

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

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Abstract

A heterogeneous firm model is developed allowing identification of 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 2010-13. 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 the export level of firms.

Key words: Firm heterogeneity, product quality, fixed and 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 it drawing 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 GDP per capita 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 (1961), 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

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 (Melitz, 2003).

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 analysis, 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 (2014) 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 and its impact on the environment and food safety, as well as the connection between diet and health, e.g., see, Krissoff, Bohman, and Caswell (2002). Also, in the context of vertical food marketing systems, the 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, as well as 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), and 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; and Swinnen, 2016).

Importantly, a series of recent empirical contributions by Alessandro Olper and his 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 EU food standards over the period 1995-2003 positively affected the rate of quality upgrading of imported food products. In a subsequent study of EU-15 imports of food products over the period 1995-2007, Curzi, Raimondi and Olper (2015) also find that trade liberalization in the exporting countries leads to faster upgrading of product quality for those products closer to the technology frontier. Finally, Curzi and Pacca (2015) analyzed data for EU-15 food imports over the period 1995-2007, their results indicating a poor correlation between their estimates of food product quality and unit values, confirming what was previously found by Hallack and Schott (2011). In addition, using the methodology of Khandelwal, Schott and Wei (2013), Curzi and Pacca (2015) find that the price and quality of food product exports are affected differently by *ad valorem* and specific trade costs.

An important motivation for the analysis presented in the current paper is 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. 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 once 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 (EU) members, driven by distance and size of the importing country, as well as other fixed entry costs. In the follow-up article, Chevassus-Loza, Gaigné and Le Mener (2013) find for a sample of 3,716 French agri-food firms that over the period 2001-2004, a reduction in input tariffs increased the probability that 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 zero 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 analysis of food and agricultural trade has applied the standard Heckman (1979) selection method assuming no firm-level heterogeneity, e.g., Jayasinghe, Beghin and Moschini (2009).

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), and 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 period 2001-2006, 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, the contribution of this paper is 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 period 2010-13. Drawing on Johnson's (2012) adaptation of Helpman, Melitz and Rubinstein (2008), a heterogeneous-firm trade model incorporating a link between productivity and product quality is developed, allowing for the impact of both fixed and variable trade costs on the decision of firms to export, and also the impact of variable trade costs on 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 which allows inferences to be made about firm-level behavior using aggregate trade data.

The key empirical contribution of the paper 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.

The remainder of the paper is organized as follows: first, the theoretical model which provides the basis of the empirical specification is described; second, the econometric specification and methodology are presented; third, the data are described and estimation results discussed; and, finally, the paper is summarized and some concluding remarks are offered.

Theoretical Background

Preferences

Suppose the world consist of J countries, indexed by $j = 1, 2, \dots, J$. Following Baldwin and Harrigan (2008) 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:

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

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 (2008) 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 :

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

where $p_j(\omega)$ is the price of product ω , P_j is an aggregate quality-adjusted price index,

$$\text{defined as } P_j = \left[\int_{\omega \in \Omega_j} \left(\frac{p_j(\omega)}{q(\omega)} \right)^{1-\sigma} d\omega \right]^{1/(1-\sigma)}, \text{ and } E_j \text{ is the quality adjusted aggregate}$$

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, decreases with product price, and increases with the level of income.

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 , it bears both destination-specific fixed costs f_{ij} , and iceberg transport costs τ_{ij} , where: $f_{jj} = 0$ for every j , and $f_{ij} > 0$ for $i \neq j$, and $\tau_{jj} = 1$ 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:

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

In order to allow for heterogeneity in product quality, the concept of firm ‘‘capability’’ is introduced (Sutton, 2007; Johnson, 2012). As noted earlier, Sutton (2007) defined 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 the 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, in country j , unit costs of production can be defined as,

$$c_j(a, q) = c_j \left(q^{\vartheta} + \frac{q^{\ell}}{\nu} \right), 0 < \vartheta < 1 < \ell, \text{ where } \nu = 1/a, \text{ unit costs of production decreasing in}$$

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 production of 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 pesticide residue limits 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 being expressed

as a function of firm capability: $q(A) = \bar{c}_j^\phi A^\phi$, where $\bar{c}_j = c_j \left(\frac{\ell - g}{\ell - 1} \right)$, 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. Note that, given the definition of capability, product quality is also positively related to a firm's productivity. Similar theoretical results relating product quality to productivity have been derived by Crinò and Epifani (2012), Curzi and Olper (2012), and Gaigné and Larue (2016), for which there is also empirical support in the agri-food sector, e.g., Curzi and Olper (2012), and Crozet, Head and Mayer (2012).

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

Following Baldwin and Harrigan (2008) and Johnson (2012), a reduced form relationship linking product quality and productivity is adopted:

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

where $\theta \geq 1$. Therefore, product quality increases with higher productivity, and the “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, 2008).

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

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

where the key difference between equations (5) and (3) is the exponent θ on a . If $\theta = 1$, (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 $\theta > 1$, 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 or exit from the export market after learning about its capability. This decision is based on a cutoff capability $\lambda_{ij}^* = 1/a_{ij}^\theta$ where a firm makes zero 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 $a^\theta \leq a_{ij}^\theta$, where a_{ij}^θ is defined by

$$\pi_{ij}(a_{ij}^\theta) = 0:$$

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

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

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

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:

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

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

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 export to country i , $G(a_{ij}^\theta)$. 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} :

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

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

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

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):

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

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

Econometric Analysis

Empirical Gravity Equation

Given that country- j firm capability is drawn from a truncated Pareto distribution with support $[a_L^\theta, a_H^\theta]$, and 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:

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

² In Appendix II of their article, Helpman, Melitz and Rubinstein (2008) show that under specific assumptions, expression (11) can be re-written as the well-known generalized gravity equation of Anderson and Wincoop (2003). Specifically, on the right-hand 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 zero trade flows nor asymmetries in bilateral trade.

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).

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

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

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} that 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:

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

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), 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 . Exclusion of this variable would introduce upward bias in the estimated trade barrier elasticity γ , due to co-mixing of the effect of trade barriers on firm-level exports with their effect on the proportion of firms that export. In addition, if zero 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 or not to export to country i , and if so 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, and the inverse Mill's ratio 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, zero 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:

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

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 $Z_{ijt} < 1$ - no country- j firms export. Otherwise, if $a_{ijt}^\theta > a_L^\theta$, 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} that 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:

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

where ξ_{1j}, ξ_{2i} and ξ_{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 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:

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

where $\Phi(\cdot)$ 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 i , and also let $\hat{z}_{ij}^* = \Phi^{-1} \hat{\rho}_{ijt}$ 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

$$W_{ijt} = \max \left\{ (Z_{ijt}^*)^\delta - 1, 0 \right\}, \text{ where } \delta \equiv \zeta_\eta (\theta k - \sigma + 1) / (\sigma - 1).$$

Trade Equation

Second-stage estimation of the gravity equation (16) requires a consistent estimate of $\hat{\eta}_{ijt}^*$, which

is obtained from the inverse Mills ratio, $\hat{\eta}_{ijt}^* = \phi(\hat{z}_{ijt}^*) / \Phi(\hat{z}_{ijt}^*)$, and, $\hat{z}_{ijt}^* \equiv \hat{z}_{ijt} + \hat{\eta}_{ijt}^*$, and,

$\hat{w}_{ijt}^*(\delta) = \ln \{ \exp[\delta(\hat{z}_{ijt}^* + \hat{\eta}_{ijt}^*)] - 1 \}$. Therefore, equation (16) is transformed as follows:

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

where $\beta_{un} = \text{corr}(u_{ijt}, \eta_{ijt}) (\zeta_u / \zeta_\eta)$ and e_{ijt} is an i.i.d. error term. Due to (20) being non-linear in

δ , maximum likelihood estimation (MLE) is used. Following Heckman (1979), potential

selection bias is corrected by the term $\hat{\eta}_{ijt}^*$, which used on its own, would capture a world where

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 the period 2010-13 (see Appendix A1 for the country and product details). A description of the data sources is given in Appendix A2, while summary statistics are provided in Appendix A3. 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 zero bilateral trade flows accounting for just over 40 percent of the total sample. The explanatory variables are grouped into two categories: category (1) exporting and importing country fixed effects (ξ_{1j}, ξ_{2i}), as well as a time-fixed effect (ξ_{3t}); and, category (2) variable and fixed trade costs.

In category (2), variable trade costs are typical to estimation of the gravity equation, captured by: distance between trading partners ($DIST_{ij}$), and dummy variables respectively 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 non-tariff 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, e.g., see Manova (2013). In this paper, country-level governance indicators are based on indices included in the World Bank's *Worldwide Governance Indicators* (Kaufmann, Kraay, 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..." (Kaufmann, Kraay and Mastruzzi, 2010, p.4). These indices range from -2.5 to 2.5, implying 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), showing 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 the selection by firms 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 in northern Europe (Denmark, Sweden, Finland, and Norway), included on the list (see Appendix A4). 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 countries with ineffective governance, while Latin American countries such as Venezuela and Argentina have a low freedom to trade. Arab countries, particularly Iran, Syria, and Yemen, also exhibit low levels of governance. The bottom-ranked countries are mainly composed of developing countries in Africa: Zimbabwe, Cameroon, the Central African Republic (CAR), and the Congo (see Appendix A4).

Non-tariff 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) (World Bank) and the Integrated Trade Intelligence Portal (I-TIP) (WTO) databases, an NTM variable is constructed, which 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. The number of standards for oils, processed food, and meat are significantly higher than

those 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 (see Appendix A5).

Japan has the largest number of standards relating to food safety followed by several European countries which have strict agricultural and food standards. On the other hand, large numbers of African and Arabian countries have no food safety standards. These data suggest that high-income countries, tend to become sensitive about the safety of imported food and agricultural products (see Appendix A6).

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 equation (19) where the dependent variable is a binary indicator of whether there is trade or not. 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 zero-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:

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

In the second-stage equation, the modified gravity model is estimated including a nonlinear function of the Probit index ($\hat{w}_{ijt}^*(\delta) = \ln\{\exp[\delta(\hat{z}_{ijt}^* + \hat{\eta}_{ijt}^*)] - 1\}$) and the inverse Mills ratio ($\hat{\eta}_{ijt}^*$). 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, the specification being:

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

Results

The estimates for a baseline gravity equation are presented in columns (1) to (4) of Table 1. Observations track country pairs that trade, and both exporter and importer fixed effects, as well as 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 zero trade observations in the data, and how these are handled may result in either selection bias or inconsistent estimates of the coefficients of interest (Silva and Tenreyro, 2015). Therefore, following Silva and Tenreyro (2015), pseudo Poisson maximum likelihood (PPML) estimation is used 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 zero and one, 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 an official 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 zero at the 5 percent level and have the expected signs, although the OLS coefficients are overestimated. Reg_{it} and NTM_{it} are significant at the 1 percent level for OLS estimation while Gov_{it} , $Free_{it}$, and NTM_{it} are significant at the 1 percent level for PPML estimation. The signs of the coefficients also follow prior expectations, countries with better governance and quality of regulation, a higher freedom to trade, and fewer NTMs, importing more.

Columns (5) and (6) 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 an official 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 results in a higher likelihood of importing countries participating in trade. The statistically significant coefficient on NTM_{it} provides evidence that non-tariff measures negatively influence the likelihood of trade,

importing countries with large numbers of NTMs having a lower probability of exporters entering their markets.

The second-stage estimation results are reported in Table 2. 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 Column (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 $\hat{w}_{ijt}^*(\delta)$, and the inverse Mills ratio, $\hat{\eta}_{ijt}^*$, are used to control for heterogeneity in firm capabilities and sample selection bias. Fixed trade costs are excluded from estimation of (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{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{w}_{ijt}^* for \hat{z}_{ijt}^* in equation (22) (see Helpman, Melitz and Rubinstein, 2008). Instead of constructing a precise estimate for \hat{w}_{ijt}^* , cubic polynomials in \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 non-parametric 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, a bias decomposition is also conducted. Specifically, two different specifications of the second-stage equation are used: correction for selection bias only, using the inverse Mills ratio, $\hat{\eta}_{ijt}^*$, and correction for unobserved firm heterogeneity bias only using \hat{z}_{ijt}^* , the results being reported in Columns (7) and (8) respectively of Table 2. 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, the proportion of exporting firms. Therefore, ignoring firm heterogeneity in the standard gravity equation induces significant statistical bias.

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 and non-OECD member 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 non-OECD member countries will be greater than that for imports by between OECD member countries.

In Table 3 the estimation results for imports by OECD and non-OECD member countries are provided in Panels A and B, 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 variable in Panel A is imports by OECD member countries at time t , while in Panel B the dependent variable is imports by non-OECD member countries at time t . 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 non-OECD member 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, 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 non-OECD member countries, the OLS estimates of the coefficients on variable trade costs are biased upward as compared to the MLE estimates, despite the proportion of exporting firms being statistically insignificant. According to the bias decomposition results, the correction for firm heterogeneity is more crucial than correction for sample selection bias.

Summary and Conclusions

The key point of this paper is that in a heterogeneous firm setting, the choice of, whether or not 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 firm activities are not directly observed from country-level data, a modified version of the Helpman, Melitz and Rubinstein (2008) model is used. Specifically, this model allows capture of the extensive margin in analyzing the impact of fixed and variable trade costs, with zero 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 non-tariff 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 the period 2010-13, 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 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 and non-OECD member countries respectively, indicates that importers demanding high-quality products with relatively higher capability cutoffs restricts the number of exporting firms that enter, whereas importers with relatively lower capability cutoffs requiring low-quality goods allows 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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Table 1: Baseline Gravity and Selection Equations

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	PPML	PPML	PROBIT	PROBIT
$\ln DIST_{ij}$	-1.298*** (0.0323)	-1.260*** (0.0338)	-0.652*** (0.0501)	-0.650*** (0.0504)	-0.564*** (0.0185)	-0.547*** (0.0199)
ADJ_{ij}	0.816*** (0.126)	0.880*** (0.129)	0.573*** (0.138)	0.580*** (0.137)	0.112 (0.108)	0.176 (0.114)
$LANG_{ij}$	0.874*** (0.0617)	0.876*** (0.0629)	0.272** (0.121)	0.265** (0.120)	0.370*** (0.0304)	0.395*** (0.0319)
RTA_{ij}	0.732*** (0.0676)	0.668*** (0.0706)	0.679*** (0.111)	0.640*** (0.119)	0.400*** (0.0468)	0.361*** (0.0488)
Gov_{it}		-0.0361 (0.0687)		0.437*** (0.118)		-0.0561 (0.0385)
Reg_{it}		0.262*** (0.0804)		-0.114 (0.146)		0.148*** (0.0427)
$\ln Free_{it}$		0.0441 (0.407)		1.736*** (0.615)		1.933*** (0.261)
$\ln NTM_{it}$		-0.149*** (0.0483)		-0.129*** (0.0282)		-0.363*** (0.0443)
Observations	46348	44477	77488	73116	77488	73116
R ²	0.942	0.944	0.777	0.784		

Importer, exporter, and year fixed effects are applied. Robust cluster standard errors are in parentheses. *p <10%, ** p <5%, *** p <1%

Table 2: Baseline Gravity and Trade Equations with Firm heterogeneity, and Bias Decomposition

	Baseline		Heterogeneous firms				Bias decomposition	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	PPML	Probit	MLE	Polynomial	50 bins	Sample selection	Firm heterogeneity
$\ln DIST_{ij}$	-1.260*** (0.0338)	-0.650*** (0.0504)	-0.547*** (0.0199)	-0.900*** (0.0946)	-0.931*** (0.0937)	-0.707*** (0.0523)	-1.316*** (0.0366)	-0.901*** (0.0948)
ADJ_{ij}	0.880*** (0.129)	0.580*** (0.137)	0.176 (0.114)	0.742*** (0.137)	1.031*** (0.121)	0.882*** (0.114)	0.883*** (0.133)	0.776*** (0.133)
$LANG_{ij}$	0.876*** (0.0629)	0.265** (0.120)	0.395*** (0.0319)	0.642*** (0.0899)	0.630*** (0.0878)	0.449*** (0.0694)	0.941*** (0.0650)	0.616*** (0.0897)
RTA_{ij}	0.668*** (0.0706)	0.640*** (0.119)	0.361*** (0.0488)	0.428*** (0.0949)	0.410*** (0.0942)	0.288*** (0.0766)	0.715*** (0.0686)	0.461*** (0.0942)
\hat{w}_{ijt}^*				0.765*** (0.165)				
$\hat{\eta}_{ijt}^*$				-0.341* (0.173)	1.822*** (0.367)		0.408*** (0.0865)	
\hat{z}_{ijt}^*					1.537*** (0.262)			0.655*** (0.163)
$\hat{z}_{ijt}^{* 2}$					0.022 (0.044)			
$\hat{z}_{ijt}^{* 3}$					-0.038*** (0.003)			
Observations	44477	73116	73116	44477	44477	44477	44477	44477
R ²	0.944	0.784	0.528	0.679	0.686	0.688	0.678	0.678

Importer, exporter, and year fixed effects are applied. Robust cluster standard errors are in parentheses. *p<10%, ** p<5%, ***p<1%

Table 3: OECD and Non-OECD Member Trade

		Baseline	Heterogeneous firms	Bias decomposition	
		OLS	MLE	Sample selection	Firm heterogeneity
		(1)	(2)	(3)	(4)
A: OECD Trade	$\ln DIST_{ij}$	-1.380*** (0.0550)	-1.650*** (0.279)	-1.745*** (0.0702)	-1.700*** (0.280)
	ADJ_{ij}	0.566** (0.223)	1.036** (0.480)	0.908*** (0.313)	0.935* (0.477)
	$LANG_{ij}$	0.601*** (0.0990)	0.672*** (0.176)	0.720*** (0.112)	0.639*** (0.176)
	RTA_{ij}	-0.111 (0.111)	-0.284* (0.160)	-0.300* (0.153)	-0.248 (0.160)
	\hat{w}_{ijt}^*		0.105 (0.302)		
	$\hat{\eta}_{ijt}^*$		0.609* (0.318)	0.714*** (0.135)	
	\hat{z}_{ijt}^*				-0.0811 (0.301)
	Observations	16187	12463	12463	12463
R^2	0.761	0.684	0.684	0.682	
B: Non-OECD Trade	$\ln DIST_{ij}$	-1.299*** (0.0375)	-0.955*** (0.117)	-1.350*** (0.0458)	-0.974*** (0.117)
	ADJ_{ij}	0.744*** (0.140)	0.662*** (0.160)	0.869*** (0.151)	0.704*** (0.157)
	$LANG_{ij}$	0.910*** (0.0693)	0.745*** (0.105)	1.020*** (0.0750)	0.730*** (0.104)
	RTA_{ij}	1.016*** (0.0873)	0.766*** (0.129)	1.076*** (0.0905)	0.794*** (0.128)
	\hat{w}_{ijt}^*		0.785*** (0.221)		
	$\hat{\eta}_{ijt}^*$		-0.122 (0.230)	0.626*** (0.123)	
	\hat{z}_{ijt}^*				0.534** (0.216)
	Observations	30161	28290	28290	28290
R^2	0.638	0.641	0.641	0.640	

Importer, exporter, and year fixed effects are applied. Robust cluster standard errors are in parentheses. *p < 10%, ** p < 5%, *** p < 1%

Appendix A1: 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

Appendix A2: 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_{ji}	Regional trade agreement	CEPII
Gov_{it}	Government effectiveness	<i>Worldwide Governance Indicators</i>
Reg_{it}	Regulatory quality	<i>Worldwide Governance Indicators</i>
$Free_{it}$	Freedom to trade	Fraser Institute
NTM_{ijt}	Non-tariff measures	WITS (World Bank) and I-TIP (WTO)

Appendix A3: Summary Statistics

Variable	Mean	Std. Dev.	Min	Max	Unit/ Range
<i>m_{ijt}</i>	55.586	521.712	0	33359.30	000 US\$
<i>DIST_{ij}</i>	7428.92	4423.469	6.169	19812.04	Kilometers
<i>ADJ_{ij}</i>	0.020	0.139	0	1	Indicator
<i>LANG_{ij}</i>	0.154	0.361	0	1	Indicator
<i>RTA_{ij}</i>	0.111	0.314	0	1	Indicator
<i>Gov_{it}</i>	0.177	0.929	-1.758	2.250	-2.5~2.5
<i>Reg_{it}</i>	0.181	0.902	-2.055	1.976	Indicator
<i>Free_{it}</i>	6.899	0.769	3.36	8.66	Indicator
<i>NTM_{ijt}</i>	25.333	60.573	0	375	Count

Table A4: 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	7.9
Netherlands	1.81	Luxembourg	1.77	Canada	7.9
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

*CAR: Central African Republic

Appendix A5: Number of Non-Tariff Measures (NTMs) by Product (2010-13)

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, bird's 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

Appendix A6: Top-10 Countries with the Highest Number of Non-Tariff Measures (NTMs) and Countries without Non-Tariff 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 d'Ivoire, Cameroon, Congo, Congo, Rep., 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 Is., 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