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Product Quality in Food and Agricultural Trade: Firm Heterogeneity and the Impact of Trade Costs

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We develop a heterogeneous firm model that allows us to identify the relationship between firm productivity and product quality. The model is used to analyze the impact of trade costs on food and agricultural trade based on a bilateral trade dataset covering 159 countries over the period 2010–2013. The results show that a high firm capability cutoff—implying an ability to produce high quality—limits export market entry. In addition, fixed and variable trade costs have a negative and significant impact on the probability of firms entering export markets, while variable trade costs have a negative and significant effect on firms' export levels.

Key words: fixed trade costs, variable trade costs

Introduction

In the past decade, a body of research in international economics has focused on the empirical connection between product quality and trade patterns, much of which draws on the observation that there is considerable variation in unit export values across trade partners at the 10-digit Harmonized System (HS) product classification (Bernard et al., 2012). For example, Hummels and Klenow (2005) find a link between exporter per capita gross domestic product (GDP) and product quality. Other studies use firm-level data to analyze the relationship between export price variation and trade patterns. For example, Manova and Zhang (2012) establish that the most successful Chinese exporting firms use higher-quality intermediate inputs to produce higher-quality goods and firms vary the quality of their products across destination markets. These and other empirical results suggest that trade models should explicitly incorporate vertical product differentiation.

The observation that exporting firms compete in terms of product quality as well as price has a long pedigree in international economics, originating with Linder's (1961) hypothesis that quality is an important determinant of the direction of trade. Following Linder, considerable theoretical analysis has focused on deriving general equilibrium models to formalize the role of product quality in determining trade patterns (e.g., Flam and Helpman, 1987). Sutton (2007) provides a theoretical framework for thinking about product quality. His basic idea lies in his notion of firms having "capabilities," consisting of two key elements: the maximum level of product quality a firm can achieve and the cost of production for each product line (i.e., productivity). Consequently, in order to survive in export markets, firms' capabilities must be within a "window."

Sutton's (2007) argument also resonates with the heterogeneous firms and trade literature pioneered by Melitz (2003). The typical argument here is that only the most productive firms are

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able to export and that trade liberalization results in a rightward shift in the productivity distribution of firms as less productive firms are forced from the domestic market and more productive firms are able to enter the export market.

Recent contributions by, among others, Baldwin and Harrigan (2011) and Johnson (2012) have focused on incorporating vertical product differentiation into heterogeneous firm models, drawing on Melitz's (2003, p. 1699) observation that productivity can be thought of as either a cost shifter or a demand-shifting quality variable. Essentially, this body of research points to more capable firms performing better in export markets selling higher-quality goods at higher prices. In other empirical analyses, Amiti and Khandelwal (2013) conclude that lowering tariffs raises the quality-upgrading effort for higher-quality products and decreases the quality-upgrading effort for lower-quality products, while Fan, Li, and Yeaple (2015) find that a reduction in tariffs on intermediate inputs results in firms increasing the price and quality of exported final products.

Agricultural economists have also contributed to the product quality literature in both domestic and international settings. Sexton (2013) notes that modern food and agricultural markets can no longer be characterized by firms selling homogeneous products. Instead, food-product quality characteristics demanded by consumers have expanded to include not only taste, appearance, and convenience but also dimensions such as the food production process, its impact on the environment and food safety, and the connection between diet and health (see, e.g., Krissoff, Bohman, and Caswell, 2002). In the context of vertical food marketing systems, increased demand for food quality has also meant that firms producing quality-differentiated food products have increased their demand for intermediate agricultural inputs with the characteristics required to meet relevant product-quality specifications (Sexton, 2013).

In response, firms in the food industry have adopted vertical product differentiation strategies as consumers have become less sensitive to price and more focused on utility derived from actual and perceived characteristics such as food quality and safety (Grunert, 2005). This is supported by a considerable amount of empirical evidence for consumer willingness to pay for food quality and food safety (e.g., Chang, Lusk, and Norwood, 2010; Chrysochou, Krystallis, and Giraud, 2012) as well as applied analysis of the effect of food quality and food safety labeling (e.g., Lim et al., 2013).

Given that consumers are also faced with a wide choice of vertically differentiated food products from various sources via international trade, concerns about food safety and quality have led importers to impose quality requirements in the form of voluntary private and mandatory public food standards, the latter being governed by the World Trade Organization (WTO) Agreement on Technical Barriers to Trade (TBT) and the Agreement on Sanitary and Phytosanitary (SPS) Measures (Fulponi, 2006; Swinnen, 2016).

While the distortionary effect of tariffs is well understood, there is no straightforward presumption about the trade impact of either private or public standards (Beghin, 2013). Standards may reduce trade due to their price effects but at the same time increase domestic welfare due to resolution of a market failure such as asymmetric information. Alternatively, under appropriate supply and demand conditions, standards can act as a "catalyst" to trade, with benefits to both consumers and domestic and foreign producers (Swinnen, 2016). In the case of food standards, the bulk of the empirical evidence supports the "barrier to trade" hypothesis (e.g., Olper and Raimondi, 2008; Li and Beghin, 2012). While there is currently only limited empirical support for the "catalysts to trade" hypothesis, there is evidence that—despite the technical challenges presented by food standards (Henson and Jaffee, 2008)—developing countries adapting to them have been successful in accessing export markets (Anders and Caswell, 2009; Swinnen, 2016).

Importantly, a series of recent empirical contributions by Olper and colleagues has drawn on Khandelwal's (2010) approach to measuring product quality to analyze agricultural and food trade. Olper, Curzi, and Pacca (2014) find the proliferation of private E.U. food standards over the 1995–2003 period positively affected the rate of quality upgrading of imported food products. In a subsequent study of E.U.-15 imports of food products over the 1995–2007 period, Curzi, Raimondi, and Olper (2015) also find that trade liberalization in exporting countries leads to faster upgrading of product quality for those products closer to the technology frontier. Finally, Curzi, Raimondi, and Olper (2015) analyze data for E.U.-15 food imports over the 1995–2007 period, and their results indicate a poor correlation between their estimates of food product quality and unit values, confirming Hallak and Schott's (2011) previous findings. In addition, using Khandelwal, Schott, and Wei's (2013) methodology, Curzi, Raimondi, and Olper (2015) find that the price and quality of food product exports are affected differently by *ad valorem* and specific trade costs.

Articles by Chevassus-Lozza and Latouche (2012) and Chevassus-Lozza, Gaigné, and Le Mener (2013) evaluating the export performance of French agri-food firms provide an important motivation for the analysis presented in the current article. Drawing on Chaney (2008), their research focuses on heterogeneous firms and two key margins of adjustment: the decision by a firm to enter an export market (the extensive margin) and, having entered, how much to export (the intensive margin). Importantly, entry is driven by whether a firm's productivity exceeds a threshold defined by fixed entry costs, which can include, for example, product conversion to meet the standards of the importing country (Crozet and Mayer, 2007). Using a sample of 1,733 French agri-food firms in 2004, Chevassus-Lozza and Latouche (2012) find that the productivity threshold varies across European Union (E.U.) members, driven by distance and size of the importing country as well as other fixed entry costs. In the follow-up article, Chevassus-Lozza, Gaigné, and Le Mener (2013) find that over the 2001–2004 period, a reduction in input tariffs increased the probability that a sample of 3,716 French agri-food firms would export.

While establishing that firm heterogeneity is empirically relevant to export performance in the French agri-food sector, two observations can be made about these studies. First, applying the analysis to cross-country estimation is potentially limited by a lack of pooled firm-level data. However, Helpman, Melitz, and Rubinstein (2008) offer a solution to this problem by showing there are sufficient statistics, derivable from aggregate trade data, which then predict the selection of heterogeneous firms into specific export markets and the associated aggregate trade volumes. Specifically, their null hypothesis is that 0 exports of a specific product from country j to country i is evidence for no country-j firm passing the productivity threshold required to export to country i. This is now considered an acceptable and robust methodology for estimating gravity-type equations incorporating firm heterogeneity (Head and Mayer, 2014). However, with the notable exception of Xiong and Beghin (2012), empirical analyses of food and agricultural trade (e.g., Jayasinghe, Beghin, and Moschini, 2010) have applied the standard Heckman (1979) selection method, which assumes no firm-level heterogeneity.

Second, firm-level heterogeneity in the Chaney (2008) setting is entirely driven by differences in productivity that feed into lower unit production costs and export prices. However, this is inconsistent with the observation that more efficient firms often use higher-quality inputs in producing and exporting higher-quality products at higher prices (e.g., Crinò and Epifani, 2012; Crozet, Head, and Mayer, 2012; Curzi and Olper, 2012; Gaigné and Larue, 2016; Johnson, 2012). Importantly, these contributions all develop an analytical connection between firm-level productivity, unit costs of production, and product quality, with some providing empirical evidence of a positive relationship between export product quality and productivity. For example, focusing on the behavior of a sample of 750 Italian food exporting firms over the 2001–2006 period, Curzi and Olper (2012) find that more efficient firms export high-quality goods to destinations with higher income, while Crozet, Head, and Mayer (2012) report similar empirical evidence for a sample of 1,134 French wine exporters in 2005.

Given this background, this article contributes an analysis of the impact of fixed and variable trade costs on the quality of food and agricultural exports using a bilateral trade dataset covering 159 countries over the 2010–2013 period. Drawing on Johnson's (2012) adaptation of Helpman, Melitz, and Rubinstein (2008), we develop a heterogeneous-firm trade model incorporating a link between productivity and product quality that allows both fixed and variable trade costs to impact the decision of firms to export and variable trade costs to impact the amount that firms choose to export. By construction, the model generates a structural gravity-type equation that is estimated with an econometric methodology suggested by Helpman, Melitz, and Rubinstein (2008) and that allows inferences to be made about firm-level behavior using aggregate trade data.

Our key empirical contribution is an evaluation of the impact on agri-food trade of effective governance and food standards in importing countries. Specifically, these factors are treated in the model as contributing to the fixed costs of entry into the export market, with the potential to influence the extensive margin of trade. The results show that, at the extensive margin, both fixed and variable trade costs have a negative and significant impact on the probability of firms entering export markets, while at the intensive margin, variable trade costs such as distance have a negative and significant effect on firms' export levels.

Theoretical Background

Preferences

Suppose the world consist of J countries, indexed by $j = 1, 2, ..., J$. Following Baldwin and Harrigan (2011) and Johnson (2012), it is assumed that a representative agent in j consumes a continuum of differentiated products, where products are indexed by ω and the total mass of products in country j is denoted Ω_j. Also, the utility function is assumed to take the form

(1) $$U_j = \left[\int_{\omega \in \Omega_j} (\tilde{x}_j(\omega))^{(\sigma-1)/\sigma} d\omega \right]^{\sigma/(\sigma-1)}$$

where $\sigma > 1$ is the elasticity of substitution between products. The quantity of each product consumed is $\tilde{x}(\omega) = q(\omega)x_j(\omega)$, where $x_j(\omega)$ represents physical units of the product and $q(\omega)$ is a factor that maps physical units of the product into utility units. In other words, $q(\omega)$ is a metric for product quality based on consumer valuation of a vector of characteristics embodied in a physical unit of the product. Baldwin and Harrigan (2011) refer to this modeling approach as "box-size" quality (i.e., the utility from consuming two boxes of a product with quality 1 is identical to consuming one box of a product with quality 2, as if the latter is just a larger box of the same product). In the monopolistic competition setting used here, this means that consumers make their decisions based on quality-adjusted prices. Essentially, for any price per unit of the product, higher-quality products get a larger share of consumption (Johnson, 2012)

Consumer optimization generates demand for product ω:

(2) $$x_j(\omega) = q(\omega)^{\sigma-1} p_j(\omega)^{-\sigma} E_j P_j^{\sigma-1},$$

where $p_j(\omega)$ is the price of product ω, P_j is an aggregate quality-adjusted price index, defined as $P_j = \left[\int_{\omega \in \Omega_j} \left(\frac{p_j(\omega)}{q(\omega)} \right)^{1-\sigma} d\omega \right]^{1/(1-\sigma)}$ and E_j is the quality adjusted aggregate consumption of the available products, which is equivalent to the income of country j. Demand for product ω in country j increases with improved quality and level of income and decreases with product price.

Firm Behavior

Each country j has a mass of firms, N_j, producing differentiated products, with each firm in country j having unit costs of production of $c_j(a)$, where a is the combination of inputs used to produce a unit of the product and c_j is the cost of the input combination. a is firm-specific, reflecting efficiency in input use across firms in country j, while c_j is country-specific, capturing cross-country differences in input prices (Helpman, Melitz, and Rubinstein, 2008). The productivity level of firms is indexed by the inverse of a, $1/a$, where $a > 0$. Following Melitz (2003), a is determined by a random draw from a truncated Pareto distribution, $g(a)$, with a cumulative distribution, $G(a)$, with support $[a_L, a_H]$, where $a_H > a_L > 0$. Note that the distribution function is the same across all countries.

Given monopolistic competition (and assuming for the moment there is no quality differentiation), a profit-maximizing firm in country j charges the mill price for its product variety (i.e., a constant mark-up over marginal cost), $p_j(c,a) = \left(\frac{\sigma}{\sigma-1}\right)(\tau_{ij}c_j a)$, where $(\tau_{ij}c_j a)$ are a firm's marginal costs inclusive of trade costs. A firm bears only production costs when selling to its home market, but if the product is exported to country i, then it bears both destination-specific fixed costs, f_{ij}, and iceberg transport costs, τ_{ij}, where $f_{jj} = 0$ for every j, $f_{ij} > 0$ for $i \neq j$, $\tau_{jj} = 1$ for every j, and $\tau_{ij} > 1$ for $i \neq j$. Note that neither fixed nor transport costs depend on firm productivity. Therefore, equilibrium profits of a country-j firm exporting to country i are

(3) $$\pi_{ij}(a) = \frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\left(\frac{\tau_{ij}c_j a}{qP_i}\right)^{1-\sigma} E_i - f_{ij}.$$

To allow for heterogeneity in product quality, we introduce the concept of firm "capability" (Sutton, 2007; Johnson, 2012). As noted earlier, Sutton (2007) defines a firm's capability as being comprised of two key elements: the maximum level of product quality a firm can achieve and its efficiency in utilizing inputs (productivity) to generate that quality. Drawing on this, Johnson (2012) defines capability A of a firm in country j as the ratio of its product quality to the unit costs of production, $A = \frac{q}{c_j(a,q(\omega))}$. In other words, A indexes the level of inputs a firm uses to generate a utility unit of the product.

Developing this, unit costs of production in country j can be defined as $c_j(a,q) = c_j\left(q^{\vartheta} + \frac{q^{\ell}}{\nu}\right), 0 < \vartheta < 1 < \ell$, where $\nu = 1/a$, unit costs of production decreasing in productivity and increasing in quality.[1] In the case of the agri-food sector, Gaigné and Larue (2016) argue that in producing higher quality, firms incur increased fixed and variable production costs in the form additional equipment as well as higher-quality inputs, which translates into higher unit costs of production. For example, meeting animal welfare standards requires investment in new equipment and production facilities. Olper, Curzi, and Raimondi (2017) find that producing high-quality products in the agri-food sector requires use of more complex inputs, while available empirical evidence shows that meeting high standards in importing countries increases both fixed and variable costs (Maskus, Otsuki, and Wilson, 2013). For example, Ferro, Otsuki, and Wilson (2015) find that higher limits on pesticide residues increase fixed export costs, which mainly affects exports at the extensive margin.

A profit-maximizing firm in country j chooses its product quality by minimizing the ratio of its marginal production costs to quality, $\min_{\{q(\omega)\}} \frac{c_j(a,q(\omega))}{q(\omega)}$, with product quality expressed as a function of firm capability: $q(A) = \bar{c}_j^{\phi} A^{\phi}$, where $\bar{c}_j = c_j\left(\frac{\ell-\vartheta}{\ell-1}\right)$ and $\phi = 1/1 - \alpha$. Therefore, product quality is a function of both a country-specific component (input costs) and a firm-specific component related to its idiosyncratic capability. Given the definition of capability, product quality is also positively related to a firm's productivity. Crinò and Epifani (2012), Curzi and Olper (2012), and Gaigné and Larue (2016) derive similar theoretical results relating product quality to productivity, for which there is also empirical support in the agri-food sector (e.g., Curzi and Olper, 2012; Crozet, Head, and Mayer, 2012).

Following Baldwin and Harrigan (2011) and Johnson (2012), we adopt a reduced-form relationship linking product quality and productivity:

(4) $$q = \left(\frac{1}{a}\right)^{\theta-1},$$

[1] For more details of this analysis, see the online appendix for Johnson (2012).

where $\theta \geq 1$. Therefore, product quality increases with higher productivity and "quality elasticity" $(\theta - 1)$ measures the extent to which product quality and productivity are related. The parameter θ reflects the scope for quality differentiation (i.e., capability of a firm combined with availability of technology for converting productivity into improved product quality). Therefore, with firms getting a specific productivity draw and other parameters such as input costs being common to all firms, each firm's choice of quality clearly varies with its productivity draw (Baldwin and Harrigan, 2011).

Defining quality as a power function of productivity simplifies the model and allows firm heterogeneity to be expressed in a single dimension, which we refer to as firm capability for the remainder of the article. Substituting q from equation (4) into equation (3), equilibrium profits of a country-j firm exporting a vertically differentiated product to country i are

$$\pi_{ij}(a) = \frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\left(\frac{\tau_{ij}c_j a^{\theta}}{P_i}\right)^{1-\sigma} E_i - f_{ij}, \tag{5}$$

where the key difference between equations (5) and (3) is the exponent θ on a. If $\theta = 1$, then equation (5) reduces to expression (3), where firms with high productivity have lower unit costs of production and, hence, charge lower prices for their horizontally differentiated products. Alternatively, if $\theta > 1$, then more capable firms have higher unit costs of production but sell higher-quality products at higher prices.

Participation in the Export Market

A firm chooses whether to remain in or exit from the export market after learning about its capability. This decision is based on a cutoff capability, $\lambda^*_{ij} = 1/a^{\theta}_{ij}$, where a firm makes 0 profit (Melitz, 2003). Based on equation (5), firm j's profits are always positive if they sell their product domestically, due to $f_{jj} = 0$. Therefore, no firm exits from the domestic market. On the other hand, profits from exports are only positive if $a^{\theta} \leq a^{\theta}_{ij}$, where $a^{\theta}_{ij}$is defined by $\pi_{ij}(a^{\theta}_{ij}) = 0$:

$$\frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\left(\frac{\tau_{ij}c_j a^{\theta}_{ij}}{P_i}\right)^{1-\sigma} E_i = f_{ij}. \tag{6}$$

Therefore, given equation (6), the cutoff capability is given as

$$\lambda^*_{ij} = \left[\frac{\sigma}{\sigma-1}\left(\frac{\sigma f_{ij}}{E_i}\right)^{1/(\sigma-1)}\frac{\tau_{ij}c_j}{P_i}\right]. \tag{7}$$

From equation (7), it can be noted that changes in both importer expenditure (income) and competitiveness (E_i, P_i) will result in variation in the cutoff capability. Destinations either having higher expenditure (income) (larger E_i) or that are less competitive (higher P_i) allow firms with lower capability, and hence lower product quality, to enter the export market. However, higher fixed and variable trade costs (f_{ij}, τ_{ij}) raise cutoff capability, restricting entrance to the export market to firms with higher capability and, hence, higher product quality. The comparative static results are as follows:

$$\frac{\partial \lambda^*_{ij}}{\partial f_{ij}} = \frac{1}{(\sigma-1)} f_{ij}^{\frac{1}{(\sigma-1)}-1}\left[\frac{\sigma}{\sigma-1}\left(\frac{\sigma}{E_i}\right)^{1/(\sigma-1)}\left(\frac{\tau_{ij}c_j}{P_i}\right)\right] > 0, \tag{8}$$

$$\frac{\partial \lambda^*_{ij}}{\partial \tau_{ij}} = \left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\sigma f_{ij}}{E_i}\right)^{1/(\sigma-1)}\left(\frac{c_j}{P_i}\right) > 0. \tag{9}$$

The partial derivatives in equations (8) and (9) indicate a positive relationship between trade costs and cutoff capability. Due to σ being greater than 1, cutoff capability increases (decreases) with an increase (reduction) in both fixed and variable trade costs.

Bilateral Trade Volume

Returning to equation (6), if exports to country i are profitable only when $a^{\theta} \leq a_{ij}^{\theta}$, it follows that only a proportion of country-j firms, $G(a_{ij}^{\theta})$, export to country i. In the limit, it is possible that no country-j firm is sufficiently capable to export to country i, $G(a_{ij}^{\theta}) = 0$,which occurs when the least-capable firm has a productivity draw below the support of $G(a^{\theta})$, where $a_{ij}^{\theta} \leq a_{L}^{\theta}$. Following Helpman, Melitz, and Rubinstein (2008), the bilateral trade volume between countries j and i is denoted as V_{ij}:

$$V_{ij} = \begin{Bmatrix} \int_{a_L^{\theta}}^{a_{ij}^{\theta}} a^{(1-\sigma)} dG(a^{\theta}) & \text{for } a_{ij}^{\theta} > 0 \\ 0 & \text{otherwise} \end{Bmatrix}. \tag{10}$$

From equation (2) and the output pricing relationship, the value of country i's imports from country j is given as

$$M_{ij} = \left(\frac{\sigma}{\sigma - 1}\right)^{1-\sigma} \left(\frac{\tau_{ij} c_j}{P_i}\right)^{1-\sigma} E_i N_j V_{ij}, \tag{11}$$

where $M_{ij} = 0$ if $V_{ij} = 0$. Therefore, the value of bilateral trade over time t between countries j and i, M_{ij}, is derived from a mapping of country i's expenditure, E_i; the number of exporting firms in country j, N_{ij}; the unit costs of production in country j, c_j; the fixed costs of exporting, f_{ij}; and variable trade costs, τ_{ij}.[2]

The value of bilateral trade can be used to infer the relationship between trade costs and the unobservable cutoff capability. Given that the effect of variable trade costs on the value of bilateral trade is negative by equation (12), the effect of cutoff capability on the value of bilateral trade is also negative because the effect of variable trade costs on cutoff capability is positive by equation (13):

$$\frac{\partial M_{ij}}{\partial \tau_{ij}} = -\sigma^{1-\sigma}(\sigma - 1)^{\sigma} c_j \left(\frac{c_j \tau_{ij}}{P_i}\right)^{-\sigma} \frac{E_i N_j V_{ij}}{P_i} < 0, \tag{12}$$

$$\frac{\partial M_{ij}}{\partial \tau_{ij}} = \frac{\partial M_{ij}}{\partial \lambda_{ij}^{*}} \frac{\partial \lambda_{ij}^{*}}{\partial \tau_{ij}} < 0. \tag{13}$$

Econometric Analysis

Empirical Gravity Equation

Given that country-j firm capability is drawn from a truncated Pareto distribution with support $\left[a_L^{\theta}, a_H^{\theta}\right]$; assuming $G(a^{\theta}) = (a^{\theta k} - a_L^{\theta k})/(a_H^{\theta k} - a_L^{\theta k})$, $\theta k > (\sigma - 1)$, then the bilateral trade volume between countries j and i at time t, V_{ijt}, can be written as

$$V_{ijt} = \left(\frac{\theta k}{\theta k - (\sigma - 1)}\right) \frac{a_L^{\theta k - (\sigma - 1)}}{(a_H^{\theta k} - a_L^{\theta k})} W_{ijt}, \tag{14}$$

where $W_{ijt} = \max \left\{ \left(\frac{a_{ijt}}{a_L}\right)^{\theta k - (\sigma - 1)} - 1, 0 \right\}$ and a_{ijt} is given by equation (6).

[2] In Appendix II of their article, Helpman, Melitz, and Rubinstein (2008) show that under specific assumptions, expression (11) can be rewritten as Anderson and van Wincoop's (2003) well-known generalized gravity equation. Specifically, on the right side, it would include the income of both countries, i and j, as proportions of world income, given income is equal to expenditure. However, as Helpman, Melitz, and Rubinstein (2008) show, unlike their model, the generalized gravity model explains neither observed 0 trade flows nor asymmetries in bilateral trade.

Bilateral trade over time between countries j and i at time t as given by equation (11) can be expressed in log-linear form:

$$(15) \qquad \ln M_{ijt} = \beta_0 + (\sigma - 1)\ln P_{it} + \ln E_{it} + (1-\sigma)\ln c_{jt} + \ln N_{jt} - (1-\sigma)\tau_{ijt} + \ln V_{ijt}.$$

Variable trade costs are defined as ${\tau_{ijt}}^{1-\sigma} \equiv D_{ij}^{\gamma} e^{-\mu_{ij}}$, where D_{ij} is the geographic distance between countries i and j. Note that D_{ij} could be defined as a vector of bilateral trade frictions, with an associated vector of trade elasticities. Variable trade costs are also assumed to be stochastic due to unobserved variable trade frictions μ_{ijt}, which are independent and identically distributed (*i.i.d.*), and $\mu_{ijt} \sim N(0, \zeta_{\mu}^2)$. Therefore, rewriting equation (15) as an estimating equation,

$$(16) \qquad m_{ijt} = \beta_0 + \psi_{it} + \psi_{jt} - \gamma d_{ij} - w_{ijt} + \mu_{ijt},$$

where lowercase variables are the natural logs of the associated uppercase variables, $\psi_{it} = (\sigma - 1)p_{it} + e_{it}$ is an importing country-time fixed effect, and $\psi_{jt} = (1-\sigma)\ln c_{jt} + n_{jt}$ is an exporting country-time fixed effect. In addition, $\ln V_{ijt}$ is replaced with $\ln W_{ijt} = w_{ijt}$, where the term β_0 contains the constant multiplier in V_{ijt}(see equation 14). Note that if tariffs are not explicitly included in equation (16), then the importing country fixed effect will pick up average tariff levels.

Equation (16) is a structural version of the well-known gravity equation, and in common with most empirical analysis, country fixed effects are included to account for bilateral trade resistance terms (Head and Mayer, 2014). The key difference is the inclusion of variable w_{ijt}, which captures the fraction of firms exporting from country j to country i. Excluding this variable would introduce upward bias in the estimated trade barrier elasticity γ due to comixing of the effect of trade barriers on firm-level exports with their effect on the proportion of firms that export. In addition, if 0 bilateral trade flows in the data are ignored, this introduces downward sample selection bias in the estimated coefficient, γ.

Helpman, Melitz, and Rubinstein (2008) develop a two-stage estimation procedure, nesting Heckman's (1979) selection model, that takes into account the extensive and intensive margins of trade (i.e., the choice for a country-j firm of whether to export to country i and, if they decide to trade, how much to export). Given that the variable w_{ijt} in equation (16) is typically not observable, a latent variable, Z_{ijt}, is defined as the ratio of variable export profits for the most capable firm(s) in country j to the fixed costs of exporting to country i. Although Z_{ijt} is also unobservable, positive exports occur only when $Z_{ijt} > 1$. Therefore, in the first stage, the probability of exports by firms from country j to i, conditional on observed variables, can be estimated using a probit equation, from which the inverse Mills ratio is computed. In the second stage, a log-linear gravity equation is estimated only for the observed trade flows, where sample selection bias is corrected through inclusion of the inverse Mills ratio from the first stage.

Selection Equation

Given that no country-j firm will export to country i if its most capable firm chooses not to export, 0 trade flows can be used to infer the cutoff capability and hence the ratio of firms exporting from country j to country i. The latent variable Z_{ijt} is used to control for the number of country-j firms exporting to country i at time t, where Z_{ijt} is defined as the ratio of the most capable firm's export profit to fixed trade costs:

$$(17) \qquad Z_{ijt} = \frac{\frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\left(\frac{\tau_{ijt}c_{jt}}{P_{it}}\right)^{1-\sigma} a_L^{\theta(1-\sigma)} E_{jt}}{f_{ijt}}.$$

Given a_L^{θ}, the proxy for the unobserved variable Z_{ijt} relies on the cutoff productivity, a_{ijt}^{θ}. If $a_{ijt}^{\theta} < a_L^{\theta}$, then $Z_{ijt} < 1$ and no country-j firms export. Otherwise, if $a_{ijt}^{\theta} > a_L^{\theta}$, then exports will occur with a certain number of country-j exporters and $Z_{ijt} > 1$. The fraction of exporting firms grows as the most capable exporting firm becomes more profitable, with $W_{ijt} = Z_{ijt}{}^{(\theta k-\sigma+1)/(\sigma-1)} - 1$.

Similar to variable trade costs, fixed trade costs, f_{ijt}, are assumed stochastic due to unmeasured fixed trade frictions, ε_{ijt}, which are *i.i.d.*, although they may be correlated with μ_{ijt}. Fixed trade costs are defined as $f_{ijt} = \exp(\phi_j + \phi_i + \phi_t + \kappa\phi_{ijt} + \varepsilon_{ijt})$, where $\varepsilon_{ijt} \sim N(0, \zeta_\varepsilon^2)$ and ϕ_j, ϕ_i, and ϕ_t are exporter, importer, and time-specific fixed trade costs, respectively, and $\kappa\phi_{ijt}$are any additional country-pair-specific fixed trade costs.

Taking this specification of fixed trade costs, the log of the latent variable $\ln Z_{ijt} = z_{ijt}$ is defined as

$$z_{it} = \gamma_0 + \xi_{1j} + \xi_{2i} + \xi_{3t} - \gamma d_{ijt} - \kappa\phi_{ijt} + \eta_{ijt}, \tag{18}$$

where ξ_{1j}, ξ_{2i}, and $\xi_{3t}$are exporter, importer, and time fixed effects, respectively, and the error term $\eta_{ijt} = \mu_{ijt} + \varepsilon_{ijt} \sim N(0, \zeta_\mu^2 + \zeta_\varepsilon^2)$ is assumed *i.i.d.* but correlated with the error term μ_{ijt} in equation (16). Even though z_{ijt} cannot be observed, $z_{ijt} > 0$ when country j firms export to country i and $z_{ijt} = 0$ if there are no exports. Therefore, an indicator variable, T_{ijt}, can be defined, where $T_{ijt} = 1$ when .country j firms do export to country i, and 0 otherwise.

Let the probability that country j firms export to country i be represented as ρ_{ijt}, conditional on the observed variables:

$$\begin{aligned} \rho_{ijt} &= \Pr(T_{ijt} = 1 \,|\, \text{observed variables}) \\ &= \Phi(\gamma_0^* + \xi_{1j}^* + \xi_{2i}^* + \xi_{3t}^* - \gamma d_{ijt}^* - \kappa\phi_{ijt}^*), \end{aligned} \tag{19}$$

where $\Phi(.)$ is the cumulative distribution function of the unit-normal distribution, starred coefficients indexing the original coefficient divided by the standard deviation $\zeta_\eta \equiv \zeta_u + \zeta_\varepsilon$.

Using estimates from equation (19), let $\hat{\rho}_{ijt}$ be the predicted probability that country j firms export to country i and $\hat{z}_{ij}^* = \Phi^{-1}\hat{\rho}_{ij}$ be the predicted value of the latent variable, $z^*{}_{ijt} \equiv z_{ijt}/\zeta_\eta$. Therefore, a consistent estimate of W_{ijt} can be derived from $W_{ijt} = \max\left\{(Z_{ijt}^*)^\delta - 1, 0\right\}$, where $\delta \equiv \zeta_\eta(\theta k - \sigma + 1)/(\sigma - 1)$.

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Trade Equation

Second-stage estimation of the gravity equation (16) requires a consistent estimate of $\hat{\bar{\eta}}_{ijt}^*$, which is obtained from the inverse Mills ratio, $\hat{\bar{\eta}}^*{}_{ijt} = \phi(\hat{z}_{ijt}^*)/\Phi(\hat{z}_{ijt}^*)$, $\hat{\bar{z}}_{ijt}^* \equiv \hat{z}_{ijt}^* + \hat{\bar{\eta}}_{ijt}^*$, and $\hat{\bar{w}}^*{}_{ijt}(\delta) = \ln\{\exp[\delta(\hat{z}_{ijt}^* + \hat{\bar{\eta}}_{ijt}^*)] - 1\}$. Therefore, equation (16) is transformed as follows:

$$m_{ijt} = \beta_0 + \psi_{it} + \psi_{jt} - \gamma d_{ij} + \ln\left\{\exp\left[\delta(\hat{z}_{ijt}^* + \hat{\bar{\eta}}_{ijt}^*)\right] - 1\right\} + \beta_{u\eta}\hat{\bar{\eta}}_{ijt}^* + e_{ijt}, \tag{20}$$

where $\beta_{un} = corr(u_{ijt}, \eta_{ijt})(\zeta_u/\zeta_\eta)$ and e_{ijt} is an *i.i.d.* error term. Because equation (20) is nonlinear in δ, we use maximum likelihood estimation (MLE). Following Heckman (1979), potential selection bias is corrected by the term $\hat{\bar{\eta}}_{ijt}^*$, which—used on its own—would capture a world in which firms are identical and make the same export decisions. Therefore, the additional control variable, $\hat{z}_{ijt}^*$, corrects for bias due to the unobserved firm heterogeneity.

Data

The dataset is comprised of a sample of bilateral trade flows of food and agricultural products for 159 countries over 2010–2013 (see Online Supplement Table S1 at www.jareonline.org for country and product details). Table S2 describes the data sources, and Table S3 reports summary statistics. The dependent variable in the second-stage gravity equation (m_{ijt}) is the value of bilateral trade between countries j and i at time t. In total, there are 77,488 bilateral trade flow observations, with 31,140 0 bilateral trade flows (just over 40% of the total sample). The explanatory variables are grouped into two categories: category 1 includes exporting and importing country fixed effects (ξ_{1j}, ξ_{2i}) and a time fixed effect (ξ_{3t}); category 2 includes variable and fixed trade costs.

In category 2, variable trade costs are typical to the estimation of the gravity equation, captured by distance between n trading partners ($DIST_{ij}$) and dummy variables for trading partners having a shared border (ADJ_{ij}), sharing a common language ($LANG_{ij}$) and being members of the same regional free trade agreement (RTA_{ij}). Fixed trade costs, while not directly observable, are captured by three proxy variables based on indices of governance in the importing country i: government effectiveness (Gov_{it}), quality of regulation (Reg_{it}), and freedom to trade ($Free_{it}$). In addition, an index of nontariff measures (NTM_{ijt}) is used as a proxy for trade facilitation.

Fixed trade costs associated with access to foreign markets affect selection by firms into exporting. Previous empirical analysis has used governance and regulatory cost indicators as proxies for fixed trade costs, since importers with effective governance and lower regulatory costs are easier to access and require lower entry costs (see, e.g., Manova, 2013). In this article, country-level governance indicators are based on indices included in the World Bank's *Worldwide Governance Indicators* (Kraay, Kaufmann, and Mastruzzi, 2010). Government effectiveness is defined as "capturing perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies," while quality of regulation is defined as "capturing perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development" (Kraay, Kaufmann, and Mastruzzi, 2010, p. 4). These indices range from −2.5 to 2.5, implying that more accessible countries have a higher value, close to 2.5.

The motivation for using effective governance in the analysis draws on previous research by, among others, Essaji and Fujiwara (2012), which shows that contract enforcement and a strong legal system legal system are key determinants of comparative advantage in agri-food trade. Therefore, it is expected that importing government effectiveness and higher quality of regulation, which are dimensions of trade facilitation, will have a positive effect on firms' selection into exporting.

The freedom to trade internationally index constructed by the Fraser Institute is also used to infer the effectiveness of a country's governance as it relates to cross-border trade. The index consists of controls on the movement of capital and people, regulatory trade barriers, tariffs, and black-market exchange rates (Gwartney, Lawson, and Hall, 2016). Given the focus on trade restrictions, it is expected that higher values of this index, indicating greater freedom to trade, will have a positive effect on firms' decisions to enter the export market.

In summarizing these data, most high-income countries are recorded as having effective governance, with many developed European countries, especially those in northern Europe (Denmark, Sweden, Finland, and Norway), included on the list (see Online Supplement Table S4). Singapore and Canada also have effective governance. Although Mauritius and Jordan are middle-income countries, they have a high level of freedom to trade. This is because both countries are recorded as having low controls on the movement of capital and people, low tariffs, and no black-market exchange rates (Gwartney, Lawson, and Hall, 2016).

Most African countries are recorded as having ineffective governance, while Latin American countries such as Venezuela and Argentina have low freedom to trade. Middle Eastern countries—particularly Iran, Syria, and Yemen—also exhibit low levels of governance. The bottom-ranked countries are mainly developing countries in Africa: Zimbabwe, Cameroon, the Central African Republic (CAR), and the Congo (see Online Supplement Table S4).

Nontariff measures (NTMs) also act as fixed trade costs, making it more difficult for firms to enter food and agricultural product export markets. Drawing on the World Integrated Trade Solution (WITS) and the Integrated Trade Intelligence Portal (the 1% I-TIP) databases, both from the World Bank, we construct an NTM variable that varies across countries imposing standards, partners affected, products, and the effective period, by combining the number of measures applied by importers in the agricultural and food sector. The top products with high NTM numbers when averaged across all trading partners by product category during the observed period are shown in Online Supplement Table S5. There are significantly more standards for oils, processed food, and meat than for other products. This is largely due to the frequent occurrence of various animal diseases and food additives to processed food that are subject to maximum residue limits (MRLs). In contrast, other products—such as milling and cocoa preparation—have low NTMs, implying ease of entry for exporting firms. Japan has the most standards relating to food safety, followed by several European countries with strict agricultural and food standards. Large numbers of African and Middle Eastern countries have no food safety standards. These data suggest that high-income countries tend to be sensitive about the safety of imported food and agricultural products (see Online Supplement Table S6).

Estimation

Specification

Estimation of the two-stage model controls for the heterogeneity of firm capability and, hence, product quality. The first step is to estimate the export participation in equation (19), where the dependent variable is a binary indicator of whether there is trade. A positive export flow shows that a country has at least one firm in country j whose capability, and hence product quality, is high enough to export. On the other hand, a 0 trade flow indicates that no firm in country j is capable enough to enter the export market. The estimation results from the first stage are used to control for the extensive margin and sample selection bias in the estimation-of-trade equation (20).

In specifying the first-stage equation, the probability that country j exports to importer i at time t, conditional on the variable and fixed trade costs is estimated. Accordingly, country-specific variables ($DIST_{ij}$, ADJ_{ij}, $LANG_{ij}$, and RTA_{ij}); importer-specific variables (Gov_{it}, Reg_{it}, and $Free_{it}$); country/product-specific variables (NTM_{ijt}); and importer, exporter, and time fixed effects are included in the specification of the selection equation:

$$\begin{aligned} \rho_{ijt} &= \Pr(T_{ijt} = 1|\text{observed variables}) \\ &= \Phi(\beta_0{}^* + \xi_{1i}{}^* + \xi_{2j}{}^* + \xi_{3t}{}^* - \gamma_1{}^* DIST_{ij} - \gamma_2{}^* ADJ_{ij} - \gamma_3{}^* LANG_{ij} \\ &\quad - \gamma_4{}^* RTA_{ij} - \kappa_1{}^* Gov_{it} - \kappa_2{}^* Reg_{it} - \kappa_3^* Free_{it} - \kappa_4{}^* NTM_{ijt}). \end{aligned} \tag{21}$$

The second-stage equation estimates the modified gravity model, including a nonlinear function of the probit index ($\hat{w}^*{}_{ijt}(\delta) = \ln\{\exp[\delta(\hat{z}^*_{ijt} + \hat{\bar{\eta}}^*_{ijt})] - 1\}$) and the inverse Mills ratio ($\hat{\bar{\eta}}^*_{ijt}$). The probit index term controls for the endogenous number of exporters (the extensive margin) and the inverse Mills ratio controls for sample selection bias. Use of the fixed trade cost variables in the first-stage equation satisfies the exclusion restriction requirement. These fixed costs influence the probability of exporting (the extensive margin) but do not directly influence the level of exports (the intensive margin). Accordingly, fixed trade costs are excluded from the second-stage equation:

$$\begin{aligned} m_{ijt} &= \psi_0 + \psi_{it} + \psi_{jt} + \gamma_1 \ln DIST_{ij} + \gamma_2 ADJ_{ij} + \gamma_3 LANG_{ij} + \gamma_4 RTA_{ij} \\ &\quad \ln(\exp[\delta(\hat{z}^*_{ijt} + \hat{\bar{\eta}}^*_{ijt}) - 1] + \beta_{u\eta}\hat{\bar{\eta}}^*_{ijt} + \varepsilon_{ijt}. \end{aligned} \tag{22}$$

Table 1. Baseline Gravity and Selection Equations

	OLS 1	OLS 2	PPML 3	PPML 4	PROBIT 6	PROBIT 6
$\ln DIST_{ij}$	-1.298^{***}	-1.260^{***}	-0.652^{***}	-0.650^{***}	-0.564^{***}	-0.547^{***}
	(0.032)	(0.034)	(0.050)	(0.050)	(0.019)	(0.020)
ADJ_{ij}	0.816^{***}	0.880^{***}	0.573^{***}	0.580^{***}	0.112	0.176
	(0.126)	(0.129)	(0.138)	(0.137)	(0.108)	(0.114)
$LANG_{ij}$	0.874^{***}	0.876^{***}	0.272^{**}	0.265^{**}	0.370^{***}	0.395^{***}
	(0.062)	(0.063)	(0.121)	(0.120)	(0.030)	(0.032)
RTA_{ij}	0.732^{***}	0.668^{***}	0.679^{***}	0.640^{***}	0.400^{***}	0.361^{***}
	(0.068)	(0.071)	(0.111)	(0.119)	(0.047)	(0.049)
Gov_{it}		-0.0361		0.437^{***}		-0.0561
		(0.069)		(0.118)		(0.039)
Reg_{it}		0.262^{***}		-0.114		0.148^{***}
		(0.080)		(0.146)		(0.043)
$\ln Free_{it}$		0.0441		1.736^{***}		1.933^{***}
		(0.407)		(0.615)		(0.261)
$\ln NTM_{it}$		-0.149^{***}		-0.129^{***}		-0.363^{***}
		(0.048)		(0.028)		(0.044)
No. of obs.	46,348	44,477	77,488	73,116	77,488	73,116
R^2	0.942	0.944	0.777	0.784		

Notes: Importer, exporter, and year fixed effects are applied. Robust cluster standard errors are in parentheses. Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level.

Results

Columns 1–4 of Table 1 report the estimates for a baseline gravity equation. Observations track country pairs that trade; exporter, importer, and time fixed effects are used. Columns 1 and 2 report ordinary least squares (OLS) estimates. However, it is well known that estimation of a log-linear gravity equation presents a problem if there are 0 trade observations in the data; how these are handled may result in either selection bias or inconsistent estimates of the coefficients of interest (Santos Silva and Tenreyro, 2015). Therefore, following Santos Silva and Tenreyro, we use Poisson pseudo-maximum likelihood (PPML) estimation to control for these problems. In addition, columns 1 and 3 show estimates excluding fixed trade costs, while columns 2 and 4 include these variables. A log transformation is applied to $DIST_{ij}$, $Free_{it}$, and NTM_{it} as they take values besides 0 and 1, and NTM_{it} is weighted according to the ratio of the number and the maximum number of NTMs.

The results indicate that countries i and j trade more at time t when the two countries are geographically closer, share a border and a common language, and participate in the same regional trade agreement. A majority of the estimated coefficients (using either the OLS or PPML methodologies) are statistically different from 0 at the 5% level and have the expected signs, although the OLS coefficients are overestimated. Reg_{it} and NTM_{it} are significant at level for OLS estimation, while Gov_{it}, $Free_{it}$, and NTM_{it} are significant at the 1% level for PPML estimation. The signs of the coefficients also follow prior expectations: Countries with better governance and quality of regulation, higher freedom to trade, and fewer NTMs import more.

Columns 5 and 6 of Table 1 show the probit estimation results for the selection equation. These results indicate that variable trade costs affecting the value of imports by country i from country j also affect the probability that country i imports from country j. Specifically, countries i and

j are more likely to trade at time t when the two countries are geographically closer, share a common language, and participate in the same regional trade agreement. In addition, the positive and statistically significant coefficients on the fixed trade cost variables—Reg_{it} and $Free_{it}$—indicate that better quality of regulation and greater freedom to trade result in a higher likelihood that importing countries participate in trade. The statistically significant coefficient on NTM_{it} provides evidence that nontariff measures negatively influence the likelihood of trade because importing countries with large numbers of NTMs have a lower probability of exporters entering their markets.

Table 2 reports the second-stage estimation results. In columns 1 and 2, the OLS and PPML results for estimating the baseline gravity equation are reported again. Although PPML estimation performs better statistically than OLS, in that it solves the measurement error problem, the coefficients in columns 1 and 2 are confounded by the effects of unobserved firm heterogeneity. Column 3 reports the probit estimation, and column 4 reports the results of the second-stage estimation of equation (22), where $\hat{\hat{w}}^*{}_{ijt}(\delta)$ and the inverse Mills ratio, $\hat{\hat{\eta}}^*_{ijt}$, are used to control for heterogeneity in firm capabilities and sample selection bias. Fixed trade costs are excluded from estimation of equation (22), given that they affect the probability of firms selecting to export but not how much they export.

As expected, the estimated coefficients δ and $\beta_{u\eta}$ are statistically significant, the latter indicating that sample selection bias would be an issue if the inverse Mills ratio were excluded from the trade equation. Importantly, the positive coefficient on δ indicates that a greater proportion of exporting firms increases the amount of observed bilateral trade (the intensive margin), given that $\hat{\hat{w}}^*{}_{ijt}$ captures firms' selection to export (the extensive margin). In other words, higher bilateral trade is not just a function of lower variable trade costs but also from there being a larger number of exporting firms (i.e., the coefficients shown in column 4 are consistent estimates taking account of firm heterogeneity). Also, in comparing the results in column 4 with those in column 1, it is clear that in the baseline gravity equation, the estimated coefficients on variable trade costs are biased upwards, their true effects being confounded with their indirect effect on the proportion of firms that choose to export.

These findings are not sensitive to the parameterization assumptions made concerning functional form for firm heterogeneity. First, the assumption of a Pareto distribution for firm productivity is relaxed, and thus the functional form of $\hat{\hat{w}}^*{}_{ijt}$ for $\hat{\hat{z}}^*{}_{ijt}$ in equation (22) (see Helpman, Melitz, and Rubinstein, 2008). Instead of constructing a precise estimate for $\hat{\hat{w}}^*{}_{ijt}$, cubic polynomials in $\hat{\hat{z}}^*_{ijt}$ are used as an approximation in the second-stage estimation. Second, the assumption on the joint normality of the unobserved trade costs is also relaxed. Instead of using variables representing firm heterogeneity and sample selection, a nonparametric functional form is used with directly predicted probabilities in column 6. The predicted probabilities, $\hat{\rho}_{ijt}$, are partitioned into a large set of bins and indicator variables are assigned to each bin. In this study, 50 bins of indicator variables are used to approximate the arbitrary functional form of the predicted probability, $\hat{\rho}_{ijt}$, and the dummies for each bin are included in an OLS second-stage estimation. The results of relaxing these assumptions are reported in columns 5 and 6 of Table 2, the estimated coefficients for variable trade costs being very similar to those in reported in column 4, indicating that the Pareto distribution and joint normality assumptions do not unduly influence estimation.

To evaluate the relative significance of firm heterogeneity and firms' selection into exporting, we also conduct a bias decomposition. Specifically, we use two specifications of the second-stage equation: correction for selection bias only, using the inverse Mills ratio, $\hat{\hat{\eta}}^*_{ijt}$, and correction for unobserved firm heterogeneity bias only using $\hat{\hat{z}}^*_{ijt}$; columns 7 and 8, respectively, of Table 2 report the results. All estimated coefficients in column 7 are higher in absolute value and similar to the OLS baseline estimation, while the estimated coefficients reported in column 8 are similar to the MLE estimates (i.e., most of the bias is driven by unobserved firm heterogeneity, and the proportion of exporting firms). Therefore, ignoring firm heterogeneity in the standard gravity equation induces significant statistical bias.

Table 2. Baseline Gravity and Trade Equations with Firm Heterogeneity and Bias Decomposition

	Baseline		Heterogeneous Firms				Bias Decomposition	
	OLS	**PPML**	**Probit**	**MLE**	**Polynomial**	**50 Bins**	**Sample Selection**	**Firm Heterogeneity**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
$\ln DIST_{ij}$	−1.260***	−0.650***	−0.547***	−0.900***	−0.931***	−0.707***	−1.316***	−0.901***
	(0.034)	(0.050)	(0.020)	(0.095)	(0.094)	(0.052)	(0.037)	(0.095)
ADJ_{ij}	0.880***	0.580***	0.176	0.742***	1.031***	0.882***	0.883***	0.776***
	(0.129)	(0.137)	(0.114)	(0.137)	(0.121)	(0.114)	(0.133)	(0.133)
$LANG_{ij}$	0.876***	0.265**	0.395***	0.642***	0.630***	0.449***	0.941***	0.616***
	(0.063)	(0.120)	(0.032)	(0.090)	(0.088)	(0.069)	(0.065)	(0.090)
RTA_{ij}	0.668***	0.640***	0.361***	0.428***	0.410***	0.288***	0.715***	0.461***
	(0.071)	(0.119)	(0.049)	(0.095)	(0.094)	(0.077)	(0.069)	(0.094)
$\hat{\bar{w}}^*_{ijt}$				0.765***				
				(0.165)				
$\hat{\bar{\eta}}^*_{ijt}$				−0.341*	1.822***		0.408***	
				(0.173)	(0.367)		(0.087)	
$\hat{z}^*_{ijt}$					1.537***			0.655***
					(0.262)			(0.163)
$\hat{z}^{*\,2}_{ijt}$					0.022			
					(0.044)			
$\hat{z}^{*\,3}_{ijt}$					−0.038***			
					(0.003)			
No. of obs.	44,477	73,116	73,116	44,477	44,477	44,477	44,477	44,477
R^2	0.944	0.784	0.528	0.679	0.686	0.688	0.678	0.678

Notes: Importer, exporter, and year fixed effects are applied. Robust cluster standard errors are in parentheses. Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level.

In the theoretical framework, a firm's selection into exporting is determined by a cutoff capability and hence product quality. In order to evaluate changes in the proportion of exporting firms with respect to firm heterogeneity in capability, the sample is divided into OECD member and nonmember importing countries. Importers with OECD membership are expected to have a higher cutoff and therefore seek to import higher-quality products. On the other hand, importing countries that do not have OECD membership are expected to have a lower cutoff, which results in their importing relatively lower-quality products. *A priori*, the extensive margin of trade involving imports by nonmember countries will be greater than that for trade between OECD member countries.

Panels A and B in Table 3 report the estimation results for imports by OECD member and nonmember countries, respectively. Column 1 reports estimation of the baseline gravity equation, and column 2 shows the results after controlling for firm heterogeneity and sample selection bias. The bias is then decomposed into sample selection and firm heterogeneity, the results being shown in columns 3 and 4.

The dependent variables are imports by OECD member countries at time t in Panel A of Table 3 and imports by nonmember countries at time t in Panel B. The effect of variable trade costs on imports by OECD members becomes stronger when the proportion of exporting firms is considered, since the cutoff capability is relatively higher. On the other hand, the effect of variable trade costs on imports by nonmember countries becomes weaker after consideration of the extensive margin, given that exporting firms can enter the market relatively easily due to the lower cutoff capability. Therefore, it can be concluded that importing countries requiring high-quality goods have a relatively higher capability cutoff constraining exporting firms, whereas importers with a relatively lower capability cutoff allows more firms to access the export market.

For the Panel A estimation in Table 3, the coefficients for variable trade costs are biased downward for OLS as compared to MLE estimation. The bias decomposition procedure suggests that bias in the OLS estimation comes from unobserved heterogeneity in firms exporting to OECD member countries since the estimated coefficients are closer in absolute value to the MLE estimates, as shown in column 4. In the case of exports to nonmember countries, the OLS estimates of the coefficients on variable trade costs are biased upward relative to the MLE estimates, despite the proportion of exporting firms being statistically insignificant. According to the bias decomposition results, correcting for firm heterogeneity is more crucial than correcting for sample selection bias.

Summary and Conclusions

The key point of this article is that in a heterogeneous firm setting, the choice of whether to enter the export market depends on the interaction between firms' productivity and their ability to produce high-quality products (i.e., their capability). In the presence of high fixed and variable trade costs, only capable firms producing high-quality products can profitably enter export markets. Given that firm activities are not directly observed from country-level data, we use a modified version of the Helpman, Melitz, and Rubinstein (2008) model, which allows us to capture the extensive margin in analyzing the impact of fixed and variable trade costs, with 0 trade flows being used as indicators of the export cutoff.

An important empirical contribution of the analysis is the use of governance indicators, freedom to trade, and nontariff measures as proxies for fixed trade costs in agri-food trade. In addition, these variables serve as exclusion restrictions for the second-stage estimation of a gravity equation (i.e., fixed trade costs affect the probability of firms entering the export market), but they do not influence the volume of exports. Based on a bilateral trade dataset covering 159 countries over 2010–2013 and estimation of a two-stage selection model, the key results are as follows: Fixed trade costs negatively and significantly influence the probability that firms select to enter export markets, while variable trade costs negatively and significantly influence both the probability of entering the export market and the level of exports. The estimation results also confirm that standard methodologies used to estimate the impact of trade frictions produce biased estimates. By controlling for the extensive

Table 3. OECD Member and Nonmember Trade

	Baseline	Heterogeneous Firms	Bias Decomposition	
			Sample Selection	Firm Heterogeneity
	OLS	MLE		
	1	2	3	4
Panel A. OECD Trade				
$\ln DIST_{ij}$	−1.380***	−1.650***	−1.745***	−1.700***
	(0.055)	(0.279)	(0.070)	(0.280)
ADJ_{ij}	0.566**	1.036**	0.908***	0.935*
	(0.223)	(0.480)	(0.313)	(0.477)
$LANG_{ij}$	0.601***	0.672***	0.720***	0.639***
	(0.099)	(0.176)	(0.112)	(0.176)
RTA_{ij}	−0.111	−0.284*	−0.300*	−0.248
	(0.111)	(0.160)	(0.153)	(0.160)
$\hat{\bar{w}}^*_{ijt}$		0.105		
		(0.302)		
$\hat{\bar{\eta}}^*_{ijt}$		0.609*	0.714***	
		(0.318)	(0.135)	
$\hat{z}^*_{ijt}$				−0.0811
				(0.301)
No. of obs.	16,187	12,463	12,463	12,463
R^2	0.761	0.684	0.684	0.682
Panel B. OECD Nonmember Trade				
$\ln DIST_{ij}$	−1.299***	−0.955***	−1.350***	−0.974***
	(0.038)	(0.117)	(0.046)	(0.117)
ADJ_{ij}	0.744***	0.662***	0.869***	0.704***
	(0.140)	(0.160)	(0.151)	(0.157)
$LANG_{ij}$	0.910***	0.745***	1.020***	0.730***
	(0.069)	(0.105)	(0.075)	(0.104)
RTA_{ij}	1.016***	0.766***	1.076***	0.794***
	(0.087)	(0.129)	(0.091)	(0.128)
$\hat{\bar{w}}^*_{ijt}$		0.785***		
		(0.221)		
$\hat{\bar{\eta}}^*_{ijt}$		−0.122	0.626***	
		(0.230)	(0.123)	
$\hat{z}^*_{ijt}$				0.534**
				(0.216)
No. of obs.	30,161	28,290	28,290	28,290
R^2	0.638	0.641	0.641	0.64

Notes: Importer, exporter, and year fixed effects are applied. Robust cluster standard errors are in parentheses. Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level.

margin, the alternative model specification better fits the data and produces statistically unbiased and consistent estimates. Essentially, ignoring firm heterogeneity in estimation of the standard gravity equation induces significant statistical bias.

Finally, estimation based on food and agricultural exports to OECD member and nonmember countries indicates that importers' demands for high-quality products with relatively higher capability cutoffs restrict the number of exporting firms that enter, whereas importers with relatively lower capability cutoffs requiring low-quality goods allow more exporting firms to enter their markets. Therefore, firm capability plays a role as a key determinant of the exporting cutoff.

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References

Amiti, M., and A. K. Khandelwal. "Import Competition and Quality Upgrading." *Review of Economics and Statistics* 95(2013):476–490. doi: 10.1162/REST_a_00271.

Anders, S. M., and J. A. Caswell. "Standards as Barriers versus Standards as Catalysts: Assessing the Impact of HACCP Implementation on U.S. Seafood Imports." *American Journal of Agricultural Economics* 91(2009):310–321. doi: 10.1111/j.1467-8276.2008.01239.x.

Anderson, J. E., and E. van Wincoop. "Gravity with Gravitas: A Solution to the Border Puzzle." *American Economic Review* 93(2003):170–192. doi: 10.1257/000282803321455214.

Baldwin, R., and J. Harrigan. "Zeros, Quality, and Space: Trade Theory and Trade Evidence." *American Economic Journal: Microeconomics* 3(2011):60–88. doi: 10.1257/mic.3.2.60.

Beghin, J. C., ed. *Nontariff Measures with Market Imperfections: Trade and Welfare Implications*, *Frontiers of Economics and Globalization*, vol. 12. Bingley, UK: Emerald, 2013.

Bernard, A. B., J. B. Jensen, S. J. Redding, and P. K. Schott. "The Empirics of Firm Heterogeneity and International Trade." *Annual Review of Economics* 4(2012):283–313. doi: 10.1146/annurev-economics-080511-110928.

Chaney, T. "Distorted Gravity: The Intensive and Extensive Margins of International Trade." *American Economic Review* 98(2008):1707–1721. doi: 10.1257/aer.98.4.1707.

Chang, J. B., J. L. Lusk, and F. B. Norwood. "The Price of Happy Hens: A Hedonic Analysis of Retail Egg Prices." *Journal of Agricultural and Resource Economics* 35(2010):406–423. doi: 10.22004/ag.econ.97855.

Chevassus-Lozza, E., C. Gaigné, and L. Le Mener. "Does Input Trade Liberalization Boost Downstream Firms' Exports? Theory and Firm-Level Evidence." *Journal of International Economics* 90(2013):391–402. doi: 10.1016/j.jinteco.2013.02.004.

Chevassus-Lozza, E., and K. Latouche. "Firms, Markets and Trade Costs: Access of French Exporters to European Agri-Food Markets." *European Review of Agricultural Economics* 39(2012):257–288. doi: 10.1093/erae/jbr009.

Chrysochou, P., A. Krystallis, and G. Giraud. "Quality Assurance Labels as Drivers of Customer Loyalty in the Case of Traditional Food Products." *Food Quality and Preference* 25(2012):156–162. doi: 10.1016/j.foodqual.2012.02.013.

Crinò, R., and P. Epifani. "Productivity, Quality and Export Behaviour." *Economic Journal* 122(2012):1206–1243. doi: 10.1111/j.1468-0297.2012.02529.x.

Crozet, M., K. Head, and T. Mayer. "Quality Sorting and Trade: Firm-Level Evidence for French Wine." *Review of Economic Studies* 79(2012):609–644. doi: 10.1093/restud/rdr030.

Crozet, M., and T. Mayer. "The Very Select Club of Exporting Firms." *Lettre du CEPII* (2007):1–4.

Curzi, D., and A. Olper. "Export Behavior of Italian Food Firms: Does Product Quality Matter?" *Food Policy* 37(2012):493–503. doi: 10.1016/j.foodpol.2012.05.004.

Curzi, D., V. Raimondi, and A. Olper. "Quality Upgrading, Competition and Trade Policy: Evidence from the Agri-Food Sector." *European Review of Agricultural Economics* 42(2015):239–267. doi: 10.1093/erae/jbu021.

Essaji, A., and K. Fujiwara. "Contracting Institutions and Product Quality." *Journal of Comparative Economics* 40(2012):269–278. doi: 10.1016/j.jce.2011.07.005.

Fan, H., Y. A. Li, and S. R. Yeaple. "Trade Liberalization, Quality, and Export Prices." *Review of Economics and Statistics* 97(2015):1033–1051. doi: 10.1162/REST_a_00524.

Ferro, E., T. Otsuki, and J. S. Wilson. "The Effect of Product Standards on Agricultural Exports." *Food Policy* 50(2015):68–79. doi: 10.1016/j.foodpol.2014.10.016.

Flam, H., and E. Helpman. "Vertical Product Differentiation and North-South Trade." *American Economic Review* 77(1987):810–822.

Fulponi, L. "Private Voluntary Standards in the Food System: The Perspective of Major Food Retailers in OECD Countries." *Food Policy* 31(2006):1–13. doi: 10.1016/j.foodpol.2005.06.006.

Gaigné, C., and B. Larue. "Quality Standards, Industry Structure, and Welfare in a Global Economy." *American Journal of Agricultural Economics* 98(2016):1432–1449. doi: 10.1093/ajae/aaw039.

Grunert, K. G. "Food Quality and Safety: Consumer Perception and Demand." *European Review of Agricultural Economics* 32(2005):369–391. doi: 10.1093/eurrag/jbi011.

Gwartney, J., R. Lawson, and J. Hall. *Economic Freedom of the World: 2016 Annual Report*. Vancouver, BC: Fraser Institute, 2016.

Hallak, J. C., and P. K. Schott. "Estimating Cross-Country Differences in Product Quality." *Quarterly Journal of Economics* 126(2011):417–474. doi: 10.1093/qje/qjq003.

Head, K., and T. Mayer. "Gravity Equations: Workhorse,Toolkit, and Cookbook." In G. Gopinath, E. Helpman, and K. Rogoff, eds., *Handbook of International Economics,* vol. 4. Amsterdam, Netherlands: Elsevier, 2014, 131–195.

Heckman, J. J. "Sample Selection Bias as a Specification Error." *Econometrica* 47(1979):153–161. doi: 10.2307/1912352.

Helpman, E., M. Melitz, and Y. Rubinstein. "Estimating Trade Flows: Trading Partners and Trading Volumes." *Quarterly Journal of Economics* 123(2008):441–487. doi: 10.1162/qjec.2008.123.2.441.

Henson, S., and S. Jaffee. "Understanding Developing Country Strategic Responses to the Enhancement of Food Safety Standards." *World Economy* 31(2008):548–568. doi: 10.1111/j.1467-9701.2007.01034.x.

Hummels, D., and P. J. Klenow. "The Variety and Quality of a Nation's Exports." *American Economic Review* 95(2005):704–723. doi: 10.1257/0002828054201396.

Jayasinghe, S., J. C. Beghin, and G. Moschini. "Determinants of World Demand for U.S. Corn Seeds: The Role of Trade Costs." *American Journal of Agricultural Economics* 92(2010):999–1010. doi: 10.1093/ajae/aaq056.

Johnson, R. C. "Trade and Prices with Heterogeneous Firms." *Journal of International Economics* 86(2012):43–56. doi: 10.1016/j.jinteco.2011.09.004.

Khandelwal, A. "The Long and Short (of) Quality Ladders." *Review of Economic Studies* 77(2010):1450–1476. doi: 10.1111/j.1467-937X.2010.00602.x.

Khandelwal, A. K., P. K. Schott, and S.-J. Wei. "Trade Liberalization and Embedded Institutional Reform: Evidence from Chinese Exporters." *American Economic Review* 103(2013):2169–2195. doi: 10.1257/aer.103.6.2169.

Kraay, A., D. Kaufmann, and M. Mastruzzi. "The Worldwide Governance Indicators: Methodology and Analytical Issues." Policy Research Working Paper 5430, World Bank, Washington, DC, 2010.

Krissoff, B., M. Bohman, and J. Caswell, eds. *Global Food Trade and Consumer Demand for Quality*. New York, NY: Kluwer Academic, 2002.

Li, Y., and J. C. Beghin. "A Meta-Analysis of Estimates of the Impact of Technical Barriers to Trade." *Journal of Policy Modeling* 34(2012):497–511. doi: 10.1016/j.jpolmod.2011.11.001.

Lim, K. H., W. Hu, L. J. Maynard, and E. Goddard. "U.S. Consumers' Preference and Willingness to Pay for Country-of-Origin-Labeled Beef Steak and Food Safety Enhancements." *Canadian Journal of Agricultural Economic* 61(2013):93–118. doi: 10.1111/j.1744-7976.2012.01260.x.

Linder, S. B. *An Essay on Trade and Transformation*. Stockholm, Sweden: Almqvist and Wicksell, 1961.

Manova, K. "Credit Constraints, Heterogeneous Firms, and International Trade." *Review of Economic Studies* 80(2013):711–744. doi: 10.1093/restud/rds036.

Manova, K., and Z. Zhang. "Export Prices across Firms and Destinations." *Quarterly Journal of Economics* 127(2012):379–436. doi: 10.1093/qje/qjr051.

Maskus, K. E., T. Otsuki, and J. S. Wilson. "Do Foreign Product Standards Matter? Impact on Costs for Developing Country Exporters." *Asia-Pacific Journal of Accounting & Economics* 20(2013):37–57. doi: 10.1080/16081625.2013.744685.

Melitz, M. J. "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity." *Econometrica* 71(2003):1695–1725. doi: 10.1111/1468-0262.00467.

Olper, A., D. Curzi, and L. Pacca. "Do Food Standards Affect the Quality of EU Imports?" *Economics Letters* 122(2014):233–237. doi: 10.1016/j.econlet.2013.11.031.

Olper, A., D. Curzi, and V. Raimondi. "Imported Intermediate Inputs and Firms' Productivity Growth: Evidence from the Food Industry." *Journal of Agricultural Economics* 68(2017):280–300. doi: 10.1111/1477-9552.12164.

Olper, A., and V. Raimondi. "Market Access Asymmetry in Food Trade." *Review of World Economics* 144(2008):509–537. doi: 10.1007/s10290-008-0158-8.

Santos Silva, J. M. C., and S. Tenreyro. "Trading Partners and Trading Volumes: Implementing the Helpman-Melitz-Rubinstein Model Empirically." *Oxford Bulletin of Economics and Statistics* 77(2015):93–105. doi: 10.1111/obes.12055.

Sexton, R. J. "Market Power, Misconceptions, and Modern Agricultural Markets." *American Journal of Agricultural Economics* 95(2013):209–219. doi: 10.1093/ajae/aas102.

Sutton, J. "Quality, Trade and the Moving Window: The Globalisation Process." *Economic Journal* 117(2007):F469–F498. doi: 10.1111/j.1468-0297.2007.02119.x.

Swinnen, J. "Economics and Politics of Food Standards, Trade, and Development." *Agricultural Economics* 47(2016):7–19. doi: 10.1111/agec.12316.

Xiong, B., and J. C. Beghin. "Does European Aflatoxin Regulation Hurt Groundnut Exporters from Africa?" *European Review of Agricultural Economics* 39(2012):589–609. doi: 10.1093/erae/jbr062.

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Online Supplement: Product Quality in Food and Agricultural Trade: Firm Heterogeneity and the Impact of Trade Costs

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Table S1. Countries and Products

Countries	Afghanistan, Albania, Algeria, Antigua and Barbuda, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bhutan, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cabo Verde, Cambodia, Cameroon, Canada, Central African Republic, Chile, China, Colombia, Comoros, Congo, Costa Rica, Croatia, Cuba, Cyprus, Czech Republic, Côte d'Ivoire, Denmark, Djibouti, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Ethiopia, Fiji, Finland, France, Gabon, Gambia, Georgia, Germany, Ghana, Greece, Grenada, Guatemala, Guinea, Guyana, Honduras, Hungary, Iceland, India, Indonesia, Iran, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kiribati, Kuwait, Kyrgyzstan, Latvia, Lebanon, Libya, Lithuania, Luxembourg, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Mauritania, Mauritius, Mexico, Mongolia, Morocco, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Republic of Korea, Republic of Moldova, Russian Federation, Rwanda, Saint Kitts and Nevis, Saint Lucia, Saint Vincent, Sao Tome and Principe, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Singapore, Slovakia, Slovenia, Solomon Islands, South Africa, Spain, Sri Lanka, Suriname, Swaziland, Sweden, Switzerland, Syrian Arab Republic, Thailand, The former Yugoslav Republic of Maced.., Togo, Tonga, Trinidad and Tobago, Tunisia, Turkey, Tuvalu, Uganda, Ukraine, United Arab Emirates, United Kingdom, Tanzania, United States of America, Uruguay, Vanuatu, Venezuela, Viet Nam, Yemen, Zambia, Zimbabwe
Products	1 Live animals; animal products
	2 Meat and edible meat offal
	4 Dairy produce, birds' eggs
	5 Products of animal origin
	7 Edible vegetables and certain roots
	8 Edible fruit and nuts
	9 Coffee, tea, mate
	10 Cereals
	11 Products of the milling industry
	12 Oil seeds and oleaginous fruits
	13 Lac; gums, resins and other vegetable saps
	14 Vegetable plaiting materials
	15 Animal or vegetable fats and oils
	16 Preparations of meat, of fish
	17 Sugars and sugar confectionery
	18 Cocoa and cocoa preparations
	19 Preparations of cereals, flour, starch
	20 Preparations of vegetables, fruit, nuts
	21 Miscellaneous edible reparations
	22 Beverages, spirits and vinegar
	23 Residues and waste from the food industries

Table S2. Data Sources

Variable	Definition	Data source
m_{ijt}	Bilateral trade	FAO
$DIST_{ij}$	Distance	CEPII
ADJ_{ij}	Shared border	CEPII
$LANG_{ij}$	Common language	CEPII
RTA_{ij}	Regional trade agreement	CEPII
Gov_{it}	Government effectiveness	Worldwide Governance Indicators
Reg_{it}	Regulatory quality	Worldwide Governance Indicators
$Free_{it}$	Freedom to trade	Fraser Institute
NTM_{ijt}	Non-tariff measures	WITS (World Bank) and I-TIP (WTO)

Table S3. Summary Statistics

Variable	Mean	Std. Dev.	Min	Max	Unit/Range
m_{ijt}	55.586	521.712	0	33,359.30	U.S.$thousands
$DIST_{ij}$	7,428.92	4,423.47	6.169	19,812.04	Kilometers
ADJ_{ij}	0.02	0.139	0	1	Indicator
$LANG_{ij}$	0.154	0.361	0	1	Indicator
RTA_{ij}	0.111	0.314	0	1	Indicator
Gov_{it}	0.177	0.929	-1.758	2.25	-2.5–2.5
Reg_{it}	0.181	0.902	-2.055	1.976	Indicator
$Free_{it}$	6.899	0.769	3.36	8.66	Indicator
NTM_{ijt}	25.333	60.573	0	375	Count

Table S4. Effective Governance, 2012

Top-10 countries					
Government effectiveness		**Regulatory quality**		**Freedom to trade**	
Finland	2.23	Singapore	1.97	Singapore	8.54
Singapore	2.17	Sweden	1.90	New Zealand	8.24
Denmark	1.98	New Zealand	1.85	Switzerland	8.19
Sweden	1.95	Finland	1.83	Mauritius	8.09
Norway	1.91	Denmark	1.80	UAE	8.08
Switzerland	1.89	Australia	1.78	Ireland	7.90
Netherlands	1.81	Luxembourg	1.77	Canada	7.90
New Zealand	1.80	Netherlands	1.76	Australia	7.87
Canada	1.77	Canada	1.70	Jordan	7.86
Luxembourg	1.67	Switzerland	1.67	UK	7.83

Bottom-10 countries					
Government effectiveness		**Regulatory quality**		**Freedom to trade**	
Comoros	-1.55	Zimbabwe	-1.88	Venezuela	3.88
Libya	-1.48	Libya	-1.65	Congo	4.54
CAR*	-1.45	Cuba	-1.57	Zimbabwe	5.06
Afghanistan	-1.38	Syria	-1.54	Algeria	5.14
Zimbabwe	-1.33	Venezuela	-1.51	Argentina	5.15
Burundi	-1.32	Iran	-1.41	Togo	5.22
Togo	-1.31	Comoros	-1.39	Iran	5.28
Guinea	-1.26	Congo	-1.36	CAR	5.30
Yemen	-1.26	Kiribati	-1.34	Burundi	5.32
Sierra Leone	-1.21	Algeria	-1.28	Gabon	5.53

Notes: [a]Central African Republic.

Table S5. Number of Nontariff Measures (NTMs) by Product, 2010–2013

Product Code (HS2)	Product description	Average NTM by product
1	Live animals	0.938
2	Meat and edible meat offal	2.466
4	Dairy produce, birdâĂŹs eggs	0.825
5	Products of animal origin	0.786
7	Edible vegetables and certain roots	1.969
8	Edible fruit and nuts	1.389
9	Coffee, tea, mate	2.486
10	Cereals	1.457
11	Products of the milling industry	0.958
12	Oil seeds and oleaginous fruits	1.321
13	Lac; gums, resins	0.091
14	Vegetable plaiting materials	0.063
15	Animal or vegetable fats and oils	3.063
16	Preparations of meat, of fish	1.403
17	Sugars and sugar confectionery	1.226
18	Cocoa and cocoa preparations	0.844
19	Preparations of cereals, flour, starch	0.978
20	Preparations of vegetables, fruit, nuts	2.855
21	Miscellaneous edible preparations	1.244
22	Beverages, spirits and vinegar	1.217
23	Residues and waste from the food industries	0.464

Table S6. Top 10 Countries with the Most Nontariff Measures (NTMs) and Countries without Nontariff Measures (NTMs), 2012

Top 10 countries imposing NTMs (numbers)	Japan (297), France (238), Netherland (237), Italy (235), Germany (235), England (232), Spain (223), Belgium (220), Denmark (215), Bulgaria (208)
Countries without NTMs	Afghanistan, United Arab Emirates, Armenia, Antigua and Barbuda, Azerbaijan, Burundi, Benin, Burkina Faso, Bangladesh, Bahrain, Bahamas, Bosnia and Herzegovina, Belarus, Belize, Bolivia, Barbados, Brunei, Bhutan, Botswana, Central African Republic, Switzerland, Cote dâĂŹIvoire, Cameroon, Congo, Cook Islands, Comoros, Cape Verde, Cuba, Djibouti, Dominica, Algeria, Ethiopia, Fiji, Gabon, Georgia, Ghana, Guinea, Gambia, Grenada, Guyana, Iran, Israel, Jamaica, Jordan, Kazakhstan, Kyrgyz Republic, Cambodia, Kiribati, St. Kitts and Nevis, Kuwait, Lebanon, Libya, St. Lucia, Moldova, Madagascar, Maldives, Macedonia, Mali, Montenegro, Mongolia, Mauritania, Mauritius, Malawi, Malaysia, Namibia, Niger, Nigeria, Norway, Pakistan, Papua New Guinea, Paraguay, Rwanda, Senegal, Solomon Islands, Sierra Leon, Serbia, Sao Tome and Principe, Suriname, Swaziland, Seychelles, Syria, Togo, Tonga, Trinidad and Tobago, Tunisia, Tuvalu, Tanzania, Uganda, St. Vincent and Grenadines, Venezuela, Vanuatu, Yemen, Zambia

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