Product Safety in International Trade
(Preliminary and Incomplete)

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ABSTRACT: We examine the determinants of the equilibrium level of product safety and the pattern of trade in a two country model where there is a safe product and a risky product. We compare the role of systems of consumer liability, producer liability, and setting of minimum standards for determining the level of product safety. With complete information and no transactions costs, changes in the degree of producer liability have no effect on equilibrium. Minimum quality regulation will increase the price of the risky good in the imposing country, and will benefit the exporting country. When there are transactions costs and consumers cannot identify the safety of products, higher levels of producer liability will raise consumer price and improve product safety. The country with the higher level of producer liability (other factors constant) will import the risky good if the efficiency of consumer compensation is sufficiently high. The importing country may gain or lose from stricter producer liability, depending on the extent to which damage costs are shifted onto foreign producers.

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1 Introduction

Recent cases of tainted food products from China, which have resulted in hundreds of deaths in China as well as injuries in a number of importing countries, have focused attention on the problem of assuring product quality in international trade.[2] One suggestion for dealing with this problem is to adopt stricter standards for the regulation of the quality of goods to ensure safe products. However, it is recognized that in an open economy, countries may be tempted to use regulatory standards for protectionist purposes. Therefore, the approach to these issues taken by the World Trade Organization has been to allow countries to set individual standards, but to provide guidelines that prevent countries from discriminating against particular partner countries and discourage them from using product regulation as a disguised form of trade barrier. [3]

The discussion of safety standards in international trade often neglects the fact that product safety is ensured by producer concerns about product liability lawsuits and loss of reputation as well as by government regulation.[4] The US in particular has a long history of product liability laws, which where significantly strengthened in the 1960s. The use of product liability laws has also spread to most industrialized countries, and is also becoming much more common in developing countries. [5] This raises the question of the role played

[2]Weiss ([8]) reports that 107 imports of food products from China, along with 1000 shipments of dietary supplements and medicines were were detained at US ports in one month in 2007. The rate of the Department of Commerce detained imports He reports that the rejection rate for Chinese agricultural products is more than 25 times that for comparable imports from Canada

[3]This approach is reflected in the agreement on Sanitary and Phytosanitary Standards (SPS) , which covers food safety and animal and plant health standards, and in the agreement on Technical Barriers to Trade, which addresses product safety, and environmental and technical standards for manufactured goods.

[4]Studies of the determinants of product safety suggest that each of these components plays a role, although their relative importance varies by sector. Based on surveys of corporate executives in the US, Eads and Reuters [2] conclude that with the exception of a few highly regulated industries, product liability laws are the most important consideration for firms in product safety efforts. On the other hand, Polinsky and Shavell (2010) argue that a number of industry studies suggest that product liability concerns play a relatively minor role for products that are widely sold.

[5]TIn the mid 1980's, the European Union relaxed the requirement for a finding of producer responsibility for losses from requiring evidence of producer negligence to requiring only that the product was defective. Japan, which was the last major developed country to introduce product liability laws, did so in 1994 (Takaoka ([7]))

by product liability laws in ensuring product quality in an open economy. One aspect to this question is the extent to which the quality of a country's institutions for insuring product quality affect the pattern of trade. This question fits with a growing literature on how the quality of a country's institutions may affect the pattern of trade (eg. Levchneko [3]), although that literature has tended to focus on contract enforcement in the production process. A second question concerns the extent to which a country might have incentives to use its product liability law strategically.

The purpose of this paper is to present a model that is capable of addressing some of these policy questions. We focus on the factors that affect the level of product quality in a country that is not open to international trade, and then examine how these standards respond to the opening of international trade. This allows us to examine whether trade will lead to the convergence of product safety levels. In particular, we are interested in how the addressing the question of how transactions costs and imperfect information affect the method countries choose for dealing with product safety issues. As a byproduct of this analysis, we also can analyze the positive question of how the quality of a country's institutions for dealing with product safety affect the pattern and volume of trade.

We analyze a two sector model in which one of the products is a risky product whose consumption can cause damage to consumers. The probability that the product will cause damage to the consumers is a function of the investment made by the producers in improving product safety. Section 2 analyzes the benchmark case in which consumers have perfect information about the investment in product safety made by consumers and there are no transactions costs, so that strict product liability will achieve an efficient level of product safety. A primary goal of this section is to determine how a a country's tastes, technology, and endowments and affect the pattern of trade in the risky good when there is strict producer liability. In particular we focus on the role of a a country's taste for product safety (as reflected in the cost of damages resulting from failure of the product) and its cost of providing product safety in determining the pattern of trade and the safety level of goods in the free trade equilibrium.

We show that when the cost of damages from the risky good is the same across countries, the equilibrium with trade can be be treated as an integrated market equilibrium where the equilibrium pattern of trade can be determined by a comparison of autarky prices. The country with the lower cost of providing product safety will produce the safer version of the risky product in the free trade equilibrium, although it will not necessarily be the exporter of the risky good. Also, the opening of trade could lead to a divergence of product safety levels. We also show that if the cost of damages differs across countries, the markets will be segmented with trade and the country with the higher cost of damages will have a higher free trade price. Autarkic prices will not necessarily predict the pattern of trade in this case, since they will reflect market-specific damage costs. We develop a market-specific notion of comparative advantage based on a comparison of the difference in return to capital across markets at autarky that is sufficient for determining whether a country sells in a particular market. We also show that if the country with a lower cost of providing product safety has the lower cost of damages, there will be two say trade in the risky product.

When there are no transactions cost, the Coase theorem will apply and the equilibrium levels of trade and welfare will be independent of the degree of liability for damages that is imposed on producers. Government regulation in the form of minimum quality standards is redundant in the closed economy case due to the absence of transactions costs, but can be utilized in the open economy to influence the terms of trade. Exporting countries benefit from the setting of minimum quality standards.

Section 3 considers the role of product liability in the case where there are transactions costs. We focus on the case where consumers are unable to distinguish the safety level of goods prior to purchase, so that all goods from a particular location must sell at the same price. This assumption makes consumer liability ineffective as a means of providing incentives for safe products. Increases in the level of producer liability will reduce the probability of loss, in contrast to the full information case. As a result, differences in the degree of product liability across countries will result in segmentation of markets (even when tasted for damages are the same across countries), because firms face differing costs of selling in the two markets. Autarkic prices will not necessarily reflect comparative advantage in this case, so comparative advantage will be based on a market-specific comparison of returns to capital.

Our analysis shows that the country with the greater degree of product liability will be the importer of the risky good in equilibrium if the product liability system is sufficiently productive, but could export the good if inefficiencies are large. If the efficiency of compensation of consumers is high, the expected return to the consumer from purchase will increase and the willingness to pay for the product will be higher. Firms will prefer to sell in the market where the return is higher, so the country with the more effective institutions will import the good. In the free trade equilibrium, stricter product liability will raise the price in that market and have an ambiguous effect in the other market. It is also shown that the terms of trade effect for stricter product liability is the difference between the change in the price of the the risky good and the increase in the damages imposed on producers of imported goods. Whether an importing country will benefit from stricter product standards depends on the elasticity of price with respect to producer liability.

2 The Basic Model with No Transactions Costs

We consider a two country model of trade in which each country produces two goods, a safe good (good 1) and a risky good (good 2). We begin by describing the technology, endowment and preferences for the home country. Foreign country variables (which will be denoted by a $*$) are defined analogously. The emphasis in this section is on competitive equilibrium in the case where agents have perfect information and there are no transactions costs. We characterize the autarkic equilibrium, and use the results to find the determinants of the pattern of trade and the level of product safety in the competitive equilibrium. We then extend the analysis to consider the cases where consumers are liable for any damages caused by products (caveat emptor) and where the level of product safety is determined by a government standard.

On the demand side, we assume a continuum of households with measure N that demand a single unit of good 2 and spend the remainder of their income on good 1. Each household is indexed by its taste parameter for good 2, θ, which is its valuation of the services of a unit of good 2 (in units of the numeraire commodity, good 1). The distribution function for θ is denoted $H(\theta)$, which has positive support on $[0, \bar{\theta}]$. Consumption of good 2 is risky in that there is a probability $\pi \in (0, 1)$ that the household will incur a loss of amount αL from consuming the product. L can be thought of as representing the physical damage caused by a defective unit of good 2, while the parameter α converts these damages to units of good 1. α is assumed to be the same for all households within a country, but is allowed to vary across countries to allow for the possibility that consumers in some countries have a higher financial cost from defective products.[6] L is assumed to be common across households and across countries. The probability of loss, π, will be a result of decisions made by the producer (to be analyzed below) and is assumed to be observable to consumers in the full information case. Letting D^C denote the amount of compensation for damages received by the consumer in the event of a loss, the benefit received by a consumer of type θ from a unit of the product

$$B(\theta, \pi, D^C) = \theta - \pi(\alpha L - D^C), \tag{1}$$

A system of strict producer liability is one where $D^C = \alpha L$, whereas $D^C = 0$ in a system of consumer liability. Taste differences across countries can be captured by differences in the distribution of taste for good 2, $H(\theta)$, and the cost of damages, α.

On the production side, good 1 is produced under conditions of perfect competition and constant returns to scale using a single input, which will be referred to as labor. The competitive profit condition will require that $w = b$ if good 1 is produced, where b denotes

[6] For example, the cost of injuries might differ depending on differences in the cost of medical care across countries. Similarly, the lost wages resulting from an injury may differ across countries.

the output per unit labor in producing good 1 and w the wage rate. The output of good 1 will be $X_1 = V_1 b$, where V_1 is the amount of labor employed in sector 1. Good 2 is assumed to be produced under conditions of perfect competition using inputs of labor, V_2, and sector specific capital, $\overline{K}$. The production function for good 2 is $G(V_2, \overline{K})/\varphi(\pi)$, where G is homogeneous of degree one in the factor inputs and φ is decreasing and strictly convex in π for $\pi \in [\underline{\pi}, \overline{\pi}]$. The function φ captures the notion that a good with a lower risk of loss will require more care in design and production. The unit cost for a good with probability of loss π will be $c(w, r)\varphi(\pi)$,where r is the return to the specific factor in sector 2 and c is homogeneous of degree 1 and concave in the factor prices. In addition to production costs, the producer may also be liable for damages to the consumer resulting from the use of the product.

We denote by D^P be the payment required to the consumer in the event of a loss, where $D^C = D^P$ under the assumption of zero transactions costs. The expected unit cost of supplying a unit of the risky good, including damage costs, will be

$$\psi(w, r, \pi, D^P) = c(w, r)\varphi(\pi) + \pi D^P \tag{2}$$

The unit cost function will also represent the supply price for good 2 to consumers of a unit with safety level π. Cross country differences on the supply side can arise from differences in endowments of the specific factor and from technology differences. The technology for producing the safe good is summarized by the productivity parameter, b. To capture technology differences in production of the risky good, we can express the technology as

$$\varphi(\pi) = a_0 + a_1\varphi_1(\pi) \tag{3}$$

An increase in a_0 increases costs by the same amount at all levels of product safety, whereas an increase in a_1 (evaluated at $a_0 = 0$) will increase costs proportionally at all levels of product safety. The latter exercise will be equivalent to that of a proportional change in $c(w, r)$.

Under systems of consumer and producer liability to be considered below, the level of π will be chosen by producers to maximize profits. In the case of government regulation, the firm's choice of π may be constrained by minimum safety standards for products. The common feature of all of these regimes is that the assumptions of free entry and perfect competition will ensure that for any (p, π) combination that is observed in a market equilibrium, the zero profit condition must hold.

$$p = \psi(b, r, \pi, D^P) \tag{4}$$

We will find it useful to solve for the return to the specific factor that is consistent with zero profits for a given price/safety pair, denoted $\rho(p, \pi)$, which is obtained by inverting (4). This function has the properties:

$$d\rho = \frac{1}{c_r \varphi}\left[dp - \varphi c_w db - (d\varphi\prime + D^P)d\pi - \pi dD^P - c(da_0 + \varphi da_1)\right] \tag{5}$$

The equilibrium return to capital is increasing in p and decreasing in the parameters that (a_0, a_1, b, D^P) that raise the cost of production. The return to capital is increasing (decreasing) in π when the probability of loss is above (below) the level that minimizes unit costs.

The $\rho(p, \pi)$ function can also be used to define the output/capital ratio when firms are earning zero profits, $\gamma(p, \pi) = 1/(c_r(w, \rho(p, \pi))\varphi(\pi))$. Totally differentiating this expression yields

$$\begin{gathered}
\gamma_p = -\gamma^2 \frac{c_{rr}}{c_r} > 0; \qquad \gamma_b = \frac{\gamma^2 \varphi c_{rr} bc}{c_r} \quad < \quad 0; \qquad \gamma_{D^P} = -\pi\gamma_p < 0 \\
\gamma_\pi = -\gamma^2\left[c_r\varphi' - \frac{c_{rr}}{c_r}\left(c\varphi' + D^p\right)\right] \qquad \gamma_{a_0} \quad = \quad \frac{1}{\varphi}\gamma_{a_1} = -\gamma^2\left(c_r - \frac{cc_{rr}}{c_r}\right) < 0
\end{gathered} \tag{6}$$

Output per unit capital is increasing in output price and decreasing in the parameters (a_0, a_1, b) that reflect increasing costs for sector 2. A sufficient (but not necessary) condition for an increase in π to raise the output of good 2 is that π be less then the level that minimizes unit costs.

2.1 Autarkic Equilibrium with Strict Producer Liability

Under a system of strict producer liability, the producer must fully compensate consumers for any losses incurred as a result of damages from the product, which yields $D^P = D^C = \alpha L$. With full compensation for losses, consumer willingness to pay is independent of the producer's choice of π from (1). The market clearing condition will then require that the equilibrium values of (p, π) result in zero excess supply,

$$E(p, \pi) \equiv \gamma(p, \pi)\overline{K} - (1 - H(p))N = 0 \tag{7}$$

This condition is illustrated by the **MC** locus in Figure 1. The excess supply function $E(p,\pi)$ is increasing in p, and increasing in π for all values of π below the level that minimizes unit cost by (6). Producing safer products is more costly (as long as the values of π is not too high), so a higher price is required to clear the market. Increases in the parameters (a_0, a_1, b) will be associated with increases in the cost of producing good 2, and will result in an upward shift in the **MC** locus from (6).

Since the price a firm receives is independent of its choice of product safety under producer liability, firms will choose the π to minimize unit cost. The minimization of unit cost requires

$$-c(b, r)\varphi'(\pi) = \alpha L, \tag{8}$$

from (2). The optimal level of product safety equates the cost an increment of safety to the resulting reduction in damage costs. We assume that $\lim_{\pi\to\underline{\pi}} \varphi'(\pi) = -\infty$ and $\lim_{\pi\to\overline{\pi}} \varphi'(\pi) = 0$, which ensure that there will be an interior solution, $\pi \in (\underline{\pi}, \overline{\pi})$. [7]

We can also substitute (8) into (4) to characterize the relationship between p and π in

[7] Under a strict standard of product liability, the producer is responsible for any damages that are imposed. In contrast, a negligence standard imposes liability only if the seller fails to take adequate care in the production of the product or the provision of the service. The present analysis would also apply under a system with a negligence standard if π is interpreted as the probability that a loss occurs due to negligence of the seller. This probability can be reduced by employing more skilled workers and/or monitoring the production process to make sure that employees are providing the appropriate level of effort and care.

a zero profit equilibrium where product safety is chosen optimally,

$$p = \alpha L \left(\pi - \frac{\varphi(\pi)}{\varphi'(\pi)} \right). \tag{9}$$

The cost-minimizing condition (9) can be inverted to express the probability of loss in a zero profit equilibrium with producer liability as $\pi^{PL}(p)$, which has the properties

$$\pi_p^{PL} = -\frac{\varphi'}{c\varphi\varphi''} > 0; \quad \pi_{a_0}^{PL} = \frac{\varphi'}{\varphi\varphi''} < 0; \quad \pi_\alpha^{PL} = \frac{L(\pi\varphi' - \varphi)}{c\varphi\varphi''} < 0 \tag{10}$$

A higher price requires an increase in $r = \rho(p, \pi)$ to restore zero profits from (4), which leads to an increase in the optimal level of π. This is illustrated by the upward sloping π^{PL} locus in Figure 1. A higher value of α will raise the value of safe products, and thus shift the π^{PL} locus leftward. A higher value of a_0 will lower the cost of safe products, since it reduces $-\varphi'/\varphi$, and also shift the locus leftward. On the other hand, changes in a_1 and b will have no effect on the choice of product safety because they raise the costs of products at all safety levels proportionally.

The autarkic equilibrium is determined by the intersection of the **MC** and π^{PL} loci. This equilibrium must be unique, since the **MC** locus must be downward sloping at the cost-minimizing level of π. Comparative statics results can then be used to derive the determinants of pre-trade differences in price and product quality across countries. The following comparative statics results are derived in the Appendix:

Proposition 1 *The effect of endowment and technology changes on autarky prices and probability of loss are given by*

$$\frac{dp}{dK} < 0, \quad \frac{d\pi}{dK} < 0, \quad \frac{dp}{db} > 0, \quad \frac{d\pi}{db} > 0$$

$$\frac{dp}{da_0} > 0, \quad \frac{d\pi}{da_0} \gtreqless 0, \quad \frac{dp}{da_1} > 0, \quad \frac{d\pi}{da_1} > 0, \quad \frac{dp}{d\alpha} > 0, \quad \frac{d\pi}{d\alpha} < 0$$

Figure 1 illustrates the case where the home and foreign countries differ only in their relative endowment of the specific factor, $K^*/N^* > K/N$. The foreign market clearing locus, **MC***,

will lie to the left of that for the home country. Since the π^{PL} locus in unaffected by the stock of the specific factor, the outcome is a lower price and higher quality in the foreign market in the autarkic equilibrium. A similar comparison arises if $a_1^* < a_1$ or $b^* < b$. If $a_0^* < a_0$, the **MC*** curve lies below that of the home country, but the foreign zero profit locus will also lie below that in the home country. As a result, the foreign products could have either a higher or lower probability of damage than home goods in the autarky equilibrium. Finally, if $\alpha^* < \alpha$ the **MC*** curve is below
sumtextbfMC and the π^{*PL} locus will be to the right of the π^{PL} locus. Since the latter shift is proportional to the difference in the taste for damages between countries, the price of the good will be higher and the probability of loss lower in the home country.

2.2 Free Trade with Strict Producer Liability and $\alpha = \alpha^*$

We begin our analysis of the free trade equilibrium with the case in which damage costs are the same in each country. Firms face the same cost of selling in each market (in the absence of trade costs) and consumers choose the good with the lowest price, so free trade will result in the equalization of goods prices across countries and the market for the risky good can be treated as an integrated world market. The free trade price will occur where the sum of country excess demands equals 0,

$$E(p, \pi^{PL}(p)) + E(p, \pi^{*PL}(p)) = 0 \tag{11}$$

It follows from (6) and (10) that excess supply in each country is increasing in p, so the equilibrium world price with free trade will lie between the autarky prices in each country.

If $\pi^{PL}(P) = \pi^{*PL}(p)$, which occurs if $\varphi(\pi) = \lambda\varphi^*(\pi)$ for some $\lambda > 0$ from (10), the the equalization of prices will also result in the equalization of the safety level of products across countries. Each country has the same cost of improving product safety in this case, even though the technologies in the two countries are not necessarily the same. Home country firms will produce safer products in the free trade equilibrium if $\pi^{PL}(p) < \pi^{*PL}(p)$ for all p. This suggests the following characterization of the country's technologies:

Definition 1 *The home (foreign) country has a cost advantage in providing safe products if* $\pi^{PL}(p) < (>) \pi^{*PL}(p)$ *for all* p*, which requires* $-\varphi'(\pi)/\varphi(\pi) < (>) - \varphi^{*\prime}(\pi)/\varphi^*(\pi)$ *for all* π*.*

The country with the cost advantage in providing safe products will not necessarily be the exporter of the risky product in the free trade equilibrium. In particular, it can be seen from Figure 1 that if $\pi^{PL}(p) < \pi^{*PL}(p)$ and **MC=MC***, the country with the lower cost of providing safe products will import the risky good at free trade. Note also that the opening of trade would cause product safety levels to move even further apart in this case.

The results of this section can be summarized as:

Proposition 2 *If* $\alpha = \alpha^*$*, the opening of trade will equalize prices between the home and foreign country under strict producer liability, and the country with the lower autarky price of the risky product will be the exporter at autarky. The country with the lower cost of providing safe products will home (foreign) country will produce safer products with free trade.*

With producer liability and equal damage costs across countries, the pre-trade prices reflect the "full price" of the good to consumers and will be determinants of comparative advantage.

2.3 Free Trade Equilibrium with $\alpha > \alpha^*$

In the case where damage costs differ across countries, free trade will not equalize the prices of goods across countries. Firms will face higher damage costs when they sell in the home market than in the foreign market when $\alpha > \alpha^*$, so $\pi^{PL}(p, \alpha) < \pi^{*PL}(p, \alpha^*)$ by (10). We will assume that firms can provide a different quality of products for the export market than for the domestic market, which means that the free trade equilibrium will require that the firm earn non-negative profits in each country's market when evaluated at the cost-minimizing product safety for that market.[8] Since damage costs are higher in the home

[8] For example, US farmers separate products produced with genetically modified (GM) seed from those that are not. The GM products are sold in the US¡ while the non-GM products are exported to the EU

market, this will mean that the free trade price in the home market, p_H, must exceed that in the foreign market, p_F. The assumption of strict producer liability will ensure that all goods in the home (foreign) market must sell at price p_H (p_F).

In a competitive equilibrium, firms will be selling in a market if the return that can be earned in that market is no less than can be earned in the other markets. Let $r_H(p_H) = \rho(p_H, \pi^{PL}(p_H, \alpha), \alpha)$ ($r_F(p_F) = \rho(p_F, \pi^{PL}(p_F, \alpha^*), \alpha^*)$ be the return to home capital from selling in the home (foreign) home market, and $K_F \geq 0$ the quantity of capital the home country devotes to production for the foreign market. We can similarly define foreign returns from the foreign market, $r^*(p_F)$, foreign returns from the foreign market, $r^*(p_F)$, and foreign capital devoted to export sales, K_H^*. The market clearing conditions conditions will be given by

$$\gamma(p_H, \pi^{PL}(p_H, \alpha))(\overline{K} - K_F) + \gamma^*(p_H, \pi^{*PL}(p_H, \alpha))K_H^* - N(1 - H(p_H)) = 0 \quad (12)$$

$$\gamma^*(p_F, \pi^{*PL}(p_F, \alpha^*))\left(\overline{K}^* - K_H^*\right) + \gamma(p_F, \pi^{PL}(p_F, \alpha^*))K_F - N^*(1 - H^*(p_F)) = 0 \quad (13)$$

where $K_F > 0$ ($\overline{K} - K_F > 0$ requires $r(p_H) \leq r(p_F)$ ($r(p_H) \geq r(p_F)$) and $K_H^* > 0$ ($\overline{K}^* - K_H^* > 0$ requires $r(p_H) \leq r(p_F)$ ($r(p_H) \geq r(p_F)$)). The market clearing conditions, along with the profit-maximizing conditions for location of capital, $r = max(r_H(p_H), r_F(p_F)$ and $r^* = max(r_F^*(p_F), r_H^*(p_H)$, can be solved for the equilibrium values (p_H, p_F, K_F, K_H^*).

The possible equilibrium trade patterns can be illustrated using Figure 2, which illustrates iso-return loci $\rho(p, \pi^{PL}(p, \alpha), \alpha)$ in (p, α) space. These loci will have slope $\partial p/\partial \alpha = \pi^{PL}(p, \alpha)L$, with $\partial^2/\partial \alpha^2 < 0$. If neither country has an advantage in providing product safety,$\pi^{PL}(.) = \pi^{*PL}(.)$ and the home and foreign iso-return loci will coincide as in Figure 2a. Free trade equilibria must lie on the same iso-return locus in order to induce firms to sell in both markets, as shown by the price pair (p_F^0, p_H^0) when the equilibrium return at home is r_H^0 Note that this outcome is consistent with either home export or import of the

countries. Although there is debate as to whether non-GM products are safer, this does illustrate that firms target different types of products to different markets when standards differ. A similar differentiation exists in auto markets, where additional reinforcement structures are put in autos destined for the export markets where safety standards are higher.

risky good. Figure 2b illustrates the case in which the home country has an advantage in providing product safety, so that its iso-return loci are flatter than those of the foreign country. This yields two possible equilibrium outcomes in which there is trade. If tastes and technologies are such that the free trade price pair is (p_F^0, p_H^0), with equilibrium returns r^0 at home and ρ^{*0} in foreign, the home country exports to the foreign country. Similarly, the price pair (p_F^1, p_H^0) is a case where the foreign country exports to the home country in equilibrium. Finally, for price pairs (p_F^2, p_H^0) for $p_F^2 \in (p_F^0, p_F^1)$ there will be no trade between the countries.

Figure 2c illustrates the case in which the foreign country has a cost advantage in product safety, which means that foreign technology is a better match for the tastes of home country consumers than is home technology. In this case, all trade equilibria will involve two way trade. If tastes and technologies are such that the free trade price pair is (p_F^0, p_H^0), home country firms will sell in both markets in equilibrium and foreign firms will sell only in the home market. If the equilibrium price pair is (p_F^1, p_H^0), home firms will sell only in the foreign market and foreign firms will sell in both markets. For price pairs (p_F^2, p_H^0) with $p_F^2 \in (p_F^0, p_F^1)$, each country's firms will sell only in the other country's market.

Since autarky prices reflect the cost of damages as well as the cost of production when tastes differ across countries and there is strict producer liability, it is clear that a comparison of autarkic prices prices will not necessarily serve as an indicator of the pattern of trade. A notion of comparative advantage should thus be tied to the profitability of selling in the foreign market relative to the domestic market at autarky. In light of the possibility that there can be two way trade in equilibrium, we adopt a market specific definition of comparative advantage:

Definition 2 *The home country has comparative advantage in good 2 in the foreign market if*

$$r^A = r_H(p^A) < r_F(p^{*A})$$

The foreign country has comparative advantage in good 2 in the home market if

$$r^{*A} = r^*_F(p^{*A}) < r^*_H(p^A)$$

When $\alpha = \alpha^*$, the respective definitions are equivalent to $p^A < (>) p^{*A}$. If $\pi^{PL}(.) = \pi^{*PL}$ and $\rho(.) = \rho^*(.)$, the respective definitions are equivalent to $r^A < (>) r^{*A}$. In order for both of these conditions to hold simultaneously, it must be the case that the foreign country has a cost advantage in product safety.

The following result, which is proven in the Appendix, shows the relationship between this notion of comparative advantage and the pattern of trade.

Proposition 3 *Assume $\alpha > \alpha^*$.*

(a) If the home country has comparative advantage in the foreign market, then $K_F > 0$ in the free trade equilibrium. If the home country has a cost advantage in safe goods, then the converse is also true.

If the foreign country has comparative advantage in the home market, then $K^*_H > 0$ in the free trade equilibrium. If the home country has a cost advantage in safe goods, then the converse is also true.

When the foreign country does not have a cost advantage in product safety, the same country will have comparative advantage in both markets and that country must be a net exporter of the risky good. If the foreign country has an advantage in providing product safety, it was shown in Figure 2c that all of the trade equilibria must involve export of the risky good by both countries. Thus, each country will export the risky good to the other market even if the comparative advantage condition is not satisfied.

Proposition 3 can be used to derive the effect of taste differences with regard to product safety the pattern of trade. If the home and foreign country differ only in their cost of damages, then the home country will have a comparative advantage in the foreign market if $r^A < r^{*A}$. Letting η be the elasticity of demand and ε the elasticity of the marginal cost of safety improvements, we obtain the following result:

Proposition 4 *Suppose that the home country and the foreign country differ only in the cost of damage, with* $\alpha > \alpha^*$*, and let* $\eta \equiv ph(p)/(1 - H(p))$ *and* $\varepsilon = -\varphi^{"}\pi/\varphi\prime$*.*

(i) If $\eta\varepsilon > p/(c\varphi)$*,then the home country has comparative advantage in the foreign market and will export good 2 to the foreign country with* $p_H > p^A > p^{*A} > p_F$*.*

(ii) If $\eta\varepsilon < p/(c\varphi)$*, then the foreign country has comparative advantage in the home market and will export good 2 to the home country with* $p^A > p_H > p_F > p^{*A}$*.*

It is shown in the Appendix that the autarkic capital in the home country will be higher iff $\eta\varepsilon(c\varphi)/p < 1$. This condition results from two conflicting effects of the cost of damage on the demand for capital. An increase in the level of damages raises the demand for capital to improve product safety, which tends to raise r. The magnitude of this effect is proportional to $1/\varepsilon$. However, the increase in the cost of damages will reduce the demand for good 2, which tends to reduce r. This effect is larger the greater is the elasticity of demand. Part (i) identifies the condition under which the latter effect dominates the former, leading to a lower autarky return to capital in the home country. A lower autarkic return at home results in the home country having comparative advantage in good 2 in both markets, as noted above. An interesting feature of this example is that it shows that the the exporting country can have the higher price at autarky, and this will cause the price differential to increase as a result of trade.

2.4 Other Forms of Liability

The discussion so far has assumed that the assignment of property rights in each country requires that producers provide full compensation for losses. In this section we maintain the assumption that there are no transactions costs for compensation of consumers, $D^C = D^P$, but we allow for liability systems for which $D^C \neq \alpha L$. This allows for the possibility of a system under which consumers receive no compensation for losses (caveat emptor), $D^C = D^P = 0$, as well as the possibility that imposes punitive damages on producers producers that exceed the amount of losses to consumers. We show that as long as consumers can observe the probability of loss for each producer's product, the competitive equilibrium with any degree of consumer liability yields the the same values for X_2 and π as with producer liability (i.e. the Coase theorem applies).

If consumers are assumed to be able to observe the quality of products prior to purchase, the equilibrium price of a product may vary with the level of π chosen by the consumer. Letting $q(\pi, D^C)$ denote the equilibrium price schedule for a product when the legal system requires damages at level D^C from producers, the net benefit to a consumer from a product of with safety π will be $B(\theta, \pi, 0) = \theta - \alpha\pi L$. Consumers will choose the product with the safety level that maximizes net benefit, which means that the price schedule must satisfy the condition $q_\pi(\pi, D^C) = D^C - \alpha L$. For producers, the return per unit from selling a product with safety π will be $q(\pi, D^C) - \psi(b, r, \pi, D^C)$. In a competitive equilibrium, any product supplied must yield zero profits to producers. This requires that $q(\pi, D^C) = \psi(b, r, \pi, D^C)$ and $q_\pi = c(b, r)\varphi(\pi) + D^C$ for any safety level produced in equilibrium. Combining these conditions, we obtain the result that the condition for producer's choice of safety level will be identical to that in (8) for the case of producer liability. A producer who raises the safety level of his product will be compensated for the saving in uncovered consumer damages by receiving a higher output price when $D^C < \alpha L$, resulting in the efficient choice of safety level for any assignment of damages between consumer and producer.

Letting (p^A, π^A) denote the price and safety level obtained in an autarkic equilibrium with producer liability, it is clear from the above discussion that the price and safety pair $(p^A - \pi^A(\alpha L - D^C), \pi^A)$ will be an autarkic equilibrium when producers must compensate consumers at the level D^C for losses. A similar argument establishes that if the pairs (p_i^T, π_i^T) and (p_i^{*T}, π_i^{*T}) are offered by home and foreign producers in market i in a free trade equilibrium, then $(p_i^T - \pi^T(\alpha L - D^C), \pi_i^T)$ and $(p_i^{*T} - \pi^{*T}(\alpha L - D^C), \pi_i^{*T})$ will be an equilibrium with free trade when producers compensate consumers at the level D^C for losses. Note that this result also allows for the home and foreign countries to have differing liability rules for their domestic markets.

The primary difference that arises between the case of strict producer liability and that of other forms of liability involves the comparison of prices at free trade and at autarky. Proposition 2 established that if $\alpha = \alpha^*$ and $\varphi(\pi) = \lambda\varphi^*(\pi)$, trade would result in the equalization of product safety across countries. However, this will result in the equalization of goods prices across countries iff the countries have the same degree of producer liability. When the degree of producer liability differs across countries, the prices of goods with the same safety level will be higher in the country where producers bear greater liability. If the the level of producer liability is the same across countries but safety levels are not equalized by trade (i.e. $\varphi(\pi) \neq \lambda\varphi^*(\pi)$), then prices of home and foreign goods will differ if countries both countries do not have strict producer liability.

Proposition 2 also established that the principle of comparative advantage would hold if $\alpha = \alpha^*$ under strict producer liability. We can show that this result will not extend to the case where there is some degree of consumer liability. Suppose that countries differ only in their endowment of K, which by Propositions 1 and 2 yields the result that the country with the larger stock of capital will export good 2 (i.e. $dp/dK < 0$). The country with the larger stock of capital will have the lower pre-trade price of good 2 under a system of strict consumer liability if $dp/dK - \alpha L d\pi/dK < 0$.

2.5 National Welfare and Regulation

We conclude the analysis of the complete information case with no transactions costs by considering the role of product safety regulation on international trade and national welfare. We assume that an individual producer's probability of damage is observable to the government, as it is to consumers, and that regulation involves the specification of a maximum probability of loss, π^R that firms must meet in order to sell in the market. We will present the analysis of quality regulation for the case where producers are strictly liable for losses to consumers even if they meet the required level of product safety, although the arguments of the previous section can be used to show that the equilibrium level of product safety is invariant to assignment of liability with perfect information.

The market clearing condition for the autarky equilibrium with quality regulation is given by (7) with $\pi = \min(\pi^R, \pi^{PL}(p))$. Referring to Figure 1, the equilibrium level price levels under binding safety regulation will be given by the **MC** locus above the intersection with the **PL** locus. Stricter product regulation will be associated with a higher product price in autarky. For the free trade equilibrium, suppose that the foreign country imposes a minimum quality standard on products but the home market is unregulated. Prices of goods will not in general equalize across markets with trade, even when $\alpha = \alpha^*$, because firms face higher costs to meet the regulatory standard in the foreign market. Consider the case in which the foreign country is an importer of good 2, and neither country has an advantage in providing safe goods. For home firms to be indifferent between selling in the home and foreign markets, the prices must be such that returns to home capital owners are equalized across markets, $\rho(p_H, \pi^{*PL}(p_H)) = \rho^*(p_F, min\left(\pi^{PL}(p_H), \min(\pi^R, \pi^{*PL}(p_H))\right))$. This condition, combined with the market clearing conditions (19) and (20), will determine the equilibrium values of (p_H, p_F, K_H^*).

An increase in a binding home country standard will affect both home and foreign firms if neither has a cost advantage in providing safe products. If one type of firm provides safer products than the other, then the change in the standard may only affect the firm producing the lower type product. The following result shows that whether the is established in the Appendix:

Proposition 5 *Suppose that the home country is an importer of the risky goods, with home firms selling only in the home market and foreign firms selling in both markets. (i) An increase in the minimum quality standard that binds for either home or foreign firms selling in the home market will raise p_H. The effect on p_F is ambiguous, although p_F must rise if either the foreign firm is unaffected by the quality standard or the standard is in the neighborhood of $\pi^{*PL}(p_F)$. (ii) An increase in the minimum quality standard in the foreign country will raise p_F and will have an ambiguous effect on p''_H.*

An increase in the standard has two effects on the home market. The first is that it reduces the supply of any firms that are affected by the standard, because more resources are required to produce a unit of a safer product (i.e. $\partial\gamma/\partial\pi > 0$). The second is that it raises the cost of supplying the home market relative to the foreign market for foreign firms (if they are affected by the restriction), which requires an increase $p_H - p_F$ to restore equilibrium. Both of these effects tend to increase p_H, whereas they have conflicting effects on p_F. A tightening of product safety regulation must benefit home firms if they are not affected by the regulation, but it will have an ambiguous effect if it is binding on home firms. These effects operate in a similar way when the home country exports good 2, although in that case they operate through the requirement that home firms be indifferent between selling in the two markets.

To establish the welfare effects of product safety standards, note that home country welfare in a competitive equilibrium when the domestic consumers receive damages D^C in the event of a loss will be

$$W(p_H, \pi, D^C) = N \int_{\theta_M}^{\overline{\theta}} \left(\theta - p - \pi(\alpha L - D^C)\right) h(\theta) d\theta + bV + \rho(p_H, \pi)K \tag{14}$$

where $\theta_M = p + \pi(\alpha L - D^C)$ is the marginal consumer buying the good in a competitive equilibrium. Welfare is the sum of factor income and expected consumer surplus. Using the fact that The effect of regulation on welfare with strict producer liability will be

$$\frac{dW}{d\pi^R} = (X_2 - (1 - H(p))N)\frac{dp_H}{d\pi^R} - X_2\left(c\varphi' + \alpha L\right) \tag{15}$$

The first term in (15) is the terms of trade effect resulting from product safety regulation, which indicates that regulation will improve the welfare of an exporting (importing) country if it raises (reduces) the price of good 2. The second term is the effect of a change in product safety on national income, which will equal zero at the level of product safety that minimizes cost. Under autarky, the first term will equal zero and welfare is maximized under producer liability from (8). It follows from Proposition 4 shows that product safety regulation will similarly be welfare-reducing under free trade if the home country is an importer of good 2. If the home country is an exporter of good 2, then product safety regulation will be welfare-improving.

Although product safety regulation can be used to manipulate the terms of trade in the full information case, changes in the degree of producer liability will have no effect on the terms of trade.

3 Transactions Costs, Product Liability, and Regulation

In the case without transactions costs, the autarkic equilibrium will yield an efficient outcome, given the constraint of no trade between countries. Similarly, the free trade equilibrium will be efficient for the world as a whole and must leave both countries better off than at autarky. We now turn to the case in which there are transactions costs associated with using consumer and producer liability to provide market solutions for product safety problems. Our objective is to examine how the existence of transactions costs will affect the ranking of the consumer and producer liability systems, and how the presence of differences in the level of transactions costs across countries will affect the pattern of international trade. In this section we focus on two types of transactions costs. The first is that the process of establishing producer liability for losses incurred by consumers is an imperfect and costly process. Legal costs associated with winning a case are substantial. Polinsky and Shavell [4] survey studies of the cost of the tort process in the US and conclude that there is more than a dollar of legal fees for every dollar of compensation received by consumers. One component of this cost is the cost is the simple resource cost of the legal system. We model this by assuming that the level of compensation received by consumers is $D^C = (1-\mu)D^P$, so that the μ summarizes the cost of the product liability system.

The second type of transaction cost that will be introduced is that consumers are unable to observe the value of π chosen by the producer. This assumption will be most appropriate in cases where there are a large number of producers and consumers make infrequent purchases, so that it is difficult for them to identify the loss probabilities associated with individual producers.[9] When consumers are unable to distinguish firms based on π, they are unable to punish firms that provide less safe products by lowering the price they will pay. Thus, producers will choose π to minimize $\psi(s, w, r, D^P)$. Combining this result with the zero profit condition yields the locus of values of (p, π) when the producer liability for damages is D^P,

$$p = D^P \left(\pi - \frac{\varphi(\pi)}{\varphi'(\pi)} \right). \tag{16}$$

This modifies the condition from strict producer liability, (9), to allow for the possibility that the damages paid by producers are different from the true damages incurred by consumers.

3.1 Autarky Equilibrium with Transactions Costs

With transactions costs, the market clearing condition (7) must be modified to reflect the fact that consumers must pay the uncompensated portion of losses,

$$\gamma(p.\pi)\overline{K} - \left(1 - H\left[p + \pi(\alpha L - (1-\mu)D^P)\right]\right) N - = 0 \tag{17}$$

Equations (16) and (17) can be used to solve for the autarky equilibrium, given (D^P, μ).

The country's institutions for dealing with producer liability can be summarized by D^P and μ. The former represents the strictness of punishments imposed on producers and the latter is the efficiency of the system in delivering these damages to consumers. The effect of these parameters on the autarkic equilibrium are given by

Proposition 6 *If $D^C = (1-\mu)D^P$, then the autarky equilibrium will have the property that*

(a) $\dfrac{dp}{dD^P} > 0$ *and* $\dfrac{d\pi}{dD^P} < 0$.

[9] Mechanisms such as reputations or private organizations to provide quality certification could arise to provide information to consumers on the value of π for individual producers. However, such mechanisms are costly when there are many producers. We simplify by making the extreme assumption that π is unobservable.

(b) $\dfrac{dr}{dD^P} > 0$ *if* $\mu\eta - \dfrac{p}{c\varphi\varepsilon} - \dfrac{\eta(\alpha L - D^C)}{c\varphi''\pi} < 0$

(c) $\dfrac{dp}{d\mu} < 0$, $\dfrac{d\pi}{d\mu} < 0$, *and* $\dfrac{dr}{d\mu} < 0$

An increase in the compensation paid by producers will raise the unit cost of good 2 and increase the incentive to provide a safer product, leading to a higher price and lower probability of loss. There will be conflicting effects on the return to capital: the rising price benefits capital owners but the higher damage payment reduces the return. In the case where there is no resource cost of compensating consumers for losses, the former effect must dominate. However, the return to capital could fall with an increase in producer liability if consumers receive little in the way of compensation. Part (c) shows that the country with the more efficient method of compensating injured consumers will have a higher price, lower product safety, and a higher return to capital. A more efficient compensation process for damages raises price because it increases the value of the risky good to consumers. However, it does not raise the incentive of producers to take care (at given D^P), and the probability of loss increases.

3.2 Product Safety Institutions and Trade

In the closed economy case, consumers cannot identify the safety level of individual products and therefore assign the same expected quality to all products. When trade is opened, consumers will potentially be faced with both imported and domestically produced products. We will assume that consumers can identify whether a particular product is domestically produced or imported, which means that they will assign a probability of loss $\pi^{PL}(p, D^P)$ to domestic products and $\pi^{*PL}(p, D^P)$ to foreign products. [10] In order for the home consumer to be indifferent between a home produced good and a foreign produced good, it must be

[10] If consumers could not distinguish domestic goods from imports, then all goods must sell for the same price in the free trade equilibrium and it is possible that the home country could lose from trade due to the decline in the average quality of imported goods as shown in Bond ([1]).

the case that

$$p_H - p_H^* = \left(\pi^{*PL}(p_H^*, D^P) - pi^{PL}(p_H, D^P)\right)(\alpha L - (1-\mu)D^P) \tag{18}$$

where p_H (p_H^*) is the price charged by the home (foreign) firm when selling in the home market. The price difference between home and foreign firms will reflect the difference in expected damage costs, which can be inverted to express the foreign firm's price as a function of the home firm's price, $p_H^* = g(p_H)$. A similar indifference condition can be obtained for the foreign market, and corresponding relationship $p_F = g^*(p_F^*)$.

We can express the return to a foreign firm from selling in the home (foreign) market as $r_H^*(p_H^*) = \rho^*(p_H^*, \pi^{*PL}(p_H^*, D^P), D^P)$ $(r_F^*(p_F^*) = \rho^*(p_F^*, \pi^{*PL}(p_F^*, D^{*P}, D^{*P})$ A foreign firm will have comparative advantage at selling in the home market if $r_F^*(p^{*A}) < r_F(g(p^{*A}))$. Applying a similar argument to the home country firms yields the result that home firms have comparative advantage in the foreign market if $r_H(p^A) < r_F(g^*(p^A))$. These conditions yield a comparative advantage condition for the foreign market which is analogous to that defined in the case where there are taste differences across countries.

In the case where countries differ only in the level of product liability, these conditions simplify to a comparison of the autarky rentals on capital. Proposition 6 can then be used to show the role of institutions for dealing with product safety on comparative advantage. A country that has stricter rules on producer liability will be an importer of the good if the compensation process is sufficiently efficient. An efficient compensation process for losses raises the quality of the market, in that it makes it more profitable to improve product safety. If the compensation process is inefficient, however, product liability laws will spoil the domestic market for the product by making production unattractive. This will tend to make the country with strict liability rules an exporter of the product, because its firms prefer to sell in foreign markets where the returns are more attractive.

The market clearing conditions conditions for the case in which foreign firms export to the home country market in the free trade equilibrium will be

$$\begin{aligned}\gamma(p_H, \pi^{PL}(p_H, D^P))\overline{K} + \gamma^*(g^*(p_H), \pi^{*PL}(g^*(p_H), D^P))K_H^* \\ -N\left(1 - H\left[p_H + \pi^{PL}(p_H, D^P)(\alpha L - (1-\mu)D^P)\right]\right) = 0 \end{aligned} \tag{19}$$

$$\begin{aligned}\gamma^*(p_F, \pi^{*PL}(p_F^*, D^{*P}))\left(\overline{K}^* - K_H^*\right) \\ -N^*\left(1 - H^*\left[p_F^* + \pi^{*PL}(p_F^*, D^{*P})(\alpha L - (1-\mu)D^{*P})\right]\right) = 0 \end{aligned} \tag{20}$$

In order for the foreign country firms to be willing to sell in both markets, we must also have

$$r_H^*(g^*(p_H)) - r_F^*(p_F^*) = 0 \tag{21}$$

The system of equations (19) - (21) will yield solutions for (p_H, p_F^*, K_H^*).

The following result establishes the effect of changes in the product liability system for the case in which home and foreign products have the same quality in the home market, so that $p_H = p_H^*$.

Proposition 7 *Suppose that the the home country is an importer of the risky good at free trade, and that neither country has a cost advantage in product safety. The effect of an increase in product liability.*

(a) An increase in the damages imposed on producers will raise the price of good 2 in the home country, will reduce the equilibrium probability of loss for consumers of good 2, and will have an ambiguous effect on the price of good 2 in the foreign country.

(b) A reduction in the resource cost of the product liability system in the home country, $d\mu < 0$, will raise the price of good 2 in the home and foreign countries, and will raise the probability of loss to consumers.

Increasing product liability induces producers to improve the safety of their products sold in the home country market (at given prices), which makes production for the home country more costly. For $\mu < 1$, increased producer liability will raise the compensation for injured consumers, which raises the demand for risky goods at the initial price. Both of these effects will create an excess demand for good 2 in the home country, driving up its price. There are conflicting effects of this change on the foreign market. The increased demand for safety in products destined for the home market increases the amount of foreign capital devoted to the home market, while the increased relative attractiveness of the foreign market results in a shift in capital toward the foreign market. An increase in the efficiency of the product liability system in the home country will raise the demand for the risky good at home, resulting in an increase in sales by all firms in the home market and a rise in prices in both markets. The rising price in each market will result in a reduction in the equilibrium product safety from (16).

The effect of these policy changes on home country welfare can be obtained by totally differentiating (14), which yields

The effect of changes in producer liability on welfare can be obtained by totally differentiating the welfare function (14),

$$dW = -M_2(dp - \pi dD^P) - (1 - H(\theta_M))\left(\mu N dD^P + D^P d\mu\right) \tag{22}$$

$$- \left((1 - H(\theta_M))(\alpha L - (1-\mu)D^P) - X_2(c\varphi\prime + D^P)\right) d\pi \tag{23}$$

where M_2 denotes imports of the risky goods. The first term is the terms of trade effect, which is the increase in the cost of imported goods less the additional damage payments paid on imported goods. The second term is the change in the resource cost associated with product liability system. The final term is the impact of the change in the probability of loss on welfare. The first term in brackets is the effect of changes in the probability of loss on net consumer losses, which will reduce (increase) welfare when the damage payment received by consumers is less (greater) than the amount of the loss. The second term is the impact of an increase in the probability of loss on the average cost of a unit, which will be positive (negative) when π is less (greater) than the cost minimizing level. In the absence of regulation, firms will choose the cost-minimizing level and this term will equal zero.

In autarky, the first term will equal zero. Welfare will be increasing in D^P as long as $-(\alpha L - (1-\mu)D^P)\left(d\pi/dD^P\right) - \pi\mu] > 0$. If $\mu = 0$, the optimum occurs where $D^P = \alpha L$, so that consumers are fully compensated for their losses. In this case, strict producer liability can fully substitute for the inability of consumers to observe the quality of products, and the first best outcome is achieved. If $\mu > 0$, then the costliness of the transfer process will call for a degree of producer liability such that consumers are less than fully compensated for their losses. Reductions in μ be welfare improving for all $\mu \in (0, 1]$, because they reduce the resource cost of the liability system.

In the open economy, changes in the product liability system will also have an effects on the terms of trade. It can be seen from (5) that an increase in D^P will improve the terms of trade of the importing country if it reduces the return to capital in sector 2, since the importing country is importing the services of sector specific capital from the foreign country. An increase in D^P will raise the price of goods in the home market as shown in Proposition 7, but it will also increase the damage payments made on imported goods.

It is interesting to contrast this result with the one obtained in Proposition for the case of minimum quality standards.

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A Appendix

Proof of Propositions 1, 4, and 6: The autarky equilibrium with transactions costs is the solution to the market clearing condition, (17), and the optimal choice of product safety condition, $\pi^{PL}(p, a_0, D^P) = 0$, which is obtained by inverting (16). Totally differentiating this system and evaluating at $a_0 = a_1 = 1$ yields

$$\begin{pmatrix} -(hN + \gamma_p \overline{K}) & -\left(\overline{K}\gamma_\pi + (\alpha L - D^C)hN\right) \\ -\pi_p^{PL} & 1 \end{pmatrix} \begin{pmatrix} dp \\ d\pi \end{pmatrix} = \tag{A-1}$$

$$\begin{pmatrix} \gamma d\overline{K} + hN\pi(Ld\alpha - dD^C) + \overline{K}\left(\gamma_b db + \gamma_{a_1} da_1 + \gamma_{a_0} da_0 + \gamma_{D^P} dD^P\right) \\ \pi_{a_0}^{PL} da_0 + \pi_{D^P} L dD^P \end{pmatrix}$$

The determinant of the matrix is $\Delta \equiv -\left(\left(\gamma_p + \gamma_\pi \pi_p^{PL}\right)\overline{K} + (1 + \pi_p^{PL}(\alpha L - D^C))hN\right)$, where $D^C \leq \alpha L$ is a sufficient for $\Delta < 0$.

Proposition 1 considers the case of strict producer liability with full information. Comparative statics results are obtained by solving (A-3) under the assumption that $D^C = D^P = \alpha L$ and $dD^P = dD^C = Ld\alpha$, which yields

$$\frac{dp}{dK} = \frac{\gamma}{\Delta} < 0 \quad \frac{d\pi}{dK} = \pi_p^{PL}\frac{dp}{dK} < 0 \qquad \frac{dp}{db} = \frac{K\gamma_b}{\Delta} > 0 \quad \frac{d\pi}{db} = \pi_p^{PL}\frac{dp}{db} > 0$$

$$\frac{dp}{da_0} = \frac{K\left(\gamma_{a_0} + \gamma_\pi \pi_{a_0}^{PL}\right)}{\Delta} > 0 \qquad \frac{d\pi}{da_0} = \frac{-\left(hN + K\gamma_p\right)\pi_{a_0}^{PL} + \gamma_{a_0} K \pi_p^{PL}}{\Delta}$$

$$\frac{dp}{da_1} = \frac{K\gamma_{a_1}}{\Delta} > 0 \qquad \frac{d\pi}{da_1} = \pi_p^{PL}\frac{dp}{da_1} > 0$$

$$\frac{dp}{d\alpha} = \frac{\overline{K}L\left(\pi_{D^P}\gamma_\pi + \gamma_{D^P}\right)}{\Delta} > 0 \qquad \frac{d\pi}{d\alpha} = \frac{L\left(hN(\varphi - \pi\varphi') - \gamma^2(c_{rr}/c_r)\overline{K}\varphi\right)}{\Delta c\varphi''\varphi} < 0$$

To establish Proposition 4, note that the impact of a change in α on the return to capital will be $dr/d\alpha = \gamma\left((dp/d\alpha) - \pi\right)$. Substituting for $dp/d\alpha$ from above yields and using (6) and (10) yields

$$\frac{dr}{d\alpha} < 0 \Leftrightarrow hN > \gamma K \left(\frac{-\varphi'}{\pi\varphi''}\right)\left(\frac{1}{c\phi}\right)$$

Defining $\eta = hp/(1-H) > 0$ to be the elasticity of demand and $\varepsilon = -\pi\varphi''/\varphi > 0$ to be the elasticity of the marginal cost of safety improvement, the condition can be rewritten as $\eta\varepsilon > p/(c\varphi)$.

Proposition 6 examines the effect of changes in the degree of producer liability under the assumption that $D^C = (1-\mu)D^P$. The comparative statics results for (a) are obtained by solving (A-3) using $dD^C = (1-\mu)dD^P$.

$$\frac{dp}{dD^P} = \frac{\pi_{D^P}\left(\gamma_\pi \overline{K} + (\alpha L - D^C)hN\right) + \gamma_{D^P}\overline{K} - (1-\mu)\pi hN}{\Delta} > 0$$

$$\frac{d\pi}{dD^P} = \frac{\left(hN(\varphi - \mu\pi\varphi') - \gamma^2(c_{rr}/c_r)\overline{K}\varphi\right)}{\Delta c\varphi''\varphi} < 0$$

The effect on the rental on capital will be $dr/dD^P = \gamma\left((dp/dD^P) - \pi\right)$. Substituting from the solution for output price yields

$$\frac{dr}{dD^P} = \frac{X_2\gamma\pi}{\Delta p}\left[\mu\eta - \frac{p}{c\varphi\varepsilon} - \frac{\eta(\alpha L - D^C)}{c\varphi''\pi}\right] \tag{A-2}$$

This expression must be positive for $\mu = 0$, where all of the damages paid by producers are transferred to consumers. However, the return on capital could be decreasing in D^P if μ is sufficiently large and ε sufficiently small.

Proof of Proposition 3: To establish the free trade equilibrium, note that the home excess demand function (19) can be inverted to obtain $p_H = Z_H(K_F, K_H^*)$, where $\partial Z_H/\partial K_F > 0, \partial Z_H/\partial K_H^* < 0$, and $Z_H(0,0) = p^A$. Similarly, the foreign excess demand function (20) can be expressed as $p_F = Z_F(K_F, K_H^*)$, with $\partial Z_F/\partial K_F < 0, \partial Z_F/\partial K_H^* > 0$, and $Z_F(0,0) = p^{*A}$.

We first consider the case in which the foreign country does not have an advantage in safe products. Suppose that the home country has comparative advantage in the foreign market, which in this case will guarantee that the foreign does not have comparative advantage in the home market. From the properties of Z_H and Z_F, either (i) there is a $K_F \in (0, \overline{K}]$ such that $r_H(Z_H(Z_F, 0)) - r_F(Z_F(K_F, 0)) = 0$ or (ii) $r_H(Z_H(K_F, 0)) - r_F(Z_F(K_F, 0)) < 0$. If (a) holds, then $r_H^*(Z_H(Z_F, 0)) - r_F^*(Z_F(K_F, 0)) \leq 0$ and these prices are a free free trade equilibrium in which home firms sell in both markets and foreign firms sell only in the foreign market. If (b) holds, then $r_H^*(Z_H(\overline{K}, 0)) - r_F^*(Z_F(\overline{K}, 0)) < 0$ and this is a free trade equilibrium in which no firms sell in the home market. If home firms have an advantage in safe products, this will be the only free trade equilibrium. The possibility of cross-hauling of goods in equilibrium is ruled out by the discussion in the text, and the properties of Z_H and Z_F ensure that there can be no equilibrium with $K_H^* > 0$. This establishes that the home country has comparative advantage in the home market iff $K_F > 0$ at free trade. A similar argument establishes that the foreign country has comparative advantage in the home market iff $K_H^* > 0$ at free trade.

If the foreign country does have the advantage in safe products, then the argument in the text established that any free trade equilibrium must two way trade in the risky good. This implies that the home country will export the risky good whether or not it has comparative advantage in the foreign market. Thus, if the home country has comparative advantage in the home ‖

<u>Proof of Proposition 5:</u> Assume that the home country is the importer of the risky good, and the home (foreign) country sets a minimum quality standard of π^R (π^{*R}) for goods sold in its market. The market clearing conditions will be given by ()-(), where home firms choose $\pi_H = \min[\pi^R, \pi^{PL}(p_H)]$ for the home market and foreign firms choose $\pi_H^* = min[\pi^R, \pi^{*PL}(p_H)]$ ($\pi_F^* = min[\pi^{*R}, \pi^{*PL}(p_F)]$) for sales in the home (foreign) market. Totally differentiating this system and letting E (E^*) denote the excess supply in the home (foreign) market,

$$
\begin{pmatrix} -E_p & 0 & -\gamma(p_H, \pi_H^*) \\ -0 & -E_p^* & \gamma(p_F, \pi_F^*) \\ \rho_p^*(p_h, \pi_H^*) & -\rho_p^*(p_f, \pi_F^*) & 0 \end{pmatrix} \begin{pmatrix} dp_H \\ dp_F \\ dK_H^* \end{pmatrix} = \tag{A-3}
$$

$$
\begin{pmatrix} E_{\pi^R} d\pi^R \\ E_{\pi^{*R}}^* d\pi^{*R} \\ -\rho_\pi^*(p_H, \pi_H^*)\frac{d\pi_H^*}{d\pi^R} + \rho_\pi^*(p_F, \pi_F^*)\frac{d\pi_F^*}{d\pi^{*R}} \end{pmatrix}
$$

where $E_p = hN + (\gamma_p + \gamma_\pi(\partial\pi_H/\partial p))\,\overline{K} + \left(\gamma_p^* + \gamma_\pi^*(\partial\pi_H^*/\partial p)\right) K_H^* > 0$, $E_p^* = h^*N^* + \left(\gamma_p^* + \gamma_\pi^*(\partial\pi_F^*/\partial p)\right)(\overline{K}^* - K_H^*) > 0$, $E_{\pi^R} = \gamma_\pi\overline{K}(\partial\pi_H/\partial\pi_R) + \gamma_\pi^* K_H^*(\partial\pi_H^*/\partial\pi^R) \geq 0$, and $E_{\pi^{*R}}^* = \gamma_{\pi_H^*}^*(\overline{K}^* - K_H^*)(\partial\pi_H^*/\partial\pi^{*R}) \geq 0$.

Solving for the effect of home minimum quality standards yields

$$
\begin{aligned}
\frac{dp_H}{d\pi^R} &= \frac{E_{\pi^R}\rho_p^*(p_F, \pi_F^*)\gamma^*(p_F, \pi_F^*) + E_p^*\gamma^*(p_H, \pi_H^*)\rho_\pi^*(p_H, \pi_H^*)(\partial\pi_H^*/\partial\pi^R)}{\Delta^R} \\
\frac{dp_F}{d\pi^R} &= \frac{\gamma^*(p_F, \pi_F^*)\left[E_{\pi^R}\rho_p^*(p_H, \pi_H^*) - E_p\rho_p^*(p_H, \pi_H^*)(\partial\pi_H^*/\partial\pi^R)\right]}{\Delta^R} \\
\frac{dp_F}{d\pi^{*R}} &= \frac{E_{\pi^{*R}}^*\rho_p^*(p_H, \pi_H^*)\gamma^*(p_H, \pi_H^*) + E_p\gamma^*(p_F, \pi_F^*)\rho_\pi^*(p_H, \pi_H^*)(\partial\pi_F^*/\partial\pi^{*R})}{\Delta^R} \\
\frac{dp_H}{d\pi^{*R}} &= \frac{\gamma^*(p_H, \pi_H^*)\left[E_{\pi^{*R}}^*\rho_p^*(p_F, \pi_F^*) - E_p\rho_p^*(p_H, \pi_H^*)(\partial\pi_F^*/\partial\pi^{*R})\right]}{\Delta^R}
\end{aligned}
$$

where $\Delta^R \equiv -E_p\gamma^*(p_F, \pi_F^*)\rho_p^*(p_F, \pi_F^*) - E_p^*\gamma^*(p_H, \pi_H^*)\rho_p^*(p_H, \pi_H^*) < 0$ and $\partial\pi_H/\partial\pi^R = 0$ ($\partial\pi_H^*/\partial\pi^R = 0$) if the minimum quality standard is not binding on the home (foreign) firm in the home market. Since $E_{\pi^R} > 0$ for $\pi^R \leq min[\pi^{PL}(p_H), \pi^{*PL}(p_pH)]$ and $\rho_\pi^*(p_F, \pi_H^*) = -\gamma^*(p_F, \pi_H^*)(c\varphi' + \alpha L) \geq 0$ for $\pi \leq \pi^{PL}(p_H)$, it follows that $dp_H/d\pi^R < 0$ when the minimum quality constraint is binding. An relaxation of the minimum quality standard has two effects: it raises the output/capital ratio for capital selling in the home market and it makes selling in the home market more attractive for foreign firms. Both of these effects tend to reduce the price in the home market. In the foreign market these two effects conflict, so that the effect on the foreign price is ambiguous for $\pi < \pi^{*PL}(p_F)$. A similar argument shows that reducing quality standards in the foreign country will reduce the price in the foreign market and have an ambiguous effect on price in the home country when $\pi^R < \pi^{*PL}(p_f)$

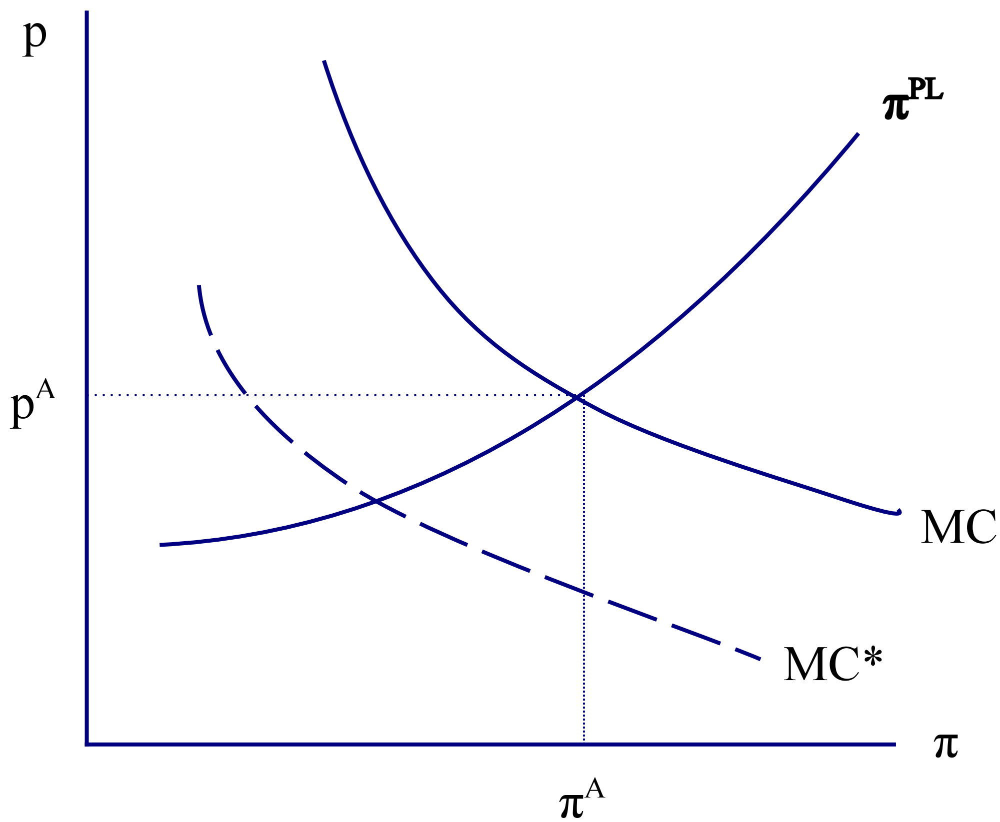

Figure 1: Autarkic Equilibrium

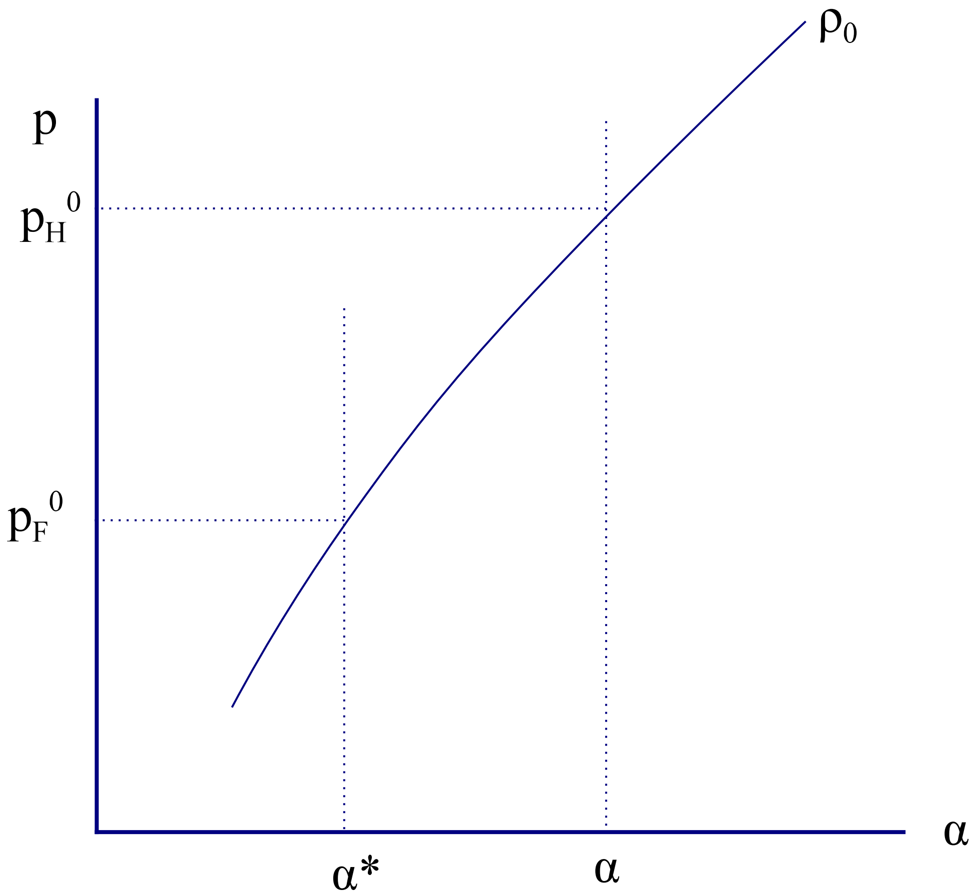

Figure 2a: Neither Country Has Cost Advantage in Product Safety

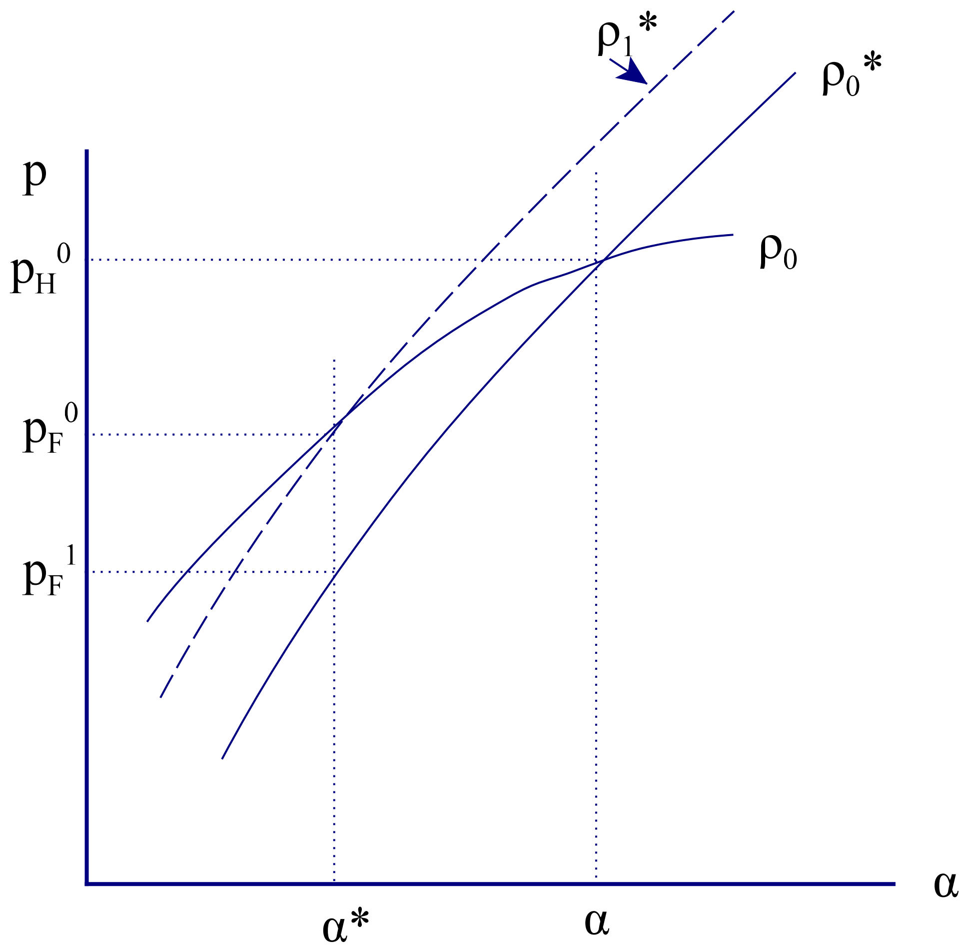

Figure 2b: Home Has Lower Cost of Product Safety

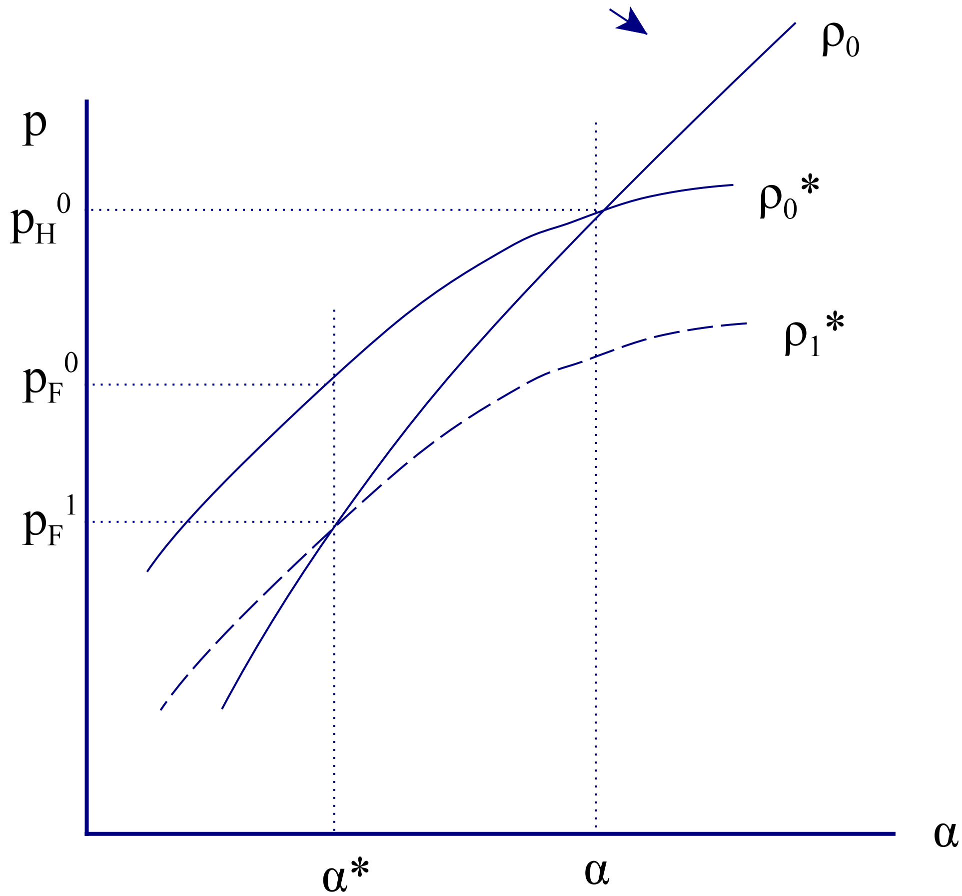

Figure 2c: Foreign Has Lower Cost of Product Safety