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Upgrading Food Product Quality: Evaluating the Impact of Competition and Nontariff Measures

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In this paper, we analyze the effect of nontariff measures (NTMs) on upgrading food product quality. Based on a multisector Schumpeterian model—and given threat of entry, compliance costs, and monopoly profits—NTMs are predicted to have heterogeneous effects on quality upgrading. Using disaggregated data for 14 European Union (EU) countries across 18 food industries for the period 2008–2019, NTM enforcement is found to deter quality upgrading for products distant from the quality frontier due to compliance costs. Conversely, NTM enforcement stimulates quality upgrading for products close to the quality frontier, given an increased probability of capturing monopoly profits.

Key words: compliance costs, entry threat, Schumpeterian model, monopoly profits

Introduction

Food product quality matters in international trade, especially with respect to human, animal, and plant health (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. In 1995, the World Trade Organization (WTO) adopted the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) and the Agreement on Technical Barriers to Trade (TBT), establishing the basic rules for protecting human, animal, and plant health. Regulations specifying maximum residue levels (MRL) of pesticides are an example of SPS, while standards for food packaging or organic labelling are an example of TBT. The number of SPS (TBT) notifications to the WTO by all importers increased from 402 (608) in 2000, to 1,610 (2,008) in 2019, while tariff rates decreased over the same period (see Figure S1 in the online supplement at www.jareonline.org).

Over the period 1995–2019, the highest number of SPS and TBT measures, henceforth referred to as nontariff measures (NTMs),[1] were applied to food and agricultural products (Grübler and Reiter, 2021). Given that NTMs are commonly rationalized as policy makers responding to consumer demand for characteristics such as improved product safety, sustainable production methods, and greater product information (Sexton, 2013), it is important to understand the economic implications of their use. For example, food safety is one of several credence attributes that cannot be verified either *ex ante* or *ex post* by consumers (Swinnen, 2016), and it is well-documented in

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[1] The corrective role of technical NTMs is different from that of NTMs such as antidumping and safeguard measures. Consequently, they are often referred to as either standard-like NTMs (Grübler and Reiter, 2021), quality standards (Disdier, Gaigné, and Herghelegiu, 2023), or regulative NTMs (Ghodsi, 2023).

the agricultural economics literature that product labeling and standards are a means to resolve this asymmetric information problem (Bonroy and Constantatos, 2015).

The key objective of this paper is to analyze the heterogeneous effects of trade policy on upgrading the quality of food products imported by the European Union (EU). The theoretical framework draws on a multisector Schumpeterian model with entry at the technology frontier (see Acemoglu, Aghion, and Zilibotti, 2006; Aghion et al., 2005, 2009). The underlying idea is that the impact of entry on incumbent firm performance depends on the firm's proximity to the technology frontier: Specifically, the threat of entry encourages innovation efforts among incumbents closer to the technological frontier and inhibits innovation among incumbents farther from the frontier.

Based on an adapted theoretical framework, three channels are identified through which reduction in tariffs and increased use of NTMs triggers changes in food product quality: (i) threat of entry, (ii) compliance costs, and (iii) exploitation of monopoly power. Specifically, the following effects can be identified: (i) the threat of entry discourages laggards (a "discouragement effect"), while encouraging leaders to intensify their innovation efforts (an "escape from entry effect"); (ii) increased compliance costs due to NTM enforcement reduces innovation by laggards (a "compliance cost effect"); and (iii) increased post-innovation monopoly profits from reduced market competition due to NTM enforcement stimulate innovation efforts (a "Schumpeterian effect").

The model predictions are tested using food and agricultural product import data (2008–2019) for 14 EU member countries,[2] the EU having the second-highest WTO notification rate for NTMs after the United States over the period 1995–2019 (Grübler and Reiter, 2021). Since innovation decisions of firms are difficult to observe, growth in imported food product quality is estimated and treated as a proxy for innovation, proximity to the technology frontier being replaced by proximity to the quality frontier. The empirical analysis is comprised of two steps: First, product quality is measured at the 6-digit Harmonized System (HS) level, following Khandelwal (2010) and Amiti and Khandelwal (2013). Second, the heterogeneous effect of reduced tariffs and greater use of NTMs on food product quality is evaluated. The empirical analysis yields three key results: First, the effect of NTMs on quality upgrading depends nonmonotonically on the relative quality level of imported food products. Products distant from the quality frontier are less likely to undergo upgrading, while the opposite is true for products close to the frontier. Second, the nonmonotonic effect of NTMs is more pronounced for EU imports from non-OECD/developing countries, implying that imports from OECD/developed countries already meet the EU's NTM requirements, while imports from developing economies may not. Third, an increased threat of entry at the quality frontier due to EU tariff reduction pushes leading firms to improve their product quality relative to laggard firms as predicted by the proximity-to-the-frontier model. Overall, the empirical findings provide no clear conclusion as to whether increased use of NTMs raises food product quality; rather, the effect of NTMs on food product quality depends on how close a product already is to the frontier.

The main contribution of this paper is introduction of the costs of complying with increased use of NTMs, along with other channels through which NTMs and tariffs influence food product quality improvement, based on an augmented version of a multisectoral Schumpeterian model (see Acemoglu, Aghion, and Zilibotti, 2006; Aghion et al., 2009). The model establishes predictions not only for the escape from entry and discouragement effects of tariff reduction but also for the compliance cost and Schumpeterian effects resulting from implementation of NTMs. Additionally, the empirical analysis indicates the relationship between increased application of NTMs and upgrading of food product quality is nonmonotonic, contingent on the relative quality level.

[2] The EU-14 includes Austria, Belgium, Germany, Denmark, Spain, Finland, France, the United Kingdom, Greece, Ireland, Italy, Netherlands, Portugal, and Sweden.

Literature Review

The key literature relevant to the current study focuses on trade liberalization and the dynamic response of exporting firms. Contributions by Verhoogen (2008), Johnson (2012), and Kugler and Verhoogen (2012) generate a common prediction that more productive firms perform better in export markets selling higher-quality goods at higher prices. Related to this, recent empirical analysis has found entry into export markets, stimulated by reductions in trade costs, is associated with increased innovation by firms (see, e.g., Verhoogen, 2008, depreciation of the Mexican peso; Lileeva and Trefler, 2010, Canadian–US Free Trade Agreement; Bustos, 2011, MERCOSUR).

In terms of the impact of trade liberalization on product quality, Amiti and Khandelwal (2013) use a model of entry and innovation that draws on Aghion et al. (2009) and find that for a sample of 10,000 products for 56 countries exporting to the United States over 1990–2005, lowering their own tariffs was associated with upgrading of quality for products close to the technology frontier but not 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 based on a sample of EU-15 imports of food and agricultural products from 70 countries that reduced their own import tariffs over 1995–2007. Curzi, Raimiondi, and Olper also find a statistically significant relationship between upgrading of food product quality and the diffusion of EU voluntary product standards that holds for all products, irrespective of their closeness to the quality frontier. Olper, Curzi, and Pacca (2014) report similar results using EU import data from 1995–2003, they find that voluntary standards have a positive effect on quality upgrading for products close to and far from the frontier.

Other recent studies examine the impact of NTMs on both food product quality and trade flows. For example, Disdier, Gaigné, and Herghelegiu (2023), using French firm-product level data for 2011, find that NTMs increase the average quality of food, beverage, and textile products, and increase the export probability and export sales of high-quality firms. Using bilateral trade data for 1996–2017, Ghodsi (2023) finds that that, in aggregate, NTMs are associated with improved product quality, although TBT-type measures are trade-restricting and SPS-type measures are trade-promoting. Using global and bilateral trade data over 1996–2011, Ghodsi and Stehrer (2022) find that flows of SPS and stocks of TBT measures have a positive impact on the quality of food and beverage products.

Theoretical Framework

A Multisector Schumpeterian Model

This section describes a discrete-time, multisector Schumpeterian model in which all agents have a lifespan limited to one period. The economy produces a final food product, Y_t, taken as the numeraire, which can be used either for consumption or as an input to produce intermediate products. In each period t, a final product Y (a basket of specific food products) is supplied by a competitive sector (food retailing), Y being produced using a continuum of intermediate inputs according to the production function

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

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.[3] In each intermediate sector v there is a single active firm with the most productive technology $A_t(v)$ in each period; this

[3] Models of supply of quality by firms typically ensure a mapping between an exogenous parameter and the endogenous supply of product quality, the exogenous parameter being referred to variously as capability (Sutton, 2007; Kugler and Verhoogen, 2012), ability (Khandelwal, 2010), and productivity (Verhoogen, 2008); an increase in this parameter implies an increase in product quality.

"leading firm" enjoys monopoly power. Thus, v represents an intermediate good, a sector, and an intermediate firm. Each intermediate good v is produced by a monopolist at a unit marginal cost in terms of the final good. A "leader" is defined as an incumbent firm that presently exports to the EU market; conversely, potential entrants are defined as "fringe firms," exerting effort to enter the EU market and compete with the incumbent firm.

As shown in Acemoglu, Aghion, and Zilibotti (2006), fringe firms can "imitate" a leader's technology, but at greater cost. These firms can produce each intermediate good at the cost of χ units of the final good, instead of one unit. Consequently, fringe firms will not be active in equilibrium. Assuming the productivity gap between a leader and the fringe is sufficiently small, the incumbent (leader) sets a limit price to deter the entry of fringe firms. This limit price is equivalent to the marginal cost of fringe firms ($p_t(v) = \chi$, where $1 < \chi \leq 1/\alpha$). The parameter χ is assumed to capture EU trade policies (i.e., NTMs).[4] A higher limit price χ corresponds to a less competitive market environment. In any given sector in which one firm (the leader) possesses more advanced technology compared to another (the "laggard"), only the leader will actively produce. Intermediate firm v faces an inverse demand schedule, and equilibrium profit for a leader is[5]

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

where $\delta \equiv (\chi - 1)\chi^{-1/(1-\alpha)}$. Note that δ is monotonically increasing in χ, implying that a higher δ corresponds to a less competitive market, resulting in higher monopoly profits. Consequently, parameter χ is also interpreted as a measure of monopoly power.

Let the technology level of a frontier firm at the end of each time t be denoted by $\overline{A}_t(v)$ and assume that it grows at exogenous rate γ:

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

At the beginning of period t, an intermediate firm has the option to either operate near the frontier, with the technology level $A_{t-1}(v) = \overline{A}_{t-1}(v)$ (type-1 firm); one step below the frontier, with $A_{t-1}(v) = \overline{A}_{t-2}(v)$ (type-2 firm); or two steps below the frontier, with $A_{t-1}(v) = \overline{A}_{t-3}(v)$ (type-3 firm). Type 2 and 3 firms are referred to as laggards.

In each time-period, there is a threat of entry from fringe firms that operate with end-of-period frontier technology $\overline{A}_t$. Under Bertrand competition, an entrant firm captures the entire market and becomes the incumbent firm, the leader, if it has more advanced technology.[6] Otherwise, the profits of both firms become 0 if the entrant has identical technology. Now, assume potential entrants can observe post-innovation technology. A potential entrant will not enter the EU market if it cannot operate on the frontier post-innovation because Bertrand competition would drive profits to 0. Laggards never innovate because, at best, they catch up to their rivals and earn 0 profits.

Prior to production, firms can innovate to improve their technology at a constant rate γ. With probability z, a type-j intermediate firm innovates successfully but incurs an innovation cost, c_i:

$$c_i\left(z_j\right) = \left(z_j^2/2\right) c_i A_{t-j}(v), \text{ for } j \in \{1,2\}. \tag{4}$$

Due to knowledge spillovers, type-3 firms undergo an automatic upgrade by one level, eliminating the necessity for them to invest in innovation. In addition to innovation cost c_i, firms must also consider the compliance costs of meeting NTMs. Let c_c denote compliance costs (i.e., the expenditure required to conform to an NTM). Compliance costs are assumed to be imposed only on a type-2 intermediate firm along with innovation cost, the technology level of a type-1 being assumed greater than the minimum required by the NTM. If the required level of technology is

[4] According to Aghion and Howitt (2006), the parameter χ can be treated as the impact of government regulation on market competition (e.g., patent protection increases χ but pro-competition policies decrease χ).

[5] The inverse demand schedule is $p_t(v) = p_t(v)/x_t(v)^{1-\alpha}$, equilibrium demand being $x_t(v) = \chi^{-1/(1-\alpha)} A_t v$.

[6] This structure bears a strong resemblance to analysis of product quality ladders by Grossman and Helpman (1991b).

$\overline{A}_{t-1}$, 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 $c_c(z_j) = (z_j^2/2)c_c A_{t-j}(v)$ for $j = 2$. Therefore, the total cost of a type-j intermediate firm, $j \in 1, 2$ is

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

Equilibrium Innovation for Type-1 Incumbent, Leader

At the beginning of the period, the incumbent is randomly categorized into one of three potential types. Consider the innovation decision of a type-1 incumbent and define p as the probability that a new firm enters the market. In this context, a reduction (increase) in tariffs (NTMs) corresponds to an increase (reduction) in the probability of entry, p (see Aghion et al., 2004). A type-1 leader maintains its market presence under only two scenarios: Either it successfully innovates, with probability of z_1, or no firm enters even if it fails to innovate, with a probability of $(1-z_1)(1-p)$. 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 follows:

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

the first-order conditions yielding

(7) $$z_1 = \delta/c_i\,(\gamma - 1 + p)$$

Equilibrium Innovation for Type-2 Incumbent, Laggard

The innovation decision of an incumbent firm, initially (or arbitrarily classified as type-2) situated far from the frontier, diverges from the previous case of a type-1 firm. Unlike a type-1 firm, if an incumbent firm is designated as type-2, it must bear compliance costs, given the assumption that its technology falls below the requirements of meeting an NTM. A type-2 incumbent chooses its innovation investment, z_2, to maximize the expected net payoff from innovation:

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

the first-order condition being

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

Effects of Entry, Compliance Costs, and Monopoly Power

To incorporate prevailing trade policy dynamics in the EU, the analysis involves assessing the effects of reduced tariff rates and increased use of NTMs on innovation through three key parameters: (i) threat of entry (p), (ii) compliance costs (c_c), and (iii) monopoly power (χ).

The impact on innovation of an escalated threat of entry into the EU market is shown by partial differentiation of equations (7) and (9) with respect to the probability p:

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

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

A higher p stimulates innovation for a type-1 firm (i.e., as the likelihood of a firm being surpassed by an entrant increases, the incentive for a leader to escape from entry grows). On the other hand, a higher p reduces the expected payoff from innovating to a type-2 firm, leading to a reduction in its innovation effort. A firm positioned far below the frontier knows it cannot survive even if it innovates. As the probability of a firm being outcompeted by a new entrant grows, the incumbent far below the frontier recognizes that its chances of prevailing against a potential entrant are negligible and therefore discourages any innovation. Since a reduction in tariffs would raise the threat of entry into the EU market, this is expected to encourage innovation by type-1 firms but discourage innovation by type-2 firms.

In the case of greater use of NTMs, increased compliance costs affect the innovation decision of a type-2 firm as follows:

$$\partial z_2 / \partial c_c = -\frac{\delta(\gamma - 1)}{(c_i + c_c)^2} < 0. \tag{11}$$

Higher compliance costs reduce its innovation activity. Accordingly, tougher NTMs, which result in increased compliance costs, discourage innovation activity while simultaneously promoting innovation by reducing the threat of entry (see equation 10b). A type-2 firm is more likely to innovate due to a reduced entry threat, but it is less likely to innovate because of the compliance costs. Therefore, if the effect of compliance costs is greater than the threat of entry, a laggard firm will reduce its innovation activity.

Finally, the impact of changes in trade policy on the level of monopoly profits can be evaluated, where enforcement of NTMs can be viewed as a form of government regulation affecting competition (see Amiti and Khandelwal, 2013). From equation (2), the degree of competition is captured by χ, expected profit monotonically increasing in χ. Therefore, protection of incumbent firms has the potential to enhance innovation by increasing χ and hence the potential rewards from innovation. More stringent NTMs, which result in less competition, reflected in a higher value of χ, stimulates innovation by both type-1 and type-2 firms, an outcome commonly referred to as a Schumpeterian (appropriability) effect.

Summary of Model Predictions

The key predictions of the model regarding the impact of reduced tariffs and increased use of NTMs on product upgrading can be summarized as follows:

i. A reduction in tariffs increases the threat of entry, discouraging laggards from allocating resources to innovation (a discouragement effect), while simultaneously encouraging leaders to increase their innovation investment (an escape from entry effect).

ii. Increased use of NTMs reduces the threat of entry, incentivizing innovation for laggards (opposite of a discouragement effect), while discouraging innovation for leaders (opposite of an escape from entry effect). Increased use of NTMs also results in reduced market competition, leading to an increase in post-innovation profits, thereby fostering innovation by both leaders and laggards (a Schumpeterian effect). Finally, implementation of NTMs raises compliance costs for laggards, discouraging their innovation efforts (a compliance cost effect).

iii. The net effect of NTMs on the innovation decision of leaders depends on (the opposite of) the escape from entry and Schumpeterian effects, resulting in an ambiguous net effect.

iv. The net effect of NTMs on the innovation decision of laggards depends on (the opposite of) the discouragement, Schumpeterian, and compliance cost effects, yielding an ambiguous net effect.

Empirical Specification

An empirical model is specified describing innovation decisions of incumbent firms as a function of trade policies and proximity to the technology frontier in order to evaluate the heterogeneous effects on leaders and laggards. The key reduced form empirical relationship is

$$\lambda = f\left(X\left(p, c_c \chi\right), PF, \boldsymbol{\psi}\right), \tag{12}$$

where λ is a measure of incumbent firms' innovation decisions, X denotes EU trade policies influencing the threat of entry (p), compliance costs (c_c), and the extent of monopoly power (χ). PF is proximity to the frontier, and $\boldsymbol{\psi}$ is a vector of additional covariates. Since firms' innovation decisions are difficult to observe empirically, increased food product quality is used as a proxy for innovation effort. As a result, proximity to the technology frontier is replaced by proximity to the quality frontier. Specifically, if quality is close to the frontier, it is regarded as the product of a leading firm; if not, it is considered the product of a laggard. The empirical strategy is as follows: First, using two-stage least squares (2SLS), the quality of EU food and agricultural imports (λ_{ijht}) is estimated at the 6-digit HS level, employing the most disaggregated production-trade data available for the EU-14 countries over the period 2008–2019. Second, given product quality measurement, the heterogeneous effects of NTMs and tariffs on product quality improvement are evaluated using a panel fixed effects model.

Quality Estimation

It is assumed the most disaggregated level describes a representative firm's products, given the limited availability of firm-level data across countries over the sample period. Typically, 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 (e.g., exchange rates or labor cost differences). In this study, product quality is measured by considering market share information along with import unit values following Khandelwal (2010). Using a nested logit system, this methodology accounts for the structure of consumer preferences as well as the horizontal component of different product varieties (e.g., vanilla- 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 value and market share.

To measure food product quality (i.e., the quality of intermediate inputs v), we use Berry's (1994) nested logit demand model. Following the notation of Amiti and Khandelwal (2013), a variety *ijh* is defined as product *h* at the HS 6-digit level imported by country *i* from exporter *j* at time *t*, and quality of variety *ijh* at time *t* is denoted as λ_{ijht}. The aggregate level of product *h* is a group of products K, the 4-digit HS code, and industry G is the upper level of aggregation, the 2-digit HS code.[7] The reduced form of the demand equation for variety *ijh* at time *t* is given as

$$\ln\left(S_{ijht}\right) - \ln\left(S_{iot}\right) = \lambda_{1,ih} + \lambda_{2,jh} + \lambda_{3,t} - \alpha_1 P_{ijht} + \alpha_2 \ln\left(ns_{ijht}\right) + \alpha_3 \ln\left(pop_{jt}\right) + \varepsilon_{ijht}, \tag{13}$$

where $S_{ijht} = IM_{ijht}/MKT_{ikt}$ and MKT_{ikt} is defined as

$$MKT_{ikt} = Y_{ikt} + IM_{ikt} - EX_{ikt} = \sum_{h}^{K} D_{iht} + \sum_{j}\sum_{h}^{K} IM_{ijht} - \sum_{j}\sum_{h}^{K} EX_{ijht}. \tag{14}$$

S_{ijht} is variety *ijh*'s market share among the group of products K at the 4-digit HS code level, and

[7] The most disaggregated product level that can be observed is at the 6-digit HS level, so quality is estimated at the 6-digit HS level for each industry G. h is the product at the 6-digit HS level, K is the product group at the 4-digit HS code, and G is the upper level of aggregation at the 2-digit HS level. Therefore, equation (13) is run a total of 18 times, with each run at the 2-digit HS level and product quality estimated at the 6-digit HS level.

IM_{ijht} is the imported quantity of a variety ijh. MKT_{ikt} is importer i's market size of group of products k at time t, which is calculated by summing domestic production (Y_{ikt}) and import quantity (IM_{ikt}) and subtracting export quantity (EX_{ikt}). S_{iot} is the market share of importer i's outside product (i.e., the domestic alternatives to imported variety ijh) at time t and is defined as $S_{iot} = (1 - IMPPN_{ikt})$, where $IMPPN_{ikt} = IM_{ikt}/MKT_{ikt} = \sum_j \sum_h^K IM_{ijht}/MKT_{ikt}$ is import penetration.

The left-hand side of equation (13) expresses consumers' indirect utility from choosing variety ijh over the domestically produced product io at time t. Indirect utility is a function of a product's unit value, P_{ijht}; the nested share, ns_{ijht}, defined as variety ijh's share within product h at time t, where $ns_{ijht} = IM_{ijht}/MKT_{ijht} = IM_{ijht}/(D_{iht} + \sum_j IM_{ihjt} - \sum_j EX_{ijht})$; and the population of exporting countries, pop_{jt}, which is included to control for hidden varieties (Feenstra, 1994; Hallak and Schott, 2011). Following Krugman (1980), the number of varieties produced is assumed to be a function of the size of a country's population (e.g., China's large population may have contributed to the number of varieties they export). In other words, excluding population may lead to overestimating quality.

The unexplained part of indirect utility λ_{ijht} is treated as the measure of product quality:

$$\lambda_{ijht} = \lambda_{1,ih} + \lambda_{2,jh} + \lambda_{3,t} + \lambda_{4,ijht}, \tag{15}$$

where $\lambda_{1,ih}$ is the time-invariant valuation of product h imported into country i, $\lambda_{2,jh}$ is the time-invariant valuation of product h from country j, and $\lambda_{3,t}$ is the time-variant common quality component. $\lambda_{4,ijht}$ is a product–time deviation from the fixed effect that consumers but not researchers can observe and is therefore treated as the error term, ε_{ijht}. Once equation (13) is estimated for each industry, the estimated parameters are then used to define product quality according to equation (15). Given that detailed product characteristics are not typically recorded in trade data, the time-invariant components of quality $\lambda_{1,ih}$ and $\lambda_{2,jh}$ are specified as importer–product and exporter–product fixed effects, respectively, and the common quality component, $\lambda_{3,t}$, is specified as a year fixed effect.

2SLS is used to estimate equation (13) in order to address a concern that the error term ε_{ijht} may be correlated with the unit value of imported products (P_{ijht}) and nest share (ns_{ijht}). The identification strategy for unit value P_{ijht} is to use transportation costs and exchange rates as instrumental variables because they are obviously correlated with prices but not with quality. Here the interaction between oil prices and average distances from partner countries is used as a proxy for transportation costs. In the case of nest share, ns_{ijht}, the identification strategy is to use the number of partners exporting product h at time t and the number of varieties exported by the country j at time t. These variables account for entry and exit of varieties in the market, which are correlated with a product's share within the nest share but not correlated with a product's quality (Amiti and Khandelwal, 2013; Curzi, Raimondi, and Olper, 2015).

Quality Upgrading, NTMs, and Proximity to the Frontier

In the second step of the analysis, the potential relationship between changes in tariffs and NTMs and changes in product quality is evaluated using a panel fixed effects model, defined as

$$\begin{aligned}\Delta\lambda_{ijht} &= \left(\lambda_{ijht} - \lambda_{ijh,\,t\text{-}n}\right)/\lambda_{ijh,\,t\text{-}n} \\ &= \beta PF_{ijh,\,t\text{-}n} + \phi_1\tau_{ijh,\,t\text{-}n} + \phi_2\tau_{ijh,\,t\text{-}n} \times PF_{ijh,\,t\text{-}n} \\ &\quad + \eta_1 NTM_{ijh,\,t\text{-}n} + \eta_2 NTM_{ijh,\,t\text{-}n} \times PF_{ijh,\,t\text{-}n} + \alpha_{gt} + \alpha_{jt} + \varepsilon_{ijht},\end{aligned} \tag{16a}$$

where

$$PF_{ijht} = \frac{\lambda^F_{ijht}}{\max_{j\in ijht}\left(\lambda^F_{ijht}\right)}, PF_{ijht} \in [0,1]. \tag{16b}$$

In equation (16a), the dependent variable $\Delta\lambda_{ijht}$ is the change in a product's quality over a period of n years. $PF_{ijh,t-n}$ is proximity to the frontier, measured by equation (16b) and lagged by n years.

This variable is constructed by first taking a monotonic transformation of λ_{ijht} in order to ensure all estimated product qualities are nonnegative (i.e., $\lambda^F_{ijht} = \exp(\lambda_{ijht})$). Proximity to the frontier of a product is then defined as the ratio of the transformed quality to the highest quality, as shown in equation (16b), where the *max* operator is maximum λ^F_{ijht} within the importer–product–year combination. A product close to the frontier ($PF_{ijh,t-n} \rightarrow 1$) corresponds to that of a leader (type-1 firm), and a product far from the frontier ($PF_{ijh,t-n} \rightarrow 0$) corresponds to that of a laggard (type-2 firm). $\tau_{ijh,t-n}$ and $NTM_{ijh,t-n}$ denote import tariffs and NTM variables lagged by n years, respectively. In addition, an interaction term between $PF_{ijh,t-n}$ and both tariffs and NTMs is included to allow for a possible nonmonotonic relationship between those and quality upgrading.

Two different indicators of NTMs are used to capture the intensity of NTMs: a coverage ratio (*CR*) and frequency index (*FI*). For instance, in Nigeria, cocoa beans are the highest-value food export, making it likely that SPS and TBT measures applied to cocoa beans will be more important than other NTMs. Both *CR* and *FI* utilize trade flow information as weights to reflect the relative significance of NTMs. The two indices are calculated as follows:

$$\text{(17a)} \qquad CR_{ijkt} = \left[\sum_{h}^{K} NTM_{ijht} IM_{ijht} \Big/ \sum_{h}^{K} IM_{ijht} \right]$$

$$\text{(17b)} \qquad FI_{ijkt} = \left[\sum_{h}^{K} NTM_{ijht} D_{ijht} \Big/ \sum_{h}^{K} D_{ijht} \right],$$

where h indicates the HS 6-digit product level (Gourdon, 2014). NTM_{ijht} is a dummy variable that equals 1 if the 6-digit HS product line reports either SPS or TBT measures being applied and 0 otherwise. D_{ijht} is a dummy variable indicating the presence of any bilateral trade flow of product h between importer i and exporter j. IM_{ijht} is the import value of product h between importer i and exporter j. Note that the baseline estimation utilizes *CR*, while *FI* is employed as a robustness check (see Table S2 in the online supplement).

Given that quality is estimated by industry, the quality of products should be compared within an industry; therefore, we include an industry–year fixed effect, α_{gt}, which also controls for systemic shocks (e.g. demand) that affect all varieties of a specific industry at a point in time. In addition, we include an exporter–year fixed effect, α_{jt}, to control for exporting country-level shocks (e.g., changes in factor endowments, productivity, or national-level technology).

The theoretical framework yields clear predictions for the coefficients of the tariff variable (ϕ_1) and the interaction term (ϕ_2). The effect of tariffs on laggard firms is captured by the coefficient (ϕ_1), with the model predicting $\phi_1 > 0$ as a reduction in tariffs results in less innovation by laggards (a discouragement effect). On the other hand, the effect of tariffs on leaders is characterized by the combined coefficients ($\phi_1 + \phi_2$), when considering leaders at the quality frontier (i.e., $PF_{ijht} = 1$). A reduction in tariffs encourages innovation by leaders (an escape from entry effect), the model predicting $(\phi_1 + \phi_2) < 0$ and, therefore, $\phi_2 < 0$.

While the model does not provide unambiguous predictions for the coefficients of the NTMs variable (η_1) and its interaction term (η_2) due to conflicting forces, the model allows an interpretation of the mechanism by which NTMs affect innovation decisions by laggards and leaders. The effect of NTMs on laggard firms is captured by the coefficient η_1. If $\eta_1 < 0$ ($\eta_1 > 0$), then the net effect of increased use of NTMs on laggards is negative (positive), thereby discouraging (encouraging) innovation for laggards. This suggests that the compliance cost effect dominates (is dominated by) the discouragement and Schumpeterian effects. Similarly, the effect of increased use of NTMs on leaders is captured by $(\eta_1 + \eta_2)$. A positive net effect $(\eta_1 + \eta_2) > 0$ is possible (i.e., NTMs encouraging innovation) if the Schumpeterian effect dominates the escape from the entry effect. Conversely, a negative net effect $(\eta_1 + \eta_2) > 0$ is also possible (i.e., NTMs discouraging innovation). The expectation on the sign of η_2 depends on that for η_1.

Data

The production–trade dataset for the EU-14 countries for the period 2008–2019 is constructed as follows: First, EU production data are obtained from the EUROSTAT-Prodcom database, whose data units are 8-digit Prodcom (PRC) codes from the Nomenclature of Economic Activities (NACE) REV 2 Classification. Using the concordance table from EUROSTAT Reference and Management of Nomenclatures (RAMON), the 8-digit codes are connected to the 8-digit Combined Nomenclature (CN) codes, which are aggregated into 6-digit HS 1996 codes. Second, bilateral trade data between the EU-14 and the world come from the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII), whose original data source is UN Comtrade. The EU production data are connected to the trade data at the 6-digit HS 1996 level.

Import tariffs and NTMs are incorporated into the production–trade dataset to capture the effects of trade barriers on food product quality. We use import tariffs from the WITS-TRAINS dataset, converted to the current 6-digit HS 1996 codes. The lowest tariff rates among all types of tariff rates available are used: either most favored nation (MFN), bound, applied, or preferential, and EU common external tariff (CET) data are used for missing tariff values. Data for NTMs are from the Vienna Institute for International Economic Studies (WIIW) NTM database (Ghodsi, Gruebler, and Stehrer, 2016; Ghodsi, 2023), which provides information on various types of NTMs in a panel structure by using NTM notifications from the WTO's Integrated Trade Intelligence Portal (I-TIP) and the World Bank's Temporary Trade Barriers Database (TTBD). It covers information on countries imposing NTMs, countries affected by those NTMs, and types of NTMs (i.e., antidumping, countervailing duties, SPS, or TBT measures) at the 6-digit HS 1996 level. The unilateral and bilateral notifications for SPS and TBT are combined and an indicator is being constructed for the existence of NTMs for each 6-digit HS 1996 tariff line.

Examination of the NTM data highlights a notably high level of notification rates within the EU-14, with the annual average sectoral *CR* exceeding 95% over 2008–2019, despite some fluctuation over time (see Figure S2 in the online supplement). In particular, NTMs are relatively higher for animals (HS 01-05) and food products (HS 16-24) relative to vegetables (HS 06-15) over the recent decade. The elevated *CR* rates in the EU-14 contrasts with the average *CR* rates of 72% observed across a sample of 75 countries around the world (WITS-TRAINS). The majority of SPS and TBT measures within the EU relate to labeling requirements (e.g., animal health and veterinary certification), inspections or scientific tests to mitigate consumption risk (e.g., maximum levels for pesticide residues), and environmental sustainability (e.g., data requirements for bactericidal products containing chemically active substances, prevention of the introduction and spread of plant diseases).

Finally, additional information required to estimate food quality is obtained from several sources. Exchange rate data are from the International Monetary Fund's (IMF) International Financial Statistics (IFS), expressed as the exporter's local currency per the importer's (EU-14) currency. Distance and population data are obtained from CEPII, and oil price data are from the Federal Reserve Economic Data (FRED) series reported by the Federal Reserve Bank of St. Louis. Information on the labor force by education level is obtained from the World Bank. All monetary variables are deflated using the Consumer Price Index (CPI) from the OECD database. (Descriptive statistics for the data are provided in Table S1 in the online supplement.)

Estimation Results

Quality Estimates

Table 1 reports the results of quality estimation based on the equation (13) for each of the subsectors at the 2-digit HS level. For most of the subsectors, the estimated coefficients of the nested share are positive and statistically significant, given the expectation that net import market share increases as a product achieves a larger nested market share. The coefficients of the unit value of imported products

Table 1. Food Product Quality Estimation Results, 2008–2019

Dependent Variable: $\ln(S_{cht}) - \ln(S_{ot})$

	HS02 Meat	HS03 Fish	HS04 Dairy	HS05 Animal Products	HS07 Vegetables	HS08 Fruits & Nuts
Unit value of imported product, P_{ijht}	−0.0390	−0.570*	−0.0318	−0.00295	0.0634*	0.187
	(0.0837)	(0.245)	(0.0575)	(0.0124)	(0.0303)	(0.182)
Log of nested share, $\ln(ns_{ijht})$	1.010***	0.505*	1.007***	0.949***	1.064***	1.173***
	(0.0669)	(0.232)	(0.0418)	(0.0468)	(0.0543)	(0.196)
Log of population, $\ln(pop_{jt})$	0.785	− 0.437	−0.520	−0.0893	0.301	0.186
	(1.056)	(0.851)	(0.786)	(0.318)	(0.220)	(0.369)
Sanderson–Windmeijer F-stat p-value: (P_{ijht})	0.54	0.07	0.81	0.12	0.01	0.31
Sanderson–Windmeijer F-stat p-value: $\ln(ns_{ijht})$	0.35	0.01	0.85	0.00	0.00	0.22
Kleibergen–Paap (weak ins.) F-stat	0.54	1.71	0.20	1.45	2.80	0.88
Sargen–Hansen J-stat. (overid.) p-value	0.08	0.01	0.05	0.91	0.00	0.58
No. of obs.	5,000	24,678	1,526	4,794	7,196	9,318

	HS09 Coffee & Tea	HS10 Cereals	HS11 Wheat & Flour	HS12 Oil Seeds	HS15 Fats & Oils	HS16 Meat & Fish Preparations
Unit value of imported product, P_{ijht}	0.0548	−0.0607	−0.0581	0.0251	−0.127	0.0707***
	(0.0286)	(0.0876)	(0.0799)	(0.0654)	(0.0817)	(0.0189)
Log of nested share, $\ln(ns_{ijht})$	1.102***	1.037***	0.984***	1.099***	0.722***	1.093***
	(0.0594)	(0.0521)	(0.0604)	(0.139)	(0.124)	(0.0551)
Log of population, $\ln(pop_{jt})$	0.290	2.403**	0.255	0.618	0.193	−0.191
	(0.247)	(0.791)	(0.183)	(0.493)	(0.392)	(0.479)
Sanderson–Windmeijer F-stat p-value: (P_{ijht})	0.05	0.11	0.32	0.28	0.21	0.00
Sanderson–Windmeijer F-stat p-value: $\ln(ns_{ijht})$	0.01	0.00	0.22	0.18	0.05	0.00
Kleibergen–Paap (weak ins.) F-stat	1.98	0.85	0.86	0.92	1.11	6.87
Sargen–Hansen J-stat. (overid.) p-value	0.10	0.91	0.53	0.34	0.63	0.42
No. of obs.	7,518	548	3,318	1,256	10,657	10,387

	HS17 Sugars & Confectionery	HS18 Cocoa & Chocolate	HS19 Food Preparations	HS20 Vegetable Preparations	HS21 Misc. Preparations	HS22 Beverages
Unit value of imported product, P_{ijht}	−0.00840	−0.161	0.141	−0.0957	0.00675	−0.0947*
	(0.0111)	(0.164)	(0.0979)	(0.127)	(0.0214)	(0.0458)
Log of nested share, $\ln(ns_{ijht})$	0.991***	0.682	1.124***	0.882***	1.005***	0.942***
	(0.0111)	(0.351)	(0.0894)	(0.110)	(0.0288)	(0.0328)
Log of population, $\ln(pop_{jt})$	−0.0776	−0.0142	0.357	0.0266	0.118	0.101
	(0.0859)	(0.487)	(0.201)	(0.0691)	(0.124)	(0.161)
Sanderson–Windmeijer F-stat p-value: (P_{ijht})	0.20	0.79	0.14	0.35	0.05	0.01
Sanderson–Windmeijer F-stat p-value: $\ln(ns_{ijht})$	0.01	0.79	0.11	0.35	0.02	0.00
Kleibergen–Paap (weak ins.) F-stat	1.12	0.26	1.36	0.82	1.93	2.60
Sargen–Hansen J-stat. (overid.) p-value	0.99	0.84	0.77	0.05	0.80	0.28
No. of obs.	6,074	4,766	8,792	38,075	22,002	20,687

Notes: The unit price of imports is trimmed at the bottom and top 1% level to alleviate outlier issues. Importer–product and exporter–product fixed effects are included in all models, generated at the importer-HS6 and exporter-HS6 levels, respectively, along with year fixed effects. Standard errors in parentheses are clustered at the importer–product (HS6)–year and exporter–product (HS6)–year level. Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level, respectively.

Table 2. OLS Results with Share of Exporters' Products with the Highest Quality

Dependent Variable: Share of Exporter's Products with $PF = 1$

	1	2	3	4
ln(GDP per capita$_{jt}$)	2.287*** (0.0209)			2.510*** (0.0286)
Share of labor force with basic education$_{jt}$		−0.0936*** (0.00217)		−0.0571*** (0.00240)
Share of labor force with advanced education$_{jt}$			0.180*** (0.00343)	0.139*** (0.00348)
Industry–year FE	Yes	Yes	Yes	Yes
Adjusted R^2	0.246	0.105	0.113	0.366
No. of obs.	204,780	145,869	148,400	144,466

Notes: Fixed effects generated at industry (HS2)–year level. Standard errors in parentheses are clustered at the exporter–product (HS6)–year level. Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level, respectively.

do not exhibit statistical significance in general, but many of them have negative signs in accordance with the expectation that an increase in the unit value of imports reduces net import market share. There is a lack of statistical significance for the population variable, the effect of population on import market share is heterogeneous across industries, and the magnitudes of the estimated coefficients also vary across industries.

Table 1 reports the results of several tests to assess the validity of the instruments. Given that quality estimation involves multiple endogenous variables, we consider Sanderson–Windmeijer (SW) 2016 weak instrument F-tests for each of the endogenous variables. The p-values of the SW F-statistic indicate that the null of weak identification is rejected for the nested share in most subsectors and is only partially rejected for the unit price of imported goods at the 5% significance level. In other words, the first-stage relationship of the nested share is strong in most subsectors, while that of unit price is somewhat weak. The Kleibergen–Paap (KP) F-statistics are also reported for the overall strength of instruments, all of which are below the value of 10, a threshold often considered a rule of thumb. Based on the individual SW F-statistics, the weak result for the KP F-statistic can be attributed to unit value. Last, results to test overidentifying restrictions are reported, with most subsectors showing p-values of the Sargen–Hansen J-statistic greater than 0.05, implying that the instruments are valid in this respect. Overall, while the instruments used in the quality estimation raise some concern about weak instruments with respect to unit price, the current specification is retained for consistency with previous literature (Hummels and Skiba, 2004; Khandelwal, 2010; Amiti and Khandelwal, 2013; Curzi, Raimondi, and Olper, 2015).

Table 2 reports the results of evaluating the reliability of the quality estimates, with a focus on exporter productivity and product quality. Specifically, the relationship between the share of exporters' products with the highest quality and proxies for exporting country productivity is analyzed, measured by exporter GDP per capita and share of labor force by education level. Columns 1–4 show panel fixed effects regression results with the share of exporters' products with the highest quality as the dependent variable. Due to highly educated workers having higher productivity and jobs that require more skill (Mincer, 1974; Weiss, 1995), it is expected 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). The results in column 1 indicate that countries with higher GDP per capita export a larger proportion of high-quality products. Column 2 shows the negative effects of the share of the labor force with basic education on the share of the highest quality among exported products. Column 3 indicates that exports of higher quality products increase from countries with a greater proportion of the labor force having tertiary education. Column 4 confirms the results of columns 1–3 jointly.

Table 3. Quality Upgrading, Trade Policies, and Proximity to the Frontier with Coverage Ratio (*CR*), 2008–2019

Panel A. Dependent Variable: Δ in Quality over 2 Years

	All Countries				Non-OECD	OECD
	1	2	3	4	5	6
$PF_{ijh,t\text{-}2}$	−0.856***	−0.975***	−0.938***	−1.001***	−1.206***	−0.733***
	(0.0440)	(0.0294)	(0.0533)	(0.0545)	(0.0771)	(0.0735)
$Tariff_{ijh,t\text{-}2}$	0.347		0.671*	0.685*	0.0836	1.690**
	(0.293)		(0.296)	(0.324)	(0.403)	(0.527)
$PF_{ijh,t\text{-}2} \times Tariff_{ijh,t\text{-}2}$	−0.574		−1.114*	−0.961	0.303	−2.839***
	(0.468)		(0.482)	(0.490)	(0.651)	(0.750)
$CR_{ijk,t\text{-}2}$		−0.123***	−0.142***	−0.0983**	−0.183***	0.0406
		(0.0237)	(0.0328)	(0.0355)	(0.0441)	(0.0620)
$PF_{ijh,t\text{-}2} \times CR_{ijk,t\text{-}2}$		0.212***	0.247***	0.283***	0.463***	0.0190
		(0.0422)	(0.0613)	(0.0625)	(0.0831)	(0.0998)
Industry–year FE	Yes	Yes	Yes	Yes	Yes	Yes
Exporter–year FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.021	0.021	0.021	0.024	0.025	0.024
No. of obs.	112,868	112,868	112,868	112,794	73,442	39,349

Panel B. Dependent Variable: Δ in Quality over 5 Years

	All Countries				Non-OECD	OECD
	7	8	9	10	11	12
$PF_{ijh,t\text{-}5}$	−0.909***	−1.091***	−1.062***	−1.133***	−1.450***	−0.778***
	(0.0638)	(0.0388)	(0.0802)	(0.0829)	(0.125)	(0.101)
$Tariff_{ijh,t\text{-}5}$	−0.0486		0.493	0.925	−0.0702	2.289**
	(0.422)		(0.433)	(0.474)	(0.595)	(0.752)
$PF_{ijh,t\text{-}5} \times Tariff_{ijh,t\text{-}5}$	0.158		−0.883	−0.879	1.318	−3.626***
	(0.670)		(0.692)	(0.714)	(0.992)	(1.035)
$CR_{ijk,t\text{-}5}$		−0.210***	−0.223***	−0.159**	−0.225***	−0.102
		(0.0306)	(0.0440)	(0.0495)	(0.0643)	(0.0840)
$PF_{ijh,t\text{-}5} \times CR_{ijk,t\text{-}5}$		0.430***	0.457***	0.492***	0.686***	0.268*
		(0.0546)	(0.0837)	(0.0867)	(0.121)	(0.131)
Industry–year FE	Yes	Yes	Yes	Yes	Yes	Yes
Exporter–year FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.030	0.031	0.031	0.034	0.033	0.039
No. of obs.	56,097	56,097	56,097	56,039	35,479	20,560

Notes: All explanatory variables in Panels A and B are 2- and 5-year lagged values, respectively. Industry–year fixed effects are generated at the HS2 level. Standard errors in parentheses are clustered at exporter–product (HS6)–year level. Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level, respectively.

Quality Upgrading, NTMs, and Proximity to the Frontier

Table 3 presents the results from estimating equations (16a) and (16b). Panels A and B show the effects of trade policies on product quality upgrading, based on a bilateral trade dataset of imports by EU-14 (2008–2019), analyzed over 2 ($n = 2$) and 5 years ($n = 5$), respectively. Columns 1 and 2 (7 and 8) show the effects of tariffs and NTMs on food quality upgrading separately, with industry (HS2)–year fixed effects included. Columns 3 and 4 (9 and 10) provide results when both trade policies are considered, without and with additional exporter–year fixed effects, respectively.

The estimation results confirm the model's predictions regarding tariffs and their nonmonotonic effects on food quality upgrading. The coefficients ϕ_1 for the lagged tariff variable ($Tariff_{ijh,t-2}$) are consistently positive, while the coefficients ϕ_2 on the interaction term with proximity to frontier

($PF_{ijh,t-2} \times Tariff_{ijh,t-2}$) are consistently negative in columns 1, 3, and 4, with some statistical significance shown in columns 3 and 4. The former result ($\phi_1 > 1$) implies that a product is less likely to undergo upgrading in response to tariff reduction when distant from the quality frontier, aligning with the prediction that lower tariffs discourage innovation efforts by laggards (the discouragement effect). The combined negative sign on the tariff variable and its interaction term ($\phi_1 + \phi_2 < 0$) in columns 3 and 4 suggests that the quality of a product closer to the frontier is more likely to get upgraded, consistent with the prediction that lower tariffs encourage innovation by leaders (the escape from entry effect). Overall, the empirical evidence supports the model prediction regarding the impact of tariffs.

The estimation results also provide evidence for the nonmonotonic impact of NTMs on food quality upgrading. The coefficients of the coverage ratio ($CR_{ijk,t-2}$) are negative, and the coefficients on the interaction term with proximity to frontier are positive and statistically significant in columns 2–4. The negative coefficient on the coverage ratio ($\eta_1 < 0$) suggests that a product distant from the frontier is less likely to be upgraded when there is increased use of NTMs. The theoretical explanation suggests that the negative compliance cost effect outweighs the discouragement and Schumpeterian effects for laggard firms. That is, laggard firms are less likely to undertake innovation due to the burden of compliance costs associated with NTMs. On the other hand, the combined coefficients of *CR* and the interaction term ($\eta_1 + \eta_2 > 0$) indicate that a product closer to the frontier is more likely to undergo upgrading when more NTMs are in place. This implies that the Schumpeterian effect dominates the escape from the entry effect for leader firms (i.e., they are motivated to make innovation investments pursuing monopoly profits once NTM enforcement increases). While the theoretical prediction for the impact of NTMs on food quality upgrading is ambiguous, the results demonstrate a strong nonmonotonic effect, similar to that observed for tariffs but in the opposite direction.

It is worth highlighting the heterogeneous impacts of trade policies on quality upgrading, particularly for imports from non-OECD and OECD member countries. When the two groups are analyzed separately, the nonmonotonic effects of tariffs are statistically significant solely for the imports from OECD member countries (column 6), while those from non-OECD countries do not exhibit any statistical significance in tariffs and their interaction terms (column 5). The opposite trend is observed concerning NTMs. Imports from non-OECD countries demonstrate strong statistical significance for both *CR* and its interaction term (column 5), whereas those from the OECD countries do not exhibit any significance. These results may be ascribed to the conformity of imports from OECD member countries with EU NTMs, resulting in NTMs having no substantial impact on food quality upgrading for imports from those countries. On the other hand, a large share of products imported from non-OECD countries may require quality improvement to meet newly established NTMs. This result suggests that NTMs are more likely to be effective trade barriers for imports from non-OECD countries into the EU-14, exhibiting nonmonotonicity among products from non-OECD exporters, while OECD countries appear not to be affected by the enforcement of NTMs.

Panel B of Table 3 reports the effects of trade policies on quality upgrading over 5 years ($n = 5$). Although some estimated coefficients lose statistical significance, their signs generally remain the same. When considering consistently significant coefficients, it is worth noting that the size of the net effect of NTMs for both laggards (η_1) and leaders ($\eta_1 + \eta_2$) is larger when evaluated over 5 years (columns 10 and 11). Similarly, the magnitude of the net effect of tariffs is greater for both laggards (ϕ_1) and leaders (ϕ_1) for the subsample of imports from OECD member countries (column 12). This finding aligns with the expectation that quality upgrading is more likely to be observed over an extended period, given that innovation requires time and financial resources. Finally, the results of robustness checks are reported in Tables S2–S4 in the online supplement, none of which significantly alter interpretation of these results.

Summary and Conclusions

In this paper, the impact of tariffs and NTMs on exporters' efforts to upgrade food product quality is examined, focusing on EU food imports over 2008–2019. Drawing on Aghion et al. (2009) and Acemoglu, Aghion, and Zilibotti (2006), a model is derived predicting that the impact of any entry threat depends on proximity to the technology frontier (i.e., a nonmonotonic relationship between innovation and entry remains valid in a trade setting). An increased threat of competition due to tariff reduction drives quality upgrading for leading products and reduces quality upgrading for laggard products. While the net effect of increased use of NTMs is ambiguous, the model identifies three channels through which enforcement of NTMs might affect innovation decisions by laggards and leaders: a threat of entry (discouragement/escape from entry) effect, a compliance cost effect, and a Schumpeterian effect.

The empirical findings support the hypothesis that tariff reduction discourages laggard firms from allocating resources to upgrading product quality but encourages leading firms to upgrade product quality. Further, new evidence for the nonmonotonic impact of NTMs on food quality upgrading is provided: Increased utilization of NTMs stimulates innovation by leading firms but hinders innovation by laggard firms. This suggests that the probability of capturing monopoly profit plays an important role in quality upgrading for leading firms, whereas compliance costs deter laggard firms from innovation efforts. Therefore, factors beyond threat of entry affect quality upgrading under stricter enforcement of NTMs.

Two major current trends in international trade are tariff reduction and increased use of NTMs designed to promote product attributes such as food safety. The findings presented in this paper suggest these trends have widened the gap between firms at the technology frontier and laggard firms in terms of food product quality. Moreover, the impact of increased use of NTMs is notably significant for leading and laggard firms in developing countries. This matters when considering the importance of producing high-quality products for export success and subsequent economic development in developing countries (Grossman and Helpman, 1991a; Kremer, 1993). In this regard, addressing the divergence in product quality between developed and developing economies is crucial in the formation and implementation of trade policies. One approach to narrowing the gap could involve allowing a grace period for developing countries after implementation of such NTMs. Alternatively, it has been argued that development aid could be targeted at developing countries' ability to meet NTMs, such as the Pesticides Initiative Program aimed at enabling African, Caribbean, and Pacific exporters of fresh fruit and vegetables to comply with EU pesticide residue requirements (Sheldon, 2012).

Finally, some limitations of this study should be acknowledged. First, due to limited access to firm-level data covering multiple countries, this study relies on HS 6-digit trade data for the EU-14 countries. Essentially, the analysis does not consider changes in the composition of firms, although heterogeneous quality of products is treated as being consistent with firm-level productivity differences in the model. Additionally, no significant difference between the impact of SPS and TBT measures is found in the analysis, implementation of the measures being highly correlated (see Table S4 in the online supplement), which may be attributed to the relatively high aggregation of the data, as well as the way in which the NTM indices are constructed. This suggests some caution should be taken in interpreting the results from a policy standpoint, especially given the difference between the definitions of SPS and TBT measures.

Second, concerns remain regarding the weak instruments used in the product quality estimation stage, even though the key results on nonmonotonicity are robust when import unit values are used instead of the product quality estimates (see Table S3 in the online supplement). Future research in this area might usefully focus on explicitly evaluating the effect of tariffs and NTMs in a heterogeneous firm-model using firm-level data, which would allow separation of heterogeneous product quality from productivity.

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Online Supplement: Upgrading Food Product Quality: Evaluating the Impact of Competition and Non-Tariff Measures

Jihyun Eum, Ian Sheldon, Hyeseon Shin, and Stanley Thompson

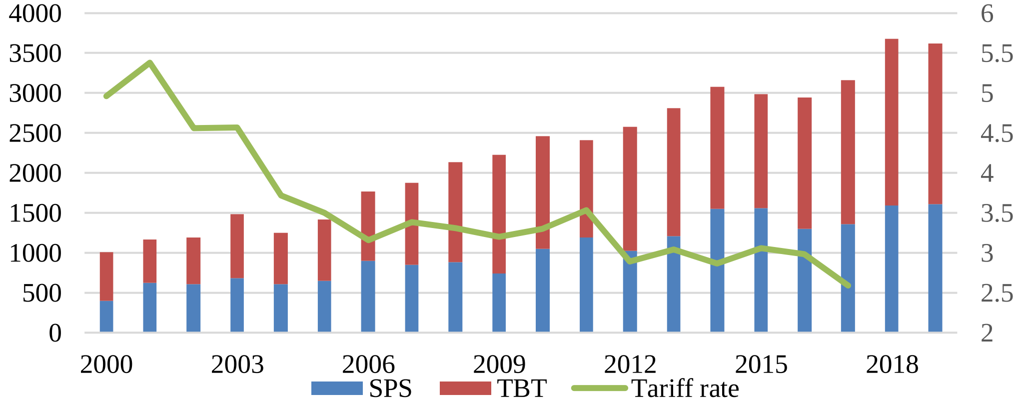

Figure S1. World SPS and TBT Notifications and Tariff Rates, 2000-2019
Notes: Total number of notifications to the WTO is used. Applied tariff rates, weighted mean, all products (percent) are used.
Source: WTO I-TIP, authors' calculations; World Development Indicators.

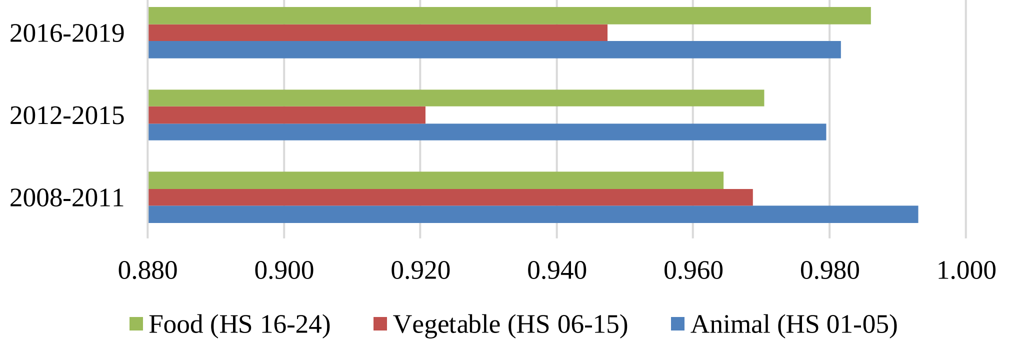

Figure S2. Annual Average of Sectoral Coverage Ratio (CR) for EU-14
Source: WIIW NTM database, authors' calculations.

The material contained herein is supplementary to the article named in the title and published in the *Journal of Agricultural and Resource Economics* (*JARE*).

Table S1. Descriptive Statistics, for EU Food Trade Data, 2008–2019 (*N* = 186,592)

	Mean	SD	Min	Max
Trade and Production				
Import quantity, IM_{ijht}, in million kg	0.74	9.93	0.00	1,143.72
Export quantity, EX_{ijht}, in million kg	0.37	4.63	0.00	511.48
Production quantity, D_{igt}, in million kg	297.75	1,253.97	0.00	31,121.55
Instrument Variables				
Distance, $dist_{ij}$, in thousand km	6.62	3.84	0.42	19.62
Brent crude oil price, Euro per Barrel	62.01	14.96	39.42	86.84
Exchange rate, *j*'s currency per *i*'s currency	1,283.49	5,006.45	0.03	48,258.91
Number of exporters in product *h*, by year and country	20.06	15.71	1.00	103.00
Number of varieties exported by country *j*, by year and country	46.83	36.03	1.00	168.00
First stage variables				
Market share of product *h*, S_{ijht}	0.01	0.04	0.00	1.00
Market share of outside products, S_{iot}	0.74	0.31	0.00	1.00
Imported product's unit value, P_{ijht}, in Euro per kg	7.24	12.30	0.26	120.67
Nested market share, ns_{ijht}	0.03	0.21	0.00	66.62
Population, pop_{jt}, in million people	167.80	353.57	0.03	1,407.74
EU Consumer price index, (2015=100)	99.01	4.33	90.64	105.04
Second stage variables				
Tariff rates, in percentage	0.05	0.06	0.00	0.32
Number of Non-tariff measures (SPS & TBT)	45.46	64.00	0.00	347.00
Coverage ratio, CR_{ijkt}	0.41	0.49	0.00	1.00
Frequency index, FI_{ijkt}	0.41	0.49	0.00	1.00
Proximity to the frontier, PF_{ijht}	0.44	0.34	0.00	1.00

Notes: EU production (EUROSTAT-Prodcom database), trade data (CEPII-Comtrade database, originally sourced from UN Comtrade), tariff (WITS-TRAINS), NTM (Ghodsi, 2023), exchange rates (IMF IFS data), distance (CEPII), population (CEPII), oil price (FRED), and CPI (OECD).

Robustness Checks

As a first robustness check, *FI* is used instead of *CR* to measure the intensity of NTMs, the results being reported in Table S2. The results using *FI* closely resemble the baseline model using *CR* in terms of both sign of coefficients and statistical significance. This suggests that the use of a different intensity measure for NTMs does not significantly affect the results.

A second robustness check is to use an alternative dependent variable, the weighted unit value of imports 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 the unit value of imports contingent on market share. Instead of using the nested logit demand model, an alternative proxy for product quality is weighted unit value of imports, measured according to the share of the products' import value in the industry. Specifically, the weight is formulated based on the share of import value at the Year-Importer-Product (HS4) level, which sums up to 1 at the Year-Importer-Industry (HS2) level. The dependent variable is the change in weighted import unit value relative to the average values between two periods.

The results from using this alternative dependent variable are shown in Table S3. The results exhibit strong statistical significance, their signs remaining the same in general. In the upper panel (*n*=2), the same sign of net effects for the tariffs and their interaction term ($\phi_1 > 0$and $\phi_1 + \phi_2 < 0$) can be observed, as well as for the NTMs and their interaction terms ($\eta_1 > 0$ and $\eta_1 + \eta_2 > 0$), all of which are statistically significant (columns 3 and 4). The heterogeneity between OECD exporters and non-OECD exporters found in the baseline model is only partially consistent with these result, as imports from OECD countries exhibit statistically significant non-monotonicity for both tariffs and NTMs, while imports from non-OECD countries lose statistical significance for the interaction term on NTMs. In the lower panel (*n*=5), some of the coefficients lose statistical significance, although the signs of the coefficients remain consistent (columns 9 and 10). Overall, the estimation results using the weighted unit value of imports are in line with the baseline model result when evaluated with the entire data.

Third, while SPS and TBT are measures with different functions, implementation of these NTMs is highly correlated. Specifically, the correlation between the SPS and TBT dummies is 0.9933 when evaluated at the 6-digit HS level. Furthermore, the coverage of SPS measures is strictly larger than that for TBT measures, implying any trade flow affected by a TBT measure is also subject to an SPS measure. Therefore, the baseline results reported in Table S3 are essentially identical to the case when only SPS measures are employed to construct the *CR* index and are very close to the case when only TBT measures are used, as reported in Table S4.

Table S2. Robustness Check: Quality Upgrading, Trade Policies, and Proximity to the Frontier with Frequency Index (*FI*), 2008–2019

Panel A. Dependent Variable: Δ in Quality over two Years

	All Countries				Non-OECD	OECD
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
$PF_{ijh,t-2}$	-0.856***	-0.972***	-0.935***	-0.998***	-1.204***	-0.729***
	(0.0440)	(0.0294)	(0.0531)	(0.0543)	(0.0770)	(0.0730)
$Tariff_{ijh,t-2}$	0.347		0.671*	0.681*	0.0821	1.674**
	(0.293)		(0.296)	(0.324)	(0.403)	(0.527)
$PF_{ijh,t-2} \times Tariff_{ijh,t-2}$	-0.574		-1.107*	-0.953	0.306	-2.812***
	(0.468)		(0.483)	(0.491)	(0.652)	(0.751)
$FI_{ijk,t-2}$		-0.121***	-0.140***	-0.0953**	-0.180***	0.0480
		(0.0238)	(0.0330)	(0.0358)	(0.0444)	(0.0622)
$PF_{ijh,t-2} \times FI_{ijk,t-2}$		0.206***	0.241***	0.277***	0.460***	0.00541
		(0.0423)	(0.0617)	(0.0629)	(0.0834)	(0.101)
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-Year FE	No	No	No	Yes	Yes	Yes
Adjusted R-squared	0.021	0.021	0.021	0.024	0.025	0.024
Observations	112,868	112,868	112,868	112,794	73,442	39,349

Panel B. Dependent Variable: Δ in Quality over five years

	All Countries				Non-OECD	OECD
	(7)	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
$PF_{ijh,t-5}$	-0.909***	-1.087***	-1.058***	-1.128***	-1.447***	-0.770***
	(0.0638)	(0.0388)	(0.0799)	(0.0825)	(0.125)	(0.100)
$Tariff_{ijh,t-5}$	-0.0486		0.494	0.920	-0.0725	2.277**
	(0.422)		(0.433)	(0.474)	(0.595)	(0.754)
$PF_{ijh,t-5} \times Tariff_{ijh,t-5}$	0.158		-0.879	-0.872	1.321	-3.605***
	(0.670)		(0.693)	(0.716)	(0.992)	(1.039)
$FI_{ijk,t-5}$		-0.209***	-0.222***	-0.155**	-0.215***	-0.101
		(0.0307)	(0.0443)	(0.0500)	(0.0646)	(0.0846)
$PF_{ijh,t-5} \times FI_{ijk,t-5}$		0.424***	0.450***	0.484***	0.683***	0.249
		(0.0549)	(0.0841)	(0.0871)	(0.121)	(0.133)
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-Year FE	No	No	No	Yes	Yes	Yes
Adjusted R-squared	0.030	0.031	0.031	0.034	0.033	0.039
Observations	56,097	56,097	56,097	56,039	35,479	20,560

Notes: For columns (1) to (6) and (7) to (12), dependent variable is change in quality over two and five years, respectively, and all explanatory variables are two- and five-year lagged values, respectively. Industry-Year fixed effects are generated at HS2 level. Standard errors in parentheses clustered at Exporter-Product (HS6)-Year level. Significant levels: ***p<0.01, **p<0.05, *p<0.1, respectively.

Table S3. Robustness Check: Weighted Import Unit Values with Coverage Ratio (*CR*), 2008–2019

Panel A. Dependent Variable: Δ in Weighted Unit Import Value over two years

	All Countries				Non-OECD	OECD
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
$PF_{ijh,t-2}$	-0.172***	-0.189***	-0.178***	-0.178***	-0.174***	-0.189***
	(0.00504)	(0.00381)	(0.00529)	(0.00533)	(0.00640)	(0.00942)
$Tariff_{ijh,t-2}$	0.103***		0.124***	0.100***	-0.00633	0.222***
	(0.0183)		(0.0190)	(0.0275)	(0.0358)	(0.0436)
$PF_{ijh,t-2}$ ×	-0.262***		-0.302***	-0.307***	-0.251***	-0.416***
$Tariff_{ijh,t-2}$	(0.0478)		(0.0496)	(0.0503)	(0.0622)	(0.0859)
$CR_{ijk,t-2}$		-0.00572*	-0.00930***	-0.0128***	-0.0135**	-0.0122*
		(0.00249)	(0.00224)	(0.00346)	(0.00422)	(0.00613)
$PF_{ijh,t-2} \times CR_{ijk,t-2}$		0.00840	0.0170***	0.0175***	0.00633	0.0415***
		(0.00462)	(0.00500)	(0.00511)	(0.00599)	(0.00964)
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-Year FE	No	No	No	Yes	Yes	Yes
Adjusted R-squared	0.253	0.253	0.253	0.253	0.265	0.243
Observations	112,785	112,785	112,785	112,711	73,332	39,299

Panel B. Dependent Variable: Δ in Weighted Unit Import Value over five years

	All Countries				Non-OECD	OECD
	(7)	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
$PF_{ijh,t-2}$	-0.308***	-0.341***	-0.322***	-0.326***	-0.262***	-0.419***
	(0.0169)	(0.00938)	(0.0176)	(0.0179)	(0.0173)	(0.0353)
$Tariff_{ijh,t-5}$	0.103**		0.126**	0.154**	0.0996	0.156
	(0.0391)		(0.0398)	(0.0595)	(0.0770)	(0.0969)
$PF_{ijh,t-5}$ ×	-0.368**		-0.483***	-0.476***	-0.584***	-0.347
$Tariff_{ijh,t-5}$	(0.134)		(0.140)	(0.142)	(0.150)	(0.268)
$CR_{ijk,t-5}$		-0.00625	-0.00960*	-0.00868	0.00758	-0.0309*
		(0.00600)	(0.00486)	(0.00892)	(0.0122)	(0.0150)
$PF_{ijh,t-5} \times CR_{ijk,t-5}$		0.0312**	0.0445**	0.0475**	0.0193	0.0944**
		(0.0111)	(0.0149)	(0.0154)	(0.0175)	(0.0303)
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-Year FE	No	No	No	Yes	Yes	Yes
Adjusted R-squared	0.222	0.222	0.222	0.218	0.244	0.215
Observations	55,828	55,828	55,828	55,769	35,283	20,428

Notes: For columns (1) to (6) and (7) to (12), dependent variable is change in quality, measured by weighted unit import value, over two and five years, respectively, and all explanatory variables are two- and five-year lagged values, respectively. Industry-Year fixed effects are generated at HS4 level. Standard errors in parentheses clustered at Exporter-Product (HS6)-Year level. Significant levels: ***p<0.01, **p<0.05, *p<0.1, respectively.

Table S4. Robustness Check: Quality Upgrading, Trade Policies, and Proximity to the Frontier with Coverage Ratio (*CR*) based on TBT, 2008–2019

Panel A. Dependent Variable: Δ in Quality over two years

	All Countries				Non-OECD	OECD
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
$PF_{ijh,t-2}$	-0.856***	-0.974***	-0.937***	-1.000***	-1.205***	-0.731***
	(0.0440)	(0.0294)	(0.0531)	(0.0543)	(0.0769)	(0.0730)
$Tariff_{ijh,t-2}$	0.347		0.670*	0.681*	0.0842	1.681**
	(0.293)		(0.296)	(0.324)	(0.403)	(0.527)
$PF_{ijh,t-2} \times Tariff_{ijh,t-2}$	-0.574		-1.123*	-0.975*	0.274	-2.828***
	(0.468)		(0.484)	(0.491)	(0.654)	(0.750)
$CR_{ijk,t-2}$		-0.121***	-0.139***	-0.0904*	-0.182***	0.0540
		(0.0237)	(0.0328)	(0.0355)	(0.0442)	(0.0620)
$PF_{ijh,t-2} \times CR_{ijk,t-2}$		0.212***	0.248***	0.285***	0.468***	0.0115
		(0.0424)	(0.0619)	(0.0631)	(0.0841)	(0.100)
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-Year FE	No	No	No	Yes	Yes	Yes
Adjusted R-squared	0.021	0.021	0.021	0.024	0.025	0.024
Observations	112,868	112,868	112,868	112,794	73,442	39,349

Panel B. Dependent Variable: Δ in Quality over five years

	All Countries				Non-OECD	OECD
	(7)	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
$PF_{ijh,t-5}$	-0.909***	-1.097***	-1.066***	-1.138***	-1.455***	-0.779***
	(0.0638)	(0.0388)	(0.0800)	(0.0826)	(0.125)	(0.101)
$Tariff_{ijh,t-5}$	-0.0486		0.505	0.940*	-0.0403	2.293**
	(0.422)		(0.433)	(0.474)	(0.596)	(0.751)
$PF_{ijh,t-5} \times Tariff_{ijh,t-5}$	0.158		-0.950	-0.959	1.196	-3.657***
	(0.670)		(0.694)	(0.716)	(0.996)	(1.036)
$CR_{ijk,t-5}$		-0.210***	-0.224***	-0.142**	-0.218***	-0.0792
		(0.0306)	(0.0440)	(0.0494)	(0.0643)	(0.0840)
$PF_{ijh,t-5} \times CR_{ijk,t-5}$		0.450***	0.479***	0.517***	0.717***	0.275*
		(0.0550)	(0.0845)	(0.0875)	(0.122)	(0.131)
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-Year FE	No	No	No	Yes	Yes	Yes
Adjusted R-squared	0.030	0.031	0.031	0.034	0.033	0.039
Observations	56,097	56,097	56,097	56,039	35,479	20,560

Notes: For columns (1) to (6) and (7) to (12), dependent variable is change in quality over two and five years, respectively, and all explanatory variables are two- and five-year lagged values, respectively. Industry-Year fixed effects are generated at HS2 level. Standard errors in parentheses clustered at Exporter-Product (HS6)-Year level. Significant levels: ***p<0.01, **p<0.05, *p<0.1, respectively.