2007); Anders and Caswell (2009); Swinnen (2016)).

A shortcoming of much of the empirical literature relating to food product standards is that it focuses on their impact on trade flows, while ignoring the potential benefits of standards for which consumers are willing to pay a higher price. Safety is essentially one of several credence attributes associated with food products, i.e., an attribute that cannot be verified either ex ante or ex post by consumers (Swinnen, 2016). It is also well-documented in the agricultural economics literature that product labeling and standards are a means to resolving this asymmetric information problem. Industrial organization research typically assumes that application of standards for credence attributes result in higher quality products being supplied to consumers at higher prices (Bonroy and Constantos, 2015), appealing to the notion of vertical product differentiation. This suggests that empirical research should focus on the effect of standards on both the quantity and quality of traded goods, at the same time taking into account the effects of trade liberalization.

An important motivation for the analysis presented in this paper can be found in the developing focus in international economics on the dynamic response of exporting firms to reduced trade costs (Melitz and Redding, 2014). Verhoogen (2008), Baldwin and Harrigan (2011), Johnson (2012), Kugler and Verhoogen (2012) incorporate vertical product differentiation into a heterogeneous firms-trade setting (Melitz, 2003) generating a common prediction that more productive firms perform better in export markets selling higher-quality goods at higher prices. In other theoretical analysis, Burstein and Melitz (2013) show that when trade liberalization is anticipated, innovation increases ahead of the reduction in trade costs, while Melitz and Redding's (2014) analysis indicates that exporting firms choose a higher rate of innovation than non-exporters.

Recent empirical analysis has also found that entry into export markets, stimulated by reductions in trade costs, is associated with increased firm innovation, e.g., Verhoogen (2008) (product quality upgrading by Mexican exporting firms occurred after depreciation of the Mexican peso); Lileeva and Trefler (2010) (lower US tariffs under the Canadian-US Free Trade Agreement induced higher rates of product innovation by Canadian exporters); Bustos (2011) (the MERCOSUR free trade agreement generated technology upgrading by Argentinian exporters); and Aw, Roberts and Xu (2011) (simulated export market expansion raises productivity of Taiwanese electronics firms).

Burstein and Melitz's (2013) model has similarities to the "distance-to-the-frontier" approach to competition and innovation of Aghion et al. (2004; 2005; 2009). In the latter approach, it is hypothesized that increased market competition due to entry of new firms influences innovation and firm productivity, and the relationship between competition and innovation depends on the closeness of products to the world technology frontier. If firms' products are initially close to the technology frontier, the threat of entry encourages firms to innovate as a means of avoiding competition (the "escape-competition" effect). On the other hand, firms with products far from the frontier anticipate losing market share through competition with new entrants and, therefore, reduce innovation (the Schumpeterian or "discouragement" effect). In other words, there is a non-monotonic relationship between increased competition and innovation.

Applying this analysis, and using Khandelwal's (2010) approach to measuring product quality, Amiti and Khandelwal (2013) find that for a sample of 10,000 products for 56 countries exporting to the US over the period 1990 to 2005, lowering their own tariffs is associated with upgrading of quality for products close to the technology frontier, but not so for products distant from the frontier. Using a similar methodology, Curzi, Raimondi and Olper (2015) also find empirical support for the distance-to-the-frontier hypothesis using a sample of EU-15 imports of food and agricultural products from 70 countries that reduced their import tariffs over the period 1995 to 2007. Interestingly, Curzi, Raimiondi and Olper (2015) also find a statistically significant relationship between upgrading of food product quality and the diffusion of EU voluntary product standards, which holds for all products, irrespective of their closeness to the technology frontier, providing support for the hypothesis that standards are a "catalyst" to trade.

The key contribution of the current paper is to analyze the impact on product quality of a reduction in tariffs as well as implementation of more rigorous product standards by an *export-destination* market (the EU). Adapting Aghion et al. (2004), the analysis predicts that in both cases it is possible for the relationship to be non-monotonic, i.e., reductions in tariffs and enhancement of standards result in upgrading of quality for products close to the technology frontier. This approach differs from Curzi, Raimondi and Olper (2015) who focus on the impact on food product quality of a reduction in tariffs by *export-source* countries as well as diffusion of EU standards.

The empirical analysis also differs from Curzi, Raimondi and Olper (2015) in two ways: first, the sample used excludes intra-EU trade data, given that all EU members share the same external trade policy; and second, weighted standards are used in this analysis. Not all standards have the same importance for trading partners because trading partners do not export all products to which standards are applied. For example, cocoa beans in Nigeria are the highest value food export, such that cocoa bean standards are likely to be of greater importance than other food safety standards. Therefore, standards are weighted according to the products' export value as a share of industry sales. As a result, the standards data vary substantially across exporters, products, and observation periods.

Using a sample of EU food imports from 159 trading partners over the period 1995 to 2003 across 28 industries, tariff reduction by the EU pushes leading exporting firms to improve their product quality relative to laggard firms as predicted by the distance-to-the-frontier model. In addition, stricter product standards are found to have a negative effect on upgrading of product quality due to exporting firms incurring compliance costs in meeting standards. Specifically, the effect of standards on quality upgrading varies non-monotonically according to the relative quality level, indicating that products far from the technology frontier are less likely to undergo quality upgrading, while the opposite is true for products close to the frontier, a result that runs counter to the findings of Curzi, Raimondi and Olper (2015), and one that holds for products exported by OECD and non-OECD countries. Overall, these results suggest that there is no clear welfare presumption for or against higher standards raising product quality, rather it depends on how close a product already is to the technology frontier. This suggests that the impact of standards on product quality is considerably more subtle than the "barriers" versus "catalyst" to trade hypotheses would suggest.

The remainder of the paper is structured as follows: EU product standards in the food and agricultural sector are described, followed by derivation of the distance-to-the-frontier model that forms the basis of the empirical analysis. The empirical specification and estimation methodology are then outlined, along with a description of the data and presentation of the estimation results. Finally, the paper is summarized and some conclusions are drawn.

EU Standards in the Food and Agricultural Sector

A standard is a technical specification indicating requirements for products, production processes, or test-methods. The focus in this paper is on the EU which maintains strict laws and regulations regarding food safety, and where it is expected that standards will have an impact on food product quality. There are three European Standardization Organizations (ESOs), that have ratified European Standards (ENs), CEN, CENELEC, and ETSI. Although the three ESOs are different in terms of their fields of specialization, they cooperate in areas of common interest. EU members have the obligation to implement standards at the national level and so ENs automatically become a national standard. Even though ENs are voluntary technical standards according to EU Regulation 1025/2012, specific EU laws and regulations refer to standards, thereby making compliance with standards compulsory. For example, genetically modified (GM) food labeling requirements laid out in regulation (EC) No 1829/2003 and 1830/2003 are mandatory. Producers have to provide information relating to products that are either GM or contain genetically modified organisms (GMOs). In terms of implementation, detailed technical methods of analysis for the detection of GMOs are guided by ENs, e.g., EN ISO 21569, CEN/TS 15568. Another example is EU regulation (EC) No 2160/2003, which lays down specific mandatory requirements for non-EU members to have a salmonella control program for food products. In Article 12 of the regulation, participating laboratories in control programs are required to apply a quality assurance system that conforms to ENs. Thus, firms in exporting countries along with firms in EU member countries must comply with these voluntary standards to enter and remain in the EU market.

In examining the data for EU food safety standards over the period 1995 to 2003, it is clear that the numbers established have risen significantly, increasing from 48 to 759 standards, which compares to an increase of 33 to 119 in the number of standards established by the International Organization for Standardization (ISO) (EU Standards Database, 2006). Also, the number of total pages of EU standards has increased from 278 to 10,049, implying increasing strictness/rigor of those standards.

Theoretical Background

Model

The model developed in this section draws on Aghion et al. (2004; 2005), Acemoglu, Zilibotti, and Aghion (2006), and Burstein and Melitz (2013). There are two countries, home and foreign, consumers in either country deriving utility from a non-traded final product Y (a basket of specific food products) supplied by a competitive sector (food retailing). In each time period t, Y is produced using a continuum of intermediate inputs $v \in [0,1]$ (specific food products) according to the production function:

$$Y_t = \int_0^1 (A_t(v)^{1-\alpha} x_t(v)^{\alpha}) dv, \qquad 0 < \alpha < 1, \tag{1}$$

where $A_t(v)$ is a productivity index measuring the quality of the intermediate input in sector v at time t, and $x_t(v)$ is the quantity of the intermediate input in sector v at time t. Burstein and Melitz (2013) argue explicitly that increased productivity can be directly interpreted as an increase in product quality, no assumptions being made in the model concerning the physical quantity units of the intermediate inputs v. In addition, models of supply of quality by firms typically ensure a mapping between an exogenous parameter and the endogenous supply of product quality, the endogenous parameter being referred to variously as: capability (Sutton, 2007; Kugler and Verhoogen, 2015); ability (Khandelwal, 2008); and, productivity (Verhoogen, 2008), an increase in this parameter implying an increase in product quality.

Intermediate inputs v produced in the home country can either be used to produce Y in the home country or they are exported for use in producing the foreign final good, subject to tariffs and standards imposed by the foreign country. The term v represents both an intermediate sector and an intermediate firm since each intermediate input is produced and sold exclusively under Bertrand competition by only one firm at time t. Intermediate firms live for one period, however, property rights over productive technology are transmitted within them between periods.

Equilibrium profit for each intermediate firm is proportional to the productivity parameter:

$$\pi_t(v) = \delta A_t(v), \tag{2}$$

where $\delta = \left(\frac{1}{\alpha} - 1\right)\left(\frac{1}{\alpha^2}\right)^{-(1/1-\alpha)}$. The parameter δ measures the extent which entry into either the home or foreign market is governed by policies such as import tariffs and standards (Acemoglu, Zilibotti, and Aghion, 2006). For example, establishment of more stringent standards will result in an increase in δ.

If a firm v successfully innovates, its productivity parameter $A_t(v)$ increases, interpreted as an increase in product quality. For example, let the technology level of a firm at the technology frontier (denoted "leader") in the previous time period $t-1$, be denoted as $\bar{A}_{t-1}$. If the leader successfully innovates, their productivity parameter $\bar{A}_{t-1}$ grows at the exogenous rate γ in the next time period t as:

(3) $$\bar{A}_t(v) = \gamma \bar{A}_{t-1} \qquad \gamma > 1$$

At the beginning of period t intermediate firms are one of three types. Type-1 firms are leaders, with a productivity level $A_{t-1}(v) = \bar{A}_{t-1}(v)$. Type-2 firms are one step behind the frontier, with $A_{t-1}(v) = \bar{A}_{t-2}(v)$, and type-3 firms are two steps behind with $A_{t-1}(v) = \bar{A}_{t-3}(v)$ (type 2 and 3 firms are denoted "laggards"). Innovation allows an incumbent firm to increase its productivity at the constant rate γ. However, it is assumed that type-3 firms have no need to invest in innovation because they can innovate automatically as a result of knowledge spillovers.

Let z denote the probability that firms successfully innovate. This probability also depends on firms' willingness to launch and complete innovation, indicating innovation intensity. Accordingly, z becomes a decision variable that represents how much firms invest in innovation based on expected profit and innovation cost. With probability z the incumbent's productivity increases and lags by $j-1$ steps behind the new frontier. A type- j intermediate firm, $j \in 1, 2$ at time t must invest in innovation at cost c_i as:

(4) $$c_i(z_j) = \left(\frac{z_j^2}{2}\right) c_i A_{t-j}(v).$$

In addition to innovation cost c_i, firms must also consider the compliance costs of meeting standards. Let c_c denote compliance costs, i.e., the expenditure required to conform to a standard. Compliance costs are assumed to be imposed only on a type-2 intermediate firm along with innovation cost, because the technology level of a type-1 firm is assumed greater than the minimum required by the standard. If the required level of technology is $\bar{A}_{t-1}$, a type-2 firm incurs compliance costs as well as the innovation cost when they wish to enter the market, but a type-1 firm incurs only innovation cost. Compliance costs have the same functional form as innovation cost denoted by $c_c(z_j) = \left(\frac{z_j^2}{2}\right) c_c A_{t-j}(v)$ for $j = 2$. Therefore, the total cost of a type-*j* intermediate firm, $j \in 1,2$ is:

(5) $$c(z_j) = \left(\frac{z_j^2}{2}\right)(c_i + (j-1)c_c) A_{t-j}(v).$$

In the current paper, the focus is on competition among firms exporting to the EU market. Incumbent firms are defined as those currently exporting to the EU while potential entrants are defined as other foreign firms who make an effort to enter the EU market and compete with the incumbent firms. In each time period there is the threat of entry from outside firms that operate with end-of-period frontier productivity $\bar{A}_t$. Under Bertrand competition an entrant firm captures the entire market and becomes the incumbent firm if it is more productive than incumbent firms. Otherwise the profits of both firms become zero if the entrant has identical productivity. Now, assume that potential entrants are able to observe post-innovation technology. A potential entrant will not pay the entry cost if it cannot operate on the frontier post-innovation because Bertrand competition would drive profits to zero. Laggards never invest in innovation because at best they catch up to their rival and earn zero profits.

Equilibrium Innovation without Compliance Cost

Let p define the probability that a new firm enters the market, where a reduction (increase) in entry costs (tariffs/standards) corresponds to an increase (decrease) in the probability of entry p (see Aghion et al., 2004). A type-1 leader retains the market under only two scenarios: either it successfully innovates with probability of z_1, or no firm enters even if it fails to innovate with probability of $(1-z_1)(1-p)$. For a type-2 firm, there are also two scenarios: they either successfully innovate with probability of $z_2(1-p)$ or they fail to innovate under the condition that no firm enters with probability of $(1-z_2)(1-p)$. A firm that is initially close to the technology frontier chooses its investment z_1, and a type-2 incumbent chooses its investment z_2 to maximize the expected net payoff from innovation as:

(6a) $$\max_{z_1} \delta[z_1\bar{A}_t + (1-z_1)(1-p)\bar{A}_{t-1}] - (z_1^2/2)c_i\bar{A}_{t-1}$$

(6b) $$\max_{z_2} \delta[z_2(1-p)\bar{A}_{t-1} + (1-z_2)(1-p)\bar{A}_{t-2}] - (z_2^2/2)c_i\bar{A}_{t-2},$$

with the first-order conditions of (6a) and (6b) yielding:

(7a) $$z_1 = \frac{\delta}{c_i}(\gamma - 1 + p)$$

(7b) $$z_2 = \frac{\delta}{c_i}(1-p)(\gamma - 1).$$

Equilibrium Innovation with Compliance Costs

Firms incur additional costs when their technology does not meet standards. As assumed above, a type-1 firm does not bear any costs of complying with standards, due to their technology satisfying the minimum required standard. In contrast, a type-2 firm has to bear costs of complying with established standards. A type-2 incumbent chooses its innovation intensity z_2 to maximize the expected net payoff from innovation:

$$(8) \qquad \max_{z_2} \delta[z_2(1-p)\bar{A}_{t-1} + (1-z_2)(1-p)\bar{A}_{t-2}] - (z_2^2/2)(c_i + c_c)\bar{A}_{t-2},$$

the first-order condition of (8) yielding:

$$(9) \qquad z_2 = \frac{\delta(1-p)(\gamma-1)}{(c_i + c_c)}.$$

The Effects of Competition and Compliance Costs

The effect on innovation of an increased threat of entry into the export market due a reduction in tariffs is shown by partial differentiation of (7a) and (7b) with respect to the probability p :

$$(10a) \qquad \frac{\partial z_1}{\partial p} = \delta / c_i > 0,$$

$$(10b) \qquad \frac{\partial z_2}{\partial p} = -\delta(\gamma-1)/c_i < 0.$$

A higher p boosts innovation for a type-1 firm. As the likelihood a firm will lose out to an entrant increases, the incentive for a leader to "escape-competition" increases. On the other hand, higher p reduces the expected payoff from innovating to the type-2 firm, so it reduces its innovation effort. A firm this far below the frontier knows it cannot survive even if it innovates.

The innovation decision of intermediate firms faced with tougher standards depends on the extent to which such a policy intervention acts as a barrier to entry relative to compliance costs. The effect of higher standards is shown by partial differentiation of (7a) and (7b) with respect to δ :

$$(11a) \qquad \frac{\partial z_1}{\partial \delta} = (\gamma - 1 + p)/c_i > 0,$$

$$(11b) \qquad \frac{\partial z_2}{\partial \delta} = (1-p)(\gamma-1)/(c_i + c_c) > 0.$$

A higher δ raises the likelihood of innovation for both firms, because increased monopoly power raises expected profits in the next period. However, the magnitude of the effect is always larger for type-1 firms, i.e., $(\gamma - 1 + p)/c_i > (1 - p)(\gamma - 1)/(c_i + c_c)$. In other words, all firms in the market expect higher profit once they know that new entrants are unlikely to enter the market in the current period, but a type-1 firm will innovate more than a type-2 firm. In addition, a type-2 firm is less likely to innovate due to the higher compliance costs that only applies to them, i.e., partially differentiating (9) with respect to c_c:

(12) $$\frac{\partial z_2}{\partial c_c} = -\frac{\delta(\gamma - 1)}{(c_i + c_c)^2} < 0.$$

Overall, however, the impact of stringent standards on innovation activity for a type-1 firm is ambiguous, where the threat of entry, p, and the extent to which trade policy raises barriers to entry, δ have conflicting effects, i.e., a type-1 firm is less likely to innovate due to a lower probability of entry, but it is more likely to innovate because of the potential to earn additional monopoly profits in the next period from innovation, (10a) and (11a). If the effect of trade policies as entry barriers is greater than the low competition effect, a type-1 firm will increase innovation activity. In the case of a type-2 firm, the effect of standards enforcement on innovation is also inconclusive in that the reduced threat of entry, which depends on the regulatory policy, and compliance costs have conflicting effects. Owing to standards enforcement, a type-2 firm is more likely to innovate due to less competition and greater monopoly power, (10b) and (11b), but they are less likely to innovate because of the effect of costs of compliance, (12). If the effect of additional compliance costs is larger than the effect of reduced competition, a laggard firm will decrease innovation activity.

The predictions of the model are summarized in table 1: policies that promote competition through lower entry costs, e.g., lower tariffs, will discourage laggards from devoting resources to innovation, but will encourage leaders to increase their innovation expenditures. However, the enforcement of more rigorous standards may not always encourage innovation because on the one hand it lessens competition for both types of intermediate firm, but on the other it increases available monopoly rents from innovation, and also increases compliance costs for type-2 firms. Therefore, the net effect of more rigorous standards on innovation is ambiguous. Under the pressure of incurring compliance costs, laggard firms may resist innovation activities whereas high expected monopoly profits for leading firms meeting standards may result in their boosting innovation efforts.

Empirical specification

Quality Estimation

Typically in the literature, product quality has been measured through either import or export unit values (Schott, 2004; Hallak, 2006). While this approach is relatively easy to implement, it is problematic in that import or export prices may differ for reasons other than quality, such as exchange rates or labor cost differences. In the current paper, product quality is measured using market share information along with import unit values (Khandelwal, 2010). A nested logit system is used to take account of the structure of consumer preferences as well as the horizontal component of different product varieties, e.g., vanilla-flavored vs. strawberry-flavored yogurt. The horizontal component is incorporated in the demand estimation to account for horizontally differentiated products having higher market shares. As a result, quality is treated as the unobserved vertical differentiation of products at a given import unit price and market share.

To measure food product quality, i.e., the quality of intermediate inputs v, the nested logit demand model of Berry (1994) is used. Following the notation of Amiti and Khandelwal (2012), a product ch is defined as product h supplied at time t by firms based in exporting country c. With industry subscripts suppressed, the reduced form of the demand equation for product ch at time t is:

$$(12) \qquad \ln(S_{cht}) - \ln(S_{ot}) = \lambda_{1,ch} + \lambda_{2,t} + \lambda_{3,cht} - \alpha_1 P_{cht} + \alpha_2 \ln(ns_{cht}) + \alpha_3 (pop_{ct}).$$

S_{cht} is the EU market share of product ch, defined as $S_{cht} = q_{cht} / MKT_t$, q_{cht} is the EU's imported quantity of a product h from exporting country c, and $MKT_t = \sum_{ch \neq o} \frac{q_{cht}}{(1 - S_{ot})}$ is the industry size within the EU. The outside product, denoted as o, represents the intra-EU alternative to ch, its market share at time t, S_{ot}, is defined as $S_{ot} = (1 - IMPPN_t)$, where import penetration of ch $IMPPN_t$ = (import quantity of ch) / [import quantity of ch + (production quantity of o - export quantity of o)]. The left hand side of (12) expresses consumers' indirect utility from choosing the imported product ch over the intra-EU produced product o. Indirect utility is a function of the imported product's unit value P_{cht}, the nested share ns_{cht} defined as product ch's share within product h, at time t, and population pop_{ct}. The unexplained part of indirect utility λ_{cht} is treated as the measure of product quality:

$$\lambda_{cht} = \lambda_{1,ch} + \lambda_{2,t} + \lambda_{3,cht},$$

where $\lambda_{1,ch}$ is the time-invariant valuation of product ch, $\lambda_{2,t}$ is the time-variant common quality component, and $\lambda_{3,cht}$ is the product-time deviation from the fixed effect unobservable to consumers.

The population of partner countries pop_{ct} is included in (12) to control for unobserved varieties (Feenstra, 1994; Hallak and Schott, 2011). For example instance, if China exports a wide variety of green tea products which are not observed in the Harmonized System, observable aggregate data would overestimate the quality of Chinese green tea. The assumption here is that the number of varieties produced increases with a country's population (Krugman, 1980).

Two-stage least square (2SLS) is used to estimate (12), due to the endogenous variables price P_{cht} and nest share ns_{cht}. In the case of price, the identification strategy is to use a proxy for transportation cost as an instrument, as it is correlated with import price but not quality. Specifically, the interaction between oil prices and average distances from partner countries to the EU-15 is used as a proxy. The exchange rate between trading partners is also used as an instrument given that import prices are influenced by exchange rate changes but quality is not (Amiti and Khandelwal, 2012; Curzi, Raimondi, and Olper, 2015). In the case of nest share ns_{cht}, the identification strategy uses the number of varieties within product *h* and the number of varieties exported by country *c* in order to account for entry and exit of varieties in the market, the latter being correlated with a product's share within the nest but not correlated with a product's quality (Amiti and Khandelwal, 2012; Curzi, Raimondi, and Olper, 2015).

Quality Upgrading and Competition

The non-monotonic relationship between competition and innovation outlined earlier is estimated by the interaction of distance-to-the-frontier *DF* with both tariffs and standards:

(13a) $$\Delta \ln(\exp(\lambda_{cht})) = \beta DF_{ch,t-3} + \phi \boldsymbol{X}_{ch,t-3} + \eta(DF_{ch,t-3} \times \boldsymbol{X}_{ch,t-3}) + \alpha_{ht} + \alpha_{ct} + \varepsilon_{cht},$$

(13b) $$\text{where: } DF_{cht} = \exp(\lambda_{cht}) / \max_{c \in ht}(\exp(\lambda_{cht})), DF_{cht} \in [0,1].$$

In (13a), the dependent variable $\Delta \ln(\exp(\lambda_{cht}))$ is the change in a product's quality over a period of three years. Distance-to-the-frontier *DF* is measured according to (13b), where for products close to the frontier $DF \to 1$, and for products far from the frontier $DF \to 0$. $\boldsymbol{X}_{ch,t-3}$ is a vector of tariff and standards variables lagged three years, while α_{ht} and α_{ct} are product-year and country-year fixed effects, respectively. Given quality is estimated by industry, the quality of products should be compared within an industry using product-year fixed effects. Product-year fixed effects also control for systemic shocks that affect all varieties of a specific product at a point in time such as demand shocks. Country-year fixed effects control for country-level shocks such as changes in either factor endowments, productivity, or national-level technology shocks.

The coefficient on the tariff variable is expected to be positive whereas the coefficient on *DF*-tariff interaction is expected to be negative. A reduction in tariffs will only result in an increase in product quality in the subsequent three years if a product is close to the world quality frontier, $DF_{ch,t-3} \rightarrow 1$, and vice-versa for a product far from the frontier $DF_{ch,t-3} \rightarrow 0$, i.e., the "escape-competition" and "discouragement" effects respectively (Aghion et al., 2004; 2005).

For standards, there are potentially conflicting effects. First, more rigorous EU standards limit the threat of entry facing exporters, positively (negatively) affecting quality upgrading for laggard (leader) firms. However, the impact of stricter standards on quality upgrading may be reinforced (outweighed) by the expected increase in monopoly profits from innovation for laggard (leader) firms, the effect being larger for firms closer to the technology frontier. Second, stricter standards may also directly affect product quality, exporters to the EU having to bear the burden of compliance costs. Given that the level of compliance cost depends on distance-from-the-frontier, these costs are greater for laggards than leaders. The most-backward firms innovate only if the compliance costs necessary to satisfy the standards requirement are close to zero. Therefore, stricter standards are more likely to have a positive effect on quality upgrading for leaders as compared to laggards.

Data

Food product trade data over the period 1995 to 2003 are constructed for the EU-15 as follows: using the concordance table from Eurostat's Reference and Management of Nomenclatures (RAMON) database to identify the industry to which products belong, trade data based on the eight-digit Combined Nomenclature (CN) code from EUROSTAT-Comext are linked to the four-digit NACE industry classification. Domestic production data are taken from Eurostat's Production Communautaire (Prodcom) database using the eight-digit PRC code. Given that the first four digits of the PRC code match the four-digit NACE industry, it is straightforward to link them together. For the second stage of estimation, we use *ad valorem* EU tariffs applied to all exporting countries from WITS (World Bank) at the HS six-digit level from 1995 to 2003.

In terms of tariffs, the sample size for estimation of (13a) is constrained according to availability of data. Data on standards are from the European Union Standard database of the World Bank. These data include product standards for textiles and agriculture issued by CEN over the period 1995 to 2003 (Shepherd, 2006). These count data link into the harmonized system (HS) four-digit level, which is also linked to the PRC code according to the concordance table from EU RAMON. In order to measure the rigor of product standards, the number of pages of standards are used, and while the data refer to voluntary standards, they have the potential to be adopted as technical regulations as indicated earlier in section 2.

Finally, data on exchange rates are from the International Monetary Fund's (IMF) International Financial Statistics (IFS) and oil prices are for Brent crude. These data are in denominated in US dollars, which are then converted to Euros based on the Euro-US dollar exchange rate from IFS, i.e., exchange rates show the exporter's local currency value in Euros. All prices are deflated using the Consumer Price Index from IFS. (See table 2 for descriptive statistics)

Estimation Results

Quality Estimates

Given that the trade data are noisy, observations above and below the 5^{th} and 95^{th} percentiles of import unit values are excluded, along with varieties that report zero import quantities. Concerns regarding the sample selection problem are addressed by using the 2SLS estimator with valid instruments. As a result, the estimators using the selected sample are consistent and asymptotically normally distributed (Wooldridge, 2010). The choice between fixed or random effects is based on the Hausman test, with the null hypothesis that random effects are preferable. For three industries in the sample, the null hypothesis is not rejected, hence random effects is used. In the case of the remaining industries, the null is rejected, hence fixed effects is used. Overall, 28 separate regression equations are estimated for the sample of industries.

The quality estimation results are reported in table 3. The signs of the estimated coefficients other than for population are as expected. The effect of population on import market share is heterogeneous across industries and the magnitudes of the estimated coefficients vary across food industries. The negative price coefficients (mean and median) indicate that an increase in export price reduces net export market share. The nested share coefficients (mean and median) also follow expectations in that net export market share increases once a product achieves a large nested market share. These coefficients are used to predict unobserved product quality.

In table 4 the reliability of the quality estimates are evaluated by examining the relationship between exporter productivity and product quality. Specifically, analysis is conducted on the relationship between the proportion of products exported with highest quality and proxies for exporting country productivity: exporter GDP per capita and the structure of their respective labor force by education level. Column (1) reports a pair-wise correlation between quality and the proxy productivity variables. Due to highly educated workers having higher productivity and jobs that require more skill (Mincer, 1974; Weiss, 1995), it is expected that a more educated-labor force will have a comparative advantage in implementing new technology, which results in higher product quality (Bartel and Lichtenberg, 1987; Rosenzweig, 1995). Columns (2)-(4) show regression results with the proportion of highest quality products as the dependent variable. The result in column (2) indicates that countries with higher GDP per capita export a larger proportion of high quality products, while Columns (3) and (4) indicate that exports of higher quality products increase from countries with a greater proportion of the labor force having tertiary education.

The plot of quality leaders for a sample of food products is shown in figure 1. All products show a positive relation between exporter GDP per capita and the fraction of high quality products. Norway, Japan, USA, and Australia are located above the fitted line, indicating their export products have relatively higher quality with respect to their income level. Since these countries are highly engaged in international trade, high quality may result from learning-by-doing. On the other hand, Middle-Eastern countries such as Oman, and Kuwait are located under the fitted line, showing relatively lower quality goods exported with respect to income level. This may be due to the fact that a large portion of their GDP per capita is based on crude oil production. In sum, it can be concluded that the product quality estimates are reliable and can be used in the second stage of the estimation.

Quality Upgrading and Competition

In the second stage of estimation the effects of tariffs and standards on the quality estimates obtained in the first stage are analyzed. Due to noise in the data, changes over three years in both the estimates of product quality and import tariffs are trimmed above and below the 5^{th} and 95^{th} percentiles. The estimation results for the second step are shown in table 5. As noted earlier, the interaction terms are used to show the presence or lack of a non-monotonic relationship between competition and innovation. The results for all countries in the sample are shown in columns (1)-(3). In order to evaluate any differences in the impact of tariffs and standards, the sample is split into OECD and non-OECD countries, the results being shown in columns (4) and (5) respectively.

In columns (1) and (2) respectively, the effect of tariffs and standards on product quality upgrading is shown. Column (3) reports the estimation results for the full equation (13a and 13b) including all trade policy measures. The signs of the coefficients remain the same in the different specifications, implying that the “escape-competition” and “discouragement” effects hold for all model specifications. Similar to the results reported by Amiti and Khandelwal (2012), and Curzi, Raimondi and Olper (2015), distance to the frontier has a negative coefficient $\beta < 0$, i.e., a product far from the frontier will experience faster quality upgrading. The tariff variable has a positive coefficient but the coefficient of the interaction term is negative. The former indicates the effect of tariff on a product far from the technology frontier and the latter indicates the effect on a product close to the technology frontier. Therefore, the positive tariff coefficient supports the "discouragement" effect, suggesting laggards are less likely to upgrade product quality when tariffs are reduced. In the case of more rigorous standards, the coefficient on the standards variable has a negative sign showing that a laggard product is less likely to undergo quality improvement due to establishment of stricter standards. On the other hand, the interaction term has a positive coefficient indicating that a product close to the technology frontier is more likely to be upgraded in terms of quality.

For all countries in the sample, the results reported in table 6(a) show the following: a 10 point reduction in tariffs decreases effort to upgrade a product by 18.3 percent if a product is located far from the technology world frontier (the "discouragement" effect). On the other hand, the interaction coefficient indicates that a firm with a product closer to the technology frontier is eager to improve quality, supporting the idea of the "escape-competition" effect, i.e., a 10 point reduction in tariffs is associated with a 2.7 percent increase in quality upgrading for products close to the technology frontier ("escape-competition"). In the case of standards, for products far from the frontier, a one page increase in standards is associated with a 23 percent decrease in quality upgrading, while equivalent standards strictness for products close to the frontier is associated with a 19.3 percent increase in quality.

These results suggest that the burden of compliance cost due to more rigorous standards is a stronger factor influencing innovation activities than the effects of increased competition due to tariff reduction. The positive coefficient of the interaction term indicates that firms producing leading products exhibit a higher level of innovation activity, implying stricter standards increase quality upgrading efforts. Exporting firms producing leading products may make greater efforts to improve product quality once standards enforcement raises the probability of capturing a larger market share, and the associated monopoly profits, by limiting the competition among exporters. The relationship between market share, standard enforcement, and quality upgrading is examined in the robustness tests in the next section.

The effect of tariffs on quality upgrading is different between exports from non-OECD and OECD member countries. With a tariff reduction, products exported by non-OECD countries show a stronger non-monotonic relationship compared to products exported by OECD countries. As shown in table 6(b), products close to the frontier exported by non-OECD and OECD members are increased in quality by 4.9 and 2.1 percent respectively in response to a 10 point reduction in tariffs. The "discouragement" effect on laggard firms of a similar tariff reduction is also larger for products exported by non-OECD countries at 25.0 percent compared to 22.1 percent for OECD countries. Overall, the results suggest that as tariffs are reduced, the gap between high and low-quality products is increasing at a faster rate for non-OECD as compared to OECD countries. These results are consistent with the view that even with trade liberalization, it may be difficult for developing countries to upgrade the quality of their products if they are located far from the technology frontier.

The effect of standards on quality upgrading is also non-monotonic. For products close to the frontier, the results indicate firms in non-OECD countries increase their efforts to upgrade quality by more relative to firms from OECD members. As shown in table 6(b), products near the technology frontier exported by non-OECD and OECD countries exhibit upgrading of quality by 23.3 and 11.9 percent respectively in response to a one page increase for standards. In contrast, for laggard products exported by non-OECD countries, firms decrease their efforts to upgrade their products by less compared to products exported by OECD countries, although the "discouragement" effect is large in both cases. Specifically, a one page increase for standards results in an 18.5 and 30.4 percent decrease in product quality for non-OECD and OECD countries respectively. This result can be interpreted as follows: increased compliance costs have less impact relative to increased profits from reduced competition for laggard products exported by non-OECD as compared to OECD countries. Overall though, the results suggest that as standards get stricter, the gap between high and low-quality products is increasing at the same rate for both non-OECD and OECD countries.

Robustness Checks

As one robustness check, an alternative dependent variable is used to represent product quality. The model outlined earlier assumes that improved product quality is the outcome of firms' innovation activities, product quality being estimated through unit values which are contingent on market share. Instead of using the nested logit demand model (Berry, 1994), an alternative proxy for product quality is a weighted unit value, measured according to the share of the products' import value in the industry. The results from using this alternative dependent variable are shown in table 7. While the sign of η_1 was not as expected, the signs of the other coefficients remain the same.

A second robustness check relates to the effect of stricter standards on leading products. Earlier, the positive effect of standards on leading products was interpreted as being due to the higher probability of firms capturing a larger market share, along with the associated monopoly profits. Regression results for high and low Herfindal-Hirschman (*HHI*) EU market concentration indices also support this interpretation. Based on the definition of the market concentration index used by the World Bank, *HHI* measures the dispersion of imported values across the EU market, and is computed as:

$$HHI_{ht} = \frac{\sum_{c=1}^{n_{ht}} \left(\frac{x_{cht}}{X_{ht}} \right)^2 - \frac{1}{n_{ht}}}{1 - \frac{1}{n_{ht}}},$$

where x_{cht} is the EU's import of product *h* from country *c*, at time *t* and X_{ht} is EU's the total import of product *h*, at time *t*, and n_{ht} is the number of exporters of product *h* time *t*.

HHI represents the products' dependency on its trading partner, EU at time *t*. For example, a higher value of *HHI* shows that exported products are concentrated in fewer EU markets, whereas a lower value of *HHI* indicates products are exported to a larger number of EU partners. First, the sample is divided into two groups, the top and bottom 10 percent of *HHI*, and then (13) is used to evaluate the different effect of standards on products in markets with relatively high and low concentration respectively, the results being shown in table 8.

Columns (1)-(3) focus on concentrated markets, the results indicating that additional standard enforcement makes leading products more likely to be upgraded in terms of quality whereas tariff reduction makes laggard products less likely to be upgraded. Columns (4)-(6) show the results for markets with low concentration, firms producing leading products being more likely to have their quality upgraded due to standard establishment while the magnitude of the coefficient is smaller than that of products in highly concentrated markets (column (3) of table 7).

These results confirm the earlier findings: in highly concentrated markets there will be greater effort to upgrade product quality as stricter standards are established. Because more rigorous standards push leaders to capture the current market by limiting entry of new firms, leading firms can boost their innovation efforts in pursuit of high profits. Therefore, the conclusion concerning the positive effect of standards on leading products remains valid.

Summary and Conclusions

The key motivation for this research draws on two strands of literature: analysis of the impact of increased access to export markets on firm-level productivity and innovation (Burstein and Melitz, 2013; Melitz and Redding, 2014); and, analysis of whether standards act as "barriers" or "catalysts" to trade (Swinnen, 2016). In order to evaluate the impact on product quality of changes in both of these policies, the competition and innovation model of Aghion et al. (2004) is adapted to include a reduction in trade costs as well as the costs of complying with enhanced food product standards. The analysis presented predicts a non-monotonic relationship between product innovation and increased competition, i.e., tariff reduction encourages (discourages) quality upgrading by leading (laggard) exporting firms, providing evidence for the "escape-competition" ("discouragement") effect(s). Similarly, a non-monotonic relationship is also possible between product innovation and more rigorous standards, i.e., higher standards may encourage (discourage) quality upgrading by leading (laggard) exporting firms. Despite a reduced threat of entry (higher standards), the expected profit from capturing additional market share plays an important role in leading firms upgrading product quality, while for laggard firms, compliance costs have a much greater influence on their decision not to upgrade product quality.

In light of the theory, the empirical analysis evaluates the impact of tariff reduction and stricter standards on exporters' efforts to upgrade product quality, focusing on EU imports from 159 trading partners of products from 28 food industries over the period 1995 to 2003. Product quality is measured using the nested logit model of Berry (1994), as applied by Khandelwal (2010), from which product-specific distances to the technology frontier are derived. Using the latter estimates, the key empirical results provide statistically significant support for the hypotheses concerning a non-monotonic relationship between EU tariff reduction as well as more rigorous EU standards and imported food product quality. The results also suggest that, for both OECD and non-OECD countries the gap between firms at the technology frontier and laggard firms is getting wider as tariffs are reduced and product standards increased.

The key findings of this research reinforce the argument that there is no clear presumption concerning the impact of product standards on trade: specifically, for firms close to (far from) the frontier, more rigorous standards are a “catalyst” (“barrier”) to increasing product quality, the relationship holding across both OECD and non-OECD countries. Also, while evidence is found for a positive effect of a reduction in trade costs on innovation, this effect is concentrated among firms that are close to the technology frontier. Importantly, from a policy standpoint, addressing the gap in food product quality for developing country exporters is critical, especially if the latter are to be included in value chains that implement high product standards. Possibilities for mitigating this gap include provision of a grace period for developing countries after the effective date of implementation of higher standards, along with aid aimed at improving their ability to meet those standards.

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Figure 1. Relation between GDP per capita and fraction of high-quality products

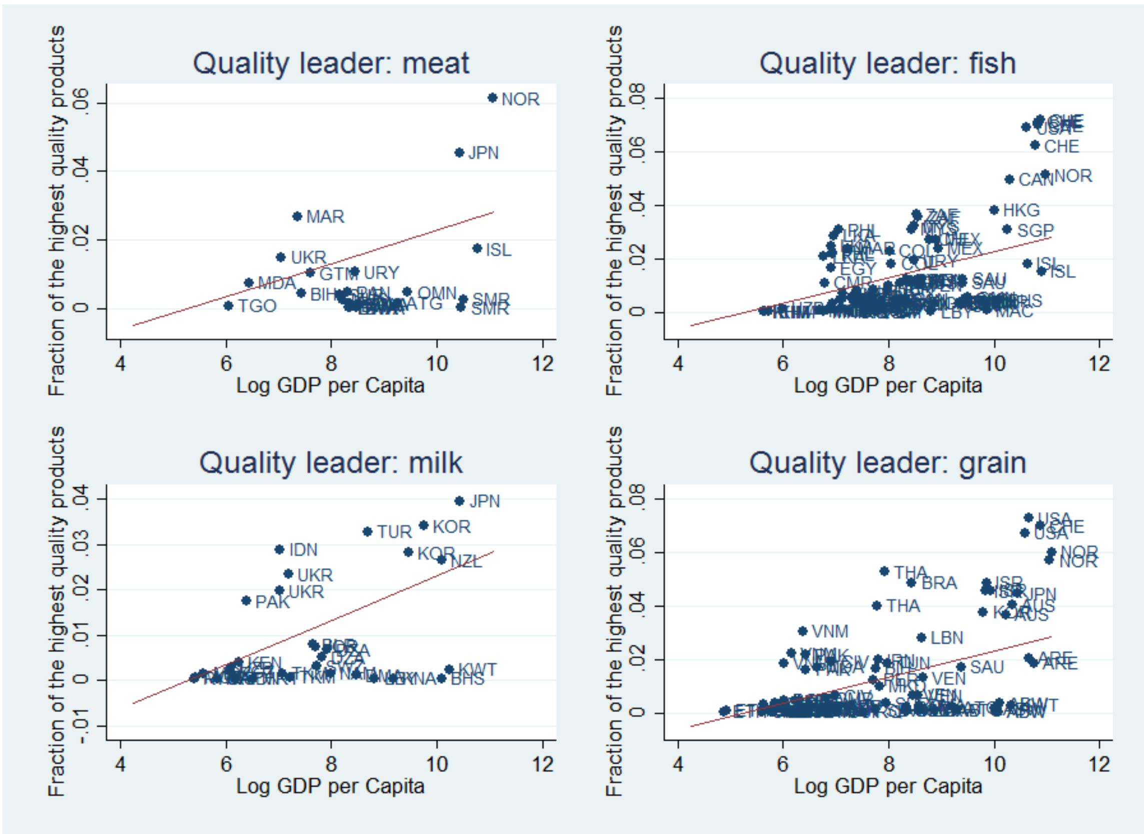

Table 1. Competition, Compliance Costs and Innovation

Policy Variables	Policy Change	Competition	Counter Effect	Type	Innovation
Tariff	Decrease	Strong	-	Type-1	More
			-	Type-2	Less
Standard	Increase	Weak	Barriers to entry	Type-1	More or Less
			Compliance costs	Type-2	More or Less

Table 2. Descriptive Statistics for EU Food Trade Data (1995-2003)

Variable	Mean	Min	Max	Unit
Import value*	1.89	0	2,128	Million Euro
Import quantity*	4.03	0	10,700	Million Kg
Export value*	1.60	0	1,103	Million Euro
Export quantity*	1.20	0	850	Million Kg
Product value*	1,937.14	0	27,000	Million Euro
Product quantity*	1,918	0	40,900	Million Kg
Population*	97.40	0.025	1,303	Million people
Exchange rate*	502.40	0	15,858.92	Local currency per Euro
Distance to EU-15*	6,178.02	970.70	18,317.67	Average distances
Oil price*	24.27	11.45	43.86	Euro
Tariff**	18.61	0	481.77	Tariff rate
Standard pages***	188.22	0	893.00	Page count
Euro-USD exchange rate*	1.13	0.90	1.33	Dollar per one Euro
CPI*	82.31	73.66	90.72	CPI in Euro

*78,012 observations, ** 62,788 observations, and *** 60,183 observations

Table 3. Food Product Quality Estimation Results (1995-2003)

Industry number			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Industry description		Meat	Poultry	Meat &	Fish	Potatoes	Fruit & Veg	Fruit &	Crude Oils
Variables	**Mean**	**Median**		Meat	Poultry			Juice	Vegetables	& Fats
Price	-0.266	-0.006	0.032	-0.262	-0.353*	0.293	-0.567***	-0.800**	-0.155	-3.578***
Nest share	0.765	0.807	0.903***	0.800***	0.283	0.914***	0.755***	0.403*	1.169***	0.575
Population	-0.307	-0.047	-0.267	1.192	0.391	1.449***	1.695	-1.015	0.032	-13.24**
Number of Varieties	427.04	355.00	505	220	298	1,388	153	464	1,557	495
Observations	2589.36	2151.50	2,907	1,061	1,419	9,396	828	2,435	10,350	2,792

	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
	Refined Oils & Fats	Margarine & Similar Fats	Dairy & Cheese	Grain Mills	Starches	Bread & Pastry	Rusks & Biscuits	Sugar	Cocoa Chocolate	Macaroni & Noodles
Price	-0.069	0.074	0.009	-2.256**	-1.060*	0.195	-1.580	0.828	0.973*	0.468
Nest Share	0.611***	1.005***	0.765***	0.352	0.479***	1.030***	0.666***	0.491*	0.986***	0.866***
Population	0.555	-0.011	-1.640**	-0.937	-1.150	0.824*	-3.486	1.003	-0.084	0.253
Number of Varieties	437	67	362	655	313	95	519	294	1,170	209
Observations	2,321	345	1,651	4,117	1,768	644	2,749	1,706	7,222	1,348

	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)
	Tea Coffee	Condiments & Seasonings	Food Preparations	Other Food Products	Distilled Alcohol	Ethyl Alcohol	Wines	Beer	Malt	Mineral Waters & Soft Drinks
Price	0.246	0.201**	-0.003	-0.210**	-0.155**	0.071	-0.008	0.491	-0.434	0.149
Nest Share	0.814***	1.050***	1.124***	0.682***	0.868***	0.947***	0.657***	0.884***	0.350	0.995***
Population	-2.379	-0.166	-0.295	-0.346	-1.080**	2.562	0.816**	-0.451	6.983	0.192
Number of Varieties	381	293	174	488	390	66	480	111	25	348
Observations	2,354	2,072	981	3,354	2,284	337	2,912	809	109	2,231

Notes: Country-product and year fixed effects are used. Robust standard errors are in parenthesis. Significant levels: *** at 1 per cent; ** at 5 per cent and * at 10 percent.

Table 4. Correlation and OLS results with Fraction of Exporters' Products with Highest Quality

Regressors	**Pair-wise Correlation (1)**	**OLS (2)**	**OLS (3)**	**OLS (4)**
Ln GDP per capita	0.507	0.306*** (0.002)		
Ln labor force with primary education	-0.333		-0.012*** (0.000)	
Ln labor force with tertiary education	0.290			0.015*** (0.000)
Fixed effects		Yes	Yes	Yes
Adj. R-squared		0.2666	0.1307	0.0995
Observations		77,009	35,517	35,510

Notes: Robust standard errors are clustered by country. Significant levels: *** at 1 per cent; ** at 5 per cent and * at 10 percent.

Table 5. Quality Upgrading and Competition

Regressors		**All countries**		**Non-OECD**	**OECD**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
$DF_{cht\text{-}3}$ (β)	-1.245***	-1.760***	-1.352***	-1.459***	-1.387***
	(0.142)	(0.131)	(0.136)	(0.219)	(0.398)
Tariff $_{cht\text{-}3}$ (θ_1)	1.864***		1.828***	2.502***	2.213***
	(0.503)		(0.506)	(0.644)	(0.777)
Trf $_{cht\text{-}3}$*$DF_{cht\text{-}3}$ (η_1)	-2.105***		-2.099**	-2.009*	-2.421
	(0.904)		(0.913)	(1.112)	(1.728)
Standards $_{cht\text{-}3}$ (θ_2)		-0.238***	-0.232***	-0.185***	-0.304*
		(0.066)	(0.066)	(0.066)	(0.159)
Stnd $_{cht\text{-}3}$*$DF_{cht\text{-}3}$ (η_2)		0.417***	0.425***	0.418***	0.423*
		(0.093)	(0.093)	(0.097)	(0.231)
Product-year FEs	Yes	Yes	Yes	Yes	Yes
Country-year FEs	Yes	Yes	Yes	Yes	Yes
Adj. R-squared	0.1393	0.1392	0.1409	0.1531	0.1561
Observations	18,825	18,825	18,825	10,771	7,789

Notes: The dependent variable is change in the log of quality and all explanatory variables are three-year lagged values. Robust standard errors are clustered by country. Significant levels: *** at 1 per cent; ** at 5 per cent and * at 10 percent respectively. The number of standards was used instead of numbers of pages for standards as a measure of their strictness, the results, which are available on request, are very similar to those reported in this table.

Table 6. Effect of Tariffs and Standards on Upgrading of Quality

a. All Countries

Variables		**Distance to frontier**	**Upgrading of quality (%)**
Tariffs	Decrease tariff by 10 points	Close	+ 2.7
		Far	-18.3
Standards	Increase by 1 page	Close	+19.3
		Far	-23.2

b. OECD vs. non-OECD Countries

Variables		**Countries**	**Distance to frontier**	**Upgrading of quality (%)**
Tariffs	Decrease tariff by 10 points	OECD	Close	+2.1
			Far	-22.1
		Non-OECD	Close	+4.9
			Far	-25
Standards	Increase by 1 page	OECD	Close	+11.9
			Far	-30.4
		Non-OECD	Close	+23.3
			Far	-18.5

Table 7. Robustness Checks – Weighted Unit Value as Dependent Variable

Regressors	Δ in log(unit price)		
	(1)	(2)	(3)
DF_{cht-3} (β)	-3.568***	-3.807***	-3.908**
	(0.126)	(0.093)	(0.136)
Tariff $_{cht-3}$ (θ_1)	2.747***		2.721***
	(0.486)		(0.481)
Trf $_{cht-3}$*DF_{cht-3} (η_1)	0.958**		0.650
	(0.484)		(0.485)
Standards $_{cht-3}$ (θ_2)		-0.777***	-0.772***
		(0.065)	(0.068)
Stnd $_{cht-3}$*DF_{cht-3} (η_2)		1.543***	1.528***
		(0.114)	(0.115)
Product-year FEs	Yes	Yes	Yes
Country-year FEs	Yes	Yes	Yes
Adj. R-squared	0.1261	0.1345	0.1370
Observations	17,092	17,092	17,092

Notes: Unit values have been trimmed at the 5th and 95th percentiles. The dependent variable is the change in the log of quality and all explanatory variables are three-year lagged values. Robust standard errors are clustered by country. Significant levels: *** at 1 per cent; ** at 5 per cent and * at 10 percent respectively.

Table 8. Robustness Checks - Quality Changes in Low and High *HHI* market

	Δ in quality (high concentration)			Δ in quality (low concentration)		
Regressors	(1)	(2)	(3)	(4)	(5)	(6)
DF_{cht-3} (β)	-1.454***	-1.888***	-1.604***	-0.019	-1.579***	-0.152
	(0.352)	(0.216)	(0.330)	(0.524)	(0.235)	(0.525)
Tariff_{cht-3} (θ_1)	0.866		0.867	0.994		0.986
	(1.365)		(1.343)	(1.213)		(1.216)
$\text{Trf}_{cht-3}*DF_{cht-3}$ (η_1)	-0.783		-1.260	-7.122**		-7.129**
	(1.377)		(1.110)	(3.043)		(3.048)
Standards_{cht-3} (θ_2)		-0.184	-0.185		-0.144	-0.141
		(0.157)	(0.158)		(0.104)	(0.104)
$\text{Stnd}_{cht-3}*DF_{cht-3}$ (η_2)		0.897***	0.928***		0.466**	0.474**
		(0.197)	(0.201)		(0.202)	(0.209)
Product-year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Country-year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R-squared	0.1069	0.1124	0.1115	0.2365	0.2269	0.2377
Observations	1,585	1,585	1,585	2,161	2,161	2,161

Notes: The dependent variable is the change in the log of quality and all explanatory variables are three-year lagged values. Robust standard errors are clustered by country. Significant levels: *** at 1 per cent; ** at 5 per cent and * at 10 percent respectively.