Voluntary Standards and International Trade: A Heterogeneous Firms Approach

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Abstract

We present a model of export participation and adoption of a voluntary standard in the heterogeneous firms and trade framework. Firms produce credence goods, the quality of which can be signaled by adopting a costly voluntary certification. Firms must simultaneously choose whether or not to adopt the standard and whether or not to enter export markets. Heterogeneity in firm behavior is driven by differences in productivity, which indexes the effective cost of each strategy. Comparative statics are derived relating participation in the voluntary standard to changes in key trade policy variables. Results indicate the direction of the relationship depends on certain market characteristics as well as the trade policy instrument in question. Regardless of the effect on adoption of the standard, reduction in trade barriers is always welfare improving.

Introduction

Scholars have long argued the global trend toward trade liberalization has delivered substantial gains to society. Liberalization raises incomes and lowers prices while increasing the range of products available in every market. At the same time, some have expressed concern that international trade flows through a legal vacuum. Liberalization shifts production abroad where domestic regulators cannot ensure goods are produced using high environmental, labor or safety standards. The General Agreement on Tariffs and Trade (GATT), and its successor the World Trade Organization (WTO), define the international legal framework that has guided much of the trend toward liberalization in the past half-century. These agreements have taken a conservative approach to determining the circumstances under which member states are allowed to restrict goods from entering their home markets. With the exception of several specific criteria listed in Article XX, Article III of the GATT stipulates member countries must not discriminate against "like products" originating from foreign countries (WTO, 2012).

Before 1998, "like products" was understood to mean products indistinguishable in their physical characteristics and performance (Deal, 2008). This meant domestic regulators could not impose restrictions on the basis of "process standards", even if those goods were produced unsustainably or using "unfair" labor practices (Maskus, 2000). In 1998, the WTO Dispute Settlement Body (DSB) handed down a ruling that further clarified Article III. The case concerned imports of shrimp to the United States caught using nets that threatened sea turtle populations. The DSB ruling allowed discriminatory treatment for processes that endanger some resources in the global commons (WTO, 1998). This ruling gave regulators freer rein to develop WTO-compliant policies that might mitigate potential negative environmental consequences of liberalization, but it is not yet clear what form these policies will take.

Limiting the ability of member states to restrict trade on the basis of process standards has led to accusations the WTO facilitates a "race to the bottom," creating incentives for countries to lower regulatory standards in order to increase export competitiveness and attract foreign direct investment (FDI) (see e.g. Tonelson, 2002; Gill, 1995). Regulators may be tempted to lower environmental or labor standards in order to minimize production costs in their home countries. While this might maximize local economic growth in the short run, many are uncomfortable with the implied unethical treatment of workers or environmental damage.

Despite widespread popular concern, there exists only mixed evidence to support the existence of a "race to the bottom" from trade liberalization. Few studies have found a link between trade flows and environmental policy (Medalla and Lazaro, 2005). Even where such a link exists, these "pollution havens" may only exist temporarily (Mani and Wheeler, 2004). The same holds true for trade and labor standards. Dehija and Samy (2008) found that *higher* labor standards were associated with larger trade flows in a study of EU member states, while Greenhill et al. (2009) found a similar result in a panel of 90 developing countries. These authors invoke the "California effect," a term coined by Vogel (1995), to explain their results.

Vogel (1995) used this term to describe how the demand for low emissions automobiles in California led to the diffusion of that state's relatively strict emissions standards to foreign automobile suppliers. California has historically imposed exceptionally high emissions standards on automobiles. The size of California's market provides a strong incentive for automobile manufacturers to sink the costs necessary to comply with these standards. Having sunk these costs, foreign manufacturers have an incentive to lobby their home governments to raise emissions standards in order to more effectively compete in their home market. High environmental standards therefore diffuse across national borders through international trade flows.

The emissions standards driving the California effect were WTO-compliant because they pertained to the function of the product in question; they were not process standards. Many of the environmental and ethical concerns cited in debates over trade liberalization pertain to production processes, not the characteristics of the goods themselves. However, a related body of research has argued increased openness can still raise production standards in the absence of formal government regulation through the use of voluntary industry standards (see e.g. Vogel, 2010; Prakash and Potoski, 2006; Kirton and Trebilcock, 2004). Voluntary standards are typically overseen by institutions, often non-governmental organizations (NGOs), which operate in parallel to formal legal institutions. Perhaps the most famous example is the International Organization for Standardization (ISO), creator of the widely adopted ISO 9001 and ISO 14001 standards. While such standards lack the enforcement power of formal legal institutions, they are designed to offer market-based incentives for firms to raise their production standards. These types of standards are especially popular in markets for "ethical" or "sustainable" goods, where some consumers are willing to pay a significant premium for high production standards (Loureiro and Lotade, 2005). Certification under a credible voluntary standard identifies the process attributes consumers value, but cannot observe directly in the products they buy.

Voluntary standards help resolve an information asymmetry problem similar to the "market for lemons" described by Akerlof (1970). Consumers are willing to pay more for ethically or sustainably produced goods, but they cannot independently observe firms' production processes. Firms have an incentive to falsely advertise they employ high labor or environmental standards, and if consumers recognize this incentive, they will no longer be willing to offer a premium. Under certain conditions, this will cause the market for ethically or sustainably produced goods to collapse. Voluntary standards solve this problem by allowing firms to credibly signal their underlying production processes.

An important question is whether or not the proliferation of voluntary standards has helped to avert the "race to the bottom" following trade liberalization. The literature on voluntary standards and international trade has produced a fairly consistent and highly suggestive set of results, but aside from a few notable exceptions (e.g. Albano and Lizzeri, 2001; Sheldon and Roe, 2009; Podhorsky, 2010, 2012), the empirical work has proceeded without a strong theoretical underpinning. This makes it difficult to interpret parameter estimates and to extrapolate from the empirical results to policy prescriptions. What follows is a model of international trade and voluntary standard adoption based in the heterogeneous firms and trade (HFT) framework developed by Meltiz (2003). Employing the HFT framework produces a rich set of firm level predictions regarding the relationship between voluntary standards and participation in international markets. The results presented here will provide help identify the conditions under which increased openness to trade in the presence of a credible voluntary standard can put upward pressure on labor, environmental and safety standards.

Section one provides a brief background on the HFT framework. Section two describes the modeling environment employed in this study and characterizes the model equilibrium. Section three illustrates model comparative statics for three policy-relevant parameters. Section four concludes.

1. Previous Literature

Adoption of a voluntary certification is best described with a model that can provide a rich set of firm-level predictions. The model presented here is an application of the Melitz (2003) heterogeneous firms and trade (HFT) framework to the provision of credence goods. The HFT model extended the work of Krugman (1979, 1980), which was part of the "modern-day revolution" in trade theory described in Feenstra (2006). Krugman, along with Helpman (1981) and Lancaster (1980), used the monopolistic competition framework of Dixit and Stiglitz (1977) to demonstrate previously unidentified gains from trade. These authors showed trade liberalization can lead to lower prices through increasing returns to scale and also improve welfare by increasing the variety of products available to consumers. Melitz (2003) contributed to this literature by showing that trade can create further gains when firms are heterogeneous in terms of productivity. Lowering trade barriers reallocates resources to the most productive firms, which leads to lower prices.

Following Dixit and Stiglitz (1977), Melitz (2003) only allowed for horizontal differentiation. No good was higher "quality" than any other, in the sense that consumers would be willing to buy a greater quantity at the same price. Subsequent work has modified the original framework to allow for vertical differentiation without losing the tractability of the original HFT. Johnson (2010), Baldwin and Harrigan (2011) and Kugler and Verhoogen (2012) modified the HFT framework to incorporate vertical differentiation by allowing quality to enter the utility function as a demand-shifter. Holding price constant, high-quality goods receive a larger budget share than low-quality goods.[1]

These authors all assumed consumers have perfect information about the quality of the goods they buy, but debates over trade policy often concern unobservable attributes, such as product safety, labor practices and sustainability. Addressing these concerns requires adapting the framework to the provision of credence goods (Darby and Karni, 1973). Credence goods are those products where consumers value quality, but cannot determine the quality of a good directly, either before or after purchase. This concept is easily applicable to process attributes such as environmental and labor practices, where the production process is not observable in the characteristics of the product itself.

Podhorsky (2010) first adapted the HFT framework for the provision of credence goods in a closed economy. Firms market "high-quality" goods to consumers by participating in a voluntary certification program. This voluntary certification improved social welfare by alleviating the information asymmetry problem described in Akerlof (1970). Podhorsky (2012) has extended this model to accommodate frictionless trade between two countries. By assuming zero trade costs, Podhorsky (2012) eliminates the endogenous exporting decision that distinguished the original HFT model. This assumption also made it impossible to explore the relationship between liberalization and participation in the voluntary certification program. A related study by Sheldon and Roe (2009) modeled trade in credence goods in the presence of a voluntary certification program, but in a game theoretic framework. They found market integration results in increased provision of quality in the presence of a third-party certifier by ensuring high-quality goods are produced even if regulators set sub-optimal legal standards.

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[1] The specification of consumer preferences adopted here and in Melitz (2003), Johnson (2010) and Baldwin and Harrigan (2011) ensure positive demand for every variety, regardless of its quality.

In the following sections, a model in the HFT framework is presented incorporating participation in a credible voluntary standard (or certification) along with fixed export market entry costs and positive transportation costs. Firms make their export and certification decisions simultaneously, so the model yields predictions concerning the relationship between liberalization and the adoption of voluntary standards. Modeling this relationship for the provision of credence goods makes these results applicable to debates over trade liberalization and product safety, sustainability and labor practices.

2. Model Framework

2.1: Consumption

Consumers in each country maximize a utility function characterized by a constant elasticity of substitution ($\sigma > 1$) among each of the $\omega \in \Omega$ varieties available in their home market.

Consumers solve:

$$\max_{x_i(\omega)} U = \left(\int_{\omega \epsilon \Omega_i} \left(\lambda(q_\omega)^{\frac{1}{\sigma}} x(\omega) \right)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}} \tag{1}$$

$$\text{s.t.} \int_{\omega \epsilon \Omega} p(\omega) x(\omega) \leq E$$

The quantity of variety ω consumed in country i is $x_i(\omega)$. The unit price of variety ω in country i is $p_i(\omega)$. Total expenditure in the country is $E_i = w_i L_i$, where w_i is the wage rate in country i, and L_i is the total labor supply in i. The term $\lambda(q_\omega)$ captures the effect of vertical differentiation on consumer behavior. It acts as a demand shifter, allocating larger budget shares to varieties with higher quality (q_ω). For simplicity, assume $\lambda(q_\omega) = q_\omega^\gamma$ and $\gamma \geq 0$.

The consumer maximization problem yields the following demand function:

$$x_i(\omega) = p_i(\omega)^{-\sigma} \lambda(q_\omega) \frac{E_i}{\tilde{P}_i^{1-\sigma}} \tag{2}$$

where $\tilde{P}$ is the quality-adjusted CES price index:

$$\tilde{P}_i \equiv \left(\int_{\omega \epsilon \Omega_i} \lambda(q_\omega) \cdot p_i(\omega)^{1-\sigma} d\omega \right)^{\frac{1}{1-\sigma}} \tag{3}$$

Following Podhorsky (2010), this model assumes that consumers derive more utility from higher quality varieties, but cannot observe the quality of the variety themselves. Consumers are aware firms can participate in a credible voluntary standard that will certify whether they meet the (exogenously determined) minimum quality standard: $q_\omega \geq q_H$. Consumers therefore perceive the quality of each variety (ω) as:

$$q_\omega = \begin{cases} q_H \text{ if certified} \\ q_L \text{ otherwise} \end{cases}$$

The sum of attributes observable by the consumer can be thought of as q_L. Even in the absence of certification, consumers can perceive q_L. Since there are no returns to investments in product quality above q_H or between q_H and q_L, this specification of consumer preferences turns the firm's choice of optimal quality into a binary decision determined exactly by the firm's optimal certification strategy.

2.2: Production

As in Melitz (2003), firms are monopolistically competitive and heterogeneous in terms of their underlying productivity, here represented by the parameter θ. Following Melitz (2003), assume θ follows a Pareto distribution with distribution function $G(\theta) = 1 - \left({}^{\theta}/_{\underline{\theta}} \right)^{-\varsigma}$, where $\underline{\theta}$ is the lower bound on the support of $G(\theta)$ and $\varsigma > 1$ is the scale parameter. Firms must sink an entry cost, F_E, expressed in labor units, to enter the differentiated products sector. Firms do not know their productivity level before entering the industry. Following entry, each firm will maximize operating profit by choosing an optimal price and quality as a function of their productivity. Firms solve:

$$\max_{p(\omega),q_\omega} \pi_j(\omega_i) = p_j(\omega_i)x_j(\omega) - w_i c(q_\omega)\, x_i(\omega) \tag{4}$$

$\pi_j(\omega_i)$ refers to the profit earned in country *j* by the firm producing variety ω in country *i.* The firm's cost function $c(q_\omega)$ is measured in labor units, paid at wage rate w_i. For simplicity, assume that $c(q_\omega) = 1$. When $j = i$, the profit maximization problem can be solved by substituting (2) into (4) and differentiating with respect to $p_j(\omega_i)$. This reveals price is the standard mark-up over marginal cost:

$$p_i(\omega_i) = w_i\left(\frac{\sigma}{\sigma-1}\right) \tag{5}$$

When $j \neq i$, firms incur the standard "iceberg" transportation costs when they ship their output to the foreign market. The firm must produce τ units of output for every unit they sell in the foreign market. The firm therefore solves

$$\max_{p(\omega),q_\omega} \pi_j(\omega_i) = p_j(\omega_i)x_j(\omega) - w_i c(q_\omega)\, \tau x_j(\omega) \tag{6}$$

Substituting (2) into (6) and solving for the profit maximizing price yields:

$$p_j(\omega_i) = \tau w_i\left(\frac{\sigma}{\sigma-1}\right) = \tau p_i(\omega_i) \tag{7}$$

Using (2) and (7) to calculate the revenue firms from country *i* earn in each market results in:

$$p_i(\omega_i)x_i\left(q_{\omega_i}\right) = p_i(\omega_i)^{1-\sigma}\lambda\left(q_{\omega_i}\right)\frac{E_i}{\tilde{P}_i^{1-\sigma}} \tag{8}$$

$$p_j(\omega_i)x_j\left(q_{\omega_i}\right) = p_j(\omega_i)^{1-\sigma}\lambda\left(q_{\omega_i}\right)\frac{E_j}{\tilde{P}_j^{1-\sigma}} \tag{9}$$

Substituting (7) into (9) and (2) yields:

$$p_j(\omega_i)x_j(q_{\omega_i}) = \tau p_i(\omega_i)x_j(q_{\omega_i}) = \{\tau p_i(\omega_i)\}^{1-\sigma}\lambda(q_{\omega_i})\frac{E_j}{\tilde{P}_j^{1-\sigma}} \tag{10}$$

Firm profit in its home market is calculated as:

$$\pi_i(\omega_i) = p_i(\omega_i)x_i(\omega_i) - w_i x_i(\omega_i)$$

Substituting from (5) yields:

$$\pi_i(\omega_i) = p_i(\omega_i)x_i(\omega_i)\left[1 - \frac{\sigma-1}{\sigma}\right] = \frac{p_i(\omega_i)x_i(\omega_i)}{\sigma} \tag{11}$$

So profits are simply a constant fraction of total revenues. A similar calculation is performed to find the profit a firm earns in a foreign market:

$$\pi_j(\omega_i) = p_j(\omega_i)x_j(\omega_i) - \tau w_i x_j(\omega_i)$$

Substituting from (6) yields:

$$\pi_j(\omega_i) = \frac{p_j(\omega_i)x_j(\omega_i)}{\sigma} \tag{12}$$

Equations (11) and (12) show that firm profit depends on the choice of output quality. The specification of consumer preferences adopted here means that firms must choose either high (q_H) or low (q_L) quality. Following Podhorsky (2010), firms that choose to produce high quality goods must pay a fixed cost (denominated in labor units) to be certified under the voluntary standard. Firms seeking certification incur the following fixed costs:

$$\delta(\theta) = \frac{(q_H - q_L)}{\theta} \tag{13}$$

Fixed certification costs are increasing in the strictness of the standard $(q_H - q_L)$, but decreasing in the firm's productivity. Equations (11) and (12) demonstrate that profits are higher for high-quality firms at every productivity level, while (13) demonstrates that the cost of marketing high-quality goods falls monotonically with productivity. This implies a cut-off productivity level (θ^*) beyond which the cost of producing and certifying high-quality goods is small enough to make q_H the profit-maximizing level of quality.

Figure 1: Determination of the Certification Cut-Off Productivity

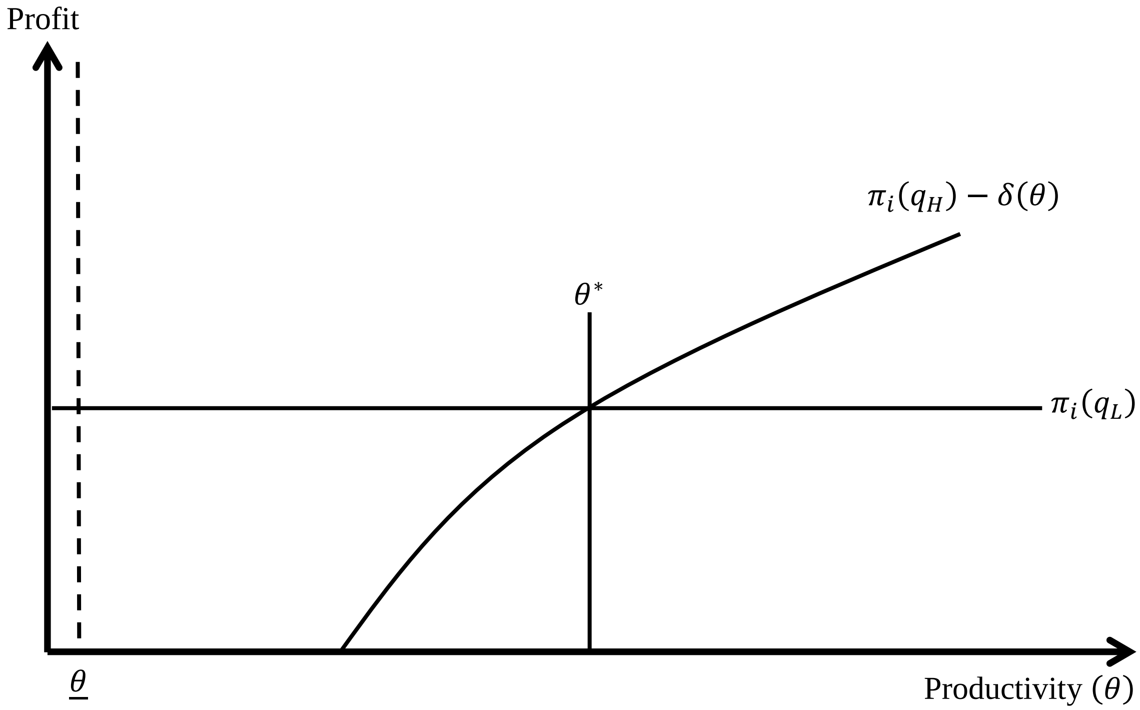


Figure 1 illustrates this cut-off condition. Consider a firm deciding whether or not to sell high-quality output in a given market. If the firm sells low-quality output, it will earn a payoff equal to $\pi_i(q_L)$. If the firm decides to market high-quality output, it will earn a payoff equal to $\pi_i(q_H) - w_i\delta(\theta)$. Equations (8), (9) and (13) ensure that the payoffs associated with this strategy are non-decreasing and concave in productivity (θ). Firms with $\theta \in [\theta_{min}, \theta^*)$ will choose to sell only low-quality products. Firms with $\theta \in [\theta^*, \infty)$ will pay for certification and sell high-quality goods.

As in Melitz (2003), firms also face a fixed export cost when they enter a foreign market. This can be specified as:

$$F_X(\theta) = \frac{F_X}{\theta} \qquad (14)$$

As with (13), it is assumed fixed export costs are decreasing in productivity.[2] Fixed export costs are also assumed to be independent of quality. If the firm sells output of a given quality only in the domestic market, it will earn a payoff equal to $\pi_i(q_\omega)$. If the firm decides to sell in both the home and foreign markets, it will earn a payoff equal to $\pi_i(q_\omega) + \pi_j(q_\omega) - w_i F_x(\theta)$. The result is a cut-off condition similar to the one illustrated for certification.

Figure 2: Determination of the Export Cut-Off Productivity

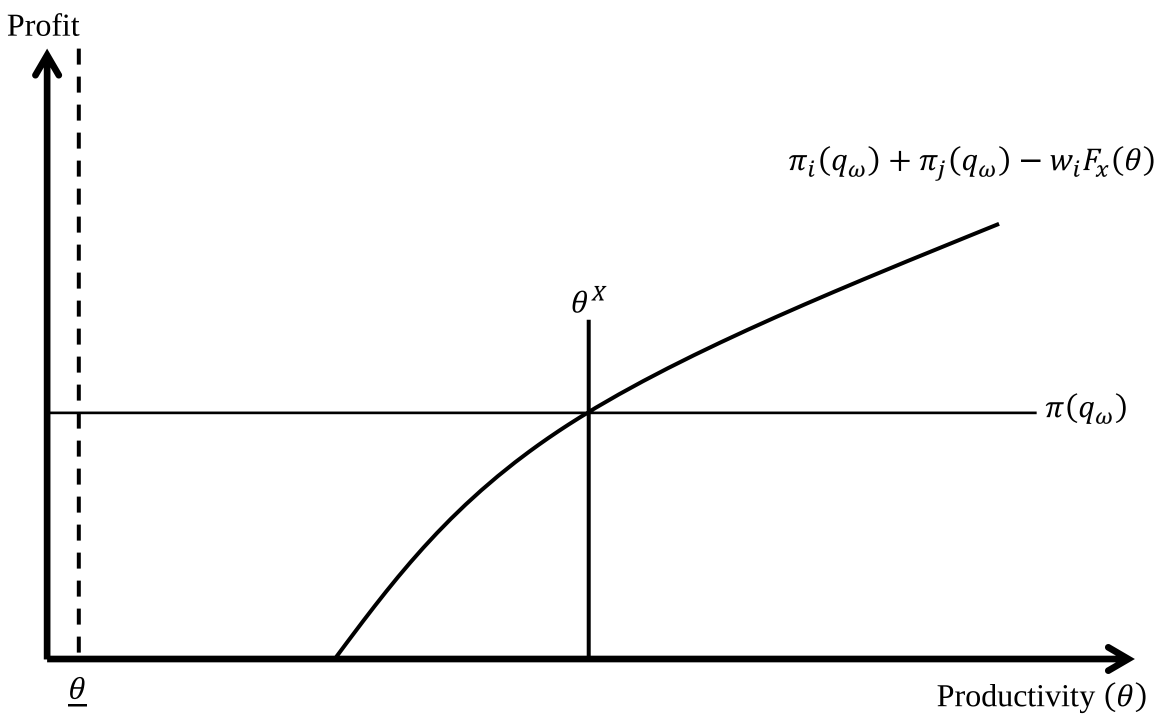


Figure 2 illustrates the profit associated with each strategy. As before, equations (8), (9) and (14) ensure the payoff functions associated with this strategy are non-decreasing and concave in productivity. Firms with $\theta \in [\theta_{min}, \theta^X)$ will choose to serve only

[2] Melitz (2003) assumes marginal production costs are decreasing in productivity, but this distinction is relatively unimportant. As long as pay-offs are monotonically increasing in productivity and slope at different rates, the assumption made here makes the model more tractable and produces an identical pattern of firm behavior.

the domestic market. Firms with $\theta \in [\theta^X, \infty)$ will sink the fixed export cost and sell output of a given quality (q_ω) in both the foreign and domestic markets.

2.3: Characterizing Model Equilibrium

The model structure outlined above implies firms must choose their export and certification strategies simultaneously. Table 1 illustrates the pay-offs to each potential strategy for firm a in country *i.*[3] The highest productivity firms will always sell high quality goods and export. Call this the *HE* strategy. To see this, note that equations (11) and (12) imply operating profit in any given market is always positive. Equations (8) and (9) imply that operating profit is always increasing in output quality. From the definition of $G(\theta)$, the support of $G(\theta)$ is such that $\theta \epsilon [\underline{\theta}, \infty)$. As θ approaches infinity, $F_x(\theta)$ and $\delta(\theta)$ go to zero. Ignoring fixed costs, firms will always maximize profit by selling high-quality output in as many markets as possible. Similarly, $F_x(\theta)$ and $\delta(\theta)$ go to infinity as θ approaches $\underline{\theta}$, for small values of $\underline{\theta}$. These firms will maximize profits by minimizing fixed costs, selling low quality output and not exporting. Call this the *LN* strategy.

Placing some reasonable restrictions on certain model parameters, it is possible for a subset of firms to adopt the strategy in either the lower-left or upper-right hand corners of Table 1. However, if one of these intermediate strategies is chosen, it will necessarily dominate the other over the relevant range of θ (see parts A and B in the appendix). Assume some firms sell only low-quality goods, but sell them at home and abroad. Call this the *LE* strategy. Firms at higher levels of productivity will be able to cover the cost of certification using revenues derived from selling high-quality goods only in the home country. Call this the *HN* strategy. Since export costs are already sunk, any firm that can

[3] For simplicity, it is assumed firms cannot sell different quality output in different markets.

earn positive profit from the *HN* strategy will maximize profits by also selling them abroad. Firms will therefore transition directly from *LE* to *HE*, without adopting the HN strategy. Conversely, assume some firms adopt the *HN* strategy in equilibrium. Firms at higher levels of productivity will be able to cover fixed export costs by selling low quality goods abroad. Since certification costs are already sunk, these same firms will maximize profits by selling high quality goods in the foreign market. Firms will therefore transition directly from the HN strategy to HE, without adopting the LE strategy.

Table 1: Payoff Functions for Firm Strategies

	No Certification (**L**ow Quality)	Certification (**H**igh Quality)
No Exports	$\pi_i(q_L)$ (LN)	$\pi_i(q_H) - \delta(\theta)$ (HN)
Exports	$\pi_i(q_L) + \pi_j(q_L) - F_x(\theta)$ (LE)	$\pi_i(q_H) + \pi_j(q_H) - \delta(\theta) - F_x(\theta)$ (HE)

3.3.1: LN/LE/HE Equilibrium

Assume model parameters are set such that firms must choose among strategies LN, LE and HE, as described in the table above. The definition of the model equilibrium can be derived using three pieces of information. First, the payoff matrix can be used to define the productivity cut-offs separating each strategy.

Call θ^A the productivity satisfying:

$$\pi_i(q_L) + \pi_j(q_L) - w_i F_x(\theta^A) = \pi_i(q_L)$$

or,

$$\pi_j(q_L) = w_i F_x(\theta^A) \tag{15}$$

This expression defines the firm that is indifferent between selling in the domestic market and sinking $F_x(\theta)$ to sell output in both the foreign and domestic markets, given it will only be selling low-quality output.

Call θ^B the productivity satisfying:

$$\pi_i(q_L) + \pi_j(q_L) - w_i F_x(\theta^B) = \pi_i(q_H) + \pi_j(q_H) - w_i\delta(\theta^B) - w_i F_x(\theta^B)$$

or,

$$[\pi_i(q_H) - \pi_i(q_L)] + [\pi_j(q_H) - \pi_j(q_L)] = w_i\delta(\theta^B) \tag{16}$$

This expression defines the firm that is indifferent between selling low-quality and sinking $\delta(\theta)$ to sell high-quality goods, given it will sell in both the domestic and foreign markets.

Finally, the model equilibrium is defined by a zero-profit condition, as in Melitz (2003). Firms do not know their productivity draw before they enter the differentiated product sector, but they do know their expected level of operating profit and the expected costs associated with each strategy. Assume further that firms must sink a fixed entry cost (F_E), denominated in labor units, to enter the industry. Firms will continue to enter until their expected profit, net of their expected fixed costs, exactly equals the fixed cost of entry. Defining expected operating profits as $E[\pi]$, this condition can be expressed as:

$$E_i[\pi] - w_i E[F_x(\theta)] - w_i E[\delta(\theta)] = w_i F_E \tag{17}$$

Equations (15), (16) and (17) allow θ^A, θ^B and the equilibrium mass of industry entrants (M) to be defined in terms of model parameters. Making the appropriate series of substitutions yields an expression defining the export cut-off (θ^A) only in terms of model parameters (see C in the appendix):

$$(\theta^A)^{-1}F_x\left\{\frac{(2s+1)\lambda(q_L)-[1+\tau^{1-\sigma}]s\lambda(q_H)}{\lambda(q_L)(s+1)\tau^{1-\sigma}}\right\}+(\theta^A)^{-(s+1)}F_x$$

$$+(\theta^A)^{-(s+1)}\left[\frac{(\lambda(q_H)-\lambda(q_L))}{\lambda(q_L)}[1+\tau^{\sigma-1}]\right]^{s+1}\frac{{F_x}^{s+1}}{(q_H-q_L)^s}=F_E \qquad (18)$$

The model yields no algebraic closed-form solution, but it is still possible to demonstrate the uniqueness and existence of the equilibrium. Call the left-hand side of (18) $H(\theta^A)$. Assume parameters are fixed such that the first bracketed term in $H(\theta^A)$ is strictly non-negative. It is straightforward to see that $H(\theta^A)$ approaches some positive value as $\theta^A \to \underline{\theta}$. It can also be seen that $H(\theta^A)$ monotonically approaches zero as $\theta^A \to \infty$. As long as $F_E$is not too high, equation (18) identifies the unique equilibrium value of $\theta^A$for this model. Having identified θ^A, it is possible to derive an expression to identify the corresponding equilibrium cut-off for HE:

$$\theta^B=\theta^A\frac{\lambda(q_L)}{F_X[1+\tau^{\sigma-1}]}\frac{q_H-q_L}{\lambda(q_H)-\lambda(q_L)}$$

A unique expression identifying θ^B only in terms of model parameters can also be found by making a series of substitutions similar to those used to derive (18). The appropriate procedure is described briefly in the appendix. The resulting expression is:

$$(\theta^B)^{-1}[q_H-q_L]\left\{\frac{(2s+1)\lambda(q_L)-[1+\tau^{1-\sigma}]s\lambda(q_H)}{[\lambda(q_H)-\lambda(q_L)][1+\tau^{1-\sigma}](s+1)}\right\}+(\theta^B)^{-(s+1)}[q_H-q_L]$$

$$+(\theta^B)^{-(s+1)}\left(\frac{[q_H-q_L]\lambda(q_L)\tau^{1-\sigma}}{[\lambda(q_H)-\lambda(q_L)][1+\tau^{1-\sigma}]}\right)^{s+1}{F_x}^{-s}=F_E \qquad (19)$$

Define $H(\theta^B)$ as the left-hand side of (19). Once again, it can be seen that $H(\theta^B)$ defines a unique equilibrium value of θ^B as long as F_E is not too high. The equilibrium mass of entrants to the differentiated products sector can also be found using (17) and the equilibrium values of θ^A and θ^B:

$$M = \frac{L}{\sigma\left\{F_E + \left(\frac{s}{s+1}\right)\left(\frac{[qh-ql]}{\theta^B} + \frac{F_X}{\theta^A}\right)\right\}} \tag{20}$$

Figure 3 illustrates the determination of the equilibrium cut-offs using (18) and (19). Equilibrium cut-offs can be found where $H(\theta^A) = H(\theta^B) = F_E$. Equilibrium exists as long as F_E is not too large, so that the points of intersection occur at some $\theta^B > \theta^A \geq \underline{\theta}$. The range of productivity in the support of $G(\theta)$ is divided by the unique equilibrium productivity cut-offs defined in Figure 3.

Figure 3: Determination of Equilibrium Productivity Cut-Offs in the LN/LE/HE Case

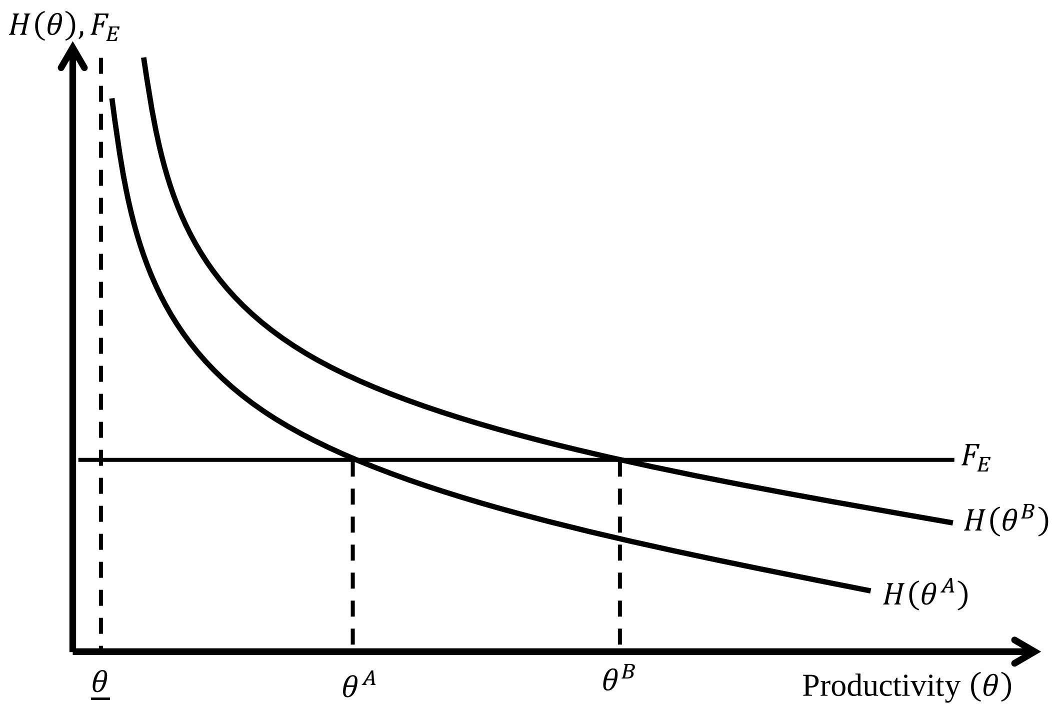
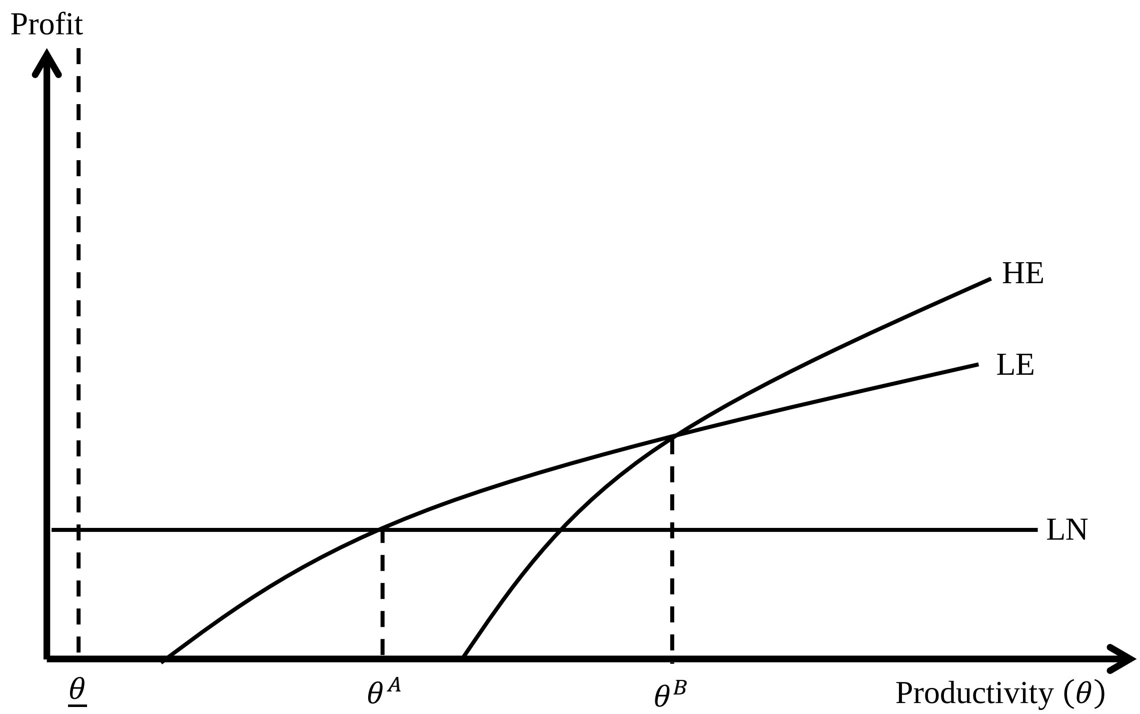


Figure 4 illustrates the full model equilibrium in productivity and profit space. The payoffs associated with each strategy are shown as a concave function of θ. While LN is constant, LE and HE are both monotonically increasing in productivity. Strategies LE and HE are everywhere steeper in slope than LN, but these payoff functions are shifted downward due to their associated fixed costs. Strategy HE is sloped more steeply everywhere than LE, so this strategy will come to dominate over higher ranges of θ. Profits earned by firms over the relevant range of θ can be seen as the upper envelope of the LN, LE and HE functions for $\theta \geq \underline{\theta}$.

Figure 4: Equilibrium Firm Payoffs in the LN/LE/HE Case:



2.3.1: LN/HN/HE Equilibrium

It is also possible to define an equilibrium in which the other intermediate case (HN) is adopted. Assume model parameters are set such that firms must choose among the strategies labeled LN, HN, or HE. As in the previous case, three pieces of information are available to help define the model equilibrium. The payoff matrix can be used to define the cut-off productivities separating each strategy.

Call θ^C the productivity satisfying:

$$\pi_i(q_L) = \pi_i(q_H) - w_i\delta(\theta^C)$$

or,

$$w_i\delta(\theta^C) = \pi_i(q_H) - \pi_i(q_L) \tag{21}$$

This expression defines the firm that is indifferent between selling low-quality and high-quality goods, given it will only sell in the home market.

Call θ^D the productivity satisfying:

$$\pi_i(q_H) - w_i\delta(\theta^D) = \pi_i(q_H) + \pi_j(q_H) - w_i\delta(\theta^D) - w_iF_x(\theta^D)$$

or,

$$\pi_j(q_H) = w_iF_x(\theta^D) \tag{22}$$

This expression defines the firm that is indifferent between selling only in the home market and selling in both the home and foreign markets, given it will be selling only high-quality goods.

The same zero-profit condition in expression (17) can be used as in the previous case to close the model. Equations (17), (21) and (22) define θ^C, θ^D and the equilibrium mass of industry entrants (M). As shown in the appendix, making the appropriate series of substitutions yields an expression defining the export cut-off (θ^D) only in terms of model parameters (see D in the appendix):

$$(\theta^D)^{-1}F_X\left\{\frac{(2s+1)\lambda(q_L)-\left(1+\tau^{1-\sigma}\right)s\lambda(q_H)}{\lambda(q_H)\tau^{1-\sigma}(s+1)}\right\} + (\theta^D)^{-(s+1)}F_X$$
$$+(\theta^D)^{-(s+1)}\left\{\frac{F_X}{\tau^{1-\sigma}}\frac{[\lambda(q_H)-\lambda(q_L)]}{\lambda(q_H)}\right\}^{s+1}[q_H-q_L]^{-s} = F_E \tag{23}$$

Once again, the model yields no algebraic closed-form solution, but it is possible to establish the uniqueness and existence of the equilibrium. Call the left-hand side of (23) $H(\theta^D)$. Once again, assume parameters are fixed such that the first bracketed term in $H(\theta^D)$ is positive[4]. $H(\theta^D)$ is monotonically decreasing in θ^D and approaches some positive value as $\theta^D \to \underline{\theta}$. $H(\theta^D)$ also approaches zero as $\theta^D \to \infty$. This implies a unique

[4] Note that this requires an identical assumption about the relative magnitudes of s, τ, $\lambda(q_L)$ and $\lambda(q_H)$ as in the first case.

equilibrium θ^D exists as long as F_E is not too high. The value of θ^D implied by (23) can be used to solve for the other endogenous variables in the model.

$$\theta^C = \theta^D \frac{\lambda(q_H)\tau^{1-\sigma}}{F_X} \frac{q_H - q_L}{\lambda(q_H) - \lambda(q_L)}$$

Alternatively, it is possible to make the appropriate series of substitutions to derive a condition defining θ^C only in terms of model parameters. The appendix demonstrates briefly how to derive this condition.

$$(\theta^C)^{-1}(q_H - q_L)\left\{\frac{(2s+1)\lambda(q_L) - s\lambda(q_H)\left(1+\tau^{1-\sigma}\right)}{[\lambda(q_H) - \lambda(q_L)](s+1)}\right\} + (\theta^C)^{-(s+1)}(q_H - q_L)$$

$$+(\theta^C)^{-(s+1)}\left\{\frac{[q_H - q_L]\tau^{1-\sigma}\lambda(q_H)}{[\lambda(q_H) - \lambda(q_L)]}\right\}^{s+1} F_X{}^{-s} = F_E \qquad (24)$$

Defining $H(\theta^C)$ as the left-hand side of (24), this expression defines a unique equilibrium value of θ^C as long as F_E is not too high.

Figure 5: Determination of Equilibrium Productivity Cut-Offs in the LN/HN/HE Case

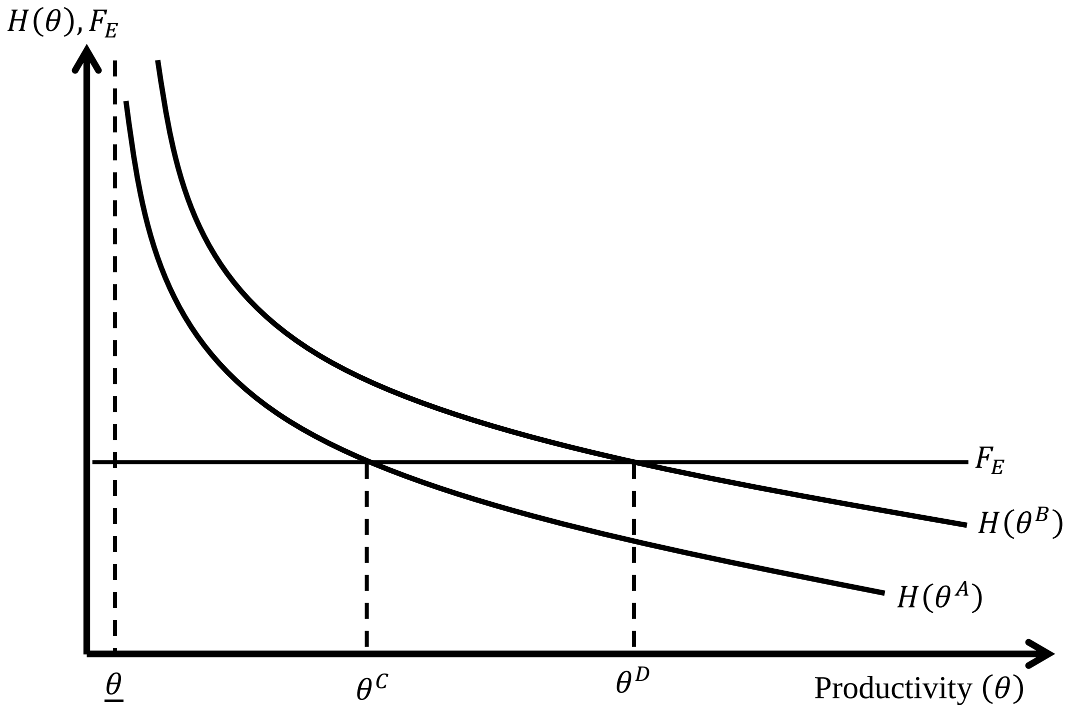


Figure 5 illustrates the determination of the equilibrium cut-offs using (23) and (24). Equilibrium cut-offs can be found where $H(\theta^C) = H(\theta^D) = F_E$. The equilibrium exists as long as F_E is not too large, so the points of intersection occur at some $\theta^D > \theta^C \geq \underline{\theta}$.

Equation (17), along with the equilibrium values of θ^C and θ^D, can be used to find the equilibrium mass of entrants (M).

$$M = \frac{L}{\sigma\left\{F_E + \left(\frac{s}{s+1}\right)\left(\frac{[qh-ql]}{\theta^C} + \frac{F_X}{\theta^D}\right)\right\}} \tag{25}$$

Figure 6: Equilibrium Firm Payoffs in the LN/HN/HE Case:

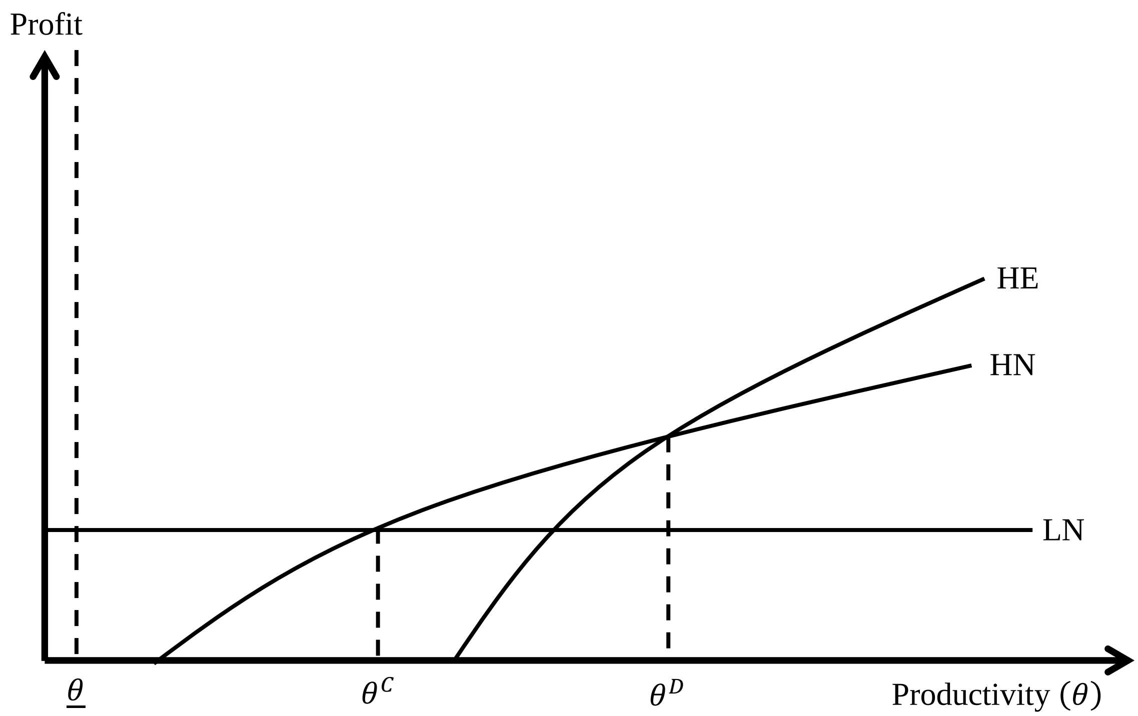


Figure 6 illustrates the model equilibrium in productivity and profit space. As before, the profit associated with each strategy is a concave function of productivity. LN is constant, but HN and HE are both monotonically increasing in productivity. Strategies HN and HE are steeper in slope than LN over the entire range of the function, but these payoffs are shifted downward due to their associated fixed costs. Strategy HE is more steeply sloped everywhere than HN, so this strategy will come to dominate over higher ranges of θ. Profits earned by firms over the relevant range of θ can be seen as the upper envelope of the LN, HN and HE functions for $\theta \geq \underline{\theta}$.

2.3.2: Determining the Prevailing Intermediate Strategy

These results demonstrate the existence and uniqueness of the model equilibrium when either intermediate strategy emerges. However, it is not yet clear how to determine which intermediate strategy will prevail. Intuitively, the relative magnitudes of the trade and the certification costs will determine how "quickly" firms begin exporting or certifying their output. If certification is expensive, relative to the additional profit that firms receive from selling high-quality output, firms in the lower ranges of θ will be more likely to sink $F_X(\theta)$ and enter export markets, instead. Conversely, if exporting is expensive relative to the additional profit from selling output in the export market, firms in the lower ranges of θ will be more likely to sink $\delta(\theta)$ and increasing output quality.

This comparison can be made more concrete by examining (D5) and (C7) from the appendix. Rearranging terms in (C7) yields:

$$\frac{\theta^B}{\theta^A} = \frac{(q_H - q_L)}{[\lambda(q_H) - \lambda(q_L)]} \frac{\lambda(q_L)}{F_X(1+\tau^{\sigma-1})} \tag{26}$$

Knowing $\theta^B > \theta^A$ implies:

$$\frac{(q_H - q_L)}{[\lambda(q_H) - \lambda(q_L)]} > \frac{F_X\left(1+\tau^{\sigma-1}\right)}{\lambda(q_L)} \tag{26a}$$

Equation (26a) is a sufficient condition for the LE strategy to dominate HN. According to this expression, the cost of certification for a given level of productivity $(q_H - q_L)$, relative to the additional profit from increasing output quality $\left(\lambda(q_H) - \lambda(q_L)\right)$, must be higher than the cost of entering the export market (F_X) relative to the benefits of selling low-quality output in both markets $\left(\lambda(q_L)\right)$. This makes certification a less appealing option for firms in lower ranges of productivity, which leads them to adopt the LE strategy over the HN strategy.

A similar expression can be found using (D5):

$$\frac{\theta^D}{\theta^C} = \frac{F_X \tau^{\sigma-1}}{\lambda(q_H)} \frac{[\lambda(q_H) - \lambda(q_L)]}{(q_H - q_L)} \tag{27}$$

Given $\theta^D > \theta^C$:

$$\frac{(q_H - q_L)}{[\lambda(q_H) - \lambda(q_L)]} < \frac{F_X \tau^{\sigma-1}}{\lambda(q_H)} \tag{27a}$$

Equation (27a) is a sufficient condition for the HN strategy to dominate LE. This expression states roughly the inverse of (26a). In order for a firm to choose the HN strategy over the LE strategy, the cost of certification $(q_H - q_L)$, relative to its benefits $\left(\lambda(q_H) - \lambda(q_L)\right)$, must be low compared to the cost of exporting (F_X), relative to its benefits $\left(\lambda(q_H)\right)$. Note that the right-hand side of (26a) is strictly greater than the right-hand side of (27a), so these represent two mutually-exclusive statements. Since no parameterization of the model can satisfy both (26a) and (27a), no more than one of these intermediate strategies can be adopted in equilibrium.

3. Comparative Statics

Although the model yields no closed-form algebraic solution for the cut-off productivities, it is still possible to derive comparative statics for the policy-relevant variables in the model. Assuming q_H is set by an independent agency, the parameters that might be of interest to policy-makers include F_E, F_X and τ. Part E of the appendix shows how to derive comparative statics for each of these variables using equations (18), (19), (23) and (24). The following section presents the results for F_E, F_X and τ.

It is also possible to illustrate the model equilibrium and comparative statics presented using simple numerical simulations of (18), (19), (23) and (24). Simulations of the baseline equilibrium were performed using the parameter values outlined in Table 2

Table 2: Baseline Simulation Parameter Values

LN/LE/HE Case	LN/HN/HE Case
$q_L = 10$	$q_L = 10$
$q_H = 12$	$q_H = 12$
$\alpha = 1.5$	$\alpha = 1.5$
$\sigma = 1.8$	$\sigma = 1.2$
$s = 1.05$	$s = 1.05$
$\tau = 1.1$	$\tau = 1.1$
$F_X = 2$	$F_X = 12$
$F_E = 2$	$F_E = 6$

The baseline values presented in Table 2 differ between cases since they must satisfy either (26a) or (27a), depending on which equilibrium is being examined. In some cases (e.g., σ, s, τ), parameter values were chosen to maintain consistency with the necessary assumptions detailed in section 3. In others, parameter values were chosen to ease visual representation of the comparative statics. Except where explicitly noted, or where bounded by (26a), (27a) and previous assumptions, many different parameter choices will yield qualitatively similar results to those shown below. Note that large changes in parameter values may violate (26a) or (27a), making the results difficult to interpret.

Figure 7 illustrates the baseline equilibrium in the LN/LE/HE case. Equilibrium values of θ^A and θ^B correspond to the values of θ at which the dotted F_E function crosses the downward sloping functions $H(\theta^A)$ and $H(\theta^B)$, respectively.

Figure 7: Simulated Equilibrium in the LN/LE/HE Case

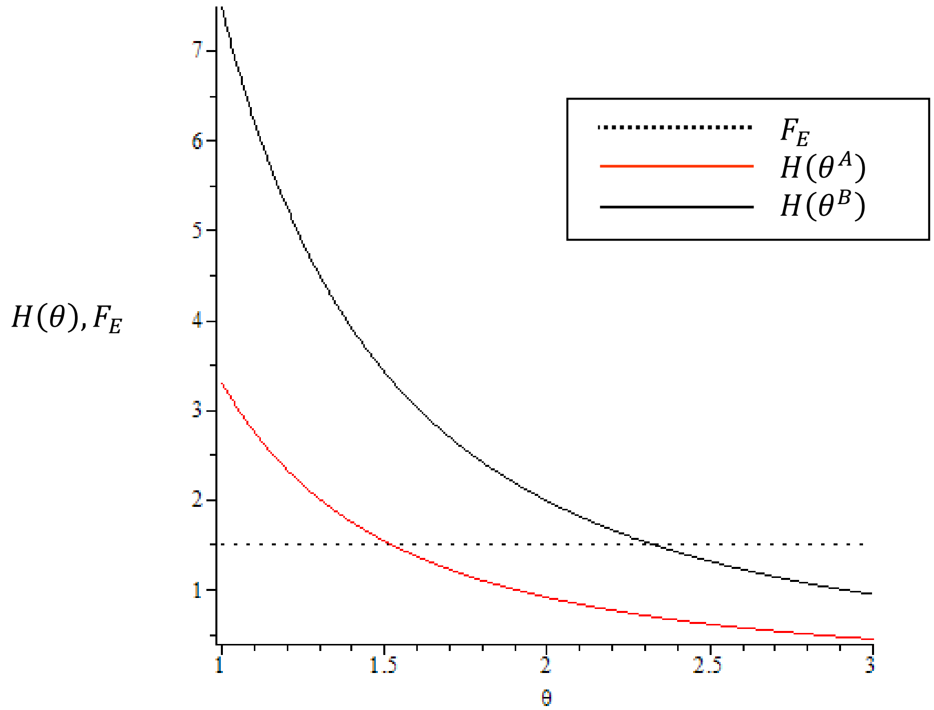
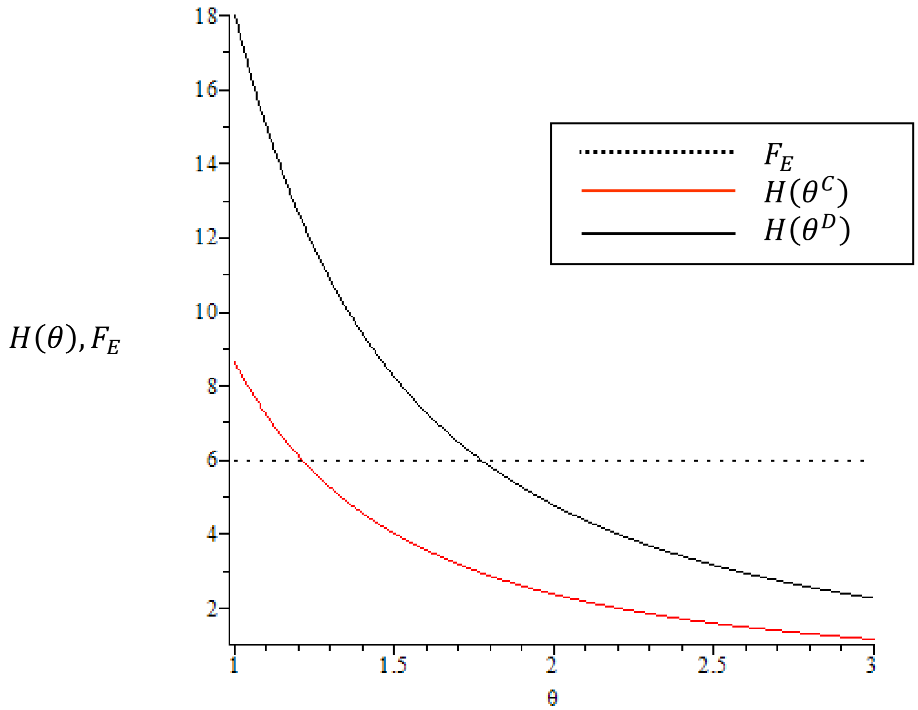


Figure 7 illustrates the baseline equilibrium in the LN/HN/HE case. Equilibrium values of θ^C and θ^D correspond to the values of θ at which the dotted F_E function crosses the downward sloping functions $H(\theta^C)$ and $H(\theta^D)$, respectively. Equilibrium is determined by the value of θ at which the dotted line representing F_E crosses the downward sloping $H(\theta^i)$ curves. These represent the values of $\theta^A, \theta^B, \theta^C$ and θ^D that satisfy equations (18), (19), (23) and (24) with equality. In Figure 7, $\theta^A \cong 1.5$ and $\theta^B \cong 2.3$. In Figure 8, $\theta^C \cong 1.2$ and $\theta^D \cong 1.8$.

Figure 8: Simulated Equilibrium in the LN/HN/HE Case



It is straightforward to relate changes in policy variables to changes in the productivity cut-offs, but the welfare impacts are less clear. Changes in the private benefits enjoyed by consumers can be measured by looking at changes in the quality-adjusted price index (3). The price index can be thought of as the quality-adjusted price of a representative basket of goods in a given market. Increases in the price index therefore imply welfare decreases for consumers. The price index is also inversely related to total quality, which is directly proportional to consumer welfare (Podhorsky, 2012).

3.1: Fixed Entry Costs

Recall that F_E is the fixed cost of entering the differentiated products sector. Changing F_E is analogous to raising or lowering the barriers to entry to the industry. As shown in part E of the appendix, deriving the comparative static $\left(\frac{d\theta^i}{dF_E}\right)$ requires totally differentiating the expression $Q(\theta^i) = H(\theta^i) - F_E = 0$ with respect to F_E and θ^i for all $i = A, B, C, D$. The resulting expression is:

$$\frac{d\theta^i}{dF_E} = -\left[\frac{\frac{\partial Q(\theta^i)}{\partial F_E}}{\frac{\partial Q(\theta^i)}{\partial \theta^i}}\right], \qquad i = A, B, C, D. \tag{28}$$

The resulting comparative statics are:

$$\frac{d\theta^A}{dF_E} < 0, \frac{d\theta^B}{dF_E} < 0, \frac{d\theta^C}{dF_E} < 0, \frac{d\theta^D}{dF_E} < 0 \tag{29}$$

Figure 9 illustrates the comparative statics for F_E in the LN/LE/HN case. As F_E increases from 1.5 to 2, θ^A falls from approximately 1.5 to 1.3. θ^B falls from approximately 2.3 to 2. Figure 10 illustrates the comparative statics for F_E in the LN/HN/HE case. As F_E increases from 6 to 7, θ^C falls from approximately 1.2 to 1.1. θ^D falls from approximately 1.8 to 1.6. Note that no equilibrium can be found following sufficiently large changes in F_E. If $F_E \geq 4$ in Figure 9 or $F_E \geq 9$ in Figure 10 the point of intersection between F_E and $H(\theta^i)$ would lie outside the support of $G(\theta)$.

Figure 9: Comparative Statics for Fixed Entry Costs in the LN/LE/HE Case

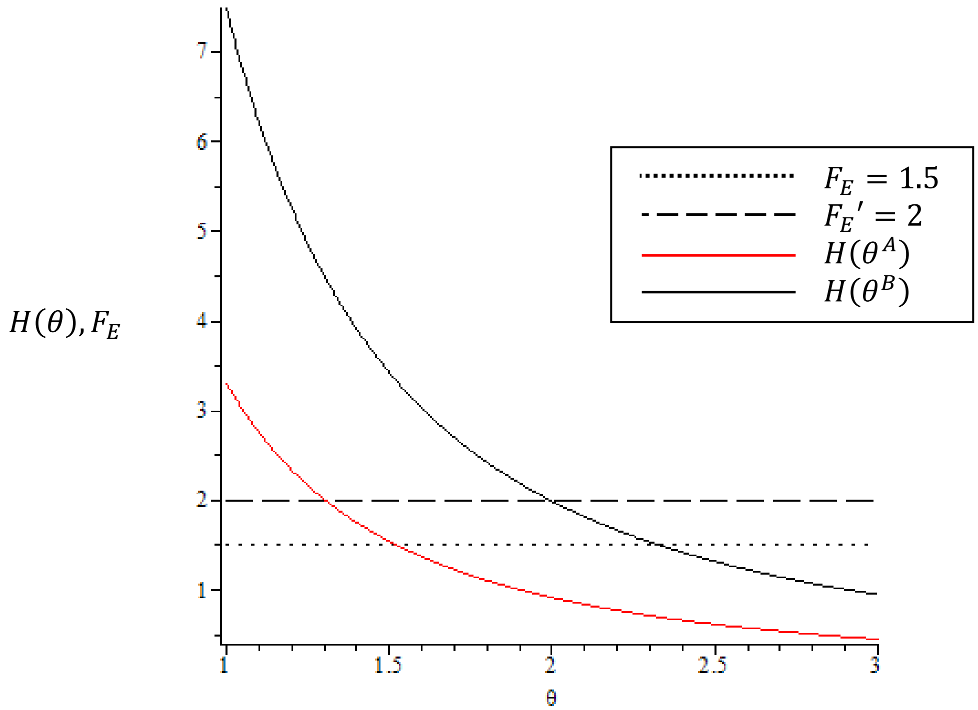


Figure 10: Comparative Statics for Fixed Entry Costs in the LN/HN/HE Case

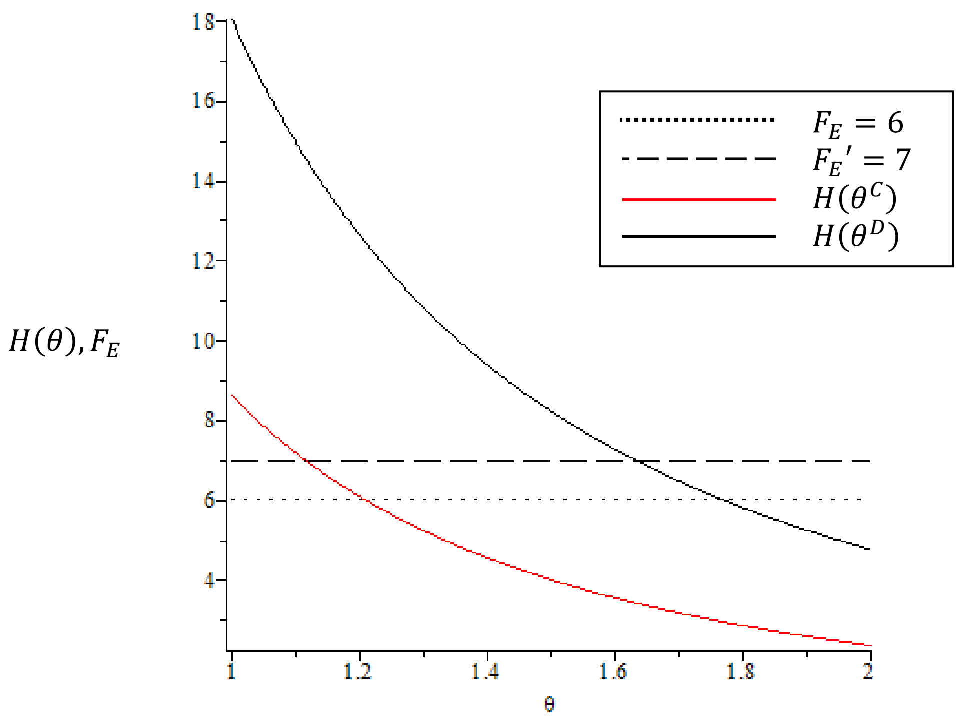


Table 3 shows percentage changes relative to baseline for each of the productivity cut-offs as well total quality (TQ) available to consumers in each market and the quality-adjusted price index (normalizing $p = 1$).

Table 3: Simulation Results for Changes in Fixed Entry Costs

	LN/LE/HE	LN/HN/HE
θ^A	-13%	
θ^B	-13%	
θ^C		-8%
θ^D		-11%
TQ	-2%	-11%
P	+2%	+78%

Raising the barriers to entry to the differentiated products sector will increase rates of participation in both the voluntary standard and export markets. These comparative statics are driven by indirect effects that are not obvious from looking at the payoff functions. Examining (20) and (25), the equilibrium number of entrants is decreasing in F_E for all $i = A, B, C, D$. An increase in F_E discourages entry, as expected. Fewer entrants means a less competitive marketplace, which will raise profits at every productivity level for all successful entrants. Firms that were previously just shy of the productivity cut-offs for exporting and certification will now find themselves sufficiently profitable to justify sinking the associated fixed costs.

The results presented in Table 3 show increasing fixed entry costs will reduce welfare, even though the productivity cut-offs have fallen. Raising F_E increases the proportion of firms adopting the voluntary standard and participating in export markets, but it also discourages entry into the industry. This ultimately reduces the total number of firms producing high-quality products. This is reflected in the higher quality-adjusted price index and reduced total quality level available in each market.

3.2: Fixed Export Costs

Fixed export costs can be interpreted as the institutional or other non-tariff barriers firms that must be overcome to enter an export market. As before, deriving the comparative static requires totally differentiating $Q\left(\theta^i\right)$ with respect to F_X and θ^i for $i = A, B, C, D$. The resulting expression is:

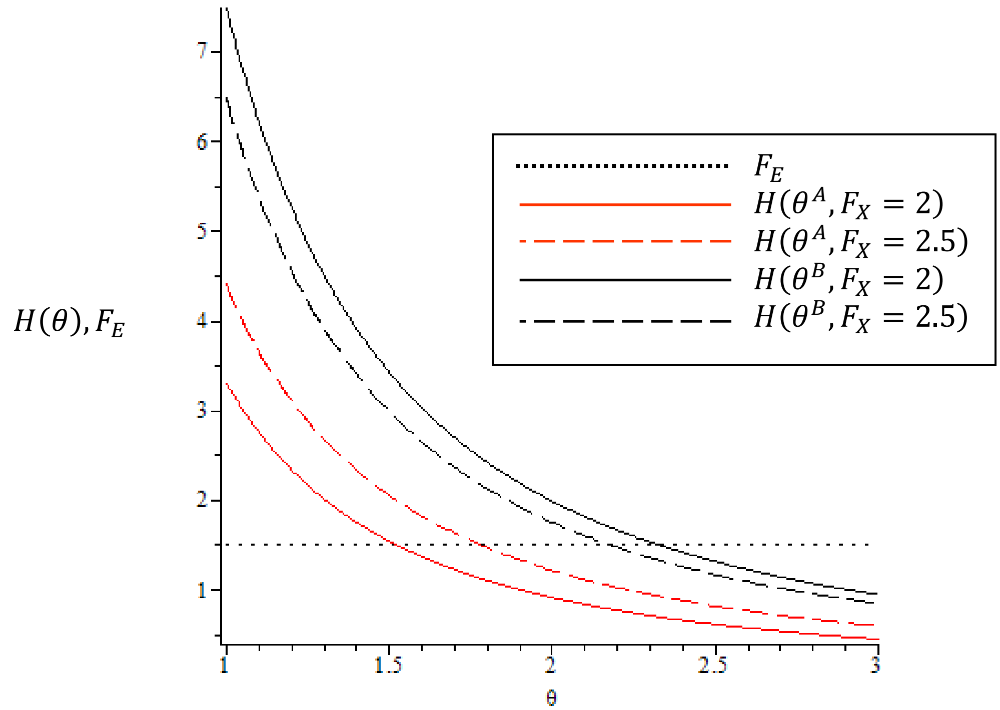
$$\frac{d\theta^i}{dF_X} = -\left[\frac{\frac{\partial H\left(\theta^i\right)}{\partial F_X}}{\frac{\partial H(\theta^i)}{\partial \theta^i}}\right], \qquad i = A, B, C, D. \tag{30}$$

The derivation for each comparative static can be found in the appendix. The results are as follows:

$$\frac{d\theta^A}{dF_X} > 0, \frac{d\theta^B}{dF_X} < 0, \frac{d\theta^C}{dF_X} < 0, \frac{d\theta^D}{dF_X} > 0 \tag{31}$$

Figure 11 and Figure 12 illustrate changes in the model equilibrium for changes in F_X, the fixed export cost. In Figure 11, F_X increases from 2 to 2.5 $H(\theta^A)$ shifts outward, while $H(\theta^B)$ shifts in the opposite direction. Holding F_E constant, the figure shows the equilibrium value of θ^A increases from 1.5 to 1.8 and the equilibrium value of θ^B decreases from 2.3 to 2.2.

Figure 11: Comparative Statics for Fixed Export Costs in the LN/LE/HE Case



In Figure 12, F_X increases from 12 to 18. The results are qualitatively similar to those shown in Figure 13. Holding F_E constant, the equilibrium value of θ^D increases from 1.8 to 2.4. The equilibrium value of θ^C decreases from 1.2 to 1.1, despite the fact firms near θ^C will never sink F_X.

Figure 12: Comparative Statics for Fixed Export Costs in the LN/HN/HE Case

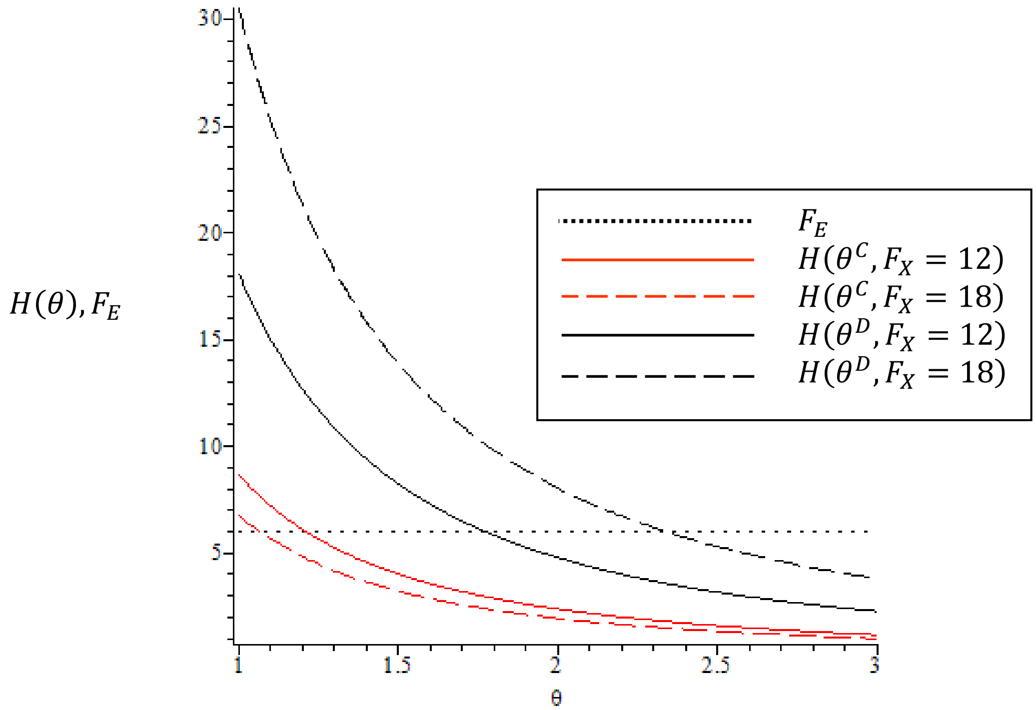


Table 4 shows percentage changes relative to baseline given a change in F_X for each of the productivity cut-offs, as well total quality (TQ) and the quality-adjusted price index (normalizing $p = 1$).

Table 4: Simulation Results for Changes in Fixed Export Costs

	LN/LE/HE	LN/HN/HE
θ^A	+20%	
θ^B	-4%	
θ^C		-8%
θ^D		+33%
TQ	-8%	-17%
P	+10%	+157%

Recalling θ^A and θ^D correspond to export cut-offs, the signs of their corresponding comparative statics should not be surprising. Raising F_X makes exporting more expensive. Firms that were previously indifferent between exporting and not exporting will choose to serve only the domestic market.

The signs on the comparative statics for θ^B and θ^C are less intuitive. These both represent certification cut-offs. θ^B is the certification cut-off conditional on participating in export markets, while θ^C is the certification cut-off conditional on *not* participating in export markets. In neither case will a (small) change in F_X induce a change in exporting behavior. For θ^B, an increase in F_X will lower the profits associated with the HE strategy, but it will not lower profits *relative* to the those associated with the LE strategy. Firms with θ close to θ^C will not sink F_X regardless of whether it increases or decreases. Changes in F_X therefore have no *direct* effect on a firm's optimal certification strategy. The relationship between the certification cut-offs and F_X operates through the CES price indices. Given $\frac{d\theta^A}{dF_X} > 0$ and $\frac{d\theta^D}{dF_X} > 0$, raising F_X will reduce the number of foreign firms entering the home market. This will make the home market less competitive overall and raise profits for domestic firms. Given a higher level of profit at every level of productivity, domestic firms with θ previously just below the certification cut-off will now be willing to adopt the voluntary certification.

As with F_E, these results show increasing fixed export costs reduces welfare, regardless of its effect on participation in the voluntary standard. In both the LN/LE/HE and LN/HN/HE cases, export participation falls while participation in the voluntary standard rises. This latter effect is generally insufficient to compensate for the negative welfare effects of lost trade. The net result is a reduction in the total number of high-quality varieties available in each market. The quality-adjusted price index also rises.

3.3: Transportation Costs

Raising transportation costs (τ) increases the per-unit costs a domestic firm must pay to sell output in the foreign country. This makes comparative statics for transportation costs of particular interest because they are a close analogy to tariff barriers. Deriving the comparative static requires totally differentiating $Q(\theta^i)$ with respect to τ and θ^i for $i = A, B, C, D$.

The resulting expression is:

$$\frac{d\theta^i}{d\tau} = -\left[\frac{\frac{\partial H(\theta^i)}{\partial \tau}}{\frac{\partial H(\theta^i)}{\partial \theta^i}}\right], \qquad i = A, B, C, D. \tag{32}$$

The derivation of each comparative static can be found in the appendix. The comparative statics for export cut-offs θ^A and θ^D are unambiguous:

$$\frac{d\theta^A}{d\tau} > 0, \frac{d\theta^D}{d\tau} > 0 \tag{33}$$

As with F_X, raising transportation costs unambiguously raises the export cut-offs. The intuition behind this result is simple: raising the costs associated with shipping each unit to the foreign market makes domestic firms less willing to engage in export markets.

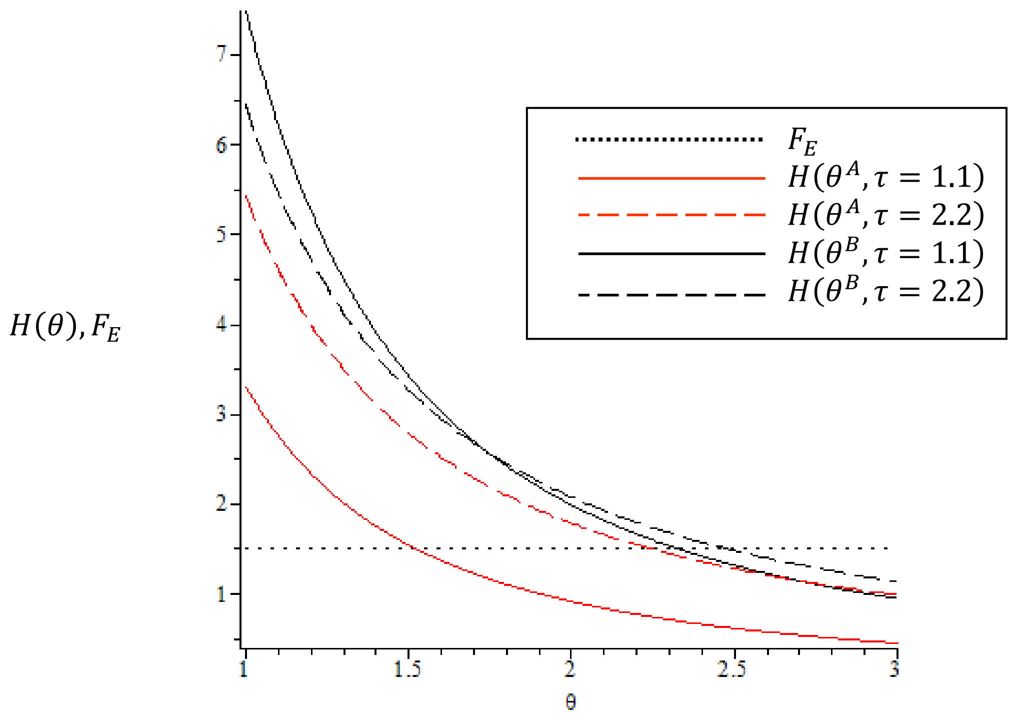
The effect of changes in τ on the certification decision is more ambiguous. As shown in the appendix, it is possible to impose restrictions on the relative magnitudes of certain model parameters such that the comparative statics for τ mirror those for F_X. This result would be reasonable for θ^B, where firms near the certification cut-off will not pay τ regardless of whether it increases or decreases. The primary effect on the certification decision would therefore be through decreased competitiveness in the domestic market as fewer foreign firms enter. An increase in τ would therefore lead to a decrease in the certification productivity cut-off for import-competing firms: $\frac{d\theta^C}{d\tau} < 0$.

Increases in F_X lower the certification cut-off for export-competing firms (θ^B). This result derives entirely from the general equilibrium effects of higher fixed export costs. While export-competing firms considering certification must pay F_X, the effect of an increase in F_X is the same whether they sell high-quality or low-quality goods. There is no direct change in the relative profitability of the LE and HE strategies. The same is not true for τ. As shown in equation (6), changes in τ affect price-setting behavior in the foreign market. When τ increases, firms must set a higher nominal price in the foreign market. This will shrink market share and profits, and given the properties expressed in (9), they will shrink faster for firms producing high-quality output. While firms will still indirectly benefit from the indirect effects of decreased market competitiveness, the direct effect will be to discourage investment in the voluntary certification. If the latter effect is sufficiently large, then an increase in τ will decrease the rate of certification adoption among export-competing firms: $\frac{d\theta^B}{d\tau} > 0$.

Figure 13 and Figure 14 illustrate changes in the model equilibrium for changes in τ, the transportation costs. In Figure 13, an increase in τ from 1.1 to 2.2 shifts $H(\theta^A)$ outward. Holding F_E constant, θ^A will increase from approximately 1.5 to 2.3. As with F_X, this is because raising τ makes exporting more expensive. The same increase in τ causes $H(\theta^B)$ to rotate around a particular value of θ^B. This corresponds to the result shown in equation E(21), which implies the sign of the comparative static with respect to τ depends on the value of θ^B from which the equilibrium deviates. Given the parameter values described in Table 2, θ^B increases from 2.3 to 2.5. This is because an increase in τ leads to a larger loss of profit for sellers of high-quality goods in the foreign market. If F_E

increased to 3, then the same increase in τ would *decrease* the equilibrium value of θ^B. The sign of the comparative static depends on the net effect of two opposing forces: the general equilibrium effects of greater domestic protection and the direct effect on revenues earned in the foreign market.

Figure 13: Comparative Statics for Transportation Costs in the LN/LE/HE Case



In Figure 14, an increase in τ from 1.1 to 3.0 shifts $H(\theta^D)$ out and causes $H(\theta^C)$ to rotate around a particular value of θ^C. Given the parameter values described in Table 2, the increase in τ decreases the equilibrium value of θ^C from 1.2 to 1.1 while the equilibrium value of θ^D increases from 1.8 to approximately 2. Once again, the result for the certification cut-off (θ^C) depends on the parameterization from which the model deviates. As Figure 16 shows, the equilibrium value of θ^C would fall if F_E were set very low.

Figure 14: Comparative Statics for Transportation Costs in the LN/HN/HE Case

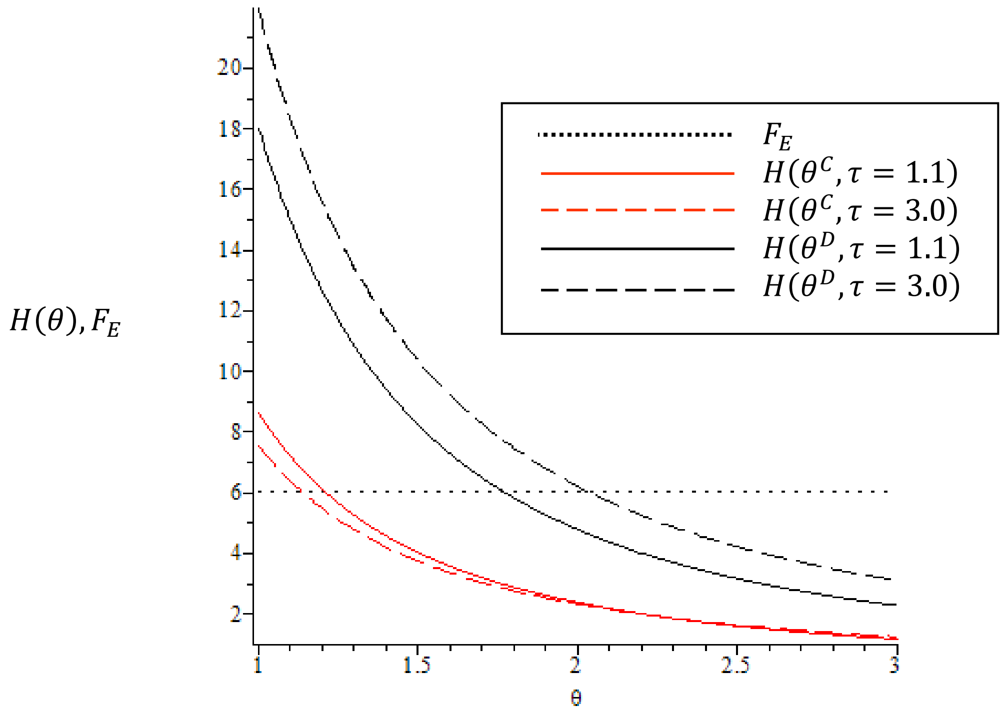


Table 5 shows percentage changes relative to baseline given a change in F_X for each of the productivity cut-off as well total quality (TQ) and the quality-adjusted price index (normalizing $p = 1$).

Table 5: Simulation Results for Changes in Transportation Costs

	LN/LE/HE	LN/HN/HE
θ^A	+53%	
θ^B	+9%	
θ^C		-8%
θ^D		+11%
TQ	-3%	-1%
P	+23%	+41%

The results for the LN/HN/HE case are similar to those shown in Table 4. Raising τ raises the export cut-off and lowers the certification cut-off. However, total quality falls and quality-adjusted price rises as the market becomes less competitive. In the LN/LE/HE case, raising τ discourages export participation *and* participation in the voluntary standard. It also decreases welfare. This case is unique because it is the only one where lowering trade costs will increase the proportion of firms participating in the voluntary standard *and* raise consumer welfare.

4. Conclusions

The results presented here can improve our understanding of the relationship between participation in international markets and the adoption of a credible voluntary standard. The theoretical model is complementary to Sheldon and Roe (2009), and builds on existing work in the HFT framework by Podhorksy (2010, 2012) by incorporating fixed export costs and transportation costs. This allows for the derivation of comparative statics for the adoption of a voluntary standard given a change in trade policy. Adoption of the voluntary standard allows firms to overcome an otherwise binding information asymmetry problem similar to the one described in Akerlof (1970) and meet consumer demand for high-quality goods. The model treats quality as a credence attribute, so the framework is broadly applicable to topics of concern in debates over trade policy including product safety, sustainability and labor practices.

Changes in trade policy have the expected effects on firms' export decisions; raising fixed trade costs or transportation costs decreased the proportion of firms willing to enter export markets. The model can only provide a qualified answer to the question of whether or not lower trade barriers lead to higher production standards in the presence of a voluntary standard. The effect of a change in trade policy on certification adoption depends on the policy instrument in question and the competitive environment of the marginal uncertified firm. Strictly import-competing firms will generally be less willing to adopt certification in response to a decrease in trade barriers. Lowering trade barriers makes the firm's domestic market more competitive, meaning lower profit levels at every level of productivity. Given the high fixed costs associated with certification, firms that were previously indifferent will choose not to certify.

The same is true when fixed export costs are lowered for export-competing firms considering certification. However, lowering transportation costs can encourage certification adoption among export-competing firms. Lowering transportation costs will increase the profits firms earn in the foreign market. The total gains from a decrease in τ will be greater for producers of high-quality goods due to their larger market share in the foreign country. Firms that were previously indifferent will therefore choose to adopt the voluntary standard to reap these higher profits.

Transportation costs are a close analogy to tariff barriers, so the latter result is the most relevant in the debate over whether or not trade liberalization can raise production standards. The answer presented here is a qualified "yes," but the general ambiguity of the results might also explain why empirical analysis of microeconomic data has produced conflicting results in different country contexts. The model can also help inform future empirical analysis by explaining why firm size, sunk environmental protection costs and export participation might be correlated with the adoption of voluntary standards.

It should also be noted that increases in entry and trade costs unambiguously lower consumer welfare, regardless of their effect on participation in export markets or the voluntary standard. These welfare impacts measured only the private benefits derived from consumption. In reality, voluntary standards play an important role in managing the production of public goods, like environmental quality. The results presented here do not incorporate the types of external costs and benefits that would be important for fully evaluating changes in trade policy in the presence of a voluntary environmental standard.

There are several key extensions that would significantly expand the set of model predictions. First, being unable to characterize an equilibrium with both export and import-competing certified firms is an unfortunate consequence of the model's simplifying assumptions. It also makes it more difficult to apply the model results to a given country context, where these two cases are likely to coexist. This result stems from the fact that heterogeneity is confined to a single dimension. Both fixed export costs and certification costs are a function of the same productivity parameter (θ). As long as fixed export costs are independent of quality and certification costs are independent of export status, the model will generate two mutually exclusive equilibria: one where firms choose certification conditional on exporting, and one where firms choose certification conditional on not exporting. This can be avoided by extending firm heterogeneity to two dimensions, as in Kugler and Verhoogen (2012), but this substantially complicates the analysis. More simply, it would be sufficient to assume higher fixed export costs for high quality goods or higher fixed certification costs for exporters.

The model would also be improved by relaxing the assumption of strict symmetry between the two countries. The comparative statics implicitly assume policymakers implement identical policy changes in both countries. It would be beneficial to see whether or not these results change when policymakers act unilaterally. Relaxing the symmetry assumption would also allow the model to illustrate trade between a small, developing country and a large, developed country. This might change the underlying relationship between liberalization and certification. It would also be of particular interest because voluntary standards have been so widely adopted in the developing world. Developing countries may lack the political institutions necessary to implement strict legal standards for product safety, environmental protection or labor practices. Voluntary certification provides firms with an incentive to raise standards independent of the action of local regulators.

It would also be important to specify an external damage function to capture the public goods aspect of many of the issues addressed by voluntary standards. The comparative statics showed that private benefits decreased as entry and trade costs rose, even when increasing these costs increased rates of participation in the voluntary standard. If adopting the voluntary standard yields substantial positive external benefits, then the overall welfare impact of a change in trade policy could be positive, even if it reduces private benefits enjoyed by consumers.

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Appendix

A: Eliminating HN from the LN/LE/HE Case

It must be shown that whenever any subset of firms chooses to export low-quality products, it must be that no firm would choose to sell high-quality products in their home market. If some firms choose the LE strategy, then there must exist some θ s.t.:

$$\pi_i(q_L) < \pi_i(q_L) + \pi_j(q_L) - w_i F_X(\theta) \tag{A1}$$

Or,

$$w_i F_X(\theta) < \pi_j(q_L) \tag{A1a}$$

This same range of θ must also satisfy:

$$\pi_i(q_H) + \pi_j(q_H) - w_i F_X(\theta) - w_i \delta(\theta) < \pi_i(q_L) + \pi_j(q_L) - w_i F_X(\theta) \tag{A2}$$

Or

$$[\pi_i(q_H) - \pi_i(q_L)] + \left[\pi_j(q_H) - \pi_j(q_L)\right] < w_i \delta(\theta) \tag{A2a}$$

Equations (A1a) and (A2a) jointly imply that the HN strategy is strictly dominated. In other words, they imply:

$$\pi_i(q_H) - w_i \delta(\theta) < \pi_i(q_L) + \pi_j(q_L) - w_i F_X(\theta) \tag{A3}$$

Rearranging terms in (A3):

$$[\pi_i(q_H) - \pi_i(q_L)] - w_i \delta(\theta) < \pi_j(q_L) - w_i F_X(\theta) \tag{A3a}$$

Equation (A2a) implies the left-hand side of (A3a) is strictly negative, given the result from (7) and (8) that operating profit is everywhere increasing in quality. Equation (A1a) implies the right-hand side of (A3a) is strictly positive. This ensures (A3a) holds as long as (A1a) and (A2a) are true. Combined with the concavity and monotonicity of the payoffs described in the matrix, this ensures that the No Exports/Certification strategy will be strictly dominated over the whole range of θ.

B: Eliminating LE from the LN/HN/HE Case

It must be shown that, whenever any subset of firms chooses to sell high-quality products only in the domestic market, it must be that no firm would choose to export low-quality products. If some firms choose the No Export/Certification strategy, then there must exist some θ s.t.:

$$\pi_i(q_l) < \pi_i(q_h) - w_i\delta(\theta) \tag{B1}$$

Or,

$$w_i\delta(\theta) < \pi_i(q_h) - \pi_i(q_l) \tag{B1a}$$

This same range of θ must also satisfy:

$$\pi_i(q_H) + \pi_j(q_H) - w_iF_X(\theta) - w_i\delta(\theta) < \pi_i(q_H) - w_i\delta(\theta) \tag{B2}$$

Or

$$\pi_j(q_H) < w_iF_X(\theta) \tag{B2a}$$

Equations (B1a) and (B2a) jointly imply that the Export/No Certification strategy is strictly dominated. In other words, they imply:

$$\pi_i(q_L) + \pi_j(q_L) - w_iF_X(\theta) < \pi_i(q_H) - w_i\delta(\theta) \tag{B3}$$

Rearranging terms in (B3):

$$\pi_j(q_L) - w_iF_X(\theta) < \pi_i(q_H) - \pi_i(q_L) - w_i\delta(\theta) \tag{B3a}$$

Equation (B2a) implies the right-hand side of (B3a) is strictly negative. Equation (B1a) implies the right-hand side of (B3a) is strictly positive. This ensures (B3) holds as long as (B1a) and (B2a) are true. Combined with the concavity and monotonicity of the payoffs described in the matrix, this ensures that the Exports/No Certification strategy will be strictly dominated over the whole range of θ.

C: Definition of the Model Equilibrium in the LN/LE/HE Case

Equations (15), (16) and (17) can be used to demonstrate the existence and uniqueness of the model equilibrium in the case where the strategies designate LN, LE, and HE dominate. It is first necessary to establish several preliminary results. Take the definition of the quality-adjusted CES price index:

$$\tilde{P}_i^{\,1-\sigma} = \int_{\omega \epsilon \Omega_i} \lambda(q_\omega) \cdot p_i(\omega)^{1-\sigma} d\omega \tag{C1}$$

For the two-country case, it can be expressed as:

$$\begin{aligned}\tilde{P}_i^{\,1-\sigma} = M_i \Big\{ &\int_{\underline{\theta}_i}^{\theta_i^A} \lambda(q_L) \cdot p_i^{\,1-\sigma} g(\theta) d\theta \\ &+ \int_{\theta_i^A}^{\theta_i^B} \lambda(q_L) \cdot p_i^{\,1-\sigma} g(\theta) d\theta + \int_{\theta_i^B}^{\infty} \lambda(q_H) \cdot p_i^{\,1-\sigma} g(\theta) d\theta \Big\} \\ &+ M_j \left\{ \int_{\theta_j^A}^{\theta_j^B} \lambda(q_L) \cdot (\tau p_j)^{1-\sigma} g(\theta) d\theta + \int_{\theta_j^B}^{\infty} \lambda(q_H) \cdot (\tau p_j)^{1-\sigma} g(\theta) d\theta \right\}\end{aligned} \tag{C2}$$

Note the asymmetry between the domestic and foreign contributions to the price index: the index for country i includes all country i firms, but only includes the subset of country j firms that opt into exporting. For simplicity, assume there are two symmetric countries, in the sense that $L_i = L_j$. This implies (C2) can be rewritten as:

$$\begin{aligned}\tilde{P}^{1-\sigma} = M p^{1-\sigma} &\left\{ \lambda(q_L) \int_{\underline{\theta}}^{\theta^B} g(\theta) d\theta + \lambda(q_H) \int_{\theta^B}^{\infty} g(\theta) d\theta \right\} \\ &+ M(\tau p)^{1-\sigma} \left\{ \lambda(q_L) \int_{\theta^A}^{\theta^B} g(\theta) d\theta + \lambda(q_H) \int_{\theta^B}^{\infty} g(\theta) d\theta \right\}\end{aligned}$$

Recalling the definition of the distribution function $G(\theta)$, this can also be rewritten as:

$$\tilde{P}^{1-\sigma} = Mp^{1-\sigma}\{\lambda(q_L)G(\theta^B) + \lambda(q_H)[1 - G(\theta^B)]\}$$

$$+ M(\tau p)^{1-\sigma}\{\lambda(q_L)[G(\theta^B) - G(\theta^A)] + \lambda(q_H)[1 - G(\theta^B)]\} \qquad \text{(C3)}$$

For convenience, define:

$$Q_i = \lambda(q_L)G(\theta_i^B) + \lambda(q_H)[1 - G(\theta_i^B)] \qquad \text{(C4)}$$

This represents the average quality level produced in a given country. Substituting from (C4), (C3) becomes:

$$\tilde{P}^{1-\sigma} = Mp^{1-\sigma}\left\{Q + \tau^{1-\sigma}\left(Q - \lambda(q_L)G(\theta^A)\right)\right\}$$

Or,

$$\tilde{P}^{1-\sigma} = Mp^{1-\sigma}\{(1 + \tau^{1-\sigma})Q - \tau^{1-\sigma}\lambda(q_L)G(\theta^A)\} \qquad \text{(C5)}$$

From (2):

$$\pi_i(\omega_i) = p_i(\omega)^{1-\sigma}\lambda(q_\omega)\frac{E_i}{\sigma\tilde{P}_i^{1-\sigma}} \qquad \text{(C6)}$$

This is the profit a firm from country *i* earns by selling output with quality q_ω in country *i*. Allowing for symmetry and substituting from (C5) yields:

$$\pi_i(\omega_i) = \lambda(q_\omega)\frac{E}{\sigma M\left\{(1+\tau^{1-\sigma})Q - \tau^{1-\sigma}\lambda(q_L)G\left(\theta^A\right)\right\}} \qquad \text{(C6a)}$$

Similarly, the profits a firm in country *i* earns by selling output with quality q_ω in country *j* can be expressed by substituting (C5) into (9) and allowing for symmetry yields:

$$\pi_j(\omega_i) = \tau^{1-\sigma}\lambda(q_\omega)\frac{E}{\sigma M\left\{(1+\tau^{1-\sigma})Q - \tau^{1-\sigma}\lambda(q_L)G\left(\theta^A\right)\right\}} \qquad \text{(C7)}$$

Substitute this result into (15):

$$\tau^{1-\sigma}\lambda(q_L)\frac{E}{\sigma M\left\{(1+\tau^{1-\sigma})Q - \tau^{1-\sigma}\lambda(q_L)G\left(\theta^A\right)\right\}} = w_i F_x(\theta^A)$$

Rearranging terms:

$$\frac{L}{\sigma M\left\{(1+\tau^{1-\sigma})Q - \tau^{1-\sigma}\lambda(q_L)G\left(\theta^A\right)\right\}} = \frac{F_x\left(\theta^A\right)}{\tau^{1-\sigma}\lambda(q_L)} \qquad \text{(C5a)}$$

Substituting (C6a) and (C7) into (15) and rearranging terms yields:

$$\frac{L\cdot[\lambda(q_H)-\lambda(q_L)]\cdot[1+\tau^{1-\sigma}]}{\sigma M\{(1+\tau^{1-\sigma})Q-\tau^{1-\sigma}\lambda(q_L)G(\theta^A)\}}=\delta(\theta^B)$$

Or,

$$\frac{L}{\sigma M\{(1+\tau^{1-\sigma})Q-\tau^{1-\sigma}\lambda(q_L)G(\theta^A)\}}=\frac{\delta(\theta^B)}{[\lambda(q_H)-\lambda(q_L)]\cdot[1+\tau^{1-\sigma}]} \qquad \text{(C9)}$$

Equating (C5a) and (C6a) yields:

$$\frac{\delta(\theta^B)}{[\lambda(q_H)-\lambda(q_L)]\cdot[1+\tau^{1-\sigma}]}=\frac{F_x(\theta^A)}{\tau^{1-\sigma}\lambda(q_L)} \qquad \text{(C10)}$$

This expression defines θ^B in terms of θ^A and model parameters, and vice-versa. Defining the equilibrium requires deriving an expression that defines one of the variables of interest only in terms of model parameters. Given (C7), it is only necessary to derive one additional expression defining θ^A and θ^B as a function of model parameters.

Finding such an expression requires making use of (15). The expected operating profit term ($E_i[\pi]$) can be expressed as:

$$E_i[\pi]\equiv\int_{\underline{\theta}_i}^{\theta_i^A}\pi_i(q_L)g(\theta)d\theta+\int_{\theta_i^A}^{\theta_i^B}\left[\pi_i(q_L)+\pi_j(q_L)\right]g(\theta)d\theta$$

$$+\int_{\theta_i^B}^{\infty}\left[\pi_i(q_H)+\pi_j(q_H)\right]g(\theta)d\theta \qquad \text{(C11)}$$

Substituting from (C6a) and (C10) and allowing for symmetry allows this to be rewritten from (C11) as:

$$E_i[\pi]=\frac{L}{\sigma M\{(1+\tau^{1-\sigma})Q-\tau^{1-\sigma}\lambda(q_L)G(\theta^X)\}}\Big\{\lambda(q_L)\int_{\underline{\theta}_i}^{\theta_i^A}g(\theta)d\theta+$$

$$[1+\tau^{1-\sigma}]\lambda(q_L)\int_{\theta_i^A}^{\theta_i^B}g(\theta)d\theta+[1+\tau^{1-\sigma}]\lambda(q_H)\int_{\theta_i^B}^{\infty}g(\theta)d\theta$$

Or,

$$E_i[\pi] = \frac{E}{\sigma M\{(1+\tau^{1-\sigma})Q - \tau^{1-\sigma}\lambda(q_L)G(\theta^A)\}}\{\lambda(q_L)G(\theta^A) +$$

$$[1+\tau^{1-\sigma}]\lambda(q_L)[G(\theta^B) - G(\theta^A)] + [1+\tau^{1-\sigma}]\lambda(q_H)[1 - G(\theta^B)]$$

And finally, after substituting from (C5):

$$E_i[\pi] = \frac{E}{\sigma M} \tag{C11a}$$

Substituting this into (15) yields:

$$\frac{E}{\sigma M} - w_i E[F_x(\theta)] - w_i E[\delta(\theta)] = w_i F_E$$

or,

$$\frac{L}{\sigma M} - E[F_x(\theta)] - E[\delta(\theta)] = F_E \tag{C12}$$

Equation (C12) can be further simplified by evaluating the expected values of the fixed export and certification costs. Because only a subset of firms will sink $F_x(\theta)$ and $\delta(\theta)$, the remaining terms in (C12) must be evaluated as conditional expectations. The expected fixed export costs are therefore:

$$E[F_x(\theta)] = E[F_x(\theta)|\theta \geq \theta^A] = \int_{\theta^A}^{\infty} F_x(\theta)\mu(\theta)d\theta \tag{C13}$$

Where $\mu(\theta) \equiv \frac{g(\theta)}{1-G(\theta^X)}$. Substituting this expression and (14) into (C13) yields:

$$E[F_x(\theta)] = \frac{F_x}{1-G(\theta^A)}\int_{\theta^A}^{\infty} \theta^{-1} g(\theta)d\theta \tag{C14}$$

From the definition of $G(\theta)$, $g(\theta) = s\theta^{-(s+1)}$. This implies:

$$E[F_x(\theta)] = \frac{sF_x}{(\theta^A)^{-s}}\int_{\theta^A}^{\infty} \theta^{-(s+2)}d\theta$$

And finally,

$$E[F_x(\theta)] = \frac{s}{s+1}\frac{F_x}{\theta^X} = \frac{s}{s+1}F_x(\theta^A) \tag{C14}$$

A similar expression for the expected certification costs can also de derived:

$$E[\delta(\theta)] = E[\delta(\theta)|\theta \geq \theta^B] = \int_{\theta^B}^{\infty} \delta(\theta)\mu(\theta)d\theta \tag{C15}$$

Which implies:

$$E[\delta(\theta)] = \frac{s}{s+1}\frac{[q_H - q_L]}{\theta^B} = \frac{s}{s+1}\delta(\theta^B) \qquad \text{(C16)}$$

Substituting (C14) and (C16) into (C12) yields:

$$\frac{L}{\sigma M} - \frac{s}{s+1}F_x(\theta^A) - \frac{s}{s+1}\delta(\theta^B) = F_E \qquad \text{(C17)}$$

This expression is now in terms of all three endogenous variables: M, θ^X and θ^C. Substituting (C5a) into (C17):

$$\frac{F_x(\theta^A)}{\tau^{1-\sigma}\lambda(q_L)}\{(1+\tau^{1-\sigma})Q - \tau^{1-\sigma}\lambda(q_L)G(\theta^A)\} - \frac{s}{s+1}F_x(\theta^A) - \frac{s}{s+1}\delta(\theta^B) = F_E \text{ (C18)}$$

Recalling the definition of Q from (C4), (C18) is now an expression in terms of only θ^A, θ^B and model parameters. Combining (C18) with (C10) will define the equilibrium value of either θ^A or θ^B in terms of only model parameters. Before proceeding to this final expression, it is possible to simplify the bracketed term on the left-hand side of (C18) by substituting from (C4) and the definition of $G(\theta)$.

$$\{(1+\tau^{1-\sigma})\big[\lambda(q_L) - G(\theta^B)\big(\lambda(q_H) - \lambda(q_L)\big)\big] - \tau^{1-\sigma}\lambda(q_L)G(\theta^A)\} =$$

$$\{(1+\tau^{1-\sigma})\big[\lambda(q_L) - (1-(\theta^B)^{-s})\big(\lambda(q_H) - \lambda(q_L)\big)\big] - \tau^{1-\sigma}\lambda(q_L)(1-(\theta^A)^{-s})\} =$$

$$\{\lambda(q_L) + (\theta^B)^{-s}\big(\lambda(q_H) - \lambda(q_L)\big)(1+\tau^{1-\sigma}) + \tau^{1-\sigma}\lambda(q_L)(\theta^A)^{-s}\} \qquad \text{(C19)}$$

Substituting (C19) into (C18) yields:

$$\frac{F_x(\theta^X)}{\tau^{1-\sigma}\lambda(q_L)}\{\lambda(q_L) + (\theta^B)^{-s}\big(\lambda(q_H) - \lambda(q_L)\big)(1+\tau^{1-\sigma}) + \tau^{1-\sigma}\lambda(q_L)(\theta^A)^{-s}\}$$

$$-\frac{s}{s+1}F_x(\theta^A) - \frac{s}{s+1}\delta(\theta^B) = F_E \qquad \text{(C20)}$$

The last two terms on the left-hand side of (C20) can be rewritten as:

$$\frac{s}{s+1}\{F_x(\theta^A) + \delta(\theta^B)\}.$$

Substituting (C10) into this expression yields:

$$\frac{s}{s+1}\left\{F_x(\theta^A)+F_x(\theta^A)\frac{[\lambda(q_H)-\lambda(q_L)]}{\lambda(q_L)}\frac{[1+\tau^{1-\sigma}]}{\tau^{1-\sigma}}\right\}$$

$$=\frac{s}{s+1}\left\{F_x(\theta^A)\frac{\lambda(q_H)}{\lambda(q_L)}[1+\tau^{\sigma-1}]-F_x(\theta^A)\tau^{\sigma-1}\right\}$$

Replacing this expression in (C20) and collecting terms yields:

$$F_x(\theta^A)\tau^{\sigma-1}+F_x(\theta^A)\frac{\left(\lambda(q_H)-\lambda(q_L)\right)}{\lambda(q_L)}\frac{(1+\tau^{1-\sigma})}{\tau^{1-\sigma}}(\theta^B)^{-s}+F_x(\theta^A)(\theta^A)^{-s}$$

$$-\frac{s}{s+1}\left\{F_x(\theta^A)\frac{\lambda(q_H)}{\lambda(q_L)}[1+\tau^{\sigma-1}]-F_x(\theta^A)\tau^{\sigma-1}\right\}=F_E$$

or equivalently,

$$\frac{F_x(\theta^A)}{s+1}\left\{\tau^{\sigma-1}\left[2s+1-s\frac{\lambda(q_H)}{\lambda(q_L)}\right]-s\frac{\lambda(q_H)}{\lambda(q_L)}\right\}+F_x(\theta^A)(\theta^A)^{-s}$$

$$+F_x(\theta^A)\frac{\left(\lambda(q_H)-\lambda(q_L)\right)}{\lambda(q_L)}[1+\tau^{\sigma-1}](\theta^B)^{-s}=F_E$$

Substituting from (C7) and (14) again yields:

$$(\theta^A)^{-1}F_x\left\{\frac{(2s+1)\lambda(q_L)-\left[1+\tau^{1-\sigma}\right]s\lambda(q_H)}{\lambda(q_L)(s+1)\tau^{1-\sigma}}\right\}+(\theta^A)^{-(s+1)}F_x$$

$$+(\theta^A)^{-(s+1)}\left[\frac{\left(\lambda(q_H)-\lambda(q_L)\right)}{\lambda(q_L)}[1+\tau^{\sigma-1}]\right]^{s+1}\frac{{F_x}^{s+1}}{(q_H-q_L)^s}=F_E \tag{C21}$$

Equation (C19) expresses the equilibrium export cut-off for the LN/LE/HE case (θ^A) in terms of only model parameters. It is possible to derive a similar expression to identify θ^B using only model parameters. Substituting (C10) into (C20) yields:

$$\frac{L}{\sigma M}-\frac{s}{s+1}\left\{\delta(\theta^B)+\delta(\theta^B)\frac{\lambda(q_L)\tau^{1-\sigma}}{[\lambda(q_H)-\lambda(q_L)][1+\tau^{1-\sigma}]}\right\}=F_E \tag{C22}$$

From (C6):

$$\frac{L}{\sigma M}=\frac{\delta(\theta^B)\left\{(1+\tau^{1-\sigma})Q-\tau^{1-\sigma}\lambda(q_L)G(\theta^A)\right\}}{[\lambda(q_H)-\lambda(q_L)]\cdot[1+\tau^{1-\sigma}]}$$

Substituting (C10) into (C19) yields:

$$\{(1+\tau^{1-\sigma})Q - \tau^{1-\sigma}\lambda(q_L)G(\theta^A)\} = \{\lambda(q_L) + (\theta^B)^{-s}\big(\lambda(q_H)-\lambda(q_L)\big)(1+\tau^{1-\sigma})$$

$$+\tau^{1-\sigma}\lambda(q_L)(\theta^B)^{-s}\left[\frac{[q_H-q_L]\lambda(q_L)\tau^{1-\sigma}}{[\lambda(q_H)-\lambda(q_L)][1+\tau^{1-\sigma}]F_x}\right]^s\Bigg\} \quad \text{(C23)}$$

Substituting (C23) (C9) and then into (C22) yields:

$$\frac{\delta(\theta^B)}{[\lambda(q_H)-\lambda(q_L)][1+\tau^{1-\sigma}]}\Bigg\{\{\lambda(q_L) + (\theta^B)^{-s}\big(\lambda(q_H)-\lambda(q_L)\big)(1+\tau^{1-\sigma}) +$$

$$\tau^{1-\sigma}\lambda(q_L)(\theta^B)^{-s}\left[\frac{[q_H-q_L]\lambda(q_L)\tau^{1-\sigma}}{[\lambda(q_H)-\lambda(q_L)][1+\tau^{1-\sigma}]F_x}\right]^s\Bigg\} - \frac{s}{s+1}\delta(\theta^B)\left\{1+\frac{\lambda(q_L)\tau^{1-\sigma}}{[\lambda(q_H)-\lambda(q_L)][1+\tau^{1-\sigma}]}\right\} = F_E$$

Or,

$$(\theta^B)^{-1}[q_H-q_L]\left\{\frac{(2s+1)\lambda(q_L)-[1+\tau^{1-\sigma}]s\lambda(q_H)}{[\lambda(q_H)-\lambda(q_L)][1+\tau^{1-\sigma}](s+1)}\right\} + (\theta^B)^{-(s+1)}[q_H-q_L]$$

$$+(\theta^B)^{-(s+1)}\left(\frac{[q_H-q_L]\lambda(q_L)}{[\lambda(q_H)-\lambda(q_L)]}\right)^{s+1}([1+\tau^{\sigma-1}])^{-(s+1)}F_x{}^{-s} = F_E \qquad \text{(C24)}$$

Equation (C24) defines the equilibrium certification productivity cut-off (θ^B) in terms of only model parameters.

D: Definition of the Model Equilibrium in the LN/HN/HE Case

It is first necessary to redefine the price index from (C2) to reflect the new productivity cut-offs:

$$\tilde{P}_i{}^{1-\sigma} = M_i\left\{\int_{\underline{\theta}_i}^{\theta_i^C}\lambda(q_L)\cdot p_i{}^{1-\sigma}g(\theta)d\theta + \int_{\theta_i^C}^{\theta_i^D}\lambda(q_H)\cdot p_i{}^{1-\sigma}g(\theta)d\theta\right.$$

$$\left.+\int_{\theta_i^D}^{\infty}\lambda(q_H)\cdot p_i{}^{1-\sigma}g(\theta)d\theta\right\} + M_j\left\{\int_{\theta_j^D}^{\infty}\lambda(q_H)\cdot\left(\tau p_j\right)^{1-\sigma}g(\theta)d\theta\right\} \qquad \text{(D1)}$$

Comparing (C2) and (D1), the domestic component of the price index is more-or-less unchanged. The foreign component reflects the fact that only high-quality varieties are exported in this specification of the model. Recalling the definition of $G(\theta)$ and allowing for symmetry:

$$\tilde{P}^{1-\sigma} = M\left[p^{1-\sigma}\{\lambda(q_L)G(\theta^C) + \lambda(q_H)[1 - G(\theta^C)]\} + (\tau p)^{1-\sigma}\lambda(q_H)[1 - G(\theta^D)]\right] \text{(D1a)}$$

The expression for the average level of quality produced in country i becomes:

$$Q_i = \lambda(q_L)G\left(\theta_i^C\right) + \lambda(q_H)[1 - G(\theta_i^D)] \qquad \text{(D2)}$$

Substituting (D2) into (D1a) yields:

$$\tilde{P}^{1-\sigma} = Mp^{1-\sigma}\left[Q + \tau^{1-\sigma}\lambda(q_H)[1 - G(\theta^D)]\right] \qquad \text{(D1b)}$$

Substituting (9) into (21) yields:

$$\frac{Ep^{1-\sigma}}{\sigma\tilde{P}^{1-\sigma}}[\lambda(q_H) - \lambda(q_L)] = w\delta(\theta^C) \qquad \text{(D3)}$$

Substituting from (D1b):

$$\frac{L}{\sigma M\left[Q + \tau^{1-\sigma}\lambda(q_H)[1-G(\theta^D)]\right]} = \frac{\delta(\theta^C)}{[\lambda(q_H)-\lambda(q_L)]} \qquad \text{(D3a)}$$

An analogous expression for θ^D can be found by substituting (10) into (22):

$$\frac{E\cdot(\tau p)^{1-\sigma}}{\sigma\tilde{P}^{1-\sigma}}\lambda(q_H) = wF_X(\theta^D) \qquad \text{(D4)}$$

Substituting again from (D1b):

$$\frac{L}{\sigma M\left[Q + \tau^{1-\sigma}\lambda(q_H)[1-G(\theta^D)]\right]} = \frac{F_X(\theta^D)}{\lambda(q_H)\tau^{1-\sigma}} \qquad \text{(D4a)}$$

Equating (D3a) and (D4a) yields an expression defining θ^C in terms of only model parameters and θ^D, and vice-versa:

$$\frac{\delta(\theta^C)}{[\lambda(q_H)-\lambda(q_L)]} = \frac{F_X(\theta^D)}{\lambda(q_H)\tau^{1-\sigma}} \qquad \text{(D5)}$$

To finish defining the model equilibrium, it is necessary to find at least one more expression in terms of only θ^C, θ^D and model parameters. As before, it is possible to use

(17) to derive such an expression. Redefining the expected profit term ($E[\pi]$) to reflect the new productivity cut-offs yields:

$$E_i[\pi] = \int_{\underline{\theta}_i}^{\theta_i^C} \pi_i(q_L)g(\theta)d\theta + \int_{\theta_i^C}^{\theta_i^D} \pi_i(q_H)g(\theta)d\theta$$

$$+ \int_{\theta_i^D}^{\infty}\left[\pi_i(q_H) + \pi_j(q_H)\right]g(\theta)d\theta \qquad \text{(D6)}$$

Allowing for symmetry and substituting from (8) and (9) yields:

$$E[\pi] = \frac{Ep^{1-\sigma}}{\sigma\tilde{P}^{1-\sigma}}\{\lambda(q_L)G(\theta^C) + \lambda(q_H)[1 - G(\theta^C)]$$

$$+\tau^{1-\sigma}\lambda(q_H)[1 - G(\theta^D)]\} \qquad \text{(D6a)}$$

Equations (D1b) and (D2) can then be used to simplify (D5a) as in the LN/LE/HE case:

$$E[\pi] = \frac{L}{\sigma M} \qquad \text{(D7)}$$

Substituting (D6) into (17) yields the same expression as (C15). The expected fixed cost terms in (C15) can be evaluated largely as before. It is necessary to adjust the expressions to reflect the different productivity cut-offs for the LN/HN/HE case.

$$E[\delta(\theta)] = \frac{s}{s+1}\frac{[q_H - q_L]}{\theta^C} = \frac{s}{s+1}\delta(\theta^C) \qquad \text{(D8)}$$

$$E[F_x(\theta)] = \frac{s}{s+1}\frac{F_x}{\theta^D} = \frac{s}{s+1}F_x(\theta^D) \qquad \text{(D9)}$$

Substituting (D7) and (D8) into (C15) yields:

$$\frac{L}{\sigma M} - \frac{s}{s+1}F_x(\theta^D) - \frac{s}{s+1}\delta(\theta^C) = F_E \qquad \text{(D10)}$$

Substitute (D5) into (D10) to eliminate the $\delta(\theta^C)$ term:

$$\frac{L}{\sigma M} - \frac{s}{s+1}\left\{F_x(\theta^D) - \frac{F_x(\theta^D)}{\lambda(q_H)\tau^{1-\sigma}}[\lambda(q_H) - \lambda(q_L)]\right\} = F_E$$

M can be eliminated from (D10) by substituting from (D4a):

$$\frac{F_X(\theta^D)}{\lambda(q_H)\tau^{1-\sigma}}\left[Q+\ \tau^{1-\sigma}\lambda(q_H)[1-G(\theta^D)]\right]$$

$$-\frac{s}{s+1}\left\{F_x(\theta^D)+\frac{F_x(\theta^D)}{\lambda(q_H)\tau^{1-\sigma}}[\lambda(q_H)-\lambda(q_L)]\right\}=F_E \qquad \text{(D11)}$$

As before, the first bracketed term can be simplified by substituting from (D2)

$$Q+\ \tau^{1-\sigma}\lambda(q_H)[1-G(\theta^D)]=\lambda(q_L)G(\theta^C)+\lambda(q_H)[1-G(\theta^C)]+\tau^{1-\sigma}\lambda(q_H)[1-G(\theta^D)]$$

$$=\lambda(q_H)+G(\theta^C)[\lambda(q_H)-\lambda(q_L)]+\tau^{1-\sigma}\lambda(q_H)[1-G(\theta^D)]$$

$$=\lambda(q_L)+(\theta^C)^{-s}[\lambda(q_H)-\lambda(q_L)]+\tau^{1-\sigma}\lambda(q_H)(\theta^D)^{-s} \qquad \text{(D12)}$$

From (D5):

$$(\theta^C)^{-1}=(\theta^D)^{-1}\frac{F_X}{\lambda(q_H)\tau^{1-\sigma}}\frac{[\lambda(q_H)-\lambda(q_L)]}{q_H-q_L}$$

Which implies:

$$(\theta^C)^{-s}=(\theta^D)^{-s}\left\{\frac{F_X}{\lambda(q_H)\tau^{1-\sigma}}\frac{[\lambda(q_H)-\lambda(q_L)]}{q_H-q_L}\right\}^s \qquad \text{(D5a)}$$

Substituting (D5a) into (D12) yields:

$$\lambda(q_L)+(\theta^D)^{-s}\left\{\frac{F_X}{\lambda(q_H)\tau^{1-\sigma}}\frac{[\lambda(q_H)-\lambda(q_L)]}{q_H-q_L}\right\}^s[\lambda(q_H)-\lambda(q_L)]+\tau^{1-\sigma}\lambda(q_H)(\theta^D)^{-s}$$

Substituting this expression into (D11):

$$\frac{F_X(\theta^D)}{\lambda(q_H)\tau^{1-\sigma}}\left[\lambda(q_L)+(\theta^D)^{-s}\left\{\frac{F_X}{\lambda(q_H)\tau^{1-\sigma}}\frac{[\lambda(q_H)-\lambda(q_L)]}{q_H-q_L}\right\}^s[\lambda(q_H)-\lambda(q_L)]+\tau^{1-\sigma}\lambda(q_H)(\theta^D)^{-s}\right]$$

$$-\frac{s}{s+1}\left\{F_x(\theta^D)+\frac{F_x(\theta^D)}{\lambda(q_H)\tau^{1-\sigma}}[\lambda(q_H)-\lambda(q_L)]\right\}=F_E$$

Substituting from (14):

$$(\theta^D)^{-1}\frac{F_X\lambda(q_L)}{\lambda(q_H)\tau^{1-\sigma}}+(\theta^D)^{-(s+1)}\left\{\frac{F_X}{\tau^{1-\sigma}}\frac{[\lambda(q_H)-\lambda(q_L)]}{\lambda(q_H)}\right\}^{s+1}[q_H-q_L]^{-s}+(\theta^D)^{-(s+1)}F_X$$

$$-(\theta^D)^{-1}F_x\frac{s}{s+1}\left\{1+\frac{[\lambda(q_H)-\lambda(q_L)]}{\lambda(q_H)\tau^{1-\sigma}}\right\}=F_E$$

Collecting common terms yields an expression that identifies the unique equilibrium value of θ^D:

$$(\theta^D)^{-1}F_X\frac{(2s+1)\lambda(q_L)-(1+\tau^{1-\sigma})s\lambda(q_H)}{\lambda(q_H)\tau^{1-\sigma}(s+1)}+(\theta^D)^{-(s+1)}\left\{\frac{F_X}{\tau^{1-\sigma}}\frac{[\lambda(q_H)-\lambda(q_L)]}{\lambda(q_H)}\right\}^{s+1}[q_H-q_L]^{-s}$$

$$+(\theta^D)^{-(s+1)}F_X=F_E \qquad \text{(D13)}$$

A similar expression can be developed to identify θ^C in terms of only model parameters. From (D5a):

$$(\theta^D)^{-s}=(\theta^C)^{-s}\left\{\frac{\lambda(q_H)\tau^{1-\sigma}}{F_X}\frac{q_H-q_L}{[\lambda(q_H)-\lambda(q_L)]}\right\}^{s}$$

Substituting this expression into (D12) and then replacing the result in (D11):

$$\frac{\delta(\theta^C)}{[\lambda(q_H)-\lambda(q_L)]}\Big[\lambda(q_L)+(\theta^C)^{-s}[\lambda(q_H)-\lambda(q_L)]+$$

$$(\theta^C)^{-s}\tau^{1-\sigma}\lambda(q_H)\left\{\frac{\lambda(q_H)\tau^{1-\sigma}}{F_X}\frac{q_H-q_L}{[\lambda(q_H)-\lambda(q_L)]}\right\}^{s}\Big]$$

$$-\frac{s}{s+1}\delta(\theta^C)\left\{1+\frac{\lambda(q_H)\tau^{1-\sigma}}{[\lambda(q_H)-\lambda(q_L)]}\right\}=F_E \qquad \text{(D14)}$$

Collecting common terms:

$$(\theta^C)^{-1}(q_H-q_L)\left\{\frac{(2s+1)\lambda(q_L)-s\lambda(q_H)(1+\tau^{1-\sigma})}{[\lambda(q_H)-\lambda(q_L)](s+1)}\right\}+(\theta^C)^{-(s+1)}(q_H-q_L)$$

$$+(\theta^C)^{-(s+1)}\left\{\frac{[q_H-q_L]\tau^{1-\sigma}\lambda(q_H)}{[\lambda(q_H)-\lambda(q_L)]}\right\}^{s+1}F_X{}^{-s}=F_E \qquad \text{(D15)}$$

This expression identifies the unique equilibrium productivity cut-off for certification in the LN/HN/HE case.

E: Derivation of Comparative Statics

Deriving comparative statics for the policy-relevant parameters in the model requires totally differentiating the expressions that define the equilibrium productivity cut-offs. Using equations (18), (19), (23) and (24), the comparative static for a given parameter *X*, can be found by evaluating:

$$\frac{\partial Q(\theta^i)}{\partial \theta^i} \cdot d\theta^i + \frac{\partial Q(\theta^i)}{\partial X} \cdot dX = 0$$

E.1: Fixed Entry Costs

Deriving the comparative static for fixed entry costs requires evaluating the following expression:

$$\frac{\partial Q(\theta^i)}{\partial \theta^i} \cdot d\theta^i + \frac{\partial Q(\theta^i)}{\partial F_E} \cdot dF_E = 0$$

Solving for ${d\theta^i}/{dF_E}$:

$$\frac{d\theta^i}{dF_E} = -\left[\frac{\frac{\partial Q(\theta^i)}{\partial F_E}}{\frac{\partial Q(\theta^i)}{\partial \theta^i}}\right] \qquad \text{(E1)}$$

This expression must be evaluated for each $\theta^i, i = A, B, C, D$. Beginning with the denominator:

$$\frac{\partial Q(\theta^A)}{\partial \theta^A} = -(\theta^A)^{-2} F_x \left\{\frac{(2s+1)\lambda(q_L) - [1+\tau^{1-\sigma}]s\lambda(q_H)}{\lambda(q_L)(s+1)\tau^{1-\sigma}}\right\} - (s+1)(\theta^A)^{-(s+2)} F_x$$

$$-(s+1)(\theta^A)^{-(s+2)} \left[\frac{(\lambda(q_H) - \lambda(q_L))}{\lambda(q_L)}[1+\tau^{\sigma-1}]\right]^{s+1} \frac{{F_x}^{s+1}}{(q_H - q_L)^s} < 0 \qquad \text{(E2)}$$

$$\frac{\partial Q(\theta^B)}{\partial \theta^B} = -(\theta^B)^{-2}[q_H - q_L]\left\{\frac{(2s+1)\lambda(q_L) - [1+\tau^{1-\sigma}]s\lambda(q_H)}{[\lambda(q_H) - \lambda(q_L)][1+\tau^{1-\sigma}](s+1)}\right\} - (s+1)(\theta^B)^{-(s+2)}[q_H - q_L]$$

$$-(s+1)(\theta^B)^{-(s+2)}\left(\frac{[q_H - q_L]\lambda(q_L)}{[\lambda(q_H) - \lambda(q_L)]}\right)^{s+1}([1+\tau^{\sigma-1}])^{-(s+1)} {F_x}^{-s} < 0 \qquad \text{(E3)}$$

$$\frac{\partial Q(\theta^C)}{\partial \theta^C} = -(\theta^C)^{-2}(q_H - q_L)\left\{\frac{(2s+1)\lambda(q_L) - s\lambda(q_H)(1+\tau^{1-\sigma})}{[\lambda(q_H) - \lambda(q_L)](s+1)}\right\} - (s+1)(\theta^C)^{-(s+2)}(q_H - q_L)$$

$$-(s+1)(\theta^C)^{-(s+2)}\left\{\frac{[q_H - q_L]\tau^{1-\sigma}\lambda(q_H)}{[\lambda(q_H) - \lambda(q_L)]}\right\}^{s+1} {F_X}^{-s} < 0 \qquad \text{(E4)}$$

$$\frac{\partial Q(\theta^D)}{\partial \theta^D} = -(\theta^D)^{-2} F_X \left\{\frac{(2s+1)\lambda(q_L)-(1+\tau^{1-\sigma})s\lambda(q_H)}{\lambda(q_H)\tau^{1-\sigma}(s+1)}\right\} - (s+1)(\theta^D)^{-(s+2)} F_X$$

$$-(s+1)(\theta^D)^{-(s+2)} \left\{\frac{F_X}{\tau^{1-\sigma}} \frac{[\lambda(q_H)-\lambda(q_L)]}{\lambda(q_H)}\right\}^{s+1} [q_H - q_L]^{-s} < 0 \qquad \text{(E5)}$$

As shown in Figure 3 and Figure 5, the equilibrium conditions for each of the productivity cut-offs are everywhere decreasing in θ. The partial differentials are therefore negative. The sign of the comparative statics will therefore depend on the signs of the partial derivatives of $Q(\theta^i)$ with respect to the parameter of interest. For the fixed entry cost:

$$\frac{\partial Q(\theta^A)}{\partial F_E} = \frac{\partial Q(\theta^B)}{\partial F_E} = \frac{\partial Q(\theta^C)}{\partial F_E} = \frac{\partial Q(\theta^D)}{\partial F_E} = -1 < 0 \qquad \text{(E6)}$$

The bracketed expression in (E1) will therefore be negative for all $i = A, B, C, D$. This implies:

$$\frac{d\theta^A}{dF_E} < 0, \frac{d\theta^B}{dF_E} < 0, \frac{d\theta^C}{dF_E} < 0, \frac{d\theta^D}{dF_E} < 0 \qquad \text{(E7)}$$

E.2: Fixed Export Costs

Deriving the comparative statics for the fixed export costs (F_X), requires evaluating:

$$\frac{\partial Q(\theta^i)}{\partial \theta^i} \cdot d\theta^i + \frac{\partial Q(\theta^i)}{\partial F_X} \cdot dF_X = 0$$

Solving for ${d\theta^i}/{dF_X}$ implies:

$$\frac{d\theta^i}{dF_X} = -\left[\frac{\frac{\partial Q(\theta^i)}{\partial F_X}}{\frac{\partial Q(\theta^i)}{\partial \theta^i}}\right] \qquad \text{(E8)}$$

Deriving the comparative statics requires evaluating (E8) for each $i = A, B, C, D$. Given the denominator of the bracketed term in (E8) is identical to (E2)-(E5), it is only necessary to solve for the term in the numerator.

$$\frac{\partial Q(\theta^A)}{\partial F_X} = (\theta^A)^{-1}\left\{\frac{(2s+1)\lambda(q_L)-[1+\tau^{1-\sigma}]s\lambda(q_H)}{\lambda(q_L)(s+1)\tau^{1-\sigma}}\right\} + (\theta^A)^{-(s+1)}$$

$$+(\theta^A)^{-(s+1)}\left[\frac{(\lambda(q_H)-\lambda(q_L))}{\lambda(q_L)}[1+\tau^{\sigma-1}]\right]^{s+1}\frac{F_X{}^s}{(q_H-q_L)^s} > 0 \qquad \text{(E9)}$$

$$\frac{\partial Q(\theta^B)}{\partial F_X} = -s(\theta^B)^{-(s+1)}\left(\frac{[q_H-q_L]\lambda(q_L)}{[\lambda(q_H)-\lambda(q_L)]}\right)^{s+1}([1+\tau^{\sigma-1}])^{-(s+1)}F_X{}^{-(s+1)} < 0 \qquad \text{(E10)}$$

$$\frac{\partial Q(\theta^C)}{\partial F_X} = -s(\theta^C)^{-(s+1)}\left\{\frac{[q_H-q_L]\tau^{1-\sigma}\lambda(q_H)}{[\lambda(q_H)-\lambda(q_L)]}\right\}^{s+1}F_X{}^{-s} < 0 \qquad \text{(E11)}$$

$$\frac{\partial Q(\theta^C)}{\partial F_X} = (\theta^D)^{-1}\left\{\frac{(2s+1)\lambda(q_L)-(1+\tau^{1-\sigma})s\lambda(q_H)}{\lambda(q_H)\tau^{1-\sigma}(s+1)}\right\} + (\theta^D)^{-(s+1)}$$

$$+(\theta^D)^{-(s+1)}\left\{\frac{[\lambda(q_H)-\lambda(q_L)]}{\tau^{1-\sigma}\lambda(q_H)}\right\}^{s+1}\frac{F_X{}^s}{[q_H-q_L]^s} > 0 \qquad \text{(E12)}$$

Evaluating E(8) by combining (E9)-E(12) with E(2)-E(7) yields:

$$\frac{d\theta^A}{dF_X} > 0, \frac{d\theta^B}{dF_X} < 0, \frac{d\theta^C}{dF_X} < 0, \frac{d\theta^D}{dF_X} > 0 \qquad \text{(E13)}$$

E.3: Transportation Costs

Deriving the comparative statics for the transportation costs (τ), requires evaluating:

$$\frac{\partial Q(\theta^i)}{\partial \theta^i}\cdot d\theta^i + \frac{\partial Q(\theta^i)}{\partial \tau}\cdot d\tau = 0$$

Solving for $d\theta^i/_{d\tau}$ implies:

$$\frac{d\theta^i}{d\tau} = -\left[\frac{\frac{\partial Q(\theta^i)}{\partial \tau}}{\frac{\partial Q(\theta^i)}{\partial \theta^i}}\right] \qquad \text{(E14)}$$

Once again, the denominator of the bracketed term in (E14) is identical to E(2)-E(5). It is only necessary to solve for the numerator in the bracketed term:

$$\frac{\partial Q(\theta^A)}{\partial \tau} = (\sigma-1)\tau^{\sigma-2}\frac{(\theta^A)^{-1}F_X}{(s+1)\lambda(q_L)}[(2s+1)\lambda(q_L) - s\lambda(q_H)]$$

$$+(s+1)(1+\tau^{\sigma-1})^s(\sigma-1)\tau^{\sigma-2}\left\{\frac{(\theta^A)^{-1}[\lambda(q_H)-\lambda(q_L)]F_X}{\lambda(q_L)}\right\}^{s+1}[q_H-q_L]^{-s} > 0 \quad \text{(E15)}$$

$$\frac{\partial Q(\theta^D)}{\partial \tau} = (\sigma-1)\tau^{\sigma-2}\frac{(\theta^D)^{-1}F_X}{(s+1)\lambda(q_H)}[(2s+1)\lambda(q_L) - s\lambda(q_H)]$$

$$+(s+1)(\sigma-1)\tau^{(s+1)(\sigma-1)-1}\left\{\frac{(\theta^D)^{-1}[\lambda(q_H)-\lambda(q_L)]F_X}{\lambda(q_H)}\right\}^{s+1}[q_H - q_L]^{-s} > 0 \qquad \text{(E16)}$$

Combining E(15) and E(16) with E(2), E(5) and E(14) yields:

$$\frac{d\theta^A}{d\tau} > 0, \frac{d\theta^D}{d\tau} > 0 \qquad \text{E(17)}$$

The comparative statics for θ^B and θ^C are ambiguous. Given (E14) and E(2)-E(5), $\frac{d\theta^i}{d\tau} > 0$ if and only if $\frac{\partial Q(\theta^i)}{\partial \tau} > 0$. Partially differentiating $Q(\theta^i)$ with respect to τ for $i = B, C$ yields:

$$\frac{\partial Q(\theta^B)}{\partial \tau} = (\sigma-1)[1+\tau^{1-\sigma}]^{-2}\tau^{-\sigma}\left\{\frac{(\theta^B)^{-1}(q_H-q_L)\lambda(q_L)}{\lambda(q_H)-\lambda(q_L)}\right\}\left(\frac{2s+1}{s+1}\right)$$

$$-(s+1)(\sigma-1)[1+\tau^{\sigma-1}]^{-(s+2)}\tau^{\sigma-2}\left\{\frac{(\theta^B)^{-1}(q_H-q_L)\lambda(q_L)}{\lambda(q_H)-\lambda(q_L)}\right\}^{s+1}{F_X}^{-s} \qquad \text{(E18)}$$

$$\frac{\partial Q(\theta^C)}{\partial \tau} = (\sigma-1)\tau^{-\sigma}\left\{\frac{(\theta^C)^{-1}(q_H-q_L)\lambda(q_H)}{\lambda(q_H)-\lambda(q_L)}\right\}\left(\frac{s}{s+1}\right)$$

$$-(s+1)(\sigma-1)\tau^{(1-\sigma)(s+1)-1}\left\{\frac{(\theta^C)^{-1}(q_H-q_L)\lambda(q_H)}{\lambda(q_H)-\lambda(q_L)}\right\}^{s+1}{F_X}^{-s} \qquad \text{(E19)}$$

It is not possible to sign (E18) or (E19) without imposing further restrictions on the relative magnitudes of certain model parameters. Given (E11) it would be reasonable to assume $\frac{\partial Q(\theta^C)}{\partial \tau} < 0$. Firms with productivity in the vicinity of θ^C will only experience general equilibrium effects given a change in τ. A change in τ should therefore mirror the effect of a change in F_X. Rearranging terms in (E19), this implies setting parameters such that:

$$\frac{s}{(s+1)^2} < (\theta^C)^{-s}\left\{\frac{(q_H-q_L)\lambda(q_H)\tau^{1-\sigma}}{\lambda(q_H)-\lambda(q_L)F_X}\right\}^{s} \qquad \text{(E20)}$$

Substituting from (D5a), this can be rewritten as:

$$\frac{s}{(s+1)^2} < (\theta^D)^{-s}$$

Given $\underline{\theta} = 1$, both sides of this expression are bound below one. This means that none of the previous assumptions preclude the result in (E20).

There is good reason to suspect the result for $\frac{d\theta^B}{d\tau}$ would not mirror the result for $\frac{d\theta^B}{dF_X}$. While changes in F_X do not change the relative profitability of the LE and HE strategies, changes in τ will. To see this, differentiate (10) with respect to τ (ignoring general equilibrium effects in $\tilde{P}$):

$$\frac{\partial \pi_F(q_\omega)}{\partial \tau} = (1-\sigma)\tau^{-\sigma}p^{1-\sigma}\lambda(q_\omega)\frac{E}{\tilde{P}^{1-\sigma}}$$

Given $\sigma > 1$ and $\lambda(q_H) > \lambda(q_L)$, profits in the foreign market fall faster for sellers of high-quality goods as τ increases. Ignoring general equilibrium effects, increases in τ will change the relative profitability of the LE and HE strategies, making certification a less attractive option. Rearranging terms in E(18), $\frac{d\theta^B}{d\tau} > 0$ implies:

$$\frac{2s+1}{(s+1)^2} > (\theta^B)^{-s}\left\{\frac{(q_H - q_L)\lambda(q_L)\tau^{1-\sigma}}{[\lambda(q_H)-\lambda(q_L)]F_X[1+\tau^{1-\sigma}]}\right\}^s \qquad \text{(E21)}$$

Substituting from (C7), this can be rewritten as:

$$\frac{2s+1}{2s+1+s^2} > (\theta^A)^{-s}$$

Once again, both sides of the expression are bound below one. None of the previous assumptions violate the condition specified in (E21). Assuming E(21) and E(20) hold, the final comparative statics for τ are:

$$\frac{d\theta^B}{d\tau} > 0, \frac{d\theta^C}{d\tau} < 0 \qquad \text{(E22)}$$