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“Food Processing Firms, Input Quality Upgrading and Trade”*

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November 2014

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Abstract:

In this paper the heterogeneous firms and trade literature is extended by integrating quality of inputs and outputs in a food and agricultural setting. Recently, Sexton (2013) has suggested that intermediate agricultural input quality is critical in food processing firms’ output quality and pricing decisions. The results presented in this paper indicate that intermediate agricultural input quality, when combined with the quality of other food processing inputs, is important in analyzing the production decision-making of firms. Extending the model of Kugler and Verhoogen (2012), the quality of food processing inputs is integrated into the analysis in two ways: first, it affects the production of the final good, in that higher quality food processing inputs lower the marginal cost of producing the final good; and, second, food processing input quality is complementary to intermediate input quality in determining quality of the final good. By choosing these elements, firms become differentiated on a vertical (quality) level not only because of their capability draw and intermediate input quality choice, but also because of their choice of food processing inputs. Three key results are developed in the paper: first, larger firms, measured by revenue, charge a higher price for their final good, pay a higher price for their inputs, and produce a higher quality final good. Second, firms that produce for export destinations with a higher preference for quality, choose higher-quality inputs. Third, if preference for quality increases in export-destinations new firms enter the export market, while less capable firms are forced to exit.

JEL Codes: F12, F61, L66

Keywords: heterogeneous firms, input quality, food processing

“Food Processing Firms, Input Quality Upgrading and Trade”

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.* 2011). For example, Schott (2004), and Hummels and Klenow (2005) find a link between exporter GDP per capita and product quality, while Hallack (2006) finds that demand for product quality is related to importer GDP per capita. Other studies use firm-level data to analyze the relationship between export price variation and trade patterns, e.g., Manova and Zhang (2012), using Chinese trade data, establish that the most successful 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 idea 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 determination of the direction of trade. Linder’s argument was based on two observations: higher income countries spend a higher proportion of their income on high-quality goods; and higher-income countries have a comparative advantage in producing higher-quality goods due to the fact that they demand those goods. As a consequence, countries with similar incomes per capita will tend to trade high-quality goods with each other.

Following Linder’s work, considerable theoretical analysis focused on deriving general equilibrium models to formalize the role of product quality in determining trade patterns, e.g., Flam and Helpman (1987). More recently, Sutton (2001; 2007) has provided a theoretical

framework for thinking about product quality. Sutton's basic idea lies in his notion of firms having "capabilities", consisting of two key elements: the maximum level of product quality a firm is able to achieve, and the cost of production for each product line, i.e., productivity. Drawing on his work on sunk costs and market structure, Sutton argues that fixed outlays by firms on R&D spending can increase product quality through process innovation or productivity through process innovation. In terms of competition, what matters is that firms will "escalate" their spending on R&D and other fixed outlays such as advertising. As a consequence, in order to survive in export markets, firms' capabilities must be within a "window", i.e., there will be a lower bound to seller concentration in markets.

The idea that international competition might impact the window in which firms' capabilities have to be located 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 and Trefler 2102). While much of the subsequent literature has followed Melitz by adopting Dixit-Stiglitz (1977) preferences in a setting of monopolistic competition, recent contributions by, *inter alia*, Verhoogen (2008), Baldwin and Harrigan (2011), and Kugler and Verhoogen (2012) have focused on incorporating vertical product differentiation into heterogeneous-firm models. Essentially these latter articles point to more capable firms performing better in export markets using higher-quality intermediate inputs in order to sell higher-quality goods at higher prices.

Agricultural economists have also begun to focus on the issue of product quality in both domestic and international settings. In his Presidential Address to the Agricultural and Applied

Economics Association (AAEA), Sexton (2013) notes that modern food and agricultural markets in developed countries can no longer be characterized by firms selling homogeneous products. Instead, food-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. Consequently, 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 food quality. Also, in the context 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. Importantly Sexton argues that due to food processing firms incurring sunk costs related to production capacity and product quality, they will not exert monopsony power, instead they will offer contracts ensuring that input suppliers receive the long-run equilibrium return of competitive firms.

At the international level, the demand for higher food quality has translated into a setting of food-quality standards, both public and private, with the potential to affect trade flows, particularly between developing and developed countries. Analysis of food-quality standards has typically focused on the possibility that they provide protection to domestic producers in developed countries, the majority of empirical analyses supporting this view (Li and Beghin 2012). An exception is Anders and Caswell (2009) who present evidence for US food safety standards being a “catalyst to trade”. A more nuanced view of the barriers to trade view of standards is that developing countries are actually hampered in their ability to meet such standards due to a lack of necessary human capital (Essaji, 2008). As a consequence there have

been both public and private efforts to improve the ability of developing countries to meet higher food-quality standards (Sheldon, 2013).

Until a recent article by Curzi, Raimondi and Olper (2014), there has been little analysis of the relationship between trade, food product-quality and the impact of trade liberalization. Curzi, Raimondi and Olper make an important applied contribution by focusing on a specific framework for thinking about food product-quality, how to measure that quality and evaluating the impact of competition through trade liberalization on upgrading food product-quality. Drawing on Aghion and Howitt (2006), the authors hypothesize that an increase in competition will result in firms closer to the world technology frontier innovating more, while firms further from the frontier innovate less. Using Khandelwal's (2010) approach to measuring product quality and data for EU-15 imports of food products from 70 countries over the period 1995-2007, Curzi, Raimondi and Olper find that trade liberalization in the exporting countries leads to faster upgrading of product quality for those products closer to the technology frontier. Interestingly, they also found that, on average, EU voluntary food-quality standards have a positive effect on the rate of quality upgrading, a result that would support the argument that standards are a catalyst to trade.

Given this background, the current paper adapts the heterogeneous-firm model of Kugler and Verhoogen (2012) to the case of food processors purchasing high-quality intermediate agricultural inputs in order to produce high-quality food products. The objective of this adaptation is to nest in one model key predictions about food product-quality and upgrading of quality due to trade liberalization, drawing from Sexton's (2013) observations concerning increased focus on food quality and Curzi *et al.*'s empirical finding that both trade liberalization and food-quality standards promote quality upgrading. The remainder of the paper is outlined as

follows: the structure of the model is outlined in the next section, followed by derivation of some key results concerning the relationship between product-quality, consumer preferences for product-quality, and trade liberalization; finally, the paper concludes with a summary and brief discussion of some implications of the analysis.

Model

The model constructed in this paper draws predominantly from Kugler and Verhoogen (2012), with some reference to the related work of Verhoogen (2008). With two countries, heterogeneous firms in a monopolistically competitive setting, produce final goods of a particular quality by processing competitively supplied intermediate agricultural inputs. Importantly, the quality of the final good is dictated not only by the firm's choice of intermediate agricultural input quality, but also their choice of a composite production input's quality, and some exogenously assigned capability draw.

Consumers

Representative consumers in both countries have utility functions corresponding to asymmetric preferences, with a constant elasticity of substitution $\sigma > 1$:

$$(1) \quad U = \left[\int_{\omega \in \Omega} (\theta(\omega) q(\omega) x(\omega))^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}} .$$

In the above utility function, $\omega \in \Omega$ represents one variety of the good out of the entire set of varieties, $q(\omega)$ and $x(\omega)$ represent quality and quantity of a particular variety. The parameter $\theta(\omega)$ represents a consumer's "preference for quality": consumers in either country have a particular preference for quality of a variety of a good that impacts the utility gained from that item. $\theta(\omega)$ can be thought of as capturing a consumer's willingness to pay for quality which is a function of income, where $\theta(\omega)$ is assumed constant across consumers within either country, but

can vary across the two countries. This allows for the possibility that one country is developed, the other developing, the former having higher per capita income. It is also assumed that $\theta(\omega) > 0$, and we abstract from the problem of asymmetric information by assuming that all quality is observable in the model. Additionally, consumers optimize the utility function to yield the following demand function:

$$(2) \quad x(\omega) = Xq(\omega)^{\sigma-1} \theta(\omega)^{\sigma-1} \left(\frac{p_o(\omega)}{P} \right)^{-\sigma},$$

where $p_o(\omega)$ is the output price of a particular variety, P is the quality-adjusted aggregate price index, and X is the quality-adjusted aggregate consumption of all varieties $x(\omega)$.

Firms

In the agricultural sector, farmers use a composite input A to produce the intermediate agricultural input. A is inelastic in supply, with the unit price l of A being normalized to one. Farmers require \bar{A} units of the composite input to produce an intermediate agricultural input of quality c , such that $c = l$. The intermediate agricultural good I is produced via the following production function F_I :

$$(3) \quad F_I(A, c) = \frac{\bar{A}}{c}.$$

Food processors purchase the intermediate agricultural input at a price $p_I(c)$, and assuming a perfectly competitive agricultural sector, the price of the intermediate agricultural input is $p_I(c) = c$. While any contractual relationship between food processors and suppliers of the intermediate agricultural input is not modeled here, the assumption that farmers receive a competitive price for supplying an intermediate input of a specific quality is in accord with Sexton's (2013) argument that farmers will receive a competitive return.

Food processors require a fixed investment cost of f_e to obtain their capability λ , where λ is drawn from a Pareto distribution with, $G(\lambda) = 1 - \left(\frac{\lambda_m}{\lambda}\right)^k$, $0 < \lambda_m \leq \lambda$. Following Sutton (2001; 2007), a firm's capability can affect both final good quality and the costs of producing that final good. In the literature, alternative interpretations of λ include skill, or the firm's entrepreneurial ability, but essentially, it is a heterogeneous measure used to sort firms into non-exporter/exporter status. Additionally, in line with the Melitz (2003) class of models, every participant in the final good market has an exogenous chance δ of exiting the market. If food processors actively participate in their domestic market, there is a fixed cost of production f , and if they also capable of exporting, they incur a fixed cost of exporting $f_x > f$ in all periods. These and the fixed costs of entry are in accord with Sexton's (2013) observation that food processing firms incur substantial investment costs. Note that since there is no cost to product differentiation, it is possible to treat the capability parameter λ , as an index of all firms and all varieties of goods.

Production of the final good by food processors requires inputs of capability, the intermediate agricultural input, and a composite input ϕ of a specific quality. The composite input ϕ is most easily thought of in terms of the quality of a capital input which plausibly affects both the quality and quantity choices of the firm. For example, it might be equipment required to ensure quality control in meeting food safety standards. It could, however, represent a mix of other inputs, including the quality of labor. The key point is that the composite input is a tangible input required in production, since intermediate agricultural inputs by themselves are unlikely to impact the final product-quality choice of the firm without being combined with some other input(s). In effect, use of a composite input more accurately reflects the technology choices

available to and made by food processing firms. Importantly, ϕ may vary across developed and developing countries, capturing the idea that the latter may have a harder time meeting developed country food standards due to endowments of lower-quality physical and/or human capital inputs.

The production function for the final good is given as:

$$\begin{aligned}
 (4) \quad & F(n) = n\phi^s \lambda^a \\
 & MC = \frac{p_I(c)}{\phi^s \lambda^a} \\
 & MC_x = \frac{\tau p_I(c)}{\phi^s \lambda^a}
 \end{aligned}$$

In (4), the variables are defined as follows: n is the number of units of the intermediate agricultural input used; $a > 0$ represents a firm's ability of reducing their costs; MC is the marginal cost of producing the good for the domestic market, and MC_x is the marginal cost of producing goods for export, where $\tau \geq 1$ are the *ad valorem* costs of exporting – including export taxes, import tariffs, the tariff-equivalent of non-tariff barriers and other transport costs; and finally, s is the opportunity cost of making a higher composite input quality choice, where $s < 0$ reflects the idea that quality choice of the composite input requires costs that make producing a higher-quality final good more expensive. The implication of assuming the parameter $s < 0$, is that the production function $F(n)$ is decreasing in s , and also that MC and MC_x are increasing in s .¹

Food processors are also constrained by their quality choice. Expanding on the first variant of Kugler and Verhoogen, quality choice reflects a complementarity between their capability draw (λ), the quality of a composite input (ϕ), and their intermediate agricultural input quality choice (c), an approach drawing on the O-ring production function concept of Kremer (1993).

All three elements in the vector $\langle \lambda, \phi, c \rangle$ are complements in producing quality, wherein quality is determined via a log-supermodular function, i.e., a food processor with higher capability, using higher-quality intermediate agricultural and composite inputs produces a higher-quality food product (Costinot 2009). Essentially this assumption rules out capability being a substitute for low-quality agricultural and composite inputs. Of course, there are other ways to formulate this quality constraint, but recent empirical evidence presented by Brambilla, Lederman and Porto (2012) suggests that it is not an unreasonable assumption.

Food product quality q , therefore, is assumed to behave according to the following function,

$$(5) \quad q = \frac{1}{1+Z\tau} \left[\frac{1}{3}(\lambda^b)^\beta + \frac{1}{3}(\phi^3)^\beta + \frac{1}{3}(c^3)^\beta \right]^{\frac{1}{\beta}},$$

where $\beta < 0$ represents the degree of complementarity between the three determinants of final good quality and $b \geq 0$ represents the scope of product-quality differentiation.

This scope of differentiation parameter has traction in the literature as an approximation to the fixed costs of investment required for product differentiation, i.e., it represents the ability of a firm to differentiate product-quality in any capacity, through say R&D expenditures. In effect, this parameter acts as an additional channel affecting firms' quality choices. In particular, a lower value of b effectively restricts the quality choices available to a given firm, such that a firm with a higher b or a larger scope of differentiation parameter will, *ceteris paribus*, have a higher quality choice available to them, i.e., a quality choice closer to the world frontier of possible quality choices. As with ϕ , b may also vary across developed and developing countries, the latter typically being farther from the world quality frontier.

Overall, this modeling of quality choice dictates that more productive firms are more capable of upgrading quality, and that this capacity to upgrade quality is contingent on matching

the productivity with higher quality intermediate agricultural and composite inputs. In this context, firms optimize the following profit function:

$$(6) \quad \pi(p_o, c, \phi, z | \lambda) = \left(p_o - \frac{p_I(c)}{\phi^s \lambda^a} \right) x - f + z \left[\left(p_o - \frac{\tau p_I(c)}{\phi^s \lambda^a} \right) x - f_x \right]$$

$$\text{s.t. } q = \frac{1}{1+Z\tau} \left[\frac{1}{3} (\lambda^b)^\beta + \frac{1}{3} (\phi^3)^\beta + \frac{1}{3} (c^3)^\beta \right]^{\frac{1}{\beta}},$$

where $Z \in \{0,1\}$ is an indicator of export status, $Z=1$ for firms that export and $Z=0$ being for firms that produce only for the domestic market.

Equilibrium

As noted earlier, the intermediate agricultural input market is assumed to be perfectly competitive in equilibrium, implying that for each and every quality choice in equilibrium, the intermediate input price $p_I(c) = c$. Therefore, optimizing equation (6) yields the following in equilibrium:

$$(7a) \quad c^*(\lambda) = p_I^*(\lambda) = \lambda^{\frac{b}{3}}$$

$$(7b) \quad \phi^*(\lambda) = \lambda^{\frac{b}{3}}$$

$$(7c) \quad q^*(\lambda) = \frac{\lambda^b}{1+Z\tau}$$

$$(7d) \quad p_o^*(\lambda) = \left(\frac{\sigma}{\sigma-1} \right) \lambda^{\frac{b}{3}(1-s)-a}$$

$$p_{o,x}^*(\lambda) = \left(\frac{\sigma}{\sigma-1} \right) \tau \lambda^{\frac{b}{3}(1-s)-a}$$

$$(7e) \quad r^*(\lambda) = \left(\frac{\sigma-1}{\sigma} \right)^{\sigma-1} \lambda^\eta X P^\sigma \left(\theta_1^{\sigma-1} + \theta_2^{\sigma-1} Z [\tau(1+Z\tau)]^{1-\sigma} \right),$$

where $c^*(\lambda) = p_I^*(\lambda)$ is the equilibrium intermediate agricultural input price and quality choice,

$\phi^*(\lambda)$ is the equilibrium quality choice of the composite input, $q^*(\lambda)$ is the equilibrium output

quality choice by the firm, $p_o^*(\lambda)$ is the domestic output price, $p_{o,x}^*(\lambda)$ is the export output price, and $r^*(\lambda)$ is the equilibrium revenue for the firm, and $\eta \equiv (\sigma - 1) \left[b - \frac{b}{3}(1-s) + a \right]$. (See Appendix for equilibrium calculations).

Model Results

Impact of Scope

Equations (7a)-7(e) can be used to derive a set of key comparative statics, although for the results to hold, $b > \frac{3a}{1-s}$ must also be true. This condition essentially states that the scope for quality differentiation b must be sufficiently large enough: in this case, b must be larger than the firm's cost-reduction capabilities for the following predictions to be true. At this point, it should be noted that the equilibria described in equations (7a) through (7e) are all increasing in the scope parameter b . In other words, firms with a larger scope parameter will make higher input and output-quality choices, implying that they will pay higher input prices, charge higher output prices, and receive higher revenues. This shows the importance of b in the equilibrium: firms with a differing scope of product differentiation will have different quality choices available to them. Potentially, this channel can help explain trade patterns: based on their ability to differentiate goods vertically, i.e. their value of b , will affect how firms across countries choose to export particular varieties of vertically differentiated products.

Output Quality, Trade and Preferences

Comparative statics that are derivable from the equilibrium yield the following results:

$$(8a) \quad \frac{\partial \ln p_o^*}{\partial \ln r^*} = \frac{1}{\eta} \left[\frac{b}{3}(1-s) - a \right] > 0, \text{ and } \frac{\partial \ln p_x^*}{\partial \ln r^*} = \frac{b}{3\eta} > 0,$$

$$(8b) \quad c^*(\lambda) = \phi^*(\lambda) = \lambda^{\frac{b}{3}},$$

$$(8c) \quad \frac{\partial \ln p_I}{\partial \ln \theta} = \frac{(\sigma-1)b}{3\eta\theta} > 0, \text{ and } \frac{\partial \ln p_o}{\partial \ln \theta} = \frac{(\sigma-1)\left[\frac{b}{3}(1-s)-a\right]}{\eta\theta} > 0,$$

$$(8d) \quad \frac{\partial q^*}{\partial \tau} = -\frac{Z\lambda^b}{(1+Z\tau)^2} < 0$$

These results can be summarized as follows:

(i) First, from (8a) it can be seen that larger firms will charge a higher price for their outputs, but correspondingly pay more for intermediate agricultural inputs. This implies that, since by (8b) all inputs are complements, firms that buy higher quality inputs choose, therefore, to produce the final good at a higher quality since $q^*(\lambda^*)$ is increasing in λ as given in (7c). Therefore, in general, larger firms will pay higher prices for their inputs, implying a higher quality choice by these larger firms.

(ii) Second, given (8c), firms that produce for destinations (either domestic or foreign) with a higher θ will pay more for the intermediate agricultural input and charge a higher output price. This implies that firms who produce for higher- θ destinations are choosing higher-quality inputs, which implies that they are choosing to produce a higher-quality good. This result follows from (7a)-(7c): if firms pay for higher-quality inputs, via (7a)-(7b), they must be using higher-quality inputs, which, in turn corresponds with a higher value for capability λ . This, combined with (7c) implies that the firm is choosing a higher output-quality level. Therefore, a firm choosing to export to a destination with a higher preference for quality $\theta_2, \theta_2 > \theta_1$, should choose to produce and export a higher-quality good.

(iii) Third, trade costs negatively impact quality choice, as given by (8d).

The first and second results are critical to firms' quality choices: larger firms charge a higher price for their output and also pay a higher price for their inputs. Therefore, they choose

to produce a good at a higher quality, which is a result in line with the extant literature. Importantly, in the context of Sexton (2013), it suggests that even as downstream food processing firms get larger, they do not exert monopolistic power, but instead have to pay farmers higher prices for higher quality intermediate agricultural inputs in order to produce higher-quality food products.

The second and third results describe countervailing effects influencing the firm's equilibrium quality choice. Firms that choose to export must face trade costs, thereby limiting the quality choice they are able to make. However, goods produced in a variety for a particular destination with a higher quality preference should cause firms in those situations to upgrade the quality of their inputs, thus improving the quality of their final output. Therefore, a firm that has the opportunity to export to a destination with a high preference for quality can end up choosing to produce at a higher quality when exporting, a result also found by Verhoogen (2008). This quality choice happens in spite of the negative impact of trade costs on a firm's quality choice.

These latter results can be tied back to Curzi, Raimondi and Olper's (2014) recent findings concerning food product quality, trade costs and higher EU food-quality standards. It is well-understood in the environmental economics and trade literature, that demand for environmental standards is income-elastic (Copeland and Taylor, 1994). Therefore, given stronger preference for quality is assumed to be a function of income, this will be embodied in higher food-quality standards. As a consequence, even if exporters face typical trade costs, higher standards may actually be a catalyst to firms improving product quality. Of course higher food quality standards may also act as a non-tariff barrier, and therefore lowering such trade costs, along with

any other trade costs will also promote an increase in the quality of exports for given values of θ .

Figure 1 is a graphical representation of the effect of trade costs and consumer preferences on quality. The line denoted $q(\lambda|\theta_1, Z=0)$ is the product quality curve for domestic production, i.e., $Z=0$, where θ_1 is the domestic preference for quality. If firms choose to export, though, they may face trade costs. Assuming θ_1 holds in the export scenario, a firm facing trade costs *cannot* choose the same quality and must choose a lower input and output quality for a given λ since trade costs impact not only the quantity produced, but the quality level as well. Of course if trade costs fall, this will push up the dotted segment $q(\lambda|\theta_1, Z=1)$ towards $q(\lambda|\theta_1, Z=0)$, thereby raising export-quality for any value of λ equal to or above the export entry cutoff point λ_x^* . In other words, lowering trade costs has the potential to raise export quality.

However, given that firms are exporting, they do not necessarily base their quality decision on domestic preferences, but on the export destination's preference for quality, θ_2 . Therefore, If $\theta_2 > \theta_1$, and θ_2 is large enough to outweigh trade costs τ , it is possible for exporting firms to select a higher quality due to the destination country's preference for quality, which will outweigh the costs associated with exporting the good to that destination. In other words, it may not be so surprising that standards can result in increased exports of high-quality food products.

Importantly, in figure 1 it is highlighted that firms might still export despite high trade costs. For trade costs of τ' , it is still possible for production and export at a given level of quality choice q' and a given preference for quality θ . At first glance, if trade costs are too high, we would expect firms to choose not to export and instead produce domestically. However, for a given quality level it is possible for these firms to still produce at that quality and export. For a

firm to still produce at a given quality level in the face of stiff trade costs, it would necessarily imply that the firm's capability or productivity λ' would have to be sufficiently greater than the export cutoff of λ_x^* to maintain production at quality level q' . This behavior would be especially true if values of θ across destinations are low enough to not be conducive to trade.

Impact of Trade Liberalization and Changes in Quality Standards

As shown in the previous section, it is possible for firms to select into producing higher quality when exporting to countries with higher preferences for quality. Establishing when firms make this switch (and what drives this switch) is critical.² By utilizing the following equilibrium conditions:

$$(9a) \quad \pi_d(\lambda^*) = \frac{r_d^*(\lambda^*)}{\sigma} - f = 0 \text{ and,}$$

$$(9b) \quad \pi_x(\lambda^*) = \frac{r_x^*(\lambda_x^*)}{\sigma} - f_x = 0,$$

it is simple to derive $\frac{r_x^*(\lambda_x^*)}{r_d^*(\lambda^*)} = \frac{f_x}{f}$, the ratio between the two revenue sources in equilibrium.³

Note also that given free entry, the firm has a particular chance of remaining in the market in each period. This condition can be written as:

$$\delta f_e = [1 - G(\lambda^*)] \left\{ \frac{E(r_d^*(\lambda))}{\sigma} - f \right\} + [1 - G(\lambda_x^*)] \left\{ \frac{E(r_x^*(\lambda))}{\sigma} - f_x \right\}.$$

With this free-entry condition and the zero-profit conditions in (9a) - (9b), the equilibrium cutoff points for entry into the domestic market and the export market can be expressed as functions of the model parameters. These equilibrium cutoffs are given in the following equations:

$$(10a) \quad \lambda^* = \lambda_m \left\{ \left(\frac{f\eta}{\delta f_e (k-\eta)} \right) \left[1 + \left(\frac{f}{f_x} \right)^{\frac{k-\eta}{\eta}} \left(\frac{\theta_1}{\theta_2} \right)^{\frac{k(1-\sigma)}{\eta}} [\tau(1+\tau)]^{\frac{k(1-\sigma)}{\eta}} \right] \right\}^{\frac{1}{k}}$$

$$(10b) \quad \lambda_x^* = \lambda^* \left[\left(\frac{f_x}{f} \right) [\tau(1+\tau)]^{\sigma-1} \left(\frac{\theta_1}{\theta_2} \right)^{\sigma-1} \right]^{\frac{1}{\eta}}.$$

From these equilibrium cutoff points, a few results immediately follow. The comparative statics below describe specifically the drivers of this export entry cutoff point and how they impact this export entry cutoff point. The following relate specifically to the effect of trade costs on these cutoff points:⁴

$$(11a) \quad \frac{\partial \lambda_x^*}{\partial \tau} = \frac{\sigma-1}{\eta} [\tau(1+\tau)]^{\frac{\sigma-\eta-1}{\eta}} [1+2\tau] \lambda^* \left(\frac{\theta_1}{\theta_2} \right)^{\frac{\sigma-1}{\eta}} \left(\frac{f_x}{f} \right)^{\frac{1}{\eta}} > 0$$

$$(11b) \quad \frac{\partial \lambda^*}{\partial \tau} = \frac{(1-\sigma)}{\eta} [1+2\tau] \left[\left(\frac{f}{f_x} \right)^{\frac{k-\eta}{\eta}} \left(\frac{\theta_1}{\theta_2} \right)^{\frac{k(1-\sigma)}{\eta}} \right] [\tau(1+\tau)]^{\frac{k(1-\sigma)-\eta}{\eta}} \lambda_m \rho^{\frac{1-k}{k}} < 0.$$

The results described in (11a) and (11b) can be summarized as follows: from (11a), given that $\frac{\partial \lambda_x^*}{\partial \tau} > 0$, falling trade costs lower the equilibrium export entry cutoff point λ_x^* , implying that more firms will choose to enter the export market. In addition, (11b) shows that given, $\frac{\partial \lambda^*}{\partial \tau} < 0$, when trade costs fall, the least productive firms will be shut out of the market and be forced out of production, since the market entry cutoff point λ^* rises given falling trade costs.

These results are intuitive, conforming to the existing literature on heterogeneous firms and trade. When trade costs decrease, more firms should be able to enter the export market, since the barriers to trade that previously hindered a given firm from entering the export market are being

reduced or eliminated altogether. However, this entry into the export market by more firms redistributes the overall revenues of the sector: firms entering the export market increase their revenue, but in doing so push out the smaller and less capable firms. Therefore, the classic heterogeneous-firms and trade conclusion is supported here: falling trade costs induce entry into the export market by the most capable non-exporters yet cause the least capable firms in the entire market to exit altogether since they are unable to compete with the larger firms. This has obvious implications in the context of Sexton's (2013) observations concerning contracts with agricultural input suppliers: some will either not be offered contracts by food processors or will at least receive lower prices if they produce lower-quality inputs, while other suppliers get higher prices for producing higher-quality inputs.

Another channel that impacts the equilibrium cutoff points is the export destination's preference for quality, θ_2 , which may be reflected in higher food-quality standards. The following comparative statics are informative:

$$(12a) \quad \frac{\partial \lambda_x^*}{\partial \theta_2} = \left(\frac{1-\sigma}{\eta} \right) \lambda^* \left(\frac{f}{f_x} \right)^{\frac{1}{\eta}} \theta_1^{\frac{\sigma-1}{\eta}} \theta_2^{-\frac{\sigma}{\eta}} [\tau(1+\tau)]^{\frac{\sigma-1}{\eta}} < 0$$

$$(12b) \quad \frac{\partial \lambda^*}{\partial \theta_2} = \left(\frac{\sigma-1}{\eta} \right) \lambda_m \rho^{\frac{1-k}{k}} \left(\frac{f}{f_x} \right)^{\frac{k-\eta}{\eta}} \theta_1^{\frac{k(1-\sigma)}{\eta}} \theta_2^{\frac{k(\sigma-1)-\eta}{\eta}} [\tau(1+\tau)]^{\frac{k(1-\sigma)}{\eta}} > 0 .$$

When the export destination experiences a change in consumer preference for quality, a re-allocative effect occurs, similar to the effect of a change in trade costs. An export destination increasing their preference for quality effectively lowers the threshold required for entry into the export market. At first this result seems slightly counter-intuitive: it might be expected that if a destination has a higher preference for quality, then it would be expected that firms might need to upgrade their quality to be able to export there, limiting their export choices. However, given

preference for quality, firms who are able to enter the market enjoy the added revenue from exporting, implying that the costs of upgrading quality are outweighed by the benefits in additional revenue. This entrance by firms into the export market forces the least capable firms out of the market, however, since the new exporters receive a larger share of the aggregate revenue, leaving the least capable firms with no choice but to exit the market altogether.

The results described in (12a) and (12b) can be summarized as follows: an increase in an export destination's preference for quality has a re-allocative effect. First, given the change in preferences, λ_x^* decreases, which implies that, the most capable non-exporters are now able to enter the export market. Second, with this change in preferences, the domestic market entry cutoff point, λ^* , increases. This implies that the least productive or capable firms in the market are forced to exit the market since they can no longer compete with other firms in the market. Again this has obvious implications for suppliers of intermediate agricultural inputs in terms of who gets a contract with a food processor, and what price they receive for supplying those inputs.

Summary and Conclusions

Two observations in the agricultural economics literature are the key motivation for this paper: first Sexton (2013) has argued that increased demand for food quality has become a defining feature of developed country food markets; and, second, Curzi, Raimondi and Olper (2014) in recent empirical research have found evidence that export product quality not only increases with trade liberalization but also with higher standards in EU importing countries. Adapting a model originally due to Kugler and Verhoogen (2012), it is possible to capture the characteristics of food processing described by Sexton, and also to provide an explanation for Curzi, Raimondi and Olper's results that focuses on a setting where the capability of food processing firms can impact

both product quality and the costs of production. Importantly, the model generates the result that higher food-quality standards may indeed be a catalyst to trade, even in the presence of other trade costs. In addition, suppliers of low-quality intermediate agricultural inputs can expect to be either squeezed out of the market with globalization, or at least receive lower prices.

However, the model also suggests that the ability of developing countries to export high-quality food products is also a function of several factors unrelated to food-quality standards in the developed countries: first, their access to endowments of high-quality food processing inputs as well as high-quality intermediate agricultural inputs is critical; and second, their food processing firms may have low scope for improving product quality, i.e., they are at a comparative disadvantage in terms of levels of R&D expenditure, thereby requiring either private transfers through multinational firms or public transfers targeted at increasing their ability to raise product quality and thereby meet food-quality standards.

Notes

1. If $s = 0$, the model reduces to Kugler and Verhoogen (2012) with additional trade costs. The minimum condition required for s to behave is $s < 1$, composite input quality choice affects the cost of producing the good by less than a positive, one-to-one relationship. For example $s \in (0,1)$ is the case where composite input quality reduces marginal cost, but at a rate *less than* the quality choice itself, implying that composite input quality choices have a diminishing marginal impact on production.

2. To solve for this equilibrium, assume that the Pareto distribution's shape parameter $k = \max(\eta, 1)$ is true, such that the means of the revenues will be finite.

3. This can be written out fully as:
$$\frac{r_x^*(\lambda_x^*)}{r_d^*(\lambda^*)} \left(\frac{\theta_2}{\theta_1} \right)^{\sigma-1} [\tau(1+\tau)]^{1-\sigma} \left(\frac{\lambda_x^*}{\lambda^*} \right) = \frac{f_x}{f}.$$

4. In (11b), for expositional clarity,
$$\rho = \left(\frac{f\eta}{\delta f_e(k-\eta)} \right) \left[1 + \left(\frac{f}{f_x} \right)^{\frac{k-\eta}{\eta}} \left(\frac{\theta_1}{\theta_2} [\tau(1+\tau)] \right)^{\frac{k(1-\sigma)}{\eta}} \right], \rho > 0.$$

Appendix

A sketch of how to derive the equilibrium results is as follows. Recall:

$$(7a) \quad c^*(\lambda) = p_I^*(\lambda) = \lambda^{\frac{b}{3}}$$

$$(7b) \quad \phi^*(\lambda) = \lambda^{\frac{b}{3}}$$

$$(7c) \quad q^*(\lambda) = \frac{\lambda^b}{1+Z\tau}$$

$$(7d) \quad p_o^*(\lambda) = \left(\frac{\sigma}{\sigma-1} \right) \lambda^{\frac{b}{3}(1-s)-a}$$

$$p_{o,x}^*(\lambda) = \left(\frac{\sigma}{\sigma-1} \right) \tau \lambda^{\frac{b}{3}(1-s)-a}$$

$$(7e) \quad r^*(\lambda) = \left(\frac{\sigma-1}{\sigma} \right)^{\sigma-1} \lambda^\eta X P^\sigma \left(\theta_1^{\sigma-1} + \theta_2^{\sigma-1} Z [\tau(1+Z\tau)]^{1-\sigma} \right),$$

$$\eta \equiv (\sigma-1) \left[b - \frac{b}{3}(1-s) + a \right].$$

Recall that with a perfectly competitive intermediate agricultural input market, $c^*(\lambda) = p^*(\lambda)$. Also, given that the quality constraint is log-supermodular and is determined by complementarity of the inputs c, λ, ϕ , then it must be true given equation (5),

$$q = \frac{1}{1+Z\tau} \left[\frac{1}{3} (\lambda^b)^\beta + \frac{1}{3} (\phi^3)^\beta + \frac{1}{3} (c^3)^\beta \right]^{\frac{1}{\beta}},$$

that the same amount of each input is required:

therefore, if λ^b of plant capability is used, then it must be true that the equivalent quality of the

other inputs used is $c^*(\lambda) = p_I^*(\lambda) = \lambda^{\frac{b}{3}}$ and $\phi^*(\lambda) = \lambda^{\frac{b}{3}}$ such that the quality choice of each input

(in terms of λ) is λ^b . This generates (7a) and (7b), and (7c) follows given (5).

Now recall equation (4) :

$$(4) \quad \begin{aligned} MC &= \frac{p_I(c)}{\phi^s \lambda^a} \\ MC_x &= \frac{\tau p_I(c)}{\phi^s \lambda^a} . \end{aligned}$$

Given (7a) and (7b), (4) generates the output price of both the domestically sold and exported good, and given that the firms are monopolistically competitive: the output price is a constant mark-up $(\sigma / \sigma - 1)$ of their marginal cost. This combined with $c^*(\lambda) = p^*(\lambda)$ yields the domestic output price $p_o^*(\lambda)$ and the export output price $p_{o,x}^*(\lambda)$ in (7d). Lastly, $r^*(\lambda)$ is derived in (7e) by utilizing $p_o^* \cdot x_D + p_{o,x}^* \cdot x_X = (p_o^* + p_{o,x}^*) \cdot x$, since by the model, domestic output $x_D = x_X = x$.

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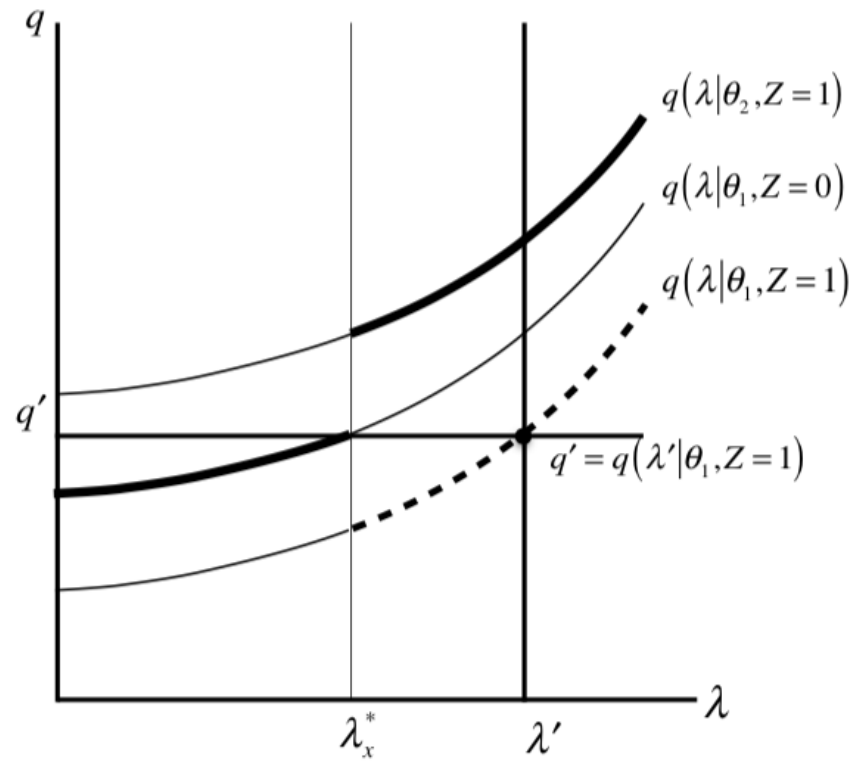


Figure 1: Effect of trade costs and preferences for quality on firms' quality