ESSAYS ON VOLUNTARY STANDARDS IN INTERNATIONAL TRADE

DISSERTATION

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By

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ABSTRACT

This dissertation explores the role of voluntary standards in averting a "race to the bottom" following the liberalization of international trade. It presents a novel theoretical framework with which to understand the relationship between participation in export markets and the adoption of a voluntary standard that credibly identifies unobservable output quality. This framework not only explains some of the ambiguity found in the empirical literature on the subject, but also provides theoretical justification for the argument that market integration can put upward pressure on production standards in the presence of a credible voluntary standard. This theme is explored further in an empirical study of ISO 14001 adoption in China. Despite popular concern that lower trade barriers would worsen China's environmental crisis, careful study suggests it had the opposite effect: encouraging the adoption of cleaner production methods. The analysis presented here demonstrates the adoption of the ISO 14001 environmental management standard improved the environmental performance of manufacturing firms in China. The work presented here provides theoretical and empirical evidence supporting the argument that trade liberalization can improve environmental, labor or safety standards, even when regulators cannot.

DEDICATION

To my loving (and patient) wife.

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FIELDS OF STUDY

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Chapter 1: 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.

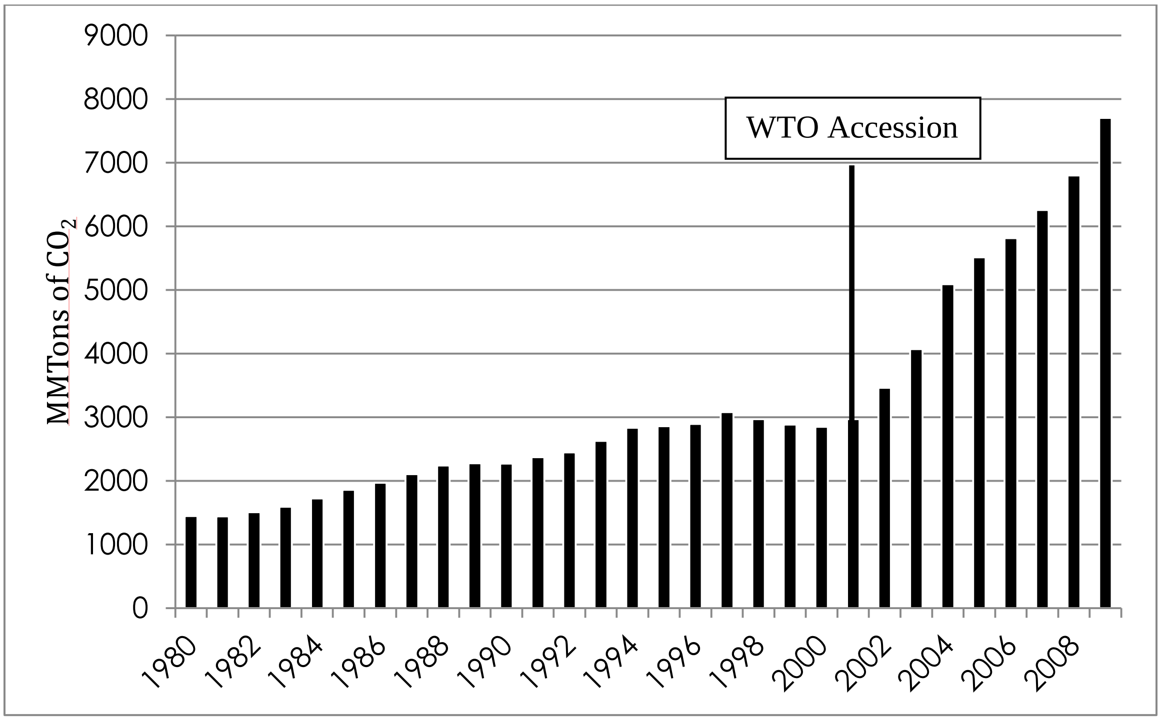
The emissions standards driving the California effect were WTO-compliant because they pertained to the function of the product in question; they were not process standards. Many of the environmental and ethical concerns cited in debates over trade liberalization pertain to production processes, not the 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. A model of international trade and voluntary certification adoption based in the heterogeneous firms and trade (HFT) framework developed by Meltiz (2003) is presented in Chapter 2. Employing the HFT framework produces a rich set of firm level predictions regarding the relationship between voluntary standards and participation in international markets. The HFT framework has demonstrated an ability to reproduce patterns of firm behavior often observed in the data but previously absent from game theoretic or perfectly competitive models of trade. The model developed here can provide a guide for future empirical work.

The implications of the model are explored in Chapter 3 in an empirical study of ISO 14001 certification in China. China provides an excellent setting for studying these types of voluntary standards because of its recent economic reforms and the poor track record of its formal regulatory institutions. China's rapid environmental deterioration has earned the country a reputation for putting economic growth ahead of sustainability. It has also earned China the dubious honor of being the largest emitter of greenhouse gasses in the world (New York Times, 2007), as well as the home of 20 of the 30 most polluted cities in the world (World Bank, 2010).

Figure 1: Rising Greenhouse Gas Emissions in China, 1980 - 2009

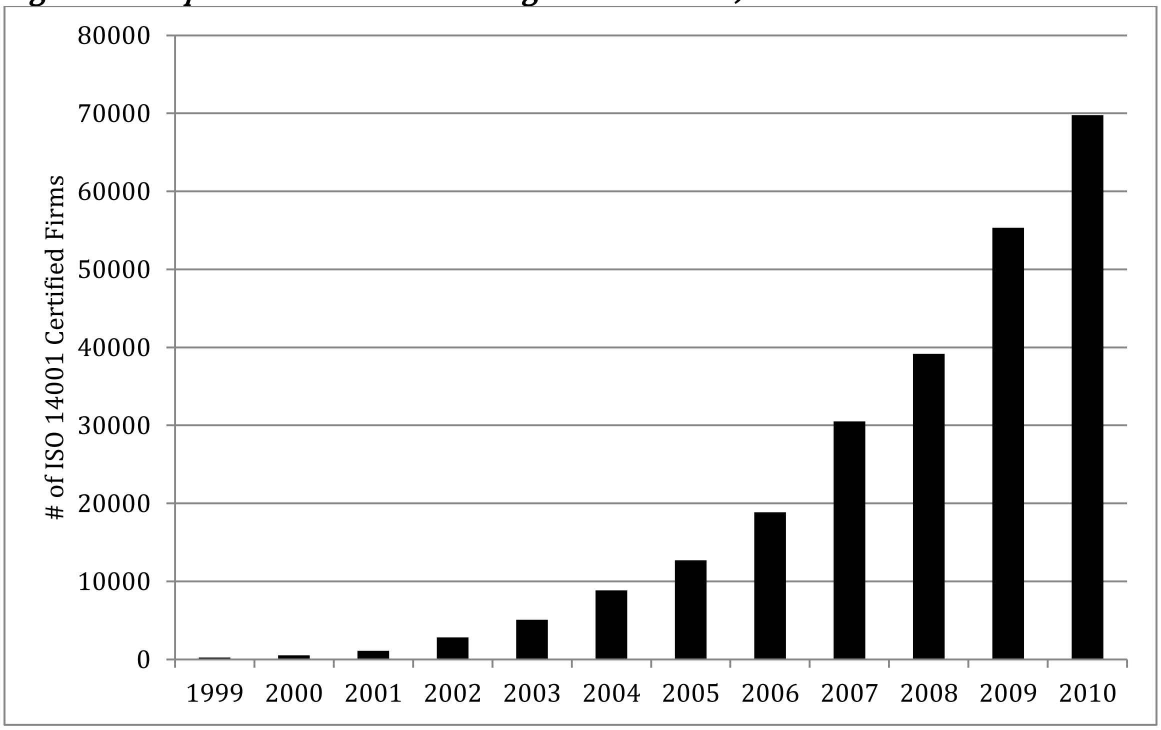


Note: Data come from the U.S. Energy Information Administration (2012)

China's environmental crisis has not only local but also global implications. Figure 1 shows China's total emissions of CO_2 from energy consumption between 1980 and 2009. CO_2 emissions have been rising steadily in China since economic reforms began around 1980. An active body of research has grown up around the question of how increased openness to trade has contributed to China's environmental problems. One might expect China, with a relatively large share of heavy industry in GDP and a weak domestic regulatory environment, to experience significant declines in environmental quality as trade barriers fall. At first glance, the data would seem to support this hypothesis. Figure 1 shows emissions accelerated sharply in 2001, the year China joined the WTO. However, careful analysis has shown WTO accession has had significant positive effects on China's environmental quality. Vennemo et al. (2008) use a computable general equilibrium (CGE) model to decompose changes in key emissions as well as GDP in China. They find WTO accession had a net positive effect on environmental performance in China, driven in large part by the reallocation of resources away from pollution-intensive sectors. These results largely concur with the industry case studies presented in a recent report by the International Institute for Sustainable Development (IISD, 2004).

Venemo et al. (2008) also find evidence that WTO accession led to reductions in certain emissions by spurring the adoption of cleaner production techniques. This result seems counterintuitive in a country known for poor enforcement of its regulatory standards (Beyer, 2006). However, at the same time that it was lowering trade barriers to comply with WTO rules, China experienced a dramatic increase in the adoption of the ISO 14001 environmental management standard. Figure 2 shows the total number of ISO 14001 certified firms in China between 1999 and 2010. Adoption has increased exponentially over this period, rising from only a few hundred firms in 1999 to nearly 70,000 firms in 2010. China is currently the largest adopter of the ISO 14001 standard in the world.

Figure 2: Adoption of ISO 14001 Among Chinese Firms, 1999 - 2010



Note: Data come from the ISO Survey of Certifications 2004-2010

ISO 14001 is an internationally recognized standard certifying a firm has implemented a system to mitigate and continuously improve its environmental impact. How adoption of ISO 14001, following WTO accession, has affected environmental performance in China remains an open question. Previous studies of ISO 14001 adoption outside of China have produced mixed evidence regarding its effectiveness (for example, see Potoski and Prakash, 2005 vs. Barla, 2007), but the trend shown in Figure 2 is highly suggestive. The analysis in Chapter 3 is intended to test this relationship in a representative sample of Chinese manufacturing firms.

The analysis proceeds by first identifying a set of determinants that predict ISO 14001 adoption. The relationship between ISO 14001 adoption and environmental performance is then modeled using single-stage estimation as well as properly specified instrumental variables models to control for potential endogeneity between ISO 14001 adoption and environmental performance.

Contribution

The results presented in the following chapters contribute to the literature on voluntary standards in international trade by presenting new theoretical and empirical evidence that voluntary standards can play a significant role in averting a "race to the bottom" following trade liberalization. The existing literature has been largely empirical, using *ad hoc* theoretical frameworks to interpret parameter estimates. The work presented here provides a new theoretical framework to understand the relationship between voluntary standards and international trade, and provides new empirical evidence from China, an important but relatively understudied country in this literature.

The theoretical model presented in Chapter 2 is the first of its kind to model firms' certification and export decisions simultaneously. This allows for the derivation of comparative statics relating participation in a credible voluntary standard to changes in trade policy. The results show that the relationship between liberalization and adoption is complex and varies, depending on the competitive environment of the marginal uncertified firm, as well as the policy instrument in question. Derivation of the model produces a set of predictions specifying the circumstances under which lower trade barriers can be expected to increase or decrease participation in a voluntary standard. The results of the model also explain some of the empirical regularities observed in previous empirical studies of voluntary standards. It correctly predicts several characteristics that have been shown to predict certification status and provides a theoretical explanation for this observed correlation.

The analysis presented in Chapter 3 contributes to the literature on voluntary standards by validating some of the predictions of the theoretical model in Chapter 2, and provides new empirical evidence on the relationship between ISO 14001 and environmental performance. It is one of the few studies of ISO 14001 adoption in China and the only one that has examined ISO 14001 adoption using a large, representative sample of Chinese firms. The analysis identifies robust predictors of ISO 14001 adoption and demonstrates a successful instrumental variables strategy for identifying the relationship between ISO 14001 and environmental performance. The findings reproduce some of the relationships observed in the existing empirical literature and provide the first evidence that ISO 14001 has improved environmental performance among Chinese manufacturing firms.

Chapter 2: Theoretical Model

2.1: Introduction

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

[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.

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.

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.

2.2: Model Framework

2.2.1: 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:

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

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

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:

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

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

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

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 voluntarily participate in a credible certification program that will identify 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.

2.2.2: 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:

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

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

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

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

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

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

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

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

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

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

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. 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^C) 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 3: Determination of the Certification Cut-Off Productivity

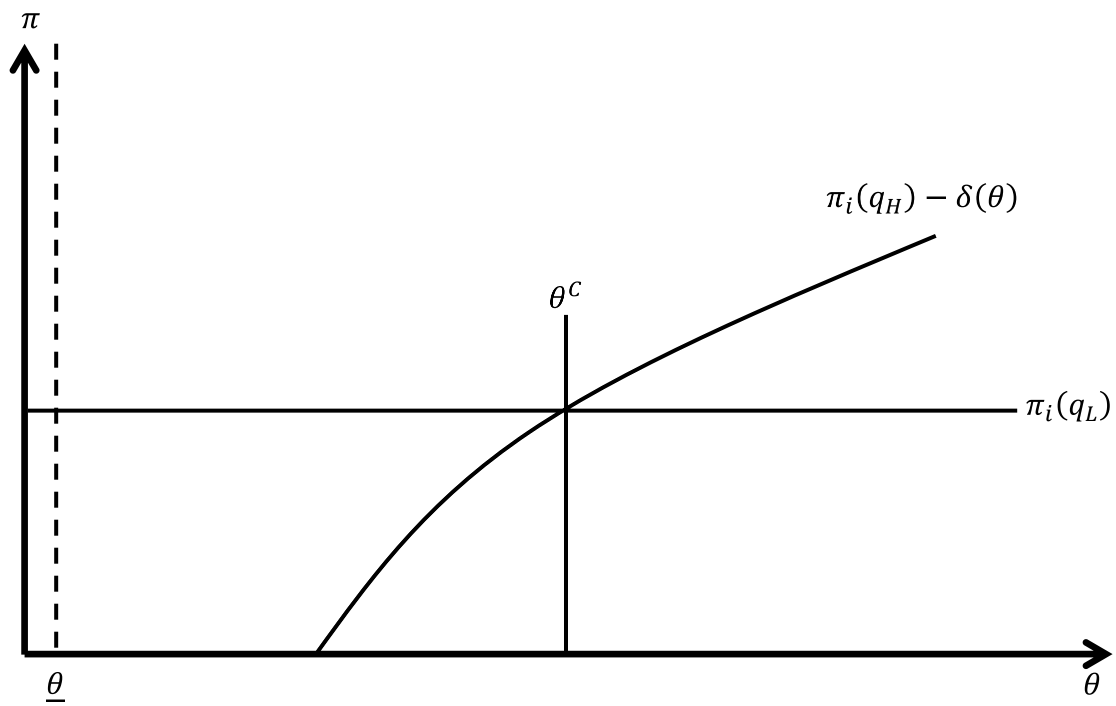


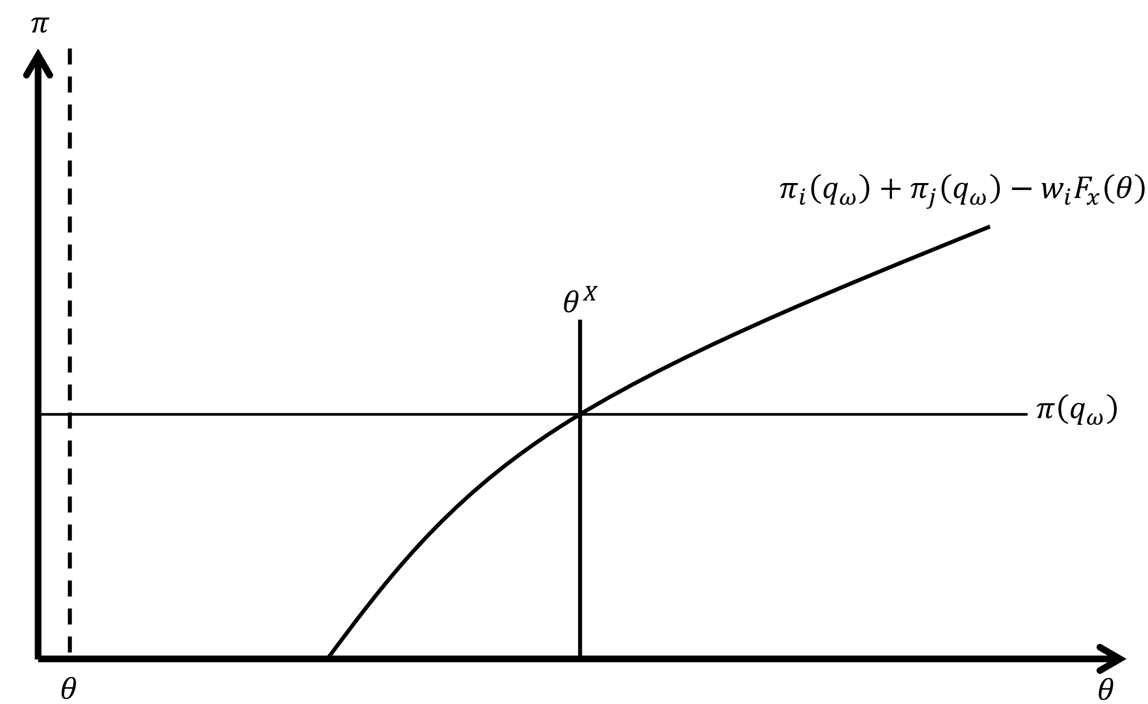
Figure 3 illustrates this cut-off condition. Consider a firm deciding whether or not to sell high-quality output in a given market. If the firm sells low-quality output, it will earn a payoff equal to $\pi_i(q_L)$. If the firm decides to market high-quality output, it will earn a payoff equal to $\pi_i(q_H) - w_i\delta(\theta)$. Equations (8), (9) and (13) ensure that the payoffs associated with this strategy are non-decreasing and concave in productivity (θ). Firms with $\theta \in [\theta_{min}, \theta^C)$ will choose to sell only low-quality products. Firms with $\theta \in [\theta^C, \infty)$ 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:

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

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 4: Determination of the Export Cut-Off Productivity



[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.

Figure 4 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 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.

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

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 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	Certification
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)

2.3.1: 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:

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

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 θ^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:

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

Figure 5 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 5.

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

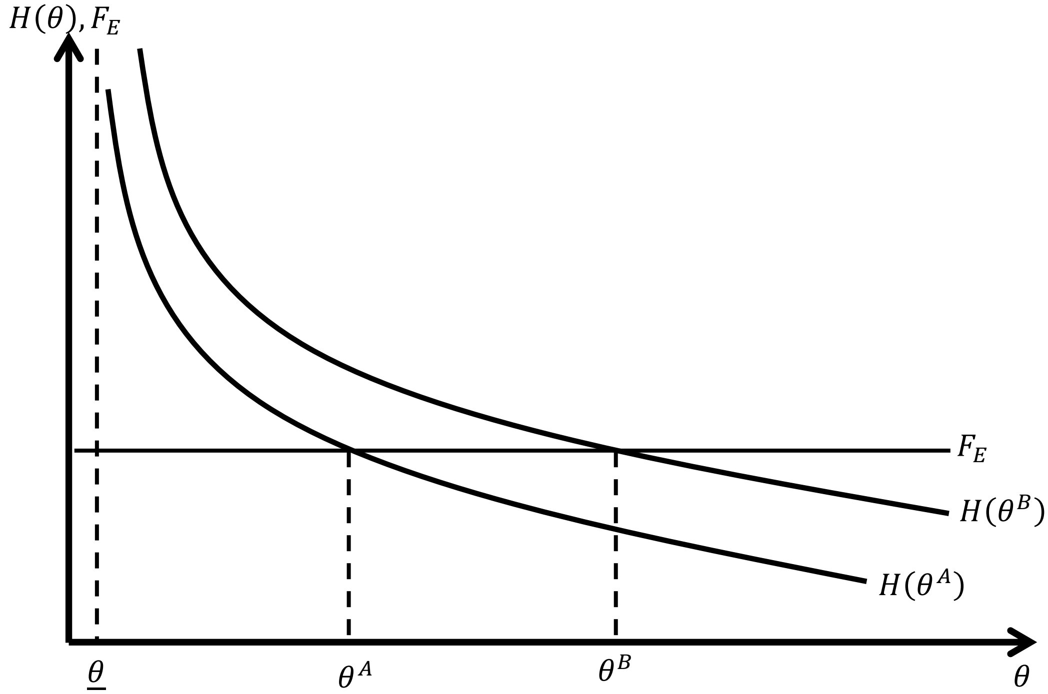
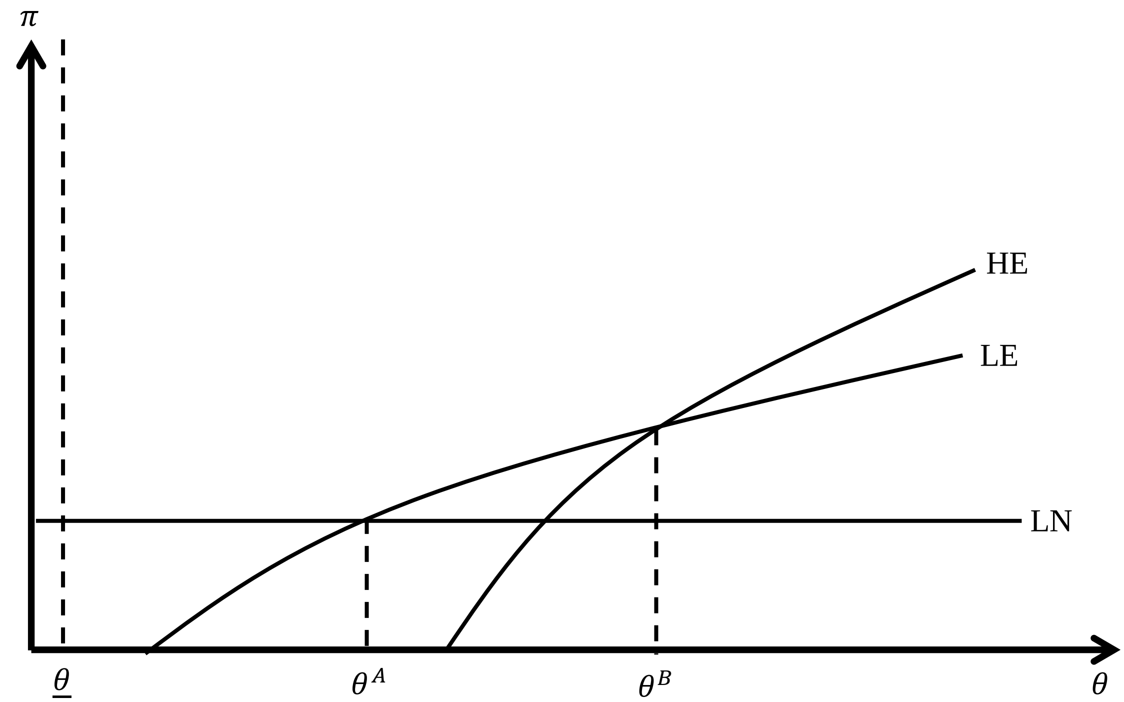


Figure 6 illustrates the full model equilibrium in productivity and profit space. The payoffs associated with each strategy are shown as a concave function of θ. While LN is constant, LE and HE are both monotonically increasing in productivity. Strategies LE and HE are everywhere steeper in slope than 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 6: Equilibrium Firm Payoffs in the LN/LE/HE Case:



2.3.2: 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,

$$w_i\delta(\theta^C) = \pi_i(q_H) - \pi_i(q_L) \qquad (21)$$

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):

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

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

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 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.

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

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

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 7 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 $\theta^D > \theta^C \geq \underline{\theta}$.

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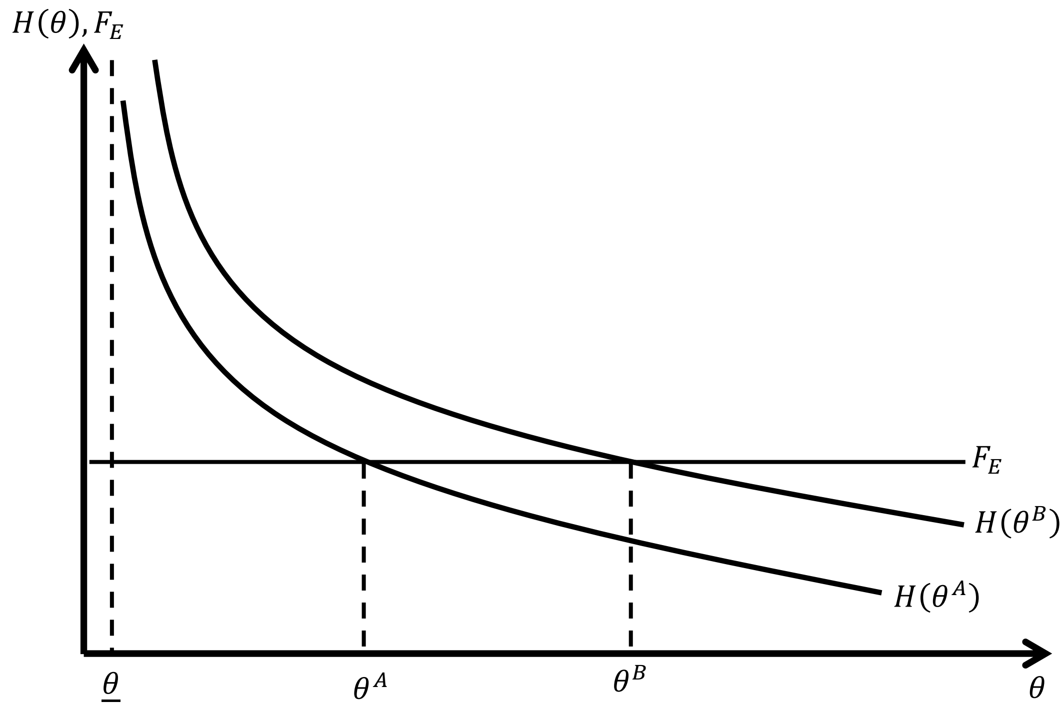
[4] Note that this requires an identical assumption about the relative magnitudes of s, τ, $\lambda(q_L)$ and $\lambda(q_H)$ as in the first case.

Figure 7: Determination of Equilibrium Productivity Cut-Offs in the LN/HN/HE Case

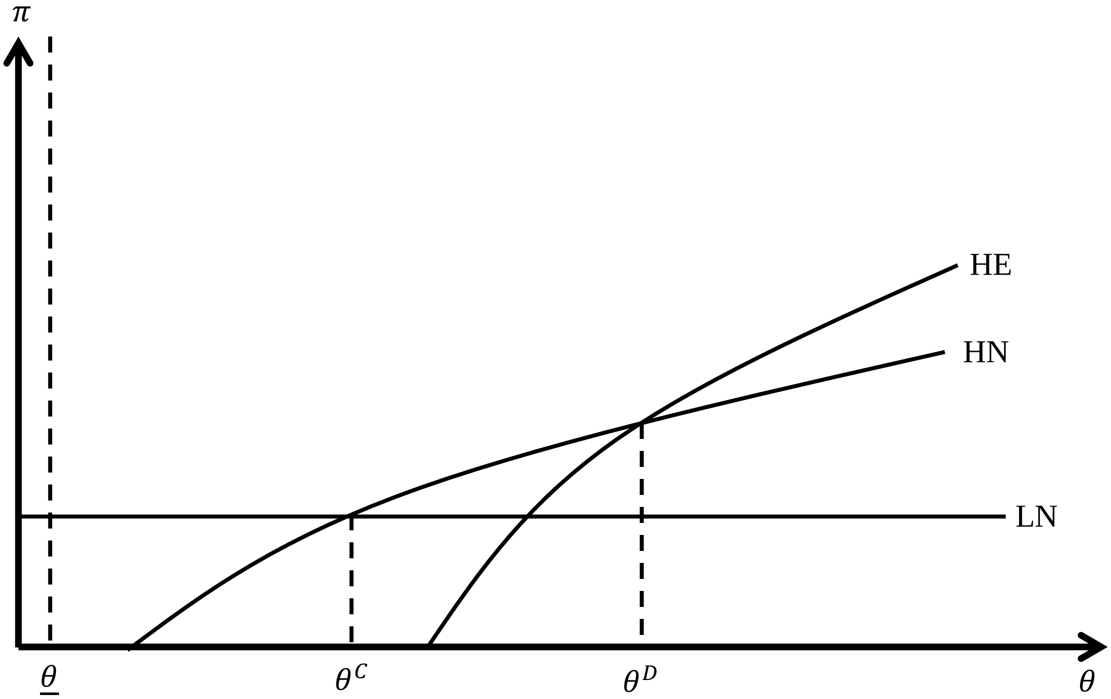


Equation (17), along with the equilibrium values of θ^C and θ^D, can be used to find the equilibrium mass of entrants (M).

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

Figure 8 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 $\theta \geq \underline{\theta}$.

Figure 8: Equilibrium Firm Payoffs in the LN/HN/HE Case:



2.3.3: 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.

2.4: 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.

2.4.1: 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 $Q\left(\theta^i\right) = H\left(\theta^i\right) - F_E = 0$ with respect to F_E and θ^i for all $i = A, B, C, D$. The resulting expression is:

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

The resulting comparative statics are:

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

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.

This implies the average level of quality produced in the home country increases with fixed entry costs, but raising the barriers to entry will also decrease the number of firms entering the industry. If policy-makers are interested in maximizing the *number* of domestic certified or export-oriented firms, they would have to balance the increased rates of export participation and certification against decreased entry to the differentiated products sector.

2.4.2: 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 $Q(\theta^i)$ with respect to F_X and θ^i for $i = A, B, C, D$. The resulting expression is:

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

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

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

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.

2.4.3: 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 $\theta^A$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: ${d\theta^B}/{d\tau} > 0$.

2.5: Model Simulation

It is possible to illustrate the equilibria and comparative statics presented in the previous sections using simple numerical simulations of (18), (19), (23) and (24). 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).

This section presents simulation results for changes in the productivity cut-offs, total quality available in a given market, and the quality-adjusted price index given changes in F_E, F_X and τ. In reality, changes in private benefits only capture a fraction of the social costs and benefits associated with the adoption of voluntary standards. Environmental standards, for example, affect the production of public goods. A full welfare analysis for an environmental standard would need to incorporate external costs and benefits, which would require specifying an external damage function. This is left for future work.

Simulations of the baseline equilibrium were performed using the parameter values outlined in Table 2. 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 2.2. 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.

Table 2: Baseline Simulation Parameter Values

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

Figure 9 illustrates the baseline equilibrium in the LN/LE/HE case.

Figure 9: Simulated Equilibrium in the LN/LE/HE Case

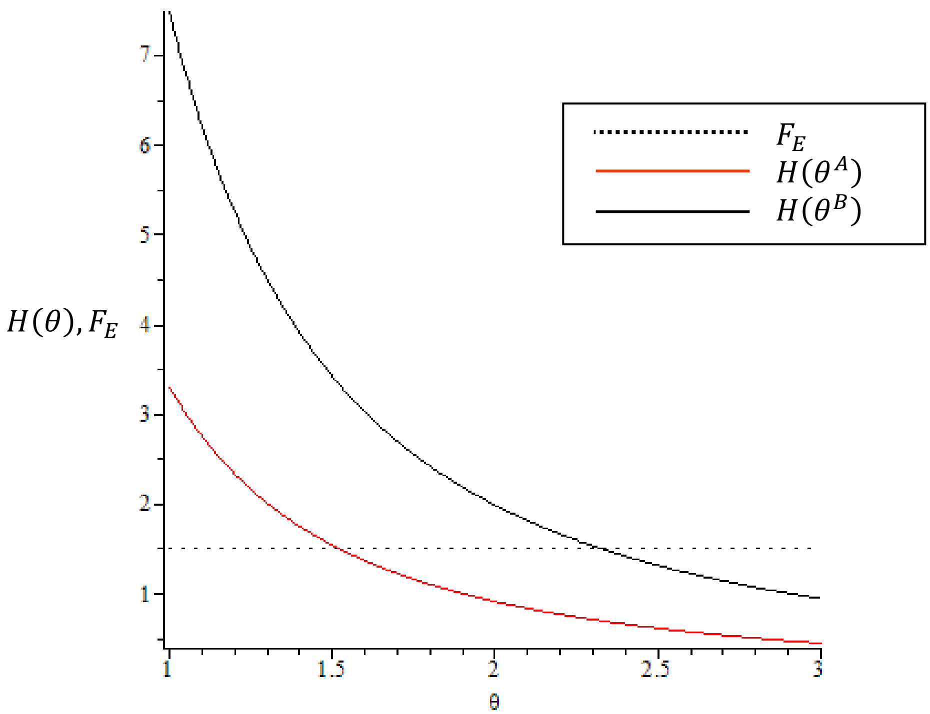
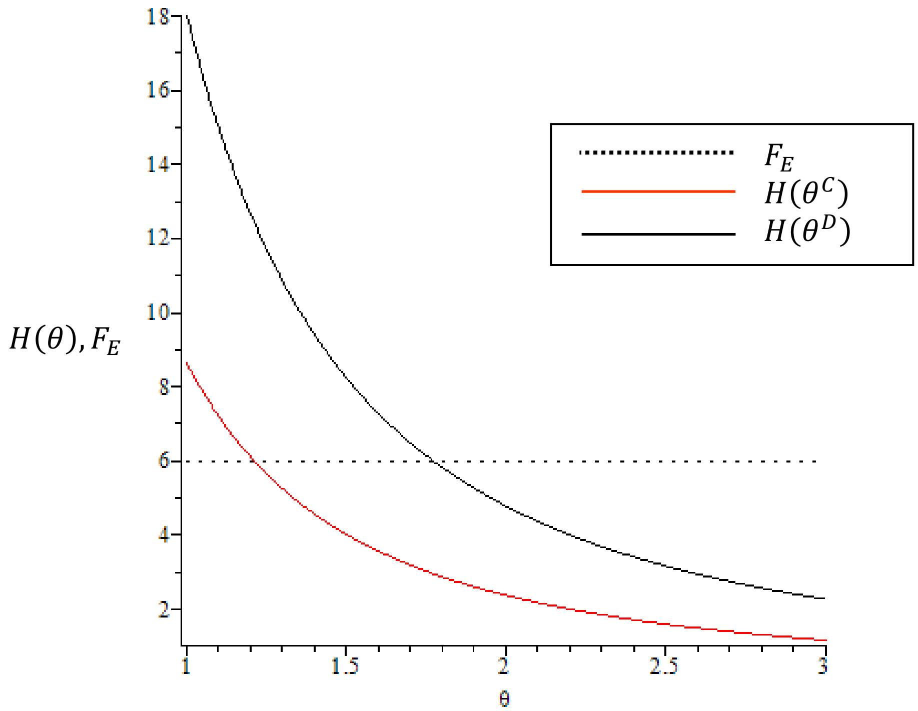


Figure 10 illustrates the baseline equilibrium in the LN/HN/HE case.

Figure 10: Simulated Equilibrium in the LN/HN/HE Case

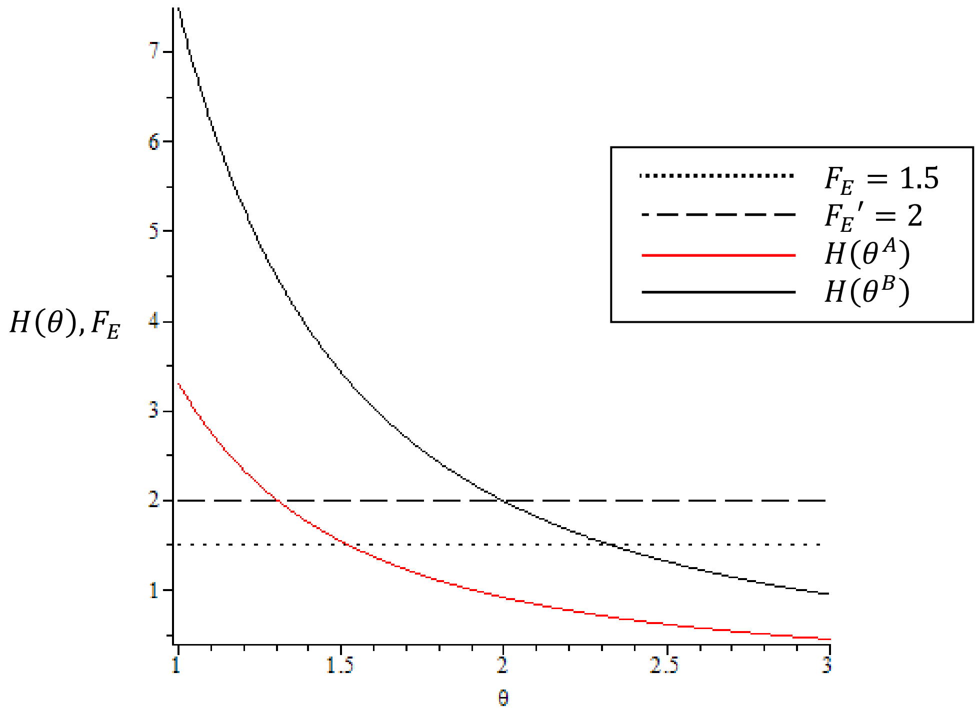


Equilibrium is determined by the value of θ at which the dotted line representing F_E crosses the downward sloping $H(\theta^i)$ curves. These represent the values of $\theta^A, \theta^B, \theta^C$ and θ^D that satisfy equations (18), (19), (23) and (24) with equality. In Figure 9, $\theta^A \cong 1.5$ and $\theta^B \cong 2.3$. In Figure 10, $\theta^C \cong 1.2$ and $\theta^D \cong 1.8$.

2.5.1 Comparative Statics for F_E

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



Raising barriers to entry will discourage entry, leading to a lower equilibrium mass of firms (M) in each market. This will raise profits at every productivity level for all successful entrants, making them more willing to sink the fixed costs associated with both exporting and certification.

Figure 12 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. Once again, higher entry barriers increase the rate of participation in exporting and certification because firms earn higher profits at every level of certification. Note that no equilibrium can be found following sufficiently large changes in F_E. If $F_E \geq 4$ in Figure 11 or $F_E \geq 9$ in Figure 12, the point of intersection between F_E and $H(\theta^i)$ would lie outside the support of $G(\theta)$.

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

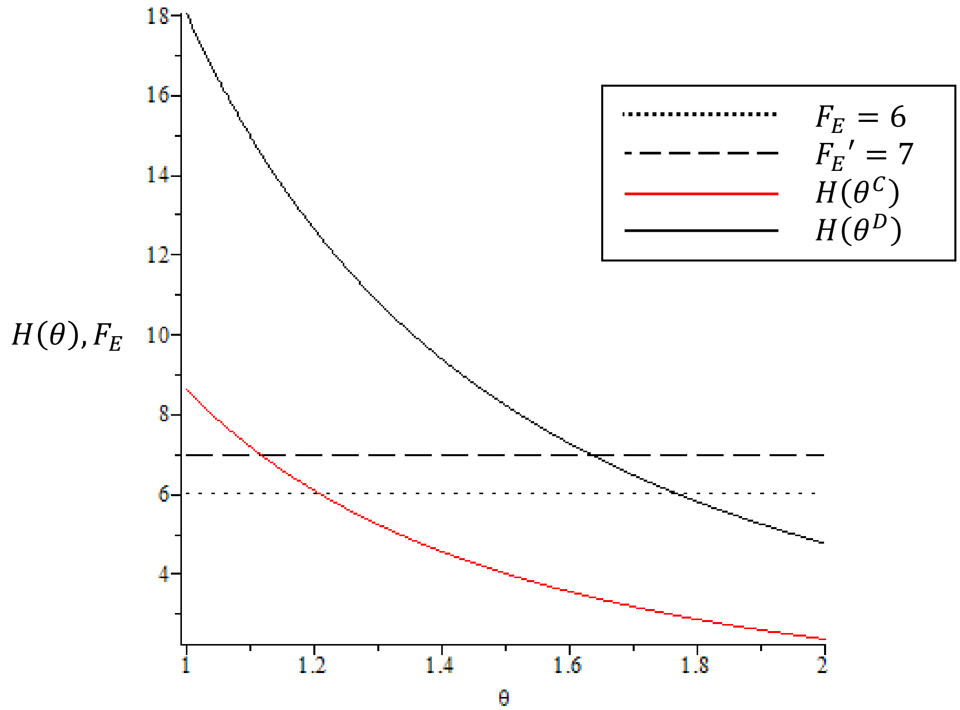


Table 3shows percentage changes relative to baseline for each of the productivity cut-offs as well total quality (TQ) available to consumers in each market and the quality-adjusted price index (normalizing $p = 1$).

Table 3: Simulation Results for Changes in Fixed Entry Costs

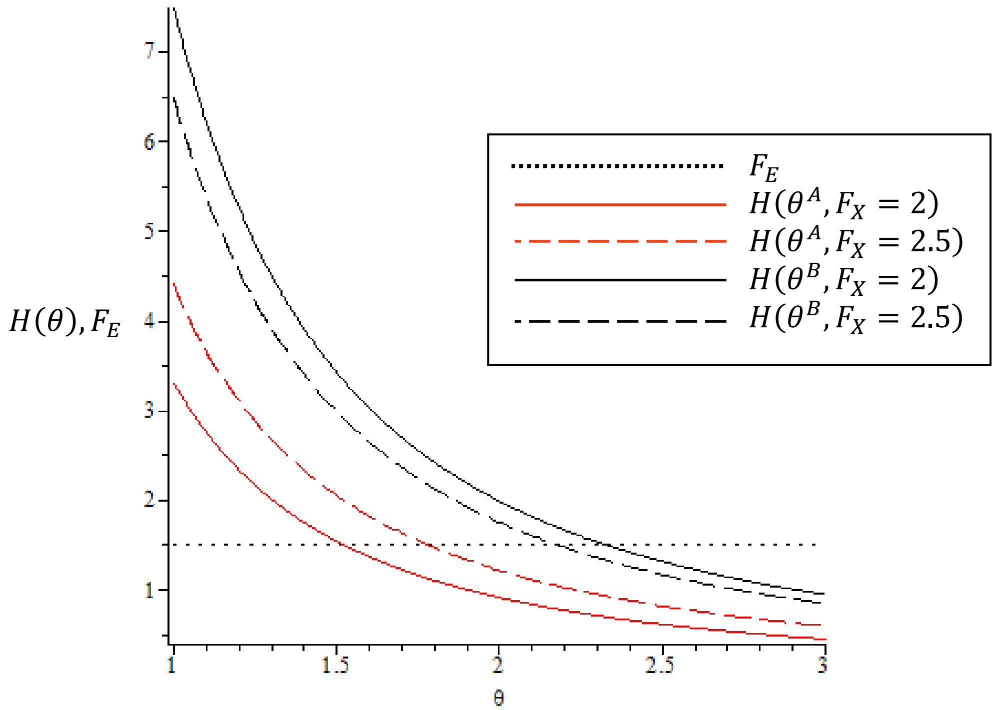
	LN/LE/HE	LN/HN/HE
θ^A	-13%	
θ^B	-13%	
θ^C		-8%
θ^D		-11%
TQ	-2%	-11%
P	+2%	+78%

These results 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 also reflected in the higher quality-adjusted price index.

2.5.2 Comparative Statics for F_X

Figure 13 and Figure 14 illustrate changes in the model equilibrium for changes in F_X, the fixed export cost. In Figure 13, F_X increases from 2 to 2.5. $H(\theta^A)$ shifts outward as firms find it more difficult to enter export markets at every productivity level. Holding F_E constant, the figure shows the equilibrium value of θ^A increases from 1.5 to 1.8, while $H(\theta^B)$ shifts in the opposite direction. Recall θ^B defines the firm that is indifferent between selling low quality and high quality goods, conditional on participating in export markets. Changes in F_X will not change the relative profitability of these two strategies, so the shift in $H(\theta^B)$ reflects the general equilibrium effects of a change in F_X. Domestic firms considering certification will operate in less competitive markets, so they will be more willing to adopt certification. Holding F_E constant, the equilibrium value of θ^B decreases from 2.3 to 2.2.

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



In Figure 14, 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. This is because exporting has become more costly. 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. This is because raising F_X protects domestic firms from foreign competition. Lowering the competitiveness of the domestic market allows domestic firms to earn higher profits at every productivity level, which will make them more willing to adopt the voluntary standard.

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

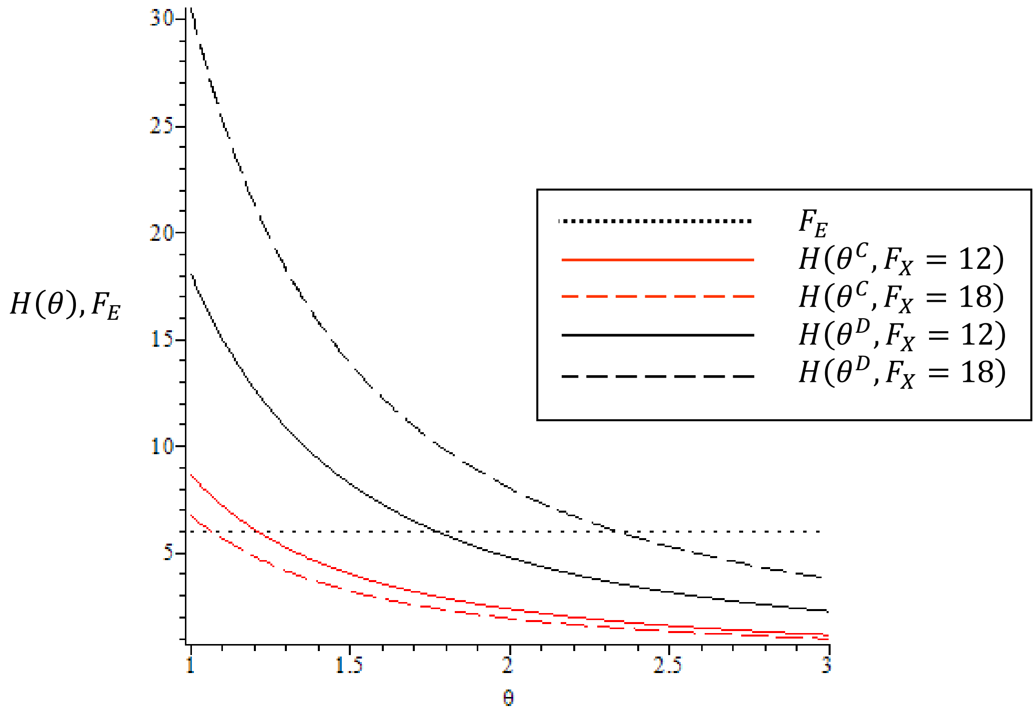


Table 4 shows percentage changes relative to baseline given a change in F_X for each of the productivity cut-offs, as well total quality (TQ) and the quality-adjusted price index (normalizing $p = 1$).

Table 4: Simulation Results for Changes in Fixed Export Costs

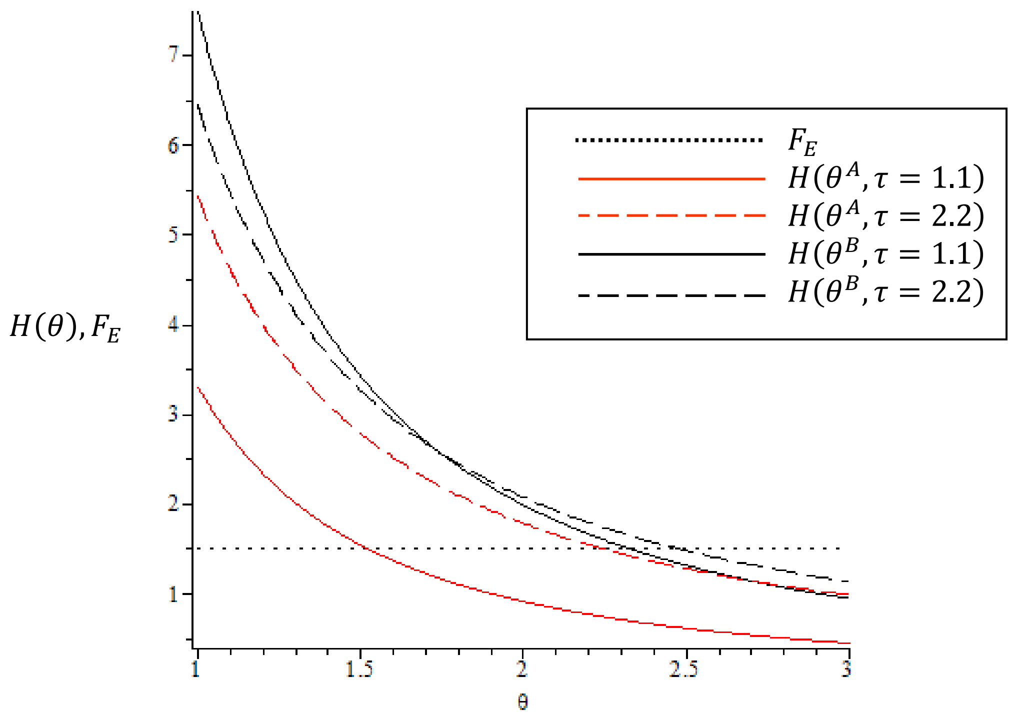
	LN/LE/HE	LN/HN/HE
θ^A	+20%	
θ^B	-4%	
θ^C		-8%
θ^D		+33%
TQ	-8%	-17%
P	+10%	+157%

As with F_E, these results show increasing fixed export costs reduces welfare. In both the LN/LE/HE and LN/HN/HE cases, export participation rises while participation in the voluntary standard falls. The result is a reduction in the total number of firms producing high-quality products. The quality-adjusted price index also rises.

2.5.2 Comparative Statics for τ

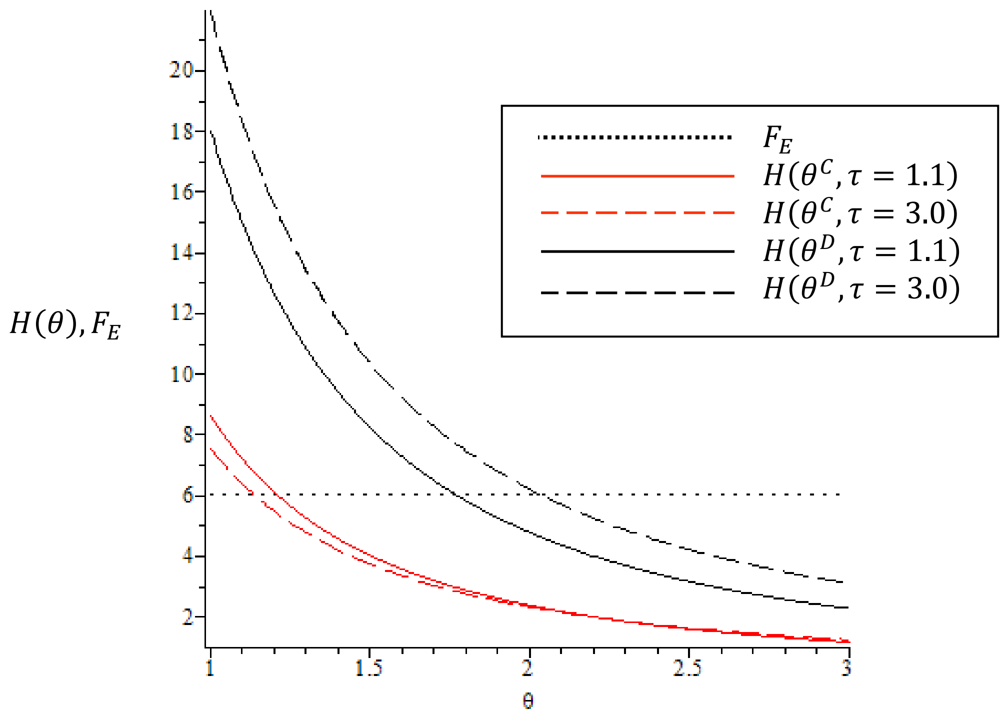
Figure 15 and Figure 16 illustrate changes in the model equilibrium for changes in τ, the transportation costs. In Figure 15, an increase in τ from 1.1 to 2.2 shifts $H(\theta^A)$ outward.

Figure 15: Comparative Statics for Transportation Costs in the LN/LE/HE Case



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



In Figure 16, 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.

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.

2.6: Discussion

The model presented here reexamines the relationship between export participation and voluntary certification through the lens of the HFT framework.

Firms are differentiated according to their productivity(θ), which indexes the ease with which they can sink the fixed costs associated with exporting and participation in a credible voluntary certification program. The model permits characterizing two separate equilibria: one where firms make their certification decision conditional on serving only the domestic market, and one where firms make their certification decision conditional on participating in domestic and export markets.

The model offers an explanation as to why adoption of voluntary standards tends to be positively correlated with firm size and export participation in empirical studies (see Nishitani, 2009). In this model, all three variables are endogenous and driven by firms' underlying productivities. Firms enter export markets and adopt voluntary certification because of the potential to earn higher revenues, either by entering new markets or increasing their market share in a given market. Firms with sufficiently high productivity will adopt both strategies because they face the lowest effective fixed costs. This will lead to a positive correlation between export participation and certification, even when the comparative static for certification with respect to trade costs is ambiguous.

Changes in trade costs have the expected effects on export participation; higher trade costs discourage firms from entering export markets. The comparative statics derived in section four show the relationship between trade costs and certification depends on the model scenario as well as the policy instrument in question. For import-competing firms, raising trade barriers can encourage adoption of the voluntary standard by protecting domestic firms from foreign competition. Under certain assumptions, this result will hold for increases in fixed trade costs (F_X) as well as transportation costs (τ). Greater domestic protection raises profits, which will encourage firms to sink the fixed costs associated with certification.

This is not necessarily the case for export-competing firms. Raising fixed trade costs will still encourage these firms to adopt the voluntary standard by protecting them from foreign competition. Under certain assumptions, raising transportation costs, analogous to raising tariff barriers, will have the opposite effect. Higher transportation costs affect price-setting behavior in the foreign market and make it more difficult for firms to recoup the fixed costs associated with adopting the voluntary certification. This can discourage adoption and lower the average level of quality following liberalization.

Raising trade costs will always decrease consumer welfare, regardless of the effect on export participation or adoption of voluntary standards. Raising trade barriers reduces entry into the industry and reduces domestic consumers' access to foreign-produced goods. This will limit the total quality of goods consumers are able to purchase, and raise quality-adjusted prices as markets become less competitive.

The model presented in this chapter is capable of reproducing the result found in Sheldon and Roe (2009), where total quality increases following liberalization in the presence of a voluntary standard. This result is mirrored in the comparative static for τ in the LN/LE/HE case. However, these results do not offer a definitive answer to the question of whether or not lower trade barriers can raise environmental or labor standards in the presence of a credible voluntary standard. In fact, they suggest the relationship between certification and trade depends critically on market conditions, including the marginal uncertified firm's participation in export markets. This might explain the difficulty that the empirical literature has had in explaining the relationship between trade liberalization and voluntary standards adoption in cross-country studies.

Chapter 3: Empirical Application

3.1: Introduction

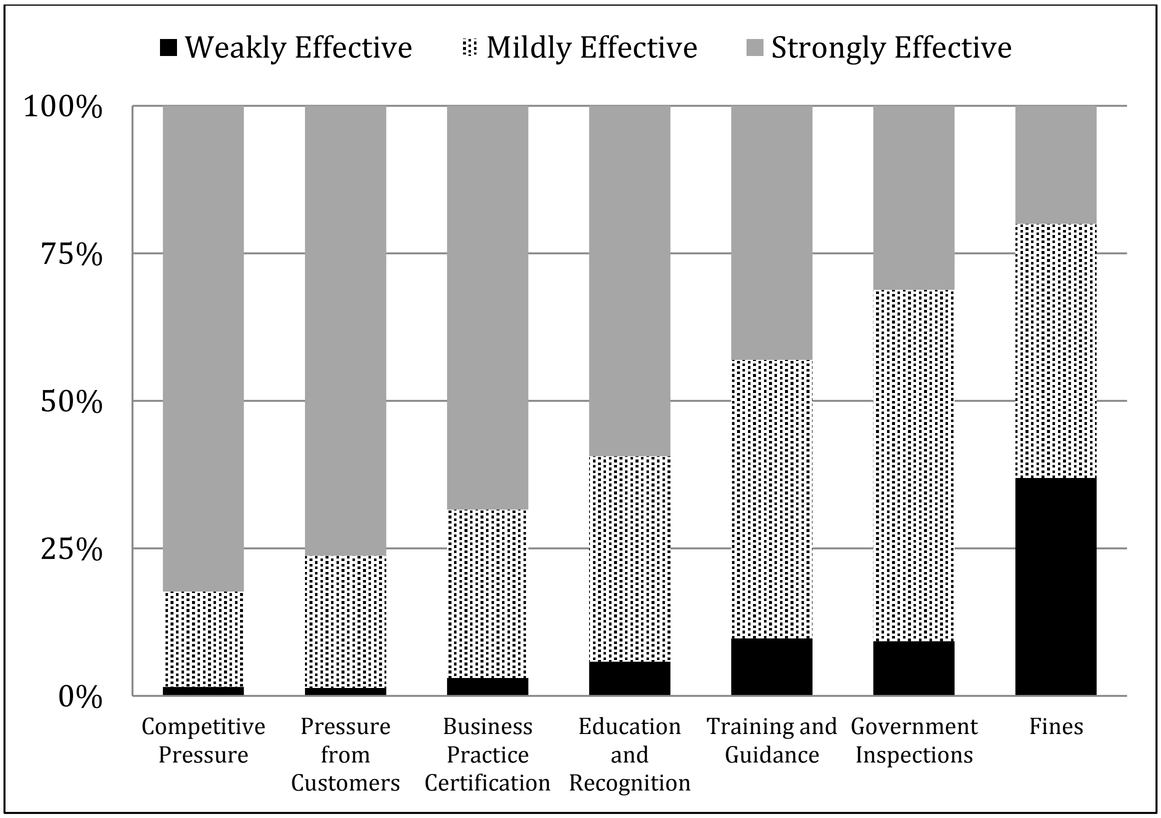
The model outlined in Chapter 2 provides a fairly general framework for understanding the relationship between openness to trade and the adoption of voluntary standards. The model shows how increased openness to trade can increase rates of adoption of voluntary standards and increase the average level of quality produced in a country, under certain conditions. The model specifically explains this relationship for standards that identify the underlying quality of credence goods, which make up a large number of the international voluntary standards that have emerged in the past few decades. These standards cover subjects as diverse as food safety, labor practices and environmental protection.

This chapter presents a study of ISO 14001 environmental management standard adoption in China. ISO 14001 is an excellent example of the type of standard described in the previous chapter. Interpreting "high-quality" as "environmentally-friendly," the model derived in Chapter 2 can explain what motivates firms to adopt ISO 14001. It can also explain why lower trade barriers may not mean lower environmental quality, even in an imperfect policy environment such as China's.

According to Copeland and Taylor (2004), the relationship between trade and the environment can be decomposed into three parts: scale, composition and technique effects. Scale effects refer to the growth of domestic industries as trade barriers fall. Composition effects refer to changes in a country's industrial composition as it adapts to international markets according to its comparative advantage. Technique effects refer to the use of "cleaner" technologies as the domestic policy environment responds to increased demand for environmental amenities driven by rising incomes. As the authors point out, scale effects will have unambiguously negative effects on the environment. Increased industrial output will increase emissions, *ceteris peribus*. Composition effects may be positive or negative, depending on the nature of the country's comparative advantage. If the country has a comparative advantage in the production of "dirty goods", then lowering trade barriers will also increase emissions. These negative effects may be offset by endogenous improvements in production technology in a flexible policy environment. As incomes rise, domestic consumers will demand greater environmental quality, and policy makers can respond to those demands by setting higher production standards. As long as these standards are enforced, trade will make domestic production techniques uniformly "cleaner."

If the ISO 14001 certification is credible, the theoretical model presented in Chapter 2 suggests the rapid increase in ISO 14001 adoption shown in Figure 2 could be the result of China's WTO accession. As trade barriers fall, firms have an increased incentive to produce "high-quality" or "environmentally friendly" goods because it is easier for them to market those products abroad and recoup the associated fixed costs. If ISO 14001 leads to superior environmental performance, this would generate a "technique" effect similar to the one described by Copeland and Taylor (2004), but without the need for intervention by regulators.

Figure 17: Reported Effectiveness of Various Means of Raising Firm Standards in China



Note: Data taken from the Industrial Enterprise Survey conducted by China's NBS

The results of a survey on Corporate Social Responsibility (CSR) in China support the hypothesis that market forces, rather than government intervention, play the biggest role in encouraging firms to adopt superior production techniques. Managers were asked to rate the effectiveness of several different ways firms are encouraged to raise production standards. As shown in Figure 17, respondents rated traditional regulatory instruments, such as inspections and fines, as the least effective means of raising production standards. At the same time, they rated certifications, demand from customers and competitive pressure as the most effective. The theoretical model presented in Chapter 2 demonstrates how a credible voluntary standard such as ISO 14001 can combine these three forces to exert upward pressure on production standards following trade liberalization.

An empirical analysis of ISO 14001 adoption in China is performed using the unique firm-level data set on CSR described above. The empirical analysis identifies several predictors of ISO 14001 adoption in China and tests whether or not ISO 14001 certification led to superior environmental performance among adopting firms. The results shed some light on how the rapid adoption of ISO 14001 could explain the difficulty researchers have had identifying a strong negative environmental impact of WTO accession, despite China's weak domestic environmental regulations.

3.2: Environmental Regulation in China

China's first environmental regulations were written in the 1980s and 1990s, beginning with standards on water pollution in 1984, air pollution in 1987, solid waste in 1995 and noise pollution in 1996.[5] Complementary laws relating to soil and water conservation as well as biodiversity were passed in the 1990s and early

[5]China's first environmental regulation, the Environmental Protection Law, was passed provisionally in 1979. It established that enterprises would have to pay a fee for discharges exceeding prescribed emissions standards.

2000s (Beyer, 2006). These regulatory standards are set at the federal level by the Ministry of Environmental Protection (MEP), formerly the State Environmental Protection Agency (SEPA). This elevation of SEPA to a ministerial-level agency in 2008 was meant to signal the central government's new focus on sustainable development.

The MEP is tasked with administering environmental policies handed down by the National People's Congress (NPC) and coordinating with local Environmental Protection Bureaus (EPB). EPB's are vested with the power to monitor emissions, perform site inspections and levy fees according to national regulatory standards. Polluters are required to submit declarations of their total emissions to their local EPB, which then determines if they are consistent with applicable environmental laws. Firms are granted licenses for emissions that do not violate legal standards. Polluters are faced with fees to acquire these licenses as well as "discharge excess fees" for emissions above the licensed level. Firms that commit gross violations of the standard are faced with escalating penalties and egregious offenders could be forced to shut down.

Official statements from the MEP tend to emphasize the progress that China has made in reducing emissions of key pollutants (see e.g. MEP, 2009), but these regulators are also keenly aware of "enforcement gaps" limiting the effectiveness of the current regulatory system (Stokoe and Gasne, 2008). The general consensus is the system is undermined by weak local enforcement. Beyer (2006) argues that the fundamental problem with China's environmental regulation system is the fact that policy is set at the federal level while there is no mechanism for federal oversight in the enforcement process, which is done locally. Excess discharge fees are often subject to individual negotiation and local regulators may be more inclined to please local business interests than a distant federal authority. This problem is compounded by the fact that the biggest polluting enterprises also tend to be state-owned (Lo et al., 2006).

The result is widespread under-enforcement of environmental regulations. Winalski (2009) found that, while the number of discharge permits issued doubled between 1996 and 2000, it still lagged far behind the number of known polluting enterprises. In some areas, only 20% of polluting enterprises applied for discharge licenses at all. Beyer (2006) also reports collected fees are often made available to local polluters in the form of "grants" for investments in cleaner technology, but without adequate supervision of how the money is used. Even when fines are levied appropriately, Stokoe and Gasne (2008) report maximum penalties are often set well below the cost of compliance.

The MEP has recently tried to address these "enforcement gaps" by developing new enforcement regimes that do not adhere so closely to the standard-and-penalty model. Zhang and Wen (2008) describe the government's recent steps toward promoting the adoption of cleaner production technologies instead of focusing exclusively on end-of-the pipe treatment and control. The government has also introduced new regional standards for total concentrations of certain air and water pollutants, though it is not clear how these total control targets are allocated into individual permits (Winalski, 2009). Certain municipalities have also experimented with emissions permit trading schemes, though these have not yet been scaled up to the national level.

Despite these innovations, environmental regulation in China still relies heavily on the discharge permit system to control emissions. The conflicting incentives faced by local EPBs lead to systemic under-enforcement of environmental regulations and contribute to environmental degradation as China continues to grow. Lack of confidence in China's formal regulatory system has led some scholars to ask what role there could be for a credible voluntary environmental standard in addressing China's environmental crisis.

3.3: The ISO 14001 Environmental Management Standard

Voluntary standards such as ISO 14001 were developed to overcome weaknesses in traditional regulatory instruments. The United States, for example, has experienced a great deal of success with its 33/50 program, a voluntary emissions reduction program introduced in 1991 to complement existing environmental regulations (Innes and Sam, 2009; Khanna and Damon, 1999). Such programs are seen as cost-effective alternatives to command-and-control regulation. Firms voluntarily over-comply with regulations in order to tap into "green" price premiums from environmentally conscious consumers (Eriksson, 2004) or to strategically preempt future tightening of environmental regulations (Lyon and Maxwell, 2003). In either case, voluntary standards provide incentives for firms to lower emissions while reducing the administrative and monitoring costs associated with traditional regulation.

ISO 14001 is one of the most popular voluntary environmental standards in the world. In 2010, there were over 250,000 ISO 14001 certified firms worldwide, with 69,784 in China alone (ISO, 2011). ISO 14001 was established in 1996 by the International Organization for Standardization (ISO) to provide an internationally-recognized gold standard for environmental management systems (EMS), and to prevent the proliferation of mutually incompatible national standards. The existing literature often uses the terms ISO 14000 and ISO 14001 interchangeably.[6] To clarify, ISO 14000 refers to a *family* of standards, ranging from the ISO 14001 environmental management system standard to other standards on environmental communication (14063), life-cycle assessment (14040), and greenhouse gas accounting (14064). Unlike the U.S.'s 33/50 program, ISO 14001 does not commit firms to an emissions target. The ISO explains that ISO 14001 provides specific guidelines for the establishment of environmental management systems that are relevant for a wide range of industries and firms at various levels of "environmental maturity" (ISO, 2012). An ISO 14001 compliant EMS must enable firms to:

- Identify and control their environmental impact

[6]See, for example, Curkovik et al. (2005) vs. Welch et al. (2002).

- Continually improve their environmental performance
- Implement a systematic approach to achieving environmental goals

Certifying firms' EMS instead of environmental performance has helped establish ISO 14001 as a brand recognizable to a wide range of public and private sector entities (Potoski and Prakash, 2005). This has also helped to encourage ISO 14001 adoption in less developed countries (Clapp, 1998). As ISO 14001 was being developed, there was some concern the standard would act as a *de facto* trade barrier, giving firms in rich countries a competitive advantage if ISO 14001 compliance required meeting strict (and costly) emissions targets. Instead, ISO 14001 requires that firms commit to meeting their local legal obligations to environmental protection. Environmental regulations vary from place to place, so ISO 14001 certified firms in different countries could have very different emissions levels.

The flexibility inherent in ISO 14001 has led to considerable skepticism over its ability to deliver improved environmental outcomes (see e.g. Krut and Gleckman, 1998; Potoski and Prakash, 2005). While firms are expected to improve their environmental performance, firms seeking certification in the ISO 14001 system are not evaluated on their actual legal compliance. They need only develop an effective internal process for achieving legal compliance (ECA, 2010). Based on the results from the previous chapter, there is good theoretical reason to believe a credible voluntary standard can improve average environmental performance, but there is some doubt as to whether or not ISO 14001 meets this criterion. This has led to a great deal of research aimed at understanding why firms choose to adopt ISO 14001 and identifying its effect on their actual environmental performance.

3.3.1: Previous Studies of ISO 14001 Adoption

The literature on the diffusion of the ISO 14001 standard has focused primarily on identifying the determinants of ISO 14001 certification (see Nishitani, 2009 for a comprehensive review). Adoption of the standard is typically understood as a profit-maximizing strategy similar to the one illustrated in the previous chapter. Several empirical findings are robust across different model specifications and country settings. Firms are more likely to adopt ISO 14001 if they deal with environmentally conscious consumers. Adoption is also correlated with firm size and profitability. Nishitani (2009) argues this is because larger and more profitable firms are better able to afford the costs of initial certification, which can range from $24,000 to $128,000. Potoski and Prakash (2005) report the total costs of compliance often exceed $1,000,000. This may be the case, but the theoretical model presented in the previous section demonstrates it would be a mistake to treat these factors as exogenous to the certification decision. Certification can be used to attract customers who value environmentally-friendly products. Certification can also increase firm size and profitability if these “green” consumers are willing to pay a premium for goods produced with high environmental standards.

There has also been considerable research on the relationship between ISO

14001 certification and export participation. Several studies have highlighted the importance of ISO 14001 as a means for firms to access global value chains (Nishitani, 2010; Prakash and Potoski, 2007), but the empirical evidence is mixed. Nishitani (2009) finds a positive correlation between ISO 14001 adoption and exporting among a sample of Japanese manufacturers, but Dasgupta et al. (2000) find no such relationship in their sample of Mexican manufacturing firms. Using country-level data, Prakash and Potoski (2006) found that countries with high levels of ISO 14001 trade more with each other. Boys and Grant (2010) perform a similar analysis, but find importing countries do not generally show a preference for partners with similar certification levels. They still found certification was associated with larger export volumes, but they argue that the absence of preferential selection among importers implies certification is correlated with some unobserved firm characteristic that is important for exporting. This is consistent with the theoretical model's explanation that both the exporting and certification decisions are driven by the firm's underlying productivity. The authors also found ISO 14001 certification was a stronger predictor of trade between developed countries than between a developed and developing or two developing countries. These results underscore the importance of allowing country-specific parameters to vary in future specifications of the theoretical model.

Very few scholars have studied ISO 14001 adoption in China, despite the standard's popularity among Chinese firms. Christmann and Taylor (2001) studied

ISO 14001 adoption in a sample of 86 firms in China and found that ties to multinational corporations and exports to Japan were associated with adoption of ISO 14001. Fryxell et al. (2004) and Zeng et al. (2005) examine the motives for ISO 14001 certification samples of ISO 14001 certified firms. They found ISO 14001 adopters sought certification to boost their reputation, enhance regulatory compliance and gain access to lucrative international markets. Unfortunately, these results are difficult to interpret because their sampling strategy did not allow comparisons between ISO 14001 adopters and non-adopters. To date, no study has examined ISO 14001 adoption in China with a large, representative sample of firms.

3.3.2: ISO 14001 and Environmental Performance

Proponents of ISO 14001 highlight the standard's potential to improve environmental outcomes even in countries where environmental regulations are weak, but the empirical evidence on ISO 14001 and environmental performance is mixed. Arimura et al. (2008), Potoski and Prakash (2005) and Dasgupta et al. (2000) find that adoption of ISO 14001 increased compliance with environmental regulations in samples of manufacturing firms. These findings are contradicted by Dahlstrom et al. (2003), who found no effect of ISO 14001 certification on compliance with the UK's Integrated Pollution Control regime. King et al. (2005) found ISO 14001 certified firms generally exhibited poorer environmental performance. Barla (2007) actually found that emissions levels rose following certification among a sample of firms in Canada's pulp and paper industry. Potoski and Prakash (2005) point out identifying the effect of ISO 14001 certification on environmental performance requires implementing the appropriate controls for endogeneity. Firms with superior environmental performance for other reasons might find it easier to meet the requirements for ISO 14001 certification. This makes it difficult to identify the direction of causality between ISO 14001 and environmental performance. Potoski and Prakash (2005) and Dasgupta et al. (2000) demonstrate how to derive a set of valid instruments for ISO 14001 certification by first identifying the predictors of certification adoption.

Potoski and Prakash (2005) also argue ISO 14001 may be more effective if customers actively monitor the certified firm's environmental performance. Since poor environmental performance is not technically grounds for decertification, firms may use ISO 14001 as a form of "green washing." It allows them to present an environmentally-friendly image without making any substantial changes in their performance. Christmann and Taylor (2006) address a similar question in a study of the ISO 9001 quality management system standard in China. They find more frequent customer inspections led to "higher quality" management standard implementation, using self-reported data in a sample of ISO 9001 certified firms. Incorporating information on this type of ex-post monitoring could also be important for understanding the relationship between ISO 14001 and environmental performance.

3.4: Estimation Strategy

The following is an empirical analysis of ISO 14001 adoption and the effect of ISO 14001 adoption on environmental performance in a sample of Chinese manufacturing firms. Following Potoski and Prakash (2005) and Dasgupta et al. (2000), the analysis begins by identifying predictors of ISO 14001 adoption. These predictors are then used as instruments to identify the relationship between ISO 14001 certification and environmental performance.

3.4.1: Data Description

The data are drawn from a unique firm-level dataset on CSR collected in 2006. The survey was funded by the International Finance Corporation and conducted by China's National Bureau of Statistics (NBS).[7] The full sample included 1,268 manufacturing firms. Approximately 100 firms were interviewed in each of 12 cities spread throughout China. After cleaning the data set and eliminating observations with missing information, 840 firms remain. Cities were not chosen randomly, but rather to represent the various stages of economic development observed within China.

Figure 18 shows the location of each city sampled in the survey. Within cities, firms were selected using a stratified sampling strategy. First, firms were stratified by ownership type and sampled in proportion with each ownership category's overall representation within the city. Firms were then stratified according to size

[7]There exists no official English translation of the data set. The questionnaire used for this study was translated from Chinese by the author.

and sampled according to each size category's representation within the city.

Figure 18: Geographical Distribution of Sampled Cities

The survey was designed to study firms' attitudes and behavior related to CSR. Firms were asked to describe their production processes, the benefits they offer their workers and the measures they take to protect the local environment. This includes coordination with local regulators and community groups as well as adoption of ISO 14001. The survey also collected information about more general firm characteristics as well as firms' perceptions of their market and regulatory environments. Although the survey provides recall data on a few of the relevant characteristics, variables relating to environmental protection and ISO certification were only recorded in cross-section. This makes it difficult to control for unobservable firm-level heterogeneity, but the data set is otherwise uniquely well-suited to studying ISO 14001 and environmental performance among manufacturing firms in China.

Including fixed effects in the can control for potential city or industry-specific sources of unobserved heterogeneity that might bias the results. The survey collected information on each firm's 4-digit industry code under China's industrial classification system. Constructing a unique dummy for each four-digit code would maximize the explanatory power of the system, but including so many dummy variables often leads to convergence problems when estimating limited-dependent variable models. This is because some categories contain very few firms, even after aggregating up from four-digit to two-digit industry categories. In order to avoid convergence problems, certain categories were combined with other, related industry categories.

Table 6 describes the how the two-digit categories were aggregated to derive this new set of industry fixed effects. This aggregation scheme reduces the number of industry categories from 36 to 13. The smallest category (Wood Products) represents 1.36% of the sample, while the largest category (Manufacturing) represents 27.12% if the sample.

Table 6: Construction of Industry Categories

Aggregate Category	Two-Digit Category	% of Sample
Mining	Coal Mining and Dressing	0.26%
	Ferrous Metal Mining & Dressing	0.17%
	Non-ferrous Metal Ores Mining and Dressing	0.43%
	Non-Metal Ores Mining and Dressing	0.43%
Agricultural Processing	Agriculture and Sideline Foods Processing	5.27%
Food and Tobacco	Food Production	2.98%
	Beverage Production	2.04%
	Tobacco Products Processing	0.09%
Textiles	Textile Industry	6.97%
Other Textiles	Clothes, Shoes and Hat Manufacture	3.66%
	Leather, Furs, Down and Related Products	1.87%
Wood Products	Timber Processing, Bamboo, Cane, Palm Fiber and Straw Products	0.51%
	Furniture Manufacturing	0.85%
Paper Products	Papermaking and Paper Products	1.87%
	Printing and Record Medium Reproduction	1.70%
	Cultural, Educational and Sports Articles Production	0.26%
Fuels	Petroleum Processing, Coking and Nuclear Fuel Processing	0.94%
Chemicals	Raw Chemical Material and Chemical Products	9.10%
	Medical and Pharmaceutical Products	2.55%
	Chemical Fiber	0.85%
	Rubber Products	0.94%
	Plastic Products	3.15%
Mineral Products	Nonmetal Mineral Products	6.72%
	Smelting & Pressing of Ferrous Metals	3.15%
	Smelting & Pressing of Non-Ferrous Metals	2.21%
Manufacturing	Metal Products	3.91%
	Ordinary Machinery Manufacturing	6.29%
	Specialty Equipment Manufacturing	4.42%
	Transport Equipment and Manufacturing	12.50%
Electrical Equipment	Electric Machines and Apparatuses Manufacturing	5.53%
	Communications Equipment	3.57%
	Instruments, Meters, Cultural and Office Machinery Manufacture	1.28%
	Craftwork and Other Manufactures	0.77%
Utilities	Electricity and Heating Production and Supply	1.96%
	Fuel Gas Production and Supply	0.26%
	Water Production and Supply	0.60%

3.4.2: ISO 14001 Adoption Model Specification

Summary statistics and definitions for each variable used in the empirical analysis are presented in Table 7.

Table 7: ISO 14001 Adoption Model Summary Statistics and Variable Definitions

Variable	Definition	Mean	S.D.
ISO 14001	=1 if ISO 14001 certified	0.16	
EPD	=1 if firm has established an environmental protection department	0.54	
Revenue	Total revenue (100k yuan)	2.64	16.03
Customer	=1 if customers demand high environmental standards	0.63	
Inspection	=1 if customers inspect the firm	0.76	
CxI	Interaction term between Customer and Inspections	0.50	
FJV	=1 if foreign joint venture	0.21	
Exporter	=1 if firm sells some output abroad	0.44	
ISO 9001	=1 if ISO 9001 certified	0.63	

ISO 14001 certification is a binary decision, so it is possible to estimate the relationship between ISO 14001 and its predictors using a standard probit model. Certification status is measured with a dummy variable (*ISO 14001*) equal to one if the firm was ISO 14001 certified when the survey was administered, and zero otherwise. The theoretical model and the existing empirical literature suggest ISO 14001 certification should be positively correlated with firm size as well as export status. Sinking the costs associated with ISO 14001 is only justified if certification delivers higher revenues. Firm size is measured using total revenues (*Revenue*), expressed in units of 100,000 yuan.[8] The model also predicts a positive correlation with export status, because both strategies require sinking substantial fixed costs

[8] Each model specification was also estimated using total employment to measure firm size. Results were robust to either specification.

and will only be adopted by the most productive firms. Export status is measured using a dummy variable (*Exporter*) equal to one if the firm reported any export revenue in the year the survey was administered, and zero otherwise. It may also be possible to predict certification status by observing the costs firms have sunk in environmental protection efforts. These sunk costs are captured using a dummy variable (*EPD)* equal to one if the firm had established an environmental protection department at the time of the survey.

The model presented in the previous chapter assumed consumers are identical within and across countries. This makes it difficult to model heterogeneity in consumer preferences, but the existing empirical literature suggests this may be an important determinant of certification. The survey asked firms whether or not any of their customers had requested they take some steps to manage the firm's environmental impact. The response to this question was used to construct a dummy variable (*Customer*) equal to one if the firm's customers had requested some environmental protection, and zero otherwise. This reflects the firm's access to potentially high-premium markets for "green" goods. As Potoski and Prakash (2005) point out, certification might not improve environmental performance unless firms are subject to some form of ex-post monitoring. The survey asked firms whether or not their customers inspected their facilities for "quality management" purposes. These inspections may also provide customers with information on firms' true environmental performance. This ex-post monitoring is measured using a dummy variable (*Inspection*) equal to one if the firm allows customers to inspect their facilities, and zero otherwise. Since these inspections would be more relevant for "green" customers, the model also includes an interaction term between these two variables (*CxI*). [9]

Following Christmann and Taylor (2001), each model includes a dummy variable (*FJV*) equal to one if the firm was a foreign joint venture, and zero otherwise. Christmann and Taylor (2001) argue foreign ownership may lead to increased scrutiny and therefore more self-regulation. Helpman, Melitz and Yeaple (2005) showed only the most productive firms engage in FDI. Since certification is also a strategy adopted by high-productivity firms, the positive correlation between ISO 14001 and foreign ownership share could also reflect differences in productivity between certified and uncertified firms. In either case, foreign joint ventures would be more likely to adopt ISO 14001.

Finally, each model includes a dummy variable (*ISO 9001*) equal to one if the firm had ISO 9001 certification when the survey was administered. The literature on ISO 14001 generally finds a positive relationship between ISO 9001 and ISO 14001 certification, for example Christmann and Taylor (2001). Researchers argue firms with ISO 9001 certification may be more likely to adopt ISO 14001 because they face lower effective costs. These firms would already know the general structure of an ISO management standard, they would be familiar with the

[9] *Customer* and *Inspection* were de-meaned before being included in the regression models in order to address the high degree of collinearity between these two variables and their interaction term.

necessary paperwork involved in certification and they may already have established relationships with local ISO auditors.

Estimating a single-stage probit model ignores any potential endogeneity between ISO 14001 certification and the determinants identified above. The theoretical model presented in Chapter 2 makes it clear many of these variables are endogenous. The estimated relationships should therefore not be interpreted causally. However, the goal of this estimation exercise is to identify a set of variables that predict certification status. This will provide a set of potential instruments for ISO 14001 certification and can provide some sense of how well the theoretical model predicts the characteristics of certified versus uncertified firms.

3.4.2: ISO 14001 Adoption Model Results

Table 8 presents results for three specifications of the ISO 14001 certification model. Each model was run on 840 observations and included city and industry fixed effects, in addition to the variables listed in the table. Reported p-values for each parameter were calculated using robust standard errors clustered at the city level. The results of the likelihood ratio tests reported at the bottom of Table 8 indicate each specification of the model had significant predictive power for ISO 14001 certification.

The results generally conform to the hypotheses derived from the theoretical model presented in the previous section and the previous empirical literature on ISO 14001. Several relationships were robust across every model specification.

Revenue was positively related to ISO 14001 certification in every specification. There was also a consistent positive and significant relationship between *ISO 9001* and ISO 14001 certification. Firms with an established *EPD* were also significantly more likely to be ISO 14001 certified in every specification.

Table 8: Predictors of ISO 14001 Certification

Dependent Variable: *ISO 14001*	(1)	(2)	(3)
ISO 9001	1.40 A	1.38 A	1.36 A
	(0.00)	(0.00)	(0.00)
Exporter	0.31 B	0.23	0.24
	(0.03)	(0.17)	(0.16)
Revenue	0.02 B	0.02 B	0.02 B
	(0.05)	(0.04)	(0.04)
FJV	0.16	0.19	0.17
	(0.37)	(0.29)	(0.33)
EPD	1.11 A	1.07 A	1.08 A
	(0.00)	(0.00)	(0.00)
Customer		0.43 B	0.42 C
		(0.01)	(0.05)
Inspection			-0.001
			(0.99)
CxI			0.73B
			(0.04)
Constant	-3.23 A	-3.15 A	-3.21 A
	(0.00)	(0.00)	(0.00)
Observations	840	840	840
Pseudo R2	0.32	0.33	0.33
LR Test P-Value	0.00	0.00	0.00

Notes:
1. Robust P-Values in parentheses. A: p<0.01, B: p<0.05, C: p<0.1
2. All specifications include city and industry fixed effects

The relationship between *Exporter* and certification was positive in every specification, but only significant in column (1). The p-value on the estimated coefficient falls after introducing controls for customer type (*Customer*). The coefficient on *Customer* is positive and significant in models (2) and (3). *Inspection* was not a significant predictor of ISO 14001 certification, but the estimated coefficient on the interaction term (*CxI*) was positive and significant in model (3). Foreign joint ownership (*FJV*) was not a significant predictor of ISO 14001 certification in any specification of the model.

3.4.2: Environmental Performance Model Specification

The previous estimation exercise identified a set of variables that can be used to predict a firm's ISO 14001 certification status. These relationships are not causal, but they can be used to identify the causal relationship between ISO 14001 certification and environmental performance. In the theoretical model, the information asymmetry between consumers and firms prevents any trade in high-quality goods in the absence of certification. Firms are only willing to produce high-quality goods because certification allows them to earn higher revenues to compensate for increased fixed costs. The model would predict a positive and significant relationship between ISO 14001 certification and some measure of environmental performance. However, estimating this relationship using a standard ordinary least squares (OLS) or single-stage limited dependent variable model might not be a sufficient test of this hypothesis. There are many potential reasons firms might exhibit superior environmental performance. They may do so in response to regulatory pressure, as part of a strategic game with regulators (Lyon and Maxwell, 2003). They may also have found some other means of resolving the information asymmetry problem. If so, firms with high environmental performance for reasons unrelated to ISO 14001 may self-select into the standard because they find it easier to meet the requirements. In order to identify the causal relationship between ISO 14001 certification and environmental performance, it is necessary to implement the appropriate controls for endogeneity.

This relationship is estimated using two separate binary indicators of environmental performance. One is a dummy variable (*Compliance*) equal to one if the firm reported it was in compliance with all relevant environmental regulations in the year the survey was administered. The second is a dummy variable (*Violation*) equal to one if the firm was cited for violating an environmental regulation in the year the survey was administered.

The environmental performance models are estimated including two additional control variables not previously included in the ISO 14001 models. One is a measure of the number of environmental standards that apply to the firm and its products (*Standards*). This controls for differences in the strictness of the regulatory environment not captured by city or industry fixed effects. Each model also includes a variable measuring the number of times the firm was inspected by their local EPB in the year the survey was administered (*GInspections*). This controls for differences in environmental performance driven by direct pressure from regulators. Summary statistics for these variables can be found in Table 9.

Table 9: Environmental Performance Model Summary Statistics and Variable Definitions

Variable	Definition	Mean	S.D.
Compliance	=1 if reports compliance with environmental regulations	0.87	
Violation	=1 if cited for violating environmental regulations	0.08	
GInspections	# of inspections by local EPB	4.23	14.25
Standards	# of applicable environmental standards	3.21	1.84

Four models are estimated for each measure of environmental performance. The sample size for the environmental performance models is smaller than the sample used in the ISO 14001 adoption model. This is because fewer firms provided information on environmental performance than on ISO certification. The sample size falls from 840 to 558. First, a naïve probit model is estimated including firms' observed ISO 14001 certification status (*ISO 14001*) as an independent variable in both regressions. Subsequent models are estimated using an instrumental variables (IV) approach to control for potential endogeneity between *ISO 14001* and environmental performance. Both measurements of environmental performance and *ISO 14001* are binary, so traditional two stage least squares and IV probit are not appropriate. Greene (2000) shows the seemingly unrelated bivariate probit estimator (SURBP) is appropriate for this case.[10]

SUR estimators are generally used to estimate systems of equations where potential correlation of the residuals across equations leads to a loss of efficiency.

[10] The same models were also estimated using traditional two-stage least squares and instrumental variables probit. The results were qualitatively similar and, in each case, supported the instrumentation strategy adopted in the SURBP models.

This framework naturally extends to the estimation of a limited dependent variable model with a potentially endogenous binary regressor. Assume a simple example where the full model is specified as:

$$Y = \alpha_1 + \beta_1 X + \varepsilon_1 \qquad Y^* = \begin{cases} 1 \; if \; Y > 0, \\ 0 \; otherwise \end{cases}$$
$$X = \alpha_2 + \beta_2 Z + \varepsilon_2 \qquad X^* = \begin{cases} 1 \; if \; X > 0, \\ 0 \; otherwise \end{cases}$$
$$\binom{\varepsilon_1}{\varepsilon_2} | Z \sim N\left(0, \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix}\right)$$

Correlation between the error terms leads to endogeneity because it induces correlation between X and ε_1 in the Y model. This endogeneity will bias parameter estimates as long as $\rho \neq 0$. Estimating this system using the bivariate probit estimator corrects for potential bias in the calculation of treatment effects of X on Y.

As in a standard IV strategy, identifying the model requires finding a set of regressors (Z) that are correlated with the binary endogenous regressor (X) but not the dependent variable of interest (Y), except through their relationship with X. Testing the restriction $\rho = 0$ is typically used as a test of exogeneity in a well-specified SURBP model with an endogenous binary regressor. The normal tests for weak instruments and the exclusion restriction do not apply. Standard procedure to test instrument quality is a joint chi-squared test of significance for the excluded instruments (Z) in the first stage (X) regression. In the case of an over-identified model, where there are two or more elements in Z, the exclusion restriction can be tested in two steps. The first step is to estimate a just-identified specification of the model, including all but one element of Z in the second stage (Y) model. The second step is to perform a chi-squared test of joint significance of the elements of Z in the second stage (Y) model. Valid instruments should fail to reject the null of joint insignificance in the second stage model (Y) (Rashad and Kaestner, 2003).

The SURBP model is first estimated using the full set of independent variables from model (3) in Table 8 as instruments for *ISO 14001*. The model is then re-estimated using a restricted subset of the determinants of *ISO 14001* to ensure the exclusion restriction is satisfied. The final specification excludes any other potentially endogenous variables from the environmental performance equation to avoid inducing bias through so-called "bad control" (Angrist and Pischke, 2008). All specifications include city and one-digit industry fixed effects.[11] Estimation results for *Violation* are presented in Table 10. Estimation results for *Compliance* are presented in Table 11.

3.4.3: Environmental Performance Model Results

Estimation results are presented in Table 10 and Table 11. Not all firms provided information on their regulatory compliance, so both models are run on a sub-sample of 558 observations. Sample sizes are slightly smaller in each column (1) because certain observations are excluded due to perfect predictability.

Chi-squared tests indicate all specifications have significant predictive power. Results of the Wald test of $\rho = 0$ indicate the null of zero correlation across

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[11] SURBP models failed to converge in for either measurement of environmental performance using two-digit industry effects. Single-stage estimation of the relationship suggests decreasing the level of aggregation from one to two-digit industries effects adds little explanatory power to the model.

error terms can only be rejected in column (2) of Table 11. Despite this generally negative result, King et al. (2005) advise proceeding with the SURBP specification when there is good theoretical justification to suspect endogeneity.

Table 10: Estimation Results for Violation

Dep. Variable:	(1)	(2)		(3)		(4)	
Violation	Probit	Violation	ISO14001	Violation	ISO14001	Violation	ISO14001
ISO 14001	-0.44^{B}	-0.81^{C}		-1.37^{A}		-1.09^{A}	
	(0.03)	(0.05)		(0.00)		(0.01)	
Standards	0.01	0.02		0.01		-0.004	
	(0.90)	(0.84)		(0.83)		(0.96)	
GInspections	0.002	0.002		-0.00			
	(0.68)	(0.48)		(0.98)			
ISO 9001			1.28^{A}		1.24^{A}		1.31^{A}
			(0.00)		(0.00)		(0.00)
Exporter			0.15		0.15		0.18
			(0.27)		(0.26)		(0.24)
Revenue			0.02^{C}		0.02^{B}		0.02^{B}
			(0.06)		(0.05)		(0.04)
FJV			0.23	-0.71^{A}	0.20	-0.76^{A}	0.21
			(0.15)	(0.02)	(0.27)	(0.00)	(0.22)
EPD			0.95^{A}	0.62^{A}	0.95^{A}	0.56^{A}	1.03^{A}
			(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Customer			0.59^{B}	0.10	0.54^{B}		
			(0.02)	(0.72)	(0.03)		
Inspection			-0.21	-0.003	-0.23		
			(0.22)	(0.99)	(0.30)		
C x I			1.05^{A}	-0.51	1.07^{A}		
			(0.01)	(0.15)	(0.01)		
Constant	-2.07^{A}	-1.36^{A}	-3.26^{A}	-1.47^{A}	-2.68^{A}	-1.53^{A}	-3.07^{A}
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	537	558		558		558	
Chi^2 (Fit) P-Val	0.04	0.00		0.00		0.00	
Anderson Stat. P-Value		0.00		0.00		0.00	
Hansen Stat. P-Value		0.03		0.72		0.53	
Wald P-Value ($\rho = 0$)		0.36		0.22		0.21	

Notes:
1. Robust P-Values in parentheses. A: $p<0.01$, B: $p<0.05$, C: $p<0.1$
2. All specifications include city and industry fixed effects

Table 11: Estimation Results for Compliance

Dep. Variable:	(1)	(2)		(3)		(4)	
Compliance	Probit	Compliance	ISO14001	Compliance	ISO14001	Compliance	ISO14001
ISO 14001	0.52^{A}	1.30^{A}		1.07^{C}		0.96^{C}	
	(0.01)	(0.00)		(0.06)		(0.06)	
Standards	-0.03	-0.05		-0.06		-0.04	
	(0.40)	(0.20)		(0.14)		(0.26)	
GInspections	-0.003	-0.003		-0.003			
	(0.39)	(0.36)		(0.33)			
ISO 9001			1.11^{A}		1.19^{A}		1.27^{A}
			(0.00)		(0.00)		(0.00)
Exporter			0.15		0.15		0.18
			(0.15)		(0.19)		(0.20)
Revenue			0.02^{C}		0.02^{C}		0.02^{B}
			(0.06)		(0.07)		(0.02)
FJV			0.17	0.14	0.16	0.18	0.19
			(0.29)	(0.53)	(0.29)	(0.49)	(0.23)
EPD			0.95^{A}	0.03	0.97^{A}	0.05	1.02^{A}
			(0.00)	(0.11)	(0.00)	(0.84)	(0.00)
Customer			0.50^{B}	0.04	0.52^{B}		
			(0.05)	(0.88)	(0.03)		
Inspection			-0.15	0.09	-0.19		
			(0.41)	(0.72)	(0.27)		
C x I			1.31^{A}	0.88^{B}	1.06^{A}		
			(0.00)	(0.01)	(0.01)		
Constant	2.13^{A}	1.40^{C}	-2.58^{A}	1.46^{B}	-2.65^{A}	1.37^{C}	-3.30^{A}
	(0.00)	(0.08)	(0.00)	(0.05)	(0.00)	(0.09)	(0.00)
Observations	542	558		558		558	
Chi^2 (Fit) P-Val	0.05	0.00		0.00		0.00	
Anderson Stat. P-Val		0.00		0.00		0.00	
Hansen Stat. P-Val		0.40		0.76		0.86	
Wald P-Value ($\rho = 0$)		0.04		0.34		0.26	

Notes:

1. Robust P-Values in parentheses. A: $p<0.01$, B: $p<0.05$, C: $p<0.1$
2. All specifications include city and industry fixed effects

Column (1) in each table shows the results for the naïve probit model of environmental performance. The coefficient estimates on *ISO 14001* indicate certification is correlated with superior environmental performance and are significant at the 5% level for *Violation* and at the 1% level for *Compliance*. These results are not sufficient to support causal inference, but are consistent with the hypothesis that ISO 14001 certification improves environmental performance. Estimated coefficients on *GInspections* and *Standards* were not significant in either model.

Column (2) in each table shows the results for the SURBP model using the full set of regressors from column (3) of Table 8 as instruments. The estimated coefficients on *ISO 14001* are the same sign as in the probit specification. The estimated coefficient is significant at the 10% level for *Violation* and at the 1% level for *Compliance*. Comparing columns (1) and (2) in both tables, the estimated coefficients on *ISO 14001* certification are larger in absolute value in the SURBP models. Once again, the additional controls in the environmental performance equations are not significant.

While the coefficient estimates are fairly consistent between the probit and SURBP results, it is not clear all of the instruments used in column (2) should be excluded from the environmental performance equation. In order for an instrument to be valid, it must be correlated with ISO 14001 certification, but uncorrelated with environmental performance. The bottom of column (2) reports test statistics derived by estimating the same model specifications using two-stage least squares (2SLS). The Anderson statistic is derived to test the null that the excluded instruments (Z) have no predictive power in the first-stage regression (X). The Anderson statistic supports rejection of the null across all model specifications. The

Hansen statistic is derived to test the null that the instruments (Z) should be excluded from the second-stage model (Y). The Hansen statistic supports rejecting the null for the specification in column (2) for the *Compliance* model. This indicates some of the excluded instruments should be included in the environmental performance equation.

Column (3) in each table shows the results for each SURBP model after re-specifying the environmental performance equations to include predictors of *ISO 14001* that could plausibly be correlated with environmental performance. These include *EPD*., *Customer*, *Inspection, CxI* and *FJV*. The first four variables are all directly related to environmental protection effort and outcomes. *FJV* is also included to reflect the hypothesis in Christmann and Taylor (2001) that multinationals exert pressure on their partners to improve their environmental performance. The estimated coefficients on *ISO 14001* retain their sign and are significant at the 1% level for *Violation* and at the 10% level for *Compliance. FJV* and *EPD* are also significant in the *Violation* model, while (*CxI*) is significant in the *Compliance* model. *GInspections* and *Standards* were not significant in either model.

The Anderson and Hansen statistics in column (3) indicate the instruments perform well in 2SLS specifications of each model. However, including other potentially endogenous regressors in the environmental performance models may have induced bias in the estimation of the coefficients. Including additional endogenous variables would make it impossible to draw causal inference using the estimated coefficients on *ISO 14001* (Angrist and Pischke, 2008).

Column (4) in each table shows the results for the SURBP estimator after excluding potentially endogenous variables from the environmental performance models. Variables relating to customer type (*Customer, Inspection, CxI*) were eliminated because firms may have attracted "green" customers by exhibiting superior environmental performance. *GInspections* was eliminated because EPBs may inspect a firm more or less frequently based on their environmental performance.

Estimated coefficients on *ISO 14001* retain their sign and significance in both models. None of the additional control variables were significant in the *Compliance* model, but *EPD* and *FJV* were both significant in the *Violation* model. The Hansen and Anderson statistics derived from the 2SLS specifications support the use of the remaining instruments (*Exporter, Revenue, ISO9001*) in both models. Chi-squared tests indicate the instruments were jointly significant in the first-stage of the SURBP models for *Compliance* (p-value=0.00) and *Violation* (p-value=0.00). Estimating just identified specifications of both SURBP models using only ISO 9001 as an instrument for ISO 14001 indicated *Exporter* and *Revenue* were not significant in the second stage of either the *Violation* (p-value = 0.66) or the *Compliance* (p-value = 0.96) models. These results strongly support their use as instruments for *ISO 14001.*

3.5: Discussion

The estimation results shed some light on the potential role of voluntary standards in managing China's environmental crisis. They broadly validate the predictions of the theoretical model linking lower trade costs to increased adoption of voluntary standards, and reproduce some of the key findings from the existing literature on ISO 14001. Size, export status and the magnitude of sunk environmental protection costs were useful predictors of certification status. This is consistent with the model's explanation that firms seek out costly certifications in order to capitalize on consumers' higher willingness to pay for environmentally-friendly products. This hypothesis is further supported by the observed positive relationship between certification and serving a "green" customer base. The positive relationship between ISO 9001 and ISO 14001 suggests previous experience with the ISO system may reduce the costs associated with seeking an additional certification.

The environmental performance equations presented in Table 10 and Table 11 present robust evidence of a causal relationship between ISO 14001 certification and superior environmental performance. Certification increased the likelihood of firms reporting compliance with all relevant environmental regulations and decreased the likelihood firms reported being cited for violating environmental regulations. This effect is observed in naïve, single-stage probit models and persists when using a valid set of instruments to control for potential endogeneity between certification and environmental performance. This is the first firm-level evidence that the widespread adoption of ISO 14001 certification may help alleviate China's environmental crisis. It also suggests the widespread adoption of ISO 14001 has played an important role in preventing further worsening of China's environmental crisis from increased openness to trade.

The results also provide some evidence to support the argument in Potoski and Prakash (2005) that programs like ISO 14001 may be more effective when combined with ex-post monitoring. The estimated coefficient on the interaction term (*CxI*) was positive and significant in column (3) of Table 8, as well as positive and significant in columns (3) and (4) of Table 10 and Table 11. This could indicate environmentally conscious customers are more willing to work with ISO 14001 certified firms if they can monitor their actual environmental performance. Otherwise, firms may be tempted to use ISO 14001 as a form of "green washing," presenting an environmentally-friendly face without changing their environmental performance.

The estimation results also present evidence of strategic behavior on the part of regulators. Dean et al. (2009) found evidence that foreign investment is attracted to provinces in China with weaker enforcement of environmental regulation. They argue this is part of a "race to the bottom" wherein EPBs competitively weaken enforcement to promote local economic growth. Comparing columns (3) and (4) between Table 10 and Table 11, *FJV* was associated with a significantly lower likelihood of being cited for violating environmental regulations, but had no effect on firms' self-reported compliance. This could indicate foreign joint ventures are not more likely to obey environmental regulations, but are cited less often for violating them.

Finally, there is some suggestive evidence firms are falsifying their environmental credentials. Comparing the naïve probit models to the bivariate probit results in Table 10 and Table 11, the estimated coefficient on ISO 14001 is consistently larger (in absolute value) when the model is estimated using the instrumented values rather than the reported certification levels.[12] This pattern can also be observed in the 2SLS results. This is consistent with a reduction in attenuation bias due to measurement error, a common use of instrumental variables analysis. Specifically, this is consistent with firms over-reporting ISO 14001 certification in the data set. This may be part of a growing trend toward falsifying environmental credentials in China. As Stalley (2010) points out, the large number of counterfeit environmental certifications in China has undermined consumer confidence in "green" products. The theoretical model in Chapter 2 predicts lower trade barriers can raise environmental performance in the presence of a voluntary standard, but only if consumers find such certifications credible. If ISO 14001 certification loses credibility in China, consumers may not be willing to compensate certified firms for the additional costs of superior environmental performance.

[12] A special thanks to Joyce Chen for pointing out this pattern.

Chapter 4: Conclusions

In the absence of a global legal framework to control process standards, many have expressed concern that lowering barriers to trade will exert downward pressure on production standards as regulators compete to attract FDI and increase export competitiveness. Despite these concerns, there is very little evidence the recent trend toward liberalization has led to such a "race to the bottom." The previous chapters provided some insight into the role voluntary standards can play in this process. The results presented here provide new theoretical and empirical evidence to support the hypothesis that the adoption of voluntary standards can improve safety, sustainability and labor standards in an era of trade liberalization.

4.1: Theoretical Model

Chapter 2 contributes to the literature on voluntary standards in international trade by developing a strong theoretical framework to understand 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.

4.1.1: Future Theoretical Work

The model presented in Chapter 2 provides a framework for understanding the relationship between trade liberalization and voluntary certification, but 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 possible to avoid this result by assuming 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 shown in Chapter 2 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 results presented in section 2.5 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.

4.2: Empirical Application

The theoretical model gives some theoretical justification for the hypothesis that trade can raise production standards in the presence of a credible voluntary certification. This argument was explored further in a study of ISO 14001 adoption in China. China has experienced significant environmental degradation in the past few decades, and many feared its accession to the WTO would only worsen the problem. However, careful study has shown a positive effect of WTO accession on environmental standards in China. The predictions of the theoretical model suggest this could be attributable, at least in part, to the rapid adoption of ISO 14001 in China following accession. This hypothesis was explored by identifying the predictors of ISO 14001 adoption in China and then testing whether or not ISO 14001 improved firms' environmental performance.

The results indicate size, sunk environmental costs and export participation were generally good predictors of ISO 14001 adoption. Following the previous literature, the results also indicate serving an environmentally conscious customer base and existing ISO 9001 certification also predict ISO 14001 adoption. These results were robust to the inclusion of city and industry-level fixed effects, but the cross-sectional nature of the data makes it difficult to control for other sources of firm-level heterogeneity.

ISO 14001 adoption was also associated with superior environmental performance, measured using self-reported compliance with environmental regulations and citations for violating environmental regulations. This effect persisted after implementing an instrumental variables strategy using the SURBP estimator to control for potential endogeneity between ISO 14001 adoption and environmental performance. Again, these results were robust to the inclusion of city and industry-level fixed effects, but the cross-sectional nature of the data makes it difficult to control for other sources of firm-level heterogeneity.

These results directly demonstrate the adoption of voluntary standards can improve environmental outcomes even where regulations are weakly enforced. They also support the hypothesis that the adoption of ISO 14001 around the time of China's WTO accession helped raise environmental standards among Chinese firms. The results are not a sufficient test of the causal link between trade liberalization and environmental performance, but they are broadly consistent with the model presented in Chapter 2, which established a theoretical justification for this hypothesis.

4.1.2: Future Empirical Work

The empirical analysis presented in Chapter 3 adopted an instrumental variables strategy to identify the effect of ISO 14001 on environmental performance. The standard tests indicate the instruments performed well, supporting a causal interpretation of the observed positive relationship between ISO 14001 and environmental performance. However, several data limitations cast doubt on these results. First, the measurements of environmental performance used in the analysis were all self-reported. These types of responses are not necessarily reliable indicators of actual performance. Second, the observations were observed only in cross-section. Although every specification included city and industry fixed effects, there may be important firm-level sources of heterogeneity that can only be addressed using panel data. This would allow for a specification of the model using firm fixed effects or a difference-in-difference estimator to control for unobserved firm-level heterogeneity.

Chapter 3 established a link between ISO 14001 certification and environmental performance, but it did not provide direct evidence of the link between trade liberalization and ISO 14001 adoption implied by the theoretical model. ISO 14001 was positively correlated with export participation, but as the theoretical model shows, it is possible to observe such a correlation without implying liberalization promotes certification adoption. Further empirical validation of the theoretical model would require analysis along the lines of Boys and Grant (2010) or Prakash and Potoski (2006). Further extensions of the theoretical model may help guide such analysis by identifying important country-level characteristics that could explain heterogeneity in the observed relationship between trade policy and the adoption of voluntary standards.

This type of cross-country analysis could also be improved by shifting focus away from the magnitude of trade flows and toward the composition of trade flows. Chapter 2 offered predictions concerning the average quality of exports given a change in trade policy in the presence of a voluntary standard. Hallak and Schott (2011) demonstrate a technique using data on unit export prices to identify underlying differences in the quality of traded goods. This technique could be used to test whether or not liberalization increased the average quality of trade flows as well as the adoption of voluntary standards such as ISO 14001.

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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

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

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):

$$\pi_j(q_L) - w_i F_X(\theta) < \pi_i(q_H) - \pi_i(q_L) - w_i \delta(\theta) \quad \text{(B3a)}$$

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:

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

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

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

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:

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

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:

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

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:

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

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:

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

Substitute this result into (15):

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

Rearranging terms:

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

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,

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

Equating (C5a) and (C6a) yields:

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

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:

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

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

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):

$$E_i[\pi] = \frac{E}{\sigma M} \qquad \text{(C11a)}$$

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:

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

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

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

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

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

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 $G(\theta)$.

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

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

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

Substituting (C19) into (C18) yields:

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

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

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:

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

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

or equivalently,

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

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

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

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

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

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:

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

From (C6):

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

Substituting (C10) into (C19) yields:

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

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

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

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

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

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:

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

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

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:

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

Substituting (D2) into (D1a) yields:

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

Substituting (9) into (21) yields:

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

Substituting from (D1b):

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

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

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

Substituting again from (D1b):

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

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

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

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:

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

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):

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

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

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

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

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

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

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

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:

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

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:

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

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

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):

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

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

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

Collecting common terms:

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

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

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

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

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 5 and Figure 7, 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:

$$\frac{d\theta^A}{dF_E} < 0, \frac{d\theta^B}{dF_E} < 0, \frac{d\theta^C}{dF_E} < 0, \frac{d\theta^D}{dF_E} < 0 \tag{E7}$$

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:

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

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.

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

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

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

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

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

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

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

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

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:

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

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:

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

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

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

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

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:

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

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:

$$\frac{d\theta^B}{d\tau} > 0, \frac{d\theta^C}{d\tau} < 0 \tag{E22}$$