Food Safety Standards and Quality Upgrading through Import Competition

Jihyun Eum
Dept. of Agricultural, Environmental and Development Economics
Ohio State University
eum.9@osu.edu

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Abstract

This paper investigates the effect of tariffs and non-tariff measures on efforts to upgrade product quality. Following conventional approaches to quality measurement, we examine disaggregated data covering the European Union's food imports from 159 trading partners from 1995 to 2003 across 28 food industries. Food product import tariffs and non-tariff measures are found to affect the rate of quality upgrading. Furthermore, we find the effect of import standard enforcement on quality upgrading to be non-monotonic, in that the products close to the world technology frontier are more likely to upgrade, while those distant from the frontier are less likely to upgrade.

Keywords: Import competition, quality upgrading, food quality, distance to frontier.

JEL Classification Numbers: F13, F14, O13

1 Introduction

The quality of traded goods plays a crucial role in international trade patterns and outcomes. With regard to food products, product quality is of prime importance in trade standards since it is directly related to human health. Concerns regarding food safety have led many countries to adopt non-tariff measures aimed at improving the quality of traded food products. The Agreement on the Application of Sanitary and Phytosanitary Measures(SPS Agreement) enforced by the World Trade Organization(WTO) in 1995 establishes the basic rules for food safety, along with animal and plant health standards. The aim of the agreement is to share common regulations across the member countries to improve overall welfare of economies. Despite this aim, such non-tariff measures could distort trade liberalization and cause negative economic outcomes.[1]

In this paper we analyze the effect of tariffs and non-tariff measures on quality improvement. We focus on the European Union(EU)-15[2] market since the EU has adopted food safety standards in line with the SPS agreement, and over time has grown stricter in their enforcement. Trade standards are technically referred to as voluntary, but in practice they are the basis for mandatory technical regulation. Since voluntary standards tend to be adopted as a part of regulatory frameworks or in legislation, they influence exporters' behavior. Our estimation is guided by the simple "distance to the frontier" model of Aghion, Blundell, Griffith, Howitt, and Prantil (hereafter ABGHP). This model predicts that enhanced market competition influences firm innovation efforts, and that relationship between competition and innovation depends on the closeness of the world technology frontier (Khandelwal, 2010; Porter and Van Der Linde, 1995). We consider tariffs and non-tariff measures as policy tools influencing competition level and quality improvement as innovation. In this

[1] See Linder (1961) and Melitz (2003) for details on the role of product quality in international trade. Country-level empirical findings can be found in Schott (2004), Hummels and Klenow (2005), Hallak (2006),Otsuki et al. (2001),Hallak and Schott (2011),Fajgelbaum and Khandelwal (2014),Essaji (2008),Anders and Caswell (2009).

[2] Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom

paper we assume product quality is improved as a result of innovation activities although innovation includes a broad range of activities, such as patenting, product differentiation, or creating new processes. This paper directly interprets firm productivity as product quality, following Burstein and Melitz (2011). Accordingly, innovation to improve productivity is equivalent to innovation that improves product quality.

Few studies observe a direct link between competition and products quality. Amiti and Khandelwal (2012) observe the effect of tariff reduction on quality improvement by using the "distance to the frontier model" with US trade data. They argue that trade liberalization by lowering tariffs is associated with quality upgrading for products close to the quality frontier, but discourages quality upgrading for products distant from the frontier. Curzi et al. (2014) investigate the impact of non-tariff measures along with tariffs on the EU's food product industry. Their result confirms that the products close to the world frontier are more likely to upgrade quality in response to an increase in import competition. In addition, they find that the EU voluntary standards positively affect quality upgrading. Their study is the first to analyze the effect of the standards but the positive effect of non-tariff measures is not consistent with the theoretical expectations.

Our study generates several new findings. First, we extend the previous competition and innovation theory of Aghion et al. (2004) by introducing compliance cost. This allows us to address changes in conditions of the import standards enforcement. Second, we suggest a way to improve the estimation process. For instance, we exclude the intra-EU trade data from the sample. This exclusion should improve the estimation of importers' competition since all EU members share the same external international trade policy. In our methodology we also weight import standards. Not all standards have the same importance because trading partners do not expect all standards to have the same effect on the product. For example, Nigeria exports cocoa beans at the highest value among their export products; therefore, they consider the standards concerning cocoa beans more crucial than any other food safety standards. The standards are weighted according to the share of the products' import value in the industry. Thus, standards data vary substantially across exporters, products, and observation periods.

We also find empirical differences from Curzi et al. (2014), who report positive effects of EU voluntary food quality standards on the rate of quality upgrading. In our study, we instead find a negative effect of standards on quality improvement because importers face the burden of compliance costs if the products do not satisfy the standards requirements. Compliance costs thus negatively affect food product quality improvement. This relationship is non-monotonic, indicating that products far from the technology frontier are less likely to undergo quality upgrades, and vice versa for products close to the frontier. Intense competition, caused by tariff reductions in the import market, drives leading products to improve their quality as oppose to the laggards, as predicted by the“distance to the frontie” model.

The remainder of this paper is structured as follows. In Section II, we describe the theoretical “distance to frontier” model which forms the basis of our empirical specification. In Section III, we explain our empirical specification and the methodology we used for the estimation. In Sections IV and V, we describe the data and provide our estimation results, receptively. In Section VI, we offer some concluding remarks.

2 Theoretical background

We follow the theoretical framework of in Aghion et al. (2004) (ABGHP) and Aghion et al. (2005). We assume two firms are innovating for each intermediate input under Bertrand competition. All agents live for one period, and a final good is produced using a continuum of intermediate inputs in sector v, 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 $x_t(v)$ is the quantity of the intermediate input used in sector v at time t and $A_t(v)$

represents productivity that measures the quality of the intermediate input to produce the final good, Y_t.

The variable v represents both an intermediate sector and intermediate firm because each intermediate product is produced and sold exclusively by only one firm at time t. The intermediate firms live for one period, and property rights are transmitted to the follower. A successful firm v improves the technology parameter A_t and can replace the early innovator until displaced by the next innovator. The equilibrium profit for each intermediate firm is proportional to the productivity parameter (Aghion et al., 2005):

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

where $\delta = (\frac{1}{\alpha} - 1)(\frac{1}{\alpha^2})^{-\frac{1}{1-\alpha}}$

Assume that the frontier technology $\overline{A}_t$ at time t grows at the exogenous rate.

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

At the beginning of period t intermediate firms follow three types. Firms of type-1 operate at the current frontier, with a productivity level $A_{t-1}(v) = \overline{A}_{t-1}(v)$. Type-2 firms are one step behind the frontier, with $A_{t-1}(v) = \overline{A}_{t-2}(v)$, and type-3 firms are two steps behind, with $A_{t-1}(v) = \overline{A}_{t-3}(v)$

Innovation allows an incumbent firm to increase its productivity by the constant factor γ. However, we assume that type-3 firms do not 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. A type-j intermediate firm with $j \in 1, 2$ at time t must invest

$$c_i(z_j) = ({z_j}^2/2)c_i A_{t-j}(v) \tag{4}$$

We also assume a type-2 intermediate firm should pay an additional compliance cost when the market has the standards for the innovation level. The compliance cost is the expenditure in conforming with the standard's requirement. We make an assumption that the required level of productivity is $\overline{A}_{t-1}$. The incumbent firms should pay the compliance cost beside innovation investment when they wish to enter the market. The compliance cost is:

$$c_c(z_j) = ({z_j}^2/2)c_c(j-1)A_{t-j}(v) \tag{5}$$

Therefore, the total cost paid by a type-j intermediate firm with $j \in 1, 2$ follows:

$$c(z_j) = ({z_j}^2/2)(c_i + (j-1)c_c)A_{t-j}(v) \tag{6}$$

With probability z, the incumbent's productivity increases and lags by *j-1* steps behind the new frontier.

In each period there is an entry threat from outside firms that are considered to operate with the end-of-period frontier productivity, $\overline{A}_t$. Under Bertrand competition a new firm captures the entire market and becomes the new incumbent firm in the sector if the entering firm is more productive. Otherwise the profits of both firms become zero, if the entrant has the same productivity. Now, assume that potential entrants are able to observe post-innovation technology. Then, the new firm would not pay the entry cost if it cannot operate on the frontier after innovation since Bertrand competition would drive its profit to zero. The incumbent laggard firms never invest in innovation because at best they would catch up to its rival and earn zero profits.

2.1 Equilibrium innovation without compliance cost

A firm that is initially close to the frontier choose its investment so as to:

$$max_{z_1} \quad \delta[z_1\overline{A}_t + (1-z_1)(1-p)\overline{A}_{t-1}] - (z_1^2/2)c\overline{A}_{t-1} \tag{7}$$

Hence, from the first order condition we get:

$$z_1 = \frac{\delta}{c}(\gamma - 1 + p) \tag{8}$$

where z_1 is the innovation decision for a type-1 firm

In other words, the type-1 leader retains the market when it successfully innovates or it does not successfully innovate and there is no entry.

A type-2 incumbent chooses its $R\&D$ investment z to maximize the expected net payoff from innovation:

$$max_{z_2} \quad \delta[z_2(1-p)\overline{A}_{t-1} + (1-z_2)(1-p)\overline{A}_{t-2}] - (z_2^2/2)c_i\overline{A}_{t-2} \tag{9}$$

from which the first order condition yields:

$$z_2 = \frac{\delta}{c}(1-p)(\gamma - 1) \tag{10}$$

where z_2 is the innovation decision for a type-2 firm

A type-2 incumbent retains the market if it successfully innovates and no firms enter (probability $z(1-p)$) or it cannot successfully innovate with no entry(probability $(1-z)(1-p)$).

2.2 Equilibrium innovation with compliance cost

As we assumed above, a type-1 firm seldom bear expenses to meet the standards requirement because their technology is close enough to the frontier. The compliance cost would not be imposed for a type-1 firm when established standards exists, whereas a type-2 firm have to bear compliance cost. In brief, when a firm's level of technology does not meet the standards requirements they need to invest additional cost.

With a consideration of compliance cost, only innovation decision for a type-2 firm changes. A type-2 incumbent chooses its $R\&D$ investment z_2 to maximize the expected net payoff from innovation:

$$max_{z_2} \quad \delta[z_2(1-p)\overline{A}_{t-1} + (1-z_2)(1-p)\overline{A}_{t-2}] - (z_2^2/2)(c_i + c_c)\overline{A}_{t-2}, \tag{11}$$

so that by the first-order condition:

$$z_2 = \frac{\delta(1-p)(\gamma-1)}{(c_i + c_c)} \tag{12}$$

2.3 The effects of the competition and compliance cost

In the case of the innovation without compliance cost, the effects on innovative activity from an increasing entry threat can be shown by differentiation of (8) and (10) with respect to the probability p. This yields:

$$\frac{\partial z_1}{\partial p} = \delta/c > 0, \tag{13a}$$

$$\frac{\partial z_2}{\partial p} = -\delta(\gamma-1)/c < 0 \tag{13b}$$

An increase in entry threat through higher p, boosts innovation by a type-1 firm. As increasing the likelihood that the firm will lose out to an entrant if it fails to innovate, thus increasing the firms' incentive to "escape from the competition" by innovating. On the other hand, higher p reduces the expected payoff from innovating to an incumbent firm two steps behind the frontier, so reduces its innovation effort. This is because a firm this far behind the frontier knows that it cannot survive entry even if it innovates.

On the other hand, if compliance cost is imposed to firms, then the innovation decision depends both on the entry threat and the compliance cost. The entry threat declines as the market enforces the standards (i.e. import standards). New firms now face difficulties in entering the market when their level of technology does not meet the requirements of the standards. On the other hand, compliance cost arises as additional standard enforces. Thus, the effects on innovative activity from changes of entry threat and compliance cost can be shown by differentiation (12) with respect to the probability p and cost c_c.

$$\frac{\partial z_2}{\partial p} = -\frac{\delta(\gamma - 1)}{c_i + c_c} < 0, \tag{14a}$$

$$\frac{\partial z_2}{\partial c_c} = -\frac{\delta(\gamma - 1)}{(c_i + c_c)^2} < 0 \tag{14b}$$

As a result, the effect of standards on innovation activity is ambiguous for a type-2 firm, in that entry threats and compliance costs have conflicting effects. Owing to standards enforcement, a type-2 firm is more likely to innovate because of less competition, but they are less likely to innovate because of compliance cost. If the effect of compliance cost is larger than the effect of competition, a laggard firm will decrease innovation activity. On the other hand, the effect of standards enforcement on innovation for a type-1 firm would be negative, in that less entry threat makes firms reduce innovation as in equations (13a).

Table 1: Competition, compliance cost and innovation

Variables		Competition	Compliance cost	Type	Innovation
Tariff	Decrease	Strong	-	Type 1	More
			-	Type 2	Less
Standard	Increase	Weak	-	Type 1	Less
			Imposed	Type 2	More or Less

Table 1 shows the predictions based on theoretical analysis. The ABGHP model shows that any policies that promote competition, such as lowering the entry cost, will discourage lagging firms from spending resources on innovation but vice versa for leading firms. However, the enforcement of a standard does not support the model because it lessens competition but simultaneously incurs compliance expense. Therefore, the net effect of a standard on innovation activity is ambiguous. Under the pressure of compliance cost, lagging firms may resist innovation activities.

3 Empirical specification

3.1 Quality estimation

Contrary to previous studies that use unit values as a proxy for product's quality (Hallak, 2006; Schott, 2004), we follow Khandelwal (2010) and estimate product quality using a consideration of market share information along with unit value. A product with a larger market share implies high quality. For example, say the unit value of Chinese green tea was $50, and that of English green tea was $80. If we just use a unit value as a proxy for quality, then the green tea from England would be recognized as a high-quality product. However, if China exports ten times more green tea than England, then we should also consider how Chinese green tea dominates the import market. Its dominance in the import market implies that consumers favor the high quality of Chinese tea. Therefore, Chinese green tea is considered as a high-quality product by virtue of its substantial import market share.

To measure product quality, we use the nested logit demand model presented by Berry (1994).[3] We define a variety ch as a product h imported from country c. The reduced form of the demand equation for an imported variety ch at time t is as follows. We suppress industry subscripts.

$$ln(S_{cht}) - ln(S_{0t}) = \lambda_{1,ch} + \lambda_{2,t} + \lambda_{3,cht} - \alpha P_{cht} + \delta ln(ns_{cht}) + \gamma ln(pop_{ct}) \qquad (15)$$

where ns_{cht} is the nest share, variety ch's share within product h at time t.

The left hand side of (17) expresses consumer preference for product h imported from country c over a domestically produced variety at time t. S_{cht} is the overall market share of variety ch and it is defined as $S_{cht} = q_{cht} \ / \ MKT_t$, where q_{cht} is the imported quantity of the variety and $MKT_t = \sum_{ch \neq 0} q_{cht}/(1 - s_{0t})$ is the industry size. S_{0t} is the outside variety, indicating the domestic alternative to the imported good and defined as one minus

[3] See Appendix.

the import penetration rate of the industry at time t.[4]

This indirect utility of the imported variety ch over the domestic alternative would be a function of a variety's unit value, nested share, and population. Population of partner countries is included in the estimation equation to control for the unobserved varieties Feenstra (1994); Hallak and Schott (2011). For instance, if China exports wide varieties of green tea products which are unobserved at the Harmonized System level(e.g., wide ranges in the extraction level or water-to-tea ratio), then the aggregate data at the observable level will overestimate the quality of Chinese green tea. Therefore, we also include the population of the partner countries to control the issue, such that the number of varieties produced increases with a country's population (Krugman, 1980).

The λ terms indicate the variety's valuation, a proxy for quality. $\lambda_{1,ch}$ is the time-invariant valuation of the variety ch, and the year-fixed effect $\lambda_{2,t}$ is the time variant common quality component. $\lambda_{3,cht}$ is a variety-time deviation from the fixed effect that is not observed. Thus, the product quality of variety ch at time t, λ_{cht}, would be the sum of the three estimated components:

$$\lambda_{cht} = \lambda_{1,ch} + \lambda_{2,t} + \lambda_{3,cht} \tag{16}$$

Two-stage least square(2SLS) analysis is applied to estimate equation (13), because there are two endogenous variables: the nest share and the price. The identification strategy in the case of the nest share is to use the number of varieties within product h and the number of varieties exported by country c as instruments, indicating the entry and the exit of varieties in the import market. The entry and exit of other varieties is correlated with a given variety's share within the nest, but not with a that variety's quality (Amiti and Khandelwal, 2012; Curzi et al., 2014). In the case of the endogenous price variable, our identification strategy is to use transportation cost. This is because transportation costs are correlated with the price but not with quality. However, as transportation cost data for the EU-15 countries is

[4] $IMPPN_t$ = import quantity / import quantity + production quantity - export quantity

limited, we proxy costs by the interaction of oil prices and the average distances between partners and the EU-15. We also include the exchange rate between trading partners since import price is under the influence of the exchange rate changes, but quality is not (Amiti and Khandelwal, 2012; Curzi et al., 2014). Using 2SLS also solves the sample selection problem, as will be discussed in Section 5.

3.2 Quality upgrading and import competition

The effect of competition on innovation is specified as below (Amiti and Khandelwal, 2012; Curzi et al., 2014). The quality differences over three years measure the innovation activity, and import tariffs and food product import standards are parameters allowing changes in the competition level.

We construct the proximity to the frontier(PF) measures according to equation (17). First, we take a monotonic transformation of the quality estimates to make the values non-negative:$\lambda^F_{cht} = exp[\lambda_{cht}]$. Second, we construct a variety's PF as the ratio of its quality to the highest quality within each product h at time t. For varieties close to the frontier, PF is close to 1, whereas it is close to 0 for varieties far from the frontier.

$$PF_{cht} = \frac{\lambda^F_{cht}}{max_{c \in ht}(\lambda^F_{cht})}, PF_{cht} \in (0, 1] \tag{17}$$

The non-monotonic relationship between competition and innovation, based on Aghion et al. (2004), can be estimated by the interaction of proximity to the frontier(PF).

$$\Delta ln\lambda^F_{cht} = \gamma PF_{ch,t-3} + \beta X_{ch,t-3} + \delta(PF_{ch,t-3} \times X_{ch,t-3}) + \alpha_{ht} + \alpha_{ct} + \epsilon_{cht} \tag{18}$$

The dependent variable, $\Delta ln\lambda^F_{cht}$, is the change in a variety's quality over three years. $X_{ch,t-3}$ includes tariff and standards variables. All independent variables are lagged by three years. Equation (18) includes both product-year fixed effects, α_{ht} and country-year fixed effects, α_{ct}. Since quality variables are estimated by industry, the quality of products should be compared within the industry with the help of product-year fixed effects. Overall, product-year fixed effects also control the systemic shocks which impact all varieties within a product at a time, such as demand shock, an invention of the new technology, and so on. Similarly, country-year fixed effects control for the country-level shocks such as changes in factor endowments or productivity, changes in institutions, or national-level technology shocks.

The hypothesis of this paper is that the coefficient of tariffs would be positive, whereas that of the interaction of PF should be negative. Therefore, a fall in tariffs would increase a variety's quality in subsequent years only if products are close to the world quality frontier ($PF_{ch,t-3}$ close to 1), and vice versa for products far from the frontier ($PF_{ch,t-3}$ close to 0). This result supports the ABGHP model showing "the escape from the competition effect" and "the discouragement effect".

Regarding import standards, we expect mixed results driven by two conflicting effects. First, standards enforcement could limit competition among importers whereas tariff reduction would produce the opposite effects. Thus, reducing competition might have a positive impact on quality upgrading for the laggards but a negative effect for the leaders. Second, standards enforcement could directly affect products' quality, in that importers would have to bear the burden of compliance costs. Importers may be reluctant to innovate products owing to high $R\&D$ costs for innovation. Since the size of the compliance costs depends on the distance from the frontier, it is greater for the laggards than for the leaders. The most backward firms innovate only if the compliance cost for satisfying the standards requirement is near zero. Therefore, standards enforcement may in fact bring about a positive effect on quality upgrading for the leaders but a negative effect for the laggards.

4 Data

We examine food products in the EU-15 from 1995 to 2005 and classify the industry according to NACE 4-digit. We use the most disaggregated level of trade data (CN eight-digit) from EUROSTAT-Comext. However, the CN code does not directly link to the four-digit NACE industry so we use the concordance table from EU RAMON to link them together.

Domestic production data is from the EUROSTAT Prodcom database at the most disaggregated level, the eight-digit PRC code. Since the first four digits of the PRC code indicate the four-digit NACE industry, we can easily link them together. For the second stage of estimation, we use *ad valorem* tariffs of the EU towards all exporting countries from WITS (World Bank) at the HS six-digit level from 1995 to 2003. Since tariff data are limited for some countries in the sample, the sample size for the second estimation is defined according to the availability of the tariff data. Standard data are from the European Union Standard Database (EUSDB) of the World Bank. These count data enable us to predict potential technical regulations although the term "standards" refer to the voluntary guidelines. In addition, the line between mandatory and voluntary standards blurs, as the WTO also recognizes in Article 2.4 of the Agreement on Technical Barriers. [5] Therefore we treat standard count data as the basis for mandatory technical regulation. The database includes European standards count data for agricultural manufacturing products from 1995 to 2003. These count data also link into the HS four-digit level. We use both the number of standards and the number of pages of standards. HS codes are also linked to PRC codes according to the concordance table from EU RAMON.

Exchange rates are from the IMF's International Financial Statistics (IFS) and oil prices are from Brent. These data are initially shown in US dollars, so we convert them into Euros based on the Euro-USD exchange rate from IFS. Therefore, the exchange rates show the

[5] Members generally use "international standards," which are most often voluntary, as the basis for their mandatory technical regulations.

Table 2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max	Unit
Import value	78,012	1,888.36	27,998.27	0	2,128,599	1000 Euro
Import quantity	78,012	4,027.13	132,993.80	0	10,700,000	1000 Kg
Export value	78,012	1,601.54	13,582.38	0	1,103,258	1000 Euro
Export quantity	78,012	1,204.93	13,750.70	0	850,110	1000 Kg
Product value	78,012	1,937,139	3,592,913	0	27,000,000	1000 Euro
Product quantity	78,012	1,918,001	5,330,030	0	40,900,000	1000 Kg
Population	78,012	97,399.14	243,879.40	25.88	1,303,720	1000 people
Exchange rate	78,012	502.40	2,008.29	0	15,858.92	Local currency per Euro
Distance to EU-15	78,012	6,178.02	4,006.97	970.70	18,317.67	Average distances
Oil price	78,012	24.27	9.72	11.45	43.86	Euro
Tariff	62,788	18.61	29.60	0	481.77	Tariff rate
Standard	60,183	17.44	15.85	0	74.00	Count
Standard pages	60,183	188.22	181.50	0	893.00	Page count
Euro-USD exchange rate	78,012	1.13	0.14	0.90	1.33	Dollar per one Euro
CPI	78,012	82.31	5.63	73.66	90.72	CPI in Euro

exporter's local currency value per one Euro. We control for inflation by converting prices, import price and oil price, in real terms by using the Consumer Price Index from IFS.

5 Estimation results

5.1 First step: quality estimates

As the disaggregated trade data are noisy, we exclude observations above and below the 5th and 95th percentile of import unit values as well as varieties with zero import quantity. Excluding zero observations might cause sample selection problems, but this problem can be neglected because the 2SLS estimator is applied. [6]. Accordingly, the estimator using the selected sample is consistent and asymptotically normally distributed (Wooldridge, 2010).

Among the 31 industries listed, three industries are excluded from the sample because their nested shares are perfectly close to the value of the dependent variable. Since there are only few products belonging to that industry, the nest market share is almost the same as the market share. Overall, we run regressions in each industry separately, excluding industry

[6]The assumption $E(u|IVs, q_{cht}) = 0$ is needed

15.52(manufacture of ice cream), 15.94(manufacture of cider), and 15.95(manufacture of other non-distilled fermented beverages).

We estimate equation (15) by using Instrumental Variable (IV) regression. A decision on the use of fixed effects or random effects depends on the results of the Hausman test. Three industries[7] accept the null hypothesis of the Hausman test, and therefore random effects are used. The other industries reject the null, so fixed effects are used.

Table 3 shows the result of quality estimation. The directions of most coefficients, other than the coefficients of population, are as expected. The effects of population on import market share are heterogeneous across industries. The magnitude of the coefficients varies depending on the estimation methodology. The average and median of price coefficients are negative, indicating that increasing the import price reduces the net import market share. For nested share coefficient, the average and median also follow expectations in that the net import market share would increase once a variety has a large nested market share. All the signs of the coefficients follow theoretical expectations, as the theory presented in equation (15) in Section 3.1. Therefore, we use these coefficients to predict unobserved quality estimates.

[7] 15.43(Manufacture of margarine), 15.81(Manufacture of bread) 15.92(Production of ethyl alcohol)

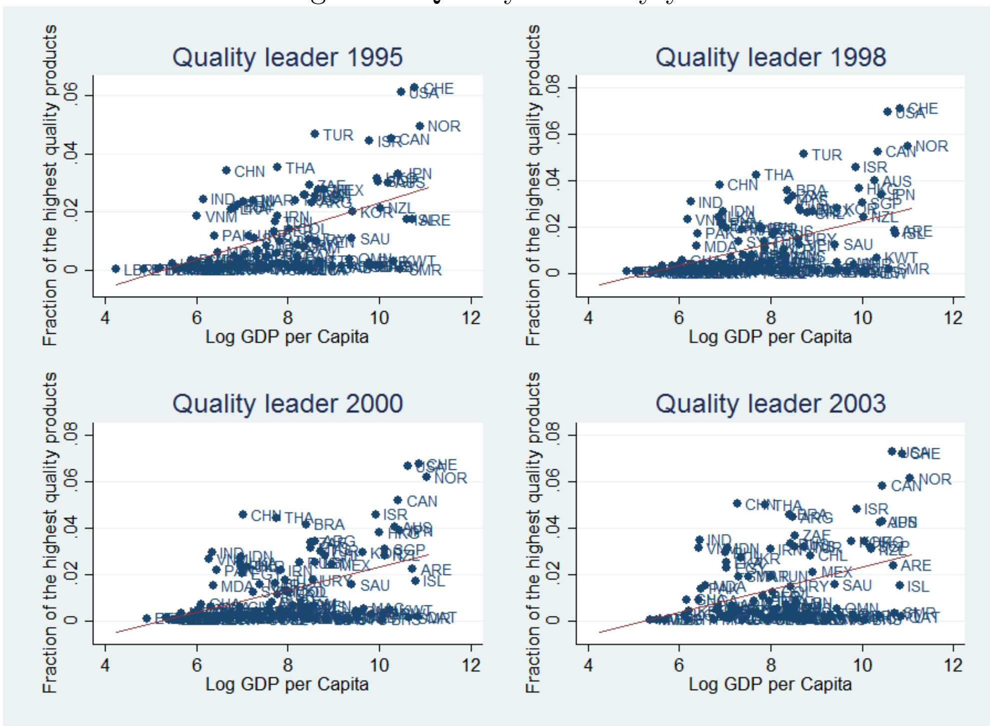
Table 3: Quality Estimation

Industry number			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Industry description			Meat	Poultry Meat	Meat & Poultry	Fish	Potatos	Fruit & veggie juice	Fruit & vegetables	Crude oils & fats
variables	**Mean**	**Median**								
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 id_prc	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	Dairies & cheese	Grain mill	Starches	Bread & pastry	Rusks & biscuit	Sugar	Cocoa chocolate	Macaroni & noodles
	-0.069	0.074	0.009	-2.256**	-1.060*	0.195	-1.580	0.828	0.973*	0.468
	0.611***	1.005***	0.765***	0.352	0.479***	1.030***	0.666***	0.491*	0.986***	0.866***
	0.555	-0.011	-1.640**	-0.937	-1.150	0.824*	-3.486	1.003	-0.084	0.253
	437	67	362	655	313	95	519	294	1,170	209
	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
	0.246	0.201**	-0.003	-0.210**	-0.155**	0.071	-0.008	0.491	-0.434	0.149
	0.814***	1.050***	1.124***	0.682***	0.868***	0.947***	0.657***	0.884***	0.350	0.995***
	-2.379	-0.166	-0.295	-0.346	-1.080**	2.562	0.816**	-0.451	6.983	0.192
	381	293	174	488	390	66	480	111	25	348
	2,354	2,072	981	3,354	2,284	337	2,912	809	109	2,231

Figure 1: Quality leader by year

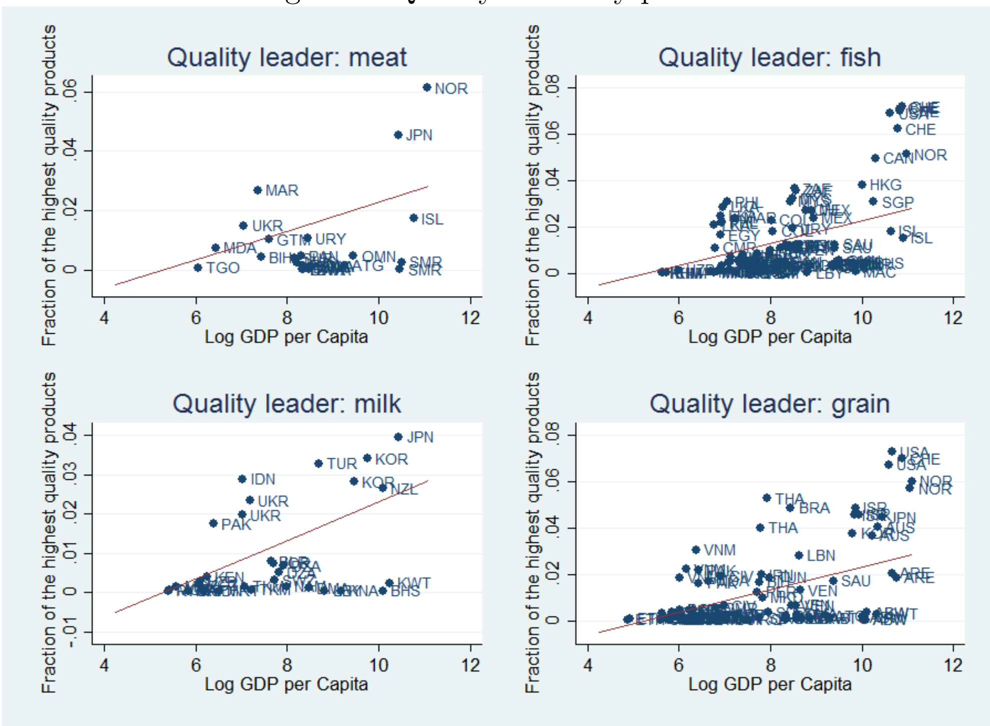


Figures 1 and 2 provide the reliability of quality estimates by describing the relationship between the importer's incomes and the imported product's quality. Since Burstein and Melitz (2011) explain that firm productivity can be directly interpreted as product quality, we consider a product's quality improvement as innovation by providing a positive relationship between productivity and quality.

Figure 1 shows the positive relationship between GDP per capita and fraction of the highest-quality products by year. Countries with high GDP per capita such as USA, Canada, Norway, and Switzerland export high quality goods over time, whereas low income countries such as Liberia, Togo, and Ethiopia export low-quality goods.

Figure 2 displays this relationship by industry. Even if quality leaders are changed within a given industry, the trend that countries with higher GDP export higher-quality goods remains the same. China, Turkey Thailand, and Brazil are located above the fitted value line, indicating their exporting products have relatively higher quality with respect to their income level. Since those countries are highly engaged in international trade, they could

Figure 2: Quality leader by product



create high-quality goods by learning-by-doing. On the other hand, Arabian countries such as Israel, Oman, and Kuwait are located under the fitted value line, showing relatively lower-quality goods are exported with respect to their income levels. This is because the majority of GDP per capita for these economies consists of oil production rather than reflecting their productivity. In sum, we conclude that the quality estimates are reliable enough to be used in the second stage of the estimation. The estimates show reasonable results such as the expected signs of the coefficients in Table 3 and positive relationship with countries' productivity in Figures 1 and 2.

5.2 Second step: quality upgrading and import competition

In the second stage of the estimation we analyze the effect of import tariffs and standards on the quality estimates we obtained in the first stage. As the quality estimates and tariff data are noisy, we trim the data by dropping the quality estimates above and below the 5th and 95th percentile of quality, and import tariff data above and below the 5th and 95th

Table 4: Quality Upgrading, Competition, and Distance to Frontier

	All countries			Non-OECD	OECD
Regressors	(1)	(2)	(3)	(4)	(5)
Lag PF (γ)	-1.157***	-1.556***	-1.258***	-1.263***	-1.348***
	(0.107)	(0.072)	(0.107)	(0.147)	(0.173)
Lag Tariff (β_1)	1.115***		1.019***	1.639***	0.921*
	(0.324)		(0.323)	(0.472)	(0.516)
Lag Trf $\times PF(\delta_1)$	-1.493**		-1.475**	-2.700**	-0.860
	(0.601)		(0.599)	(0.891)	(0.865)
Lag Standard (β_2)		-0.308***	-0.302***	-0.295***	-0.340***
		(0.036)	(0.036)	(0.043)	(0.084)
Lag Stn $\times PF(\delta_2)$		0.440***	0.442***	0.483***	0.468***
		(0.065)	(0.065)	(0.081)	(0.142)
Constant	0.398	1.006***	0.457	0.817	2.517***
	(0.490)	(0.377)	(0.502)	(0.749)	(0.354)
Product-year FEs	Yes	Yes	Yes	Yes	Yes
Country-year FEs	Yes	Yes	Yes	Yes	Yes
Adj R-squared	0.278	0.281	0.282	0.309	0.367
Observations	17,463	17,463	17,463	10,116	7,347

Robust standard errors in parentheses.
* p<0.10, ** p<0.05, *** p<0.01

percentile of changes in tariffs over three years.

The results, including the interaction of a variety's proximity to the frontier with lagged independent variables, are shown in Table 4. The interaction terms are used to show the presence or lack of a non-monotonic relationship between competition and innovation. The results, including the interaction of a variety's proximity to the frontier with lagged independent variables, are shown in Table 1. The interaction terms are used to show the presence or lack of a non-monotonic relationship between competition and innovation. The results for countries are shown in column (1)-(3). The results for the two groups (OECD and non-OECD countries) are in columns (4) and (5).

Column (1) reports the effects of tariffs on quality upgrading and that of standards is shown in column (2). Column (3) reporting the test of the main specification (8a) including all trade policy measures. The signs of the coefficients remain the same in the different specifications, which means that "the escape-competition" and "discouragement" effects hold for all model specifications. The lagged proximity to the frontier has a negative coefficient, implying that a variety with relatively lower quality improves the quality slowly. A positive coefficient of the tariff variable shows that "the discouragement effect," as the laggards are less likely to upgrade the variety quality. On the other hand, a negative coefficient of the interaction between tariffs and the distance to the frontier indicates that a variety closer to the world frontier is eager to improve quality, supporting the idea of "the escape-competition effect. Statistically, a 10 percentage point reduction in tariffs decreases a variety's upgrading effort at the rate of 10.2 percent if a variety is located far from the world frontier (discouragement effect). On the other hand, a tariff reduction is associated with a 4.6 percent increase in quality upgrading for varieties close to the world frontier (escape from the competition).

For import standards enforcement, a positive interaction coefficient indicates that a variety close to the world frontier is more likely to undergo quality improvement, whereas a negative coefficient shows that a laggard variety is less likely to do so. These results show that the burden of compliance cost for a laggard is a much stronger factor influencing innovation activities compared to the effects of competition. The positive coefficient of the interaction term is unexpected because a firm close to the frontier would reduce quality upgrading effort due to the low level of competition caused by additional standard enforcement (7a). However, import standards enforcement turns out to have increased varieties' quality upgrading effort. One possible explanation could be that a leading variety makes more efforts to improve the quality regardless of the compliance cost, because the probability of capturing a market becomes higher for them, once they meets the standards' requirements. For varieties far from the frontier, a 10 percentage point increase in import standards enforcement is associated with a 3.0 percent fall in quality growth, while equivalent standards enforcement for varieties close to the frontier is associated with a 1.4 percent increase in quality growth.

In column (4), the non-monotonicity of the effect of trade measures on quality improvement becomes strong for non-OECD member countries. These results are consistent with the view that it is difficult to upgrade the quality of products imported from low-income countries of varieties located far from the frontier. On the other hand, the non-monotonicity of the impact of tariffs and standards on quality upgrading almost disappears for OECD member countries as the result of column (5).

Statistically, for products imported from non-OECD members, this means that a 10 percentage point reduction in tariffs decreases a laggard variety's quality upgrading at the rate of 16 percent, but increases a frontier variety's quality upgrading by 11 percent. A 10 percentage point increase in standards boost quality upgrading for a frontier variety by 1.8 percent but decreases quality upgrading for a laggard variety by 3 percent. On the other hand, for products imported from OECD members, a 10 percentage point tariff increase decreases a laggard variety's quality upgrading by 9.2 percent, but increases a frontier variety's quality upgrading by 0.6 percent. In the case of standards enforcement, a 10 percentage point increase leads to a reduction in a laggard variety's quality upgrading by 3.4 percent, but raises a frontier variety's quality upgrading by 1.3 percent.

Table 5: Innovation and trade policy measures

Variables		Proximity to the Frontier	Quality improvement
Tariff	Decrease by 10% pt	Close	up by 4.6 %
		Far	down by 10.2 %
Standard	Increase by 10% pt	Close	up by 1.4 %
		Far	down by 3.0 %

As a result, varieties with relatively higher quality in the import market upgrade their quality in response to tariff reduction and import standards establishment. On the other hand, the effort to upgrade quality is reduced for varieties with a relatively lower quality in the import market, particularly when faced with tariffs reduction and import standards enforcement. The recent trends in international trade, reduction in tariffs and strong import standards, may have negatively affected innovation activities in developing countries.

6 Conclusion

In this paper, we analyzed the impact of import tariffs and standards on efforts to upgrade product quality. The direction of the effect depends on the distance from the world quality frontier. Increased competition owing to tariff reduction drives quality upgrading for leading products that have a relatively higher quality at the initial period, whereas it reduces quality upgrading for products that have relatively lower quality. This finding supports the theories of Aghion et al. (2004) and Aghion and Howitt (2006).

The effect of the import standards enforcement, however, does not follow theoretical expectations. Here there are two conflicting forces: decreasing competition and increasing compliance costs. Although the import standards enforcement shows a non-monotonic relationship with quality upgrading efforts, the directions are different from the case of an import tariff reduction. The heavy burden of compliance costs caused by standards enforcements discourages products far from the frontier from improving their quality. On the other hand, we find a positive effect of standards on quality upgrading for leading products. This might be caused by other factors beside compliance costs, such as the probability of capturing a market share. Since it becomes easier to capture a large market share for a leading variety once the variety meets the standards' requirement, the leaders make more efforts to improve quality regardless of the compliance cost. Thus, we conclude that the burden of compliance cost and probability to capture the market share are much stronger factors influencing innovation than the competition effect.

This study has several limitations in that firms' behaviors are implicitly derived from the model. Since quality is derived from the discrete choice model on the demand side, a firm's behavior is only able to be observed indirectly, under the assumption that consumers' quality choices influence firms' quality upgrading activities. In the empirical estimation section, country-level data could not provide firm-level activity.

Despite these limitations, these findings provide several implications for future research. The current trends in international trade, i.e. reducing tariffs and raising standards, tend to widen the gap between the quality frontier and the laggards. Since low-income countries mainly export low-quality goods, their efforts to improve quality may be discouraged by current trade policy measures. Therefore, it would be useful to examine the effect of current international trade measures on innovation activities in developing countries.

A Appendix: Food product industry

		Description (NACE 4 digit REV1)
15.1		**Production, processing and preserving of meat and meat products**
	15.11	Production and preserving of meat
	15.12	Production and preserving of poultrymeat
	15.13	Production of meat and poultrymeat products
15.2		**Processing and preserving of fish and fish products**
15.3		**Processing and preserving of fruit and vegetables**
	15.31	Processing and preserving of potatoes
	15.32	Manufacture of fruit and vegetable juice
	15.33	Processing and preserving of fruit and vegetables n.e.c.
15.4		**Manufacture of vegetable and animal oils and fats**
	15.41	Manufacture of crude oils and fats
	15.42	Manufacture of refined oils and fats
	15.43	Manufacture of margarine and similar edible fats
15.5		**Manufacture of dairy products**
	15.51	Operation of dairies and cheese making
	15.52	Manufacture of ice cream
15.6		**Manufacture of grain mill products, starches and starch products**
	15.61	Manufacture of grain mill products
	15.62	Manufacture of starches and starch products
15.8		**Manufacture of other food products**
	15.81	Manufacture of bread; manufacture of fresh pastry goods and cakes
	15.82	Manufacture of rusks and biscuit
	15.83	Manufacture of sugar
	15.84	Manufacture of cocoa; chocolate and sugar
	15.85	Manufacture of macaroni, noodles, couscous
	15.86	Processing of tea and coffee
	15.87	Manufacture of condiments and seasonings
	15.88	Manufacture of homogenized food preparations
	15.89	Manufacture of other food products n.e.c.
15.9		**Manufacture of beverages**
	15.91	Manufacture of distilled potable alcoholic beverages
	15.92	Production of ethyl alcohol from fermented materials
	15.93	Manufacture of wines
	15.94	Manufacture of cider and other fruit wines
	15.95	Manufacture of other non-distilled fermented beverages
	15.96	Manufacture of beer
	15.97	Manufacture of malt
	15.98	Production of mineral waters and soft drinks

B Appendix: Nested logit demand model

To measure the product quality, we follow a nested logit demand model, following Berry (1994).

Consumers have a choice between two levels of the differentiated product. First, an individual decides whether to purchase a product in each og g=1,...,G groups, and second, the individual decides which of the products in that group to purchase. Suppose that the products available in each group g are denoted by the set $J_g \in 1, ..., N$, while J_0 denotes the outside option. Utility for consumer h

$$V_j^h = u_j + \epsilon_j^h \tag{19}$$

ϵ_j^h: Random variable with CDF F(ϵ), where each consumer obtains a different draw of ϵ

$$F(\epsilon) = exp(\sum_{g=0}^{G}[\sum_{j\in J_g} -e^{-\epsilon_j/(1-\rho_g)}]^{1-\rho_g} \tag{20}$$

where ρ_g measures the correlation btw random terms ϵ_j within a group.
Computing the choice probabilities,P_j

$$P_j = e^{u_j/(1-\rho_g)}/D_g * D_g^{1-\rho_g}/[\sum_{g=0}^{G} D_g^{1-\rho_g}] \tag{21}$$

where the term D$_g\equiv \sum_{k\in J_g} e^{u_k/(1-\rho_g)}$ is called an inclusive value, since it summarizes the utility obtained from all products in the group g.
We can derive the estimation equations for market share and optimal prices. The first term on the right-hand side is the probability that an individual will choose product j $\in J_g$ conditional on having already chosen the group g. Denote this conditional probability by $s_{j|g}$. The second term on the right-hand side is the prob of choosing any product from group g, which we write the choice prob as s_j=$s_{j|g}$ $\bar{s_g}$. In addition, we suppose that the outside good has $u_0 = 0$ and inclusive value $D_0 = 1$, so s_0=P_0=$[\sum_{g=0}^{G} D_g^{1-\rho_g}]^{-1}$.

We have

$$lns_j - lns_0 = \frac{\beta' z_j - \alpha Pj + \xi_j}{1 - \rho_g} - \rho_g lnD_g \tag{22}$$

since $\bar{s_g}$ = second term, $\bar{s_g}$ /s$_0$ =D$_g^{1-\rho_g}$

$$ln\bar{s_j} - lns_0 = (1 - \rho_g)lnD_g \tag{23}$$

$$lns_j - lns_0 = \beta' z_j - \alpha P_j + \rho_g lns_{j|g} + \xi_j \tag{24}$$

$lns_{j|g}$ measures the market share of j within the group g, and is endogenous. Consumer choose variety, ch, when indirect utility from purchasing imported is greater than purchasing a domestically produced good.

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