On the Interaction of Eco-Labeling and Trade

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March 10, 2018

Abstract

While environmental certification can provide useful information to consumers, there is concern that it indirectly erects trade barriers. I construct a two-country model where some firms use an environmentally-unfriendly (brown) production technology in each country, while other firms use environmentally-friendly (green) techniques. There are two green techniques, one in each country. Obtaining the eco-label entails certification costs; green firms in the exporting country must bear an additional cost to obtain the eco-label. I discuss the impact of eco-labeling on the quantities of green goods produced in each country and resultant welfare impacts, and the impact of changes in labeling costs.

Keywords: Asymmetric Information; Eco-Labeling; Environmental Economics;
Signaling; Testing

JEL Areas: Q5, D8, L15

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†phone: +1-307-766-5336; fax: +1-307-766-5090; e-mail: bambuzlr@uwyo.edu. Earlier versions of the paper were presented at the Heartland Environmental and Resource Economics Conference at Iowa State University, the BIOECON workshop on "Trade Mechanisms for Biodiversity Conservation," and the 7th Occasional Workshop on Environmental and Resource Economics at Santa Barbara, California. I wish to thank, without implicating, participants at those conferences, for lively discussion. I am articulately grateful to Ed Barbier, Erwin Bulte, Bob Deacon, Cathy Kling, Steve Polasky and Richard Damania for their input. This research was funded in part by the National Science Foundation, under grant # SES-0214160. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

1 Introduction

In the last few decades, eco-labels have emerged in a wide range of countries (Karl and Orwatt, 2000; OECD, 1997; Vossenaar, 1997). Some of these certification programs have become quite popular, as with the German "Blue Angel," Japanese "Eco-Mark," Swedish "Environmental Choice," and "Nordic Swan" programs (OECD, 1997) or the American "ENERGY STAR" label (Houde, 2012). These eco-labels are often applied to products where consumers would generally be individually unable to determine the environmental friendliness of the product, for example the biodegrability of a paper product, or of the production process itself. One explanation for the explosion of eco-labeling programs is that they are politically expedient, as they tap into consumers' desires to protect the environment.[1] Political motivations notwithstanding, a potential economic advantage to labeling programs is that providing information to consumers can be an attractive alternative to more traditional forms of regulation (Magat and Viscusi, 1992).

While eco-labeling has a potential role to play in providing information to interested consumers, concern has been expressed that certain governments have created eco-labeling programs as an indirect way to erect import barriers. Some critics claim that the notion of "environmental friendliness" adopted by these governments is highly correlated with existing practices by firms in the home country, but not by firms in the exporting country. This correlation could be coincidental, for example because the labeling criteria reflect domestic environmental priorities and technologies which "overlook acceptable products and manufacturing processes in the country of production" (Deere, 1999). A second explanation for such correlation is that the environmental effects of products are inferred using parameter estimates that are calculated based on data from the importing country, and which may "overstate the environmental impacts in the actual country of production."[2] Irrespective of the intentions of such standards, producers in foreign countries have argued that the standards hinder their attempts to send exports to the labeling country despite the fact that the exporting firms use production techniques that are environmentally comparable or superior to those used in the importing county.[3]

To assess these aspects of eco-labeling, I construct a model wherein there are two countries, *S* and *N*. In each country, some of the firms use a production technology that is inconsistent with sustainability or the protection of biodiversity (for example, in the context of timber harvesting); I refer to these as type 1 firms. All other firms use environmentally friendly – or green – techniques, though the green technique used in country *S* differs from the green technique used in country *N*. I refer to the green firms in country *S* (respectively, country *N*) as type 2 (respectively, type 3). I assume that the degree of environmental friendliness is the same for type 2 and type 3 firms.[4] Some consumers in country *N* care about a product's environmental friendliness. Because the attribute in question is unobservable by consumers – indeed it is an example of a credence good (Darby and Karni, 2001; Caswell and Mojduszka, 1996; Feddersen and Gilligan, 2001) – these consumers can not identify the level of environmental friendliness associated with the product in question either before or after purchase.

Accordingly, the only way such information can be disseminated is through third-party provision, such as with eco-labeling.

I assume that firms may obtain an eco-label by demonstrating that their production practice meets certain criteria; that is, firms must pass a certification test. The test is costly, and so can serve as a screening device (Stiglitz, 1975). Type 3 firms are able to pass this test without adjusting their product or their technology. Type 2 firms, however, must make some design changes if they are to pass; accordingly, they bear an additional cost if they pursue the eco-label (above and beyond the cost of the test itself). Earlier conceptual analyses have neglected the cost of certification (Mattoo and Singh, 1994; Nimon and Beghin, 1999b; Swallow and Sedjo, 2000; Sedjo and Swallow, 2002). In practice, however, when a firm pursues an eco-label it must generally pay a significant application cost; this payment is required irrespective of the outcome of the assessment (Stern, 1993).[5]

A variety of equilibrium configurations are possible. At one extreme, if certification costs are sufficiently large, no firms obtain the eco-label. At the other extreme, if certification costs are very low, all green firms obtain the eco-label. In between, there are two classes: one where green firms from country N are indifferent between certifying and not, while green firms in country S prefer to not export; and one where green firms from country N strictly prefer to certify, while firms from country S are indifferent between obtaining the eco-label and exporting to country N and leaving their products in country S. I then discuss various comparative static effects, including the impact of increases in test cost, increase in licensing cost, and increases in various transactions costs. One interesting effect relates to increases in the test cost: such increases can benefit green sellers in country N.

The paper proceeds with a discussion of the modeling formalities in section 2. A discussion of the market equilibrium prior to the provision of information is given in section 3. Analysis of market equilibrium when an eco-label is available is conducted in section 4, including a discussion of the various comparative static effects. Section 5 discusses some extensions to the basic model. I conclude the paper in section 6 with a discussion of a specific application where the tension between eco-labeling motivations and possible trade restrictions has drawn attention from international authorities, namely timber certification.

2 The Model

Consider a market, such as that for forest products, where there are production techniques that vary in terms of their environmental impact. There are producers in two countries, call them countries S and N, but most of the commerce takes place in country N. In particular, some firms export from S to N, but there is no export from N to S. One might think of N as representing a "North" country, perhaps the U.S. or Canada, with S representing a "South" country, such as Brazil or the Philippines. In both countries there is a production technique that is unambiguously more damaging to the environment; I will refer to firms that use this technique as "type 1" in the pursuant discussion.

There are type 1 firms in both countries. Other firms use more environmentally friendly techniques, for example forestry practices that are consistent with sustainability or the preservation of biodiversity. Perhaps because of the relative abundance of other inputs, or other institutional aspects, the more environmentally friendly technique used in country S is not the same as that in country N. I will refer to environmentally friendly firms in country S as "type 2" firms; their counterparts in country N are "type 3" firms. There are n_2 potential type 2 sellers and n_3 potential type 3 sellers. The number of type 1 firms in country N is n_{N1}, while the number of type 1 sellers in country S is n_{S1}. All these values are exogenous, and fixed.

Throughout, I will suppose that the environmental impacts of these two techniques are largely the same. However, a perspective that focuses on specific aspects would suggest that one technique is more environmentally friendly than the other. For example, it may be the case that type 3 producers are more inclined to use recycled wood products than are type 2 producers, but that type 2 producers use a less energy-intensive procedure to process virgin timber. If one focused on the amount of recycled material in the final product, one might be inclined to regard type 3 producers as more environmentally friendly than type 2 producers.

Supply curves for all types of products are continuous and upward sloping, reflecting increasing marginal costs for each technique. In the basic model, firms within a given type have identical cost functions; *i.e.*, all type k firms have the same cost function $c_k(q)$. I discuss the extension to heterogeneous costs in section 5. Each firm's production costs are private knowledge, as is its output. The latter precludes consumers from drawing inferences about a firm's technology on the basis of its output, which greatly simplifies the discussion. The distribution over parameter combinations is assumed to be common knowledge. Accordingly, all agents can calculate the equilibrium expected outputs of green and brown products, and the associated rational expectations prices. Any products exported from S to N must bear an extra cost, which I assume is constant and identical across all sellers, and which I denote by τ. This extra cost could represent the cost of shipping an extra unit from S to N, it could reflect export barriers erected by the government in country S, or it might embody a tariff placed on goods imported into N. I assume that each firm's production technology is exogenously fixed.[6] Thus, firm behavior can be summarized by supply curves. Since there is general agreement that green production is at least as expensive as brown production in practice, I assume $c_2(q) > c_1(q)$ and $c_3(q) > c_1(q)$ for any positive output q.

Some consumers would be willing to pay extra for products that they believe to be environmentally friendly (which I will often refer to as "green" in the pursuant discussion) than for products they believe to be environmentally unfriendly (which I will often refer to as "brown" in the pursuant discussion). Firms that use green production techniques would like to capitalize on this demand, but they face a problem of asymmetric information. Consumers cannot typically tell the type of production process a particular firm has used, so they can't determine whether it is green or brown. Since the green technique is generally more costly, firms would be disinclined to choose such a technique, with larger pollution flows resulting. One possible remedy for this informational asymmetry is for firms to make use of "eco-labeling." With eco-labeling, a third party certifies a vendor's product as the result of an environmentally friendly process.

As the focus in my paper is on the impact of introducing eco-labeling into country N, and since no goods are shipped from N to S, I assume that those consumers who place a premium on green products live in country N. Accordingly, the demand curve for green products lies above the demand curve for brown products in country N.[7] In country S, consumers do not distinguish between green and brown goods, so there is only one demand curve. In the pursuant discussion, I denote the inverse demand curves for these sectors as $P_B(\cdot)$ (for brown goods in country N); $P_G(\cdot)$ (for green goods in country N); and $P_S(\cdot)$ (for all goods in country S). All inverse demand curves are continuous and weakly decreasing functions of their respective outputs.

I model eco-labeling as the result of a certification process that is conducted by a third party, such as the government within country N. Firms that apply for the eco-label must pay a one-time certification costs, C; there may also be a per-unit 'licensing fee', b.[8] The eco-label is granted to those firms that meet a certain standard. Perhaps for political reasons, this standard is based on the green technology within country N.[9] Thus, type 3 firms in country N do not have to adapt their technology to meet the standard. Ttype 2 firms, on the other hand, must bear an additional per-unit cost of β if they are to obtain the eco-label.

3 The Market without Eco-Labeling

Before describing the mechanics of the equilibrium with eco-labeling, I first discuss the outcome in the initial equilibrium, which I refer to as the "no-information" equilibrium. In the absence of third-party information about production techniques, consumers cannot distinguish a given product's type. Accordingly, the market price in country N is a weighted average of the price consumers would pay for a green product and the price they would pay for a brown product, if they were perfectly informed regarding product type. Let Q_G^0 and Q_B^0 represent the quantities of green and brown products in the no-information equilibrium in country N, respectively. Market price is then

$$P^0 = \theta_0 P_G(Q_G^0) + (1 - \theta_0 P_B(Q_G^0), \quad \text{where} \tag{1}$$

$$\theta_0 = \frac{Q_G^0}{Q_G^0 + Q_B^0} \tag{2}$$

equals the fraction of green units on offer in country N in the no-information equilibrium. These quantities are identified from the supply curves for the three types of producer, based on the price P^0, taking into account the transactions costs for producers in S who sell in N. Assuming trade takes place in both countries, and that some firms ship from S to N, sellers in S must be indifferent between selling in S or N; this requires:

$$P^0 = P_S(Q_S^0) + \tau. \tag{3}$$

Accordingly, the net revenue sellers in country S receive from one unit is $P_S^0 = P_S(Q_S^0)$, whether they sell domestically or abroad. The volume of type j units produced in country S is read off the supply curve for such units, based on the price P_S^0. The volume of type j units produced in country N is read off the supply curve for such units, based on the price P^0.

The market equilibrium when certification is possible is described as follows. The quantities of type 1 units produced in each of the two countries are Q_{S1}^0 and Q_{N1}^0; quantities of type 2 units that are produced, Q_2^0; and quantities of type 3 units that are produced, Q_3^0. In addition, ϕ_k, the fraction of type $k = 1,2$ units that are exported from S to N must be determined. Based on the values described above, the quantity of green units that are sold in country N is

$$Q_G^0 = \phi_2 Q_2^0 + Q_3^0,$$

while the volume of brown units on offer in country N is

$$Q_B^0 = \phi_1 Q_{S1}^0 + Q_{N1}^0.$$

Since the country of origin is identifiable information, the fraction of units imported into country N that are green must equal the fraction of units produced in country N that are green. Accordingly,

$$\frac{\phi_2 Q_2^0}{\phi_2 Q_2^0 + \phi_1 Q_{S1}^0}$$

Finally, the volume of units on offer in country S is

$$Q_S^0 = (1 - \phi_1)Q_{S1}^0 + (1 - \phi_2)Q_2^0.$$

Before moving on to a discussion of the market with certification, I first briefly discuss the first-best outcome. Depending upon the underlying primitives (supply and demand characteristics, and per-unit transaction cost τ), a variety of scenarios could result. In the first, the number of type 2 sellers that export to country N is such that the resultant full-information price for green units in N exceeds the price in S by an amount just equal to τ. In the second, all green items are sold in country N (*i.e.*, all type 2 units are exported from S to N). All type 1 units in S are sold at the equilibrium price that would obtain if consumers were perfectly informed, and a sufficient number of type 1 units are exported from country S to N so that the price for brown units in N exceeds the price in S by an amount just equal to τ. In the third, all type 2 units are exported to N, but all other units are sold in their home market; the resultant price for type 1 units in N differs from the price in S by an amount less than τ in magnitude (so that it does not pay to export any brown units either way). In the fourth, all green units are sold in N and some type 1 units are exported from N to S. I mention this fourth scenario for completeness, although it is inconsistent with my standing assumption that all trade flows from S to N. While all the other candidates are plausible, the third is expositionally simplest to analyze, and is most consistent with the earlier analyses.

4 The Market with Eco-Labeling

4.1 Preliminaries

Now suppose that a third party offers to certify the environmental friendliness of a firm's product, at a specified cost C. Firms that use the eco-label must also pay a per-unit charge, b. Structurally, this per-unit charge is akin to an excise tax. Type 3 firms in country N do not have to adapt their technology to meet the standard, but type 2 firms must bear an additional per-unit cost of β to obtain the standard. For example, there might be more than one production scheme that delivers a certain level of environmental friendliness. In such a scenario it is plausible that type 2 firms select one such scheme, while type 3 firms select another, for example because other input prices – such as wage rates – differ between the two countries. If the certification process favors the technique adopted in country N, then for type 2 firms to obtain certification they will need to switch technologies. This will certainly raise their costs; in the discussion below I assume that this increase in cost implies that the cost function for type 2 firms, combined with the extra unit cost β, lies above the production cost for type 3 firms. On the other hand, for the typical application I have in mind, production costs are generally no more expensive in country S than in country N. If one imagines that country S is a developing country, while country N is a developed country, then such a relation would seem reasonable. These two assumptions can be formalized as

$$\mathbf{A1}: c_2(q) + \beta q > c_3(q), \text{ for any output level } q;$$

$$\mathbf{A2}: c_3(q) \geq c_2(q), \text{ for any output level } q.$$

Each firm chooses its output level to maximize expected profits; at this output, marginal cost equals net price. For firms in country N that obtain the eco-label, net price equals $P_c - b$, the price paid for a certified product less the per-unit charge. For a type j firm in country S that obtains the eco-label, net price equals $P_c - b - \beta - \tau$: the firm must pay the per-unit charge, b, the per-unit cost of adapting its technology, β, as well as the per-unit transaction cost to sell in country N, τ. For any firm that does not obtain the eco-label, net price equals the generic price for a firm selling within their own country without obtaining certification. Writing the net price received by the typical type j firm in country k as NP_{jk}, its privately optimal output level is determined by

$$NP_{jk} = c'_{jk}(q^*_{jk}).$$

Recall that type 2 units are only found in country S, while type 3 units are only found in country N. Accordingly, to avoid notational clutter I do not subscript the country for type 2 or 3 firms in the pursuant discussion.

Consider first the incentives confronting a typical type 3 unit. The seller of this unit can opt for the generic, or unlabeled, segment of the market, or this seller can obtain the eco-label at cost C, without adapting the production technique. In the former case, the firm receives the "net price" P_{un}, while in the latter case it receives $P_c - b$. Let q_3^{**} (respectively, q_3^*) denote the profit-maximizing output for the firm if it enters the unlabeled segment of the market (respectively, if it acquires the eco-label). The corresponding profits are

$$\pi_3^* = P_{un} q_3^{**} - c_3(q_3^{**}) \tag{4}$$

if the firm enters the unlabeled segment of the market, and

$$\Pi_3^* = (P_c - b) q_3^* - c_3(q_3^*) - C \tag{5}$$

if it obtains the eco-label.

Next, consider the typical type 2 firm. If this firm does not obtain the eco-label it has two options: sell domestically at the price P_S, or export into the unlabeled segment of the market in country N, in which case it collects $P_{un} - \tau$ per unit. The former cannot be smaller than the latter, as otherwise there would be no commerce at all in country S. Accordingly, a type 2 firm that does not obtain the eco-label must receive the net price P_S. Let q_2^{**} represent the profit-maximizing output for the type 2 firm if it enters the unlabeled segment of the market. The associated profit from this decision is

$$\pi_2^* = P_S q_2^{**} - c_2(q_2^{**}) \tag{6}$$

Alternatively, a type 2 seller that obtains the eco-label and ships its product to country N receives the net price $P_c - \beta - b - \tau$. Let q_2^* represent the profit-maximizing output for the type 2 firm if it follows this approach. Such a firm then realizes profits

$$\Pi_2^* = (P_c - \beta - b - \tau)q_2^* - c_2(q_2^*) - C. \tag{7}$$

Finally, consider type 1 firms. All type 1 firms in country N sell at the unlabeled price, P_{un}; call the output they choose q_1^*. The resultant profits earned by type 1 firms in country N are thus $\pi_1^* = P_{un}q_1^* - c_3(q)_1^*)$. In country S, type 1 firms either sell domestically at price P_S or they export to country N, at cost τ, and then sell at P_{un}. Unless there are explicit barriers to export, the option to arbitrage creates a lower bound on the domestic price in country S:

$$P_S \geq P_{un} - \tau.$$

If any type 1 firms export from S to N then this constraint must be satisfied as an equality.

4.2 Equilibrium

The market equilibrium when certification is possible is described as follows. The quantities of type 1 units produced in each of the two countries are Q_{S1}^e and Q_{N1}^e; the fraction of type 1 units that are exported into the unlabeled market segment in country N from country S is μ_1; the quantity of type 2 units that are exported into the certified market segment in country N from country S is Q_{2c}^e; the quantity of type 2 units that are left in country S and sold as unlabeled is Q^e_{2un}; the quantity of type 3 units that are delivered to the certified market segment in country N is Q^e_{3c}; and the quantity of type 3 units that are delivered to the unlabeled market segment in country N is Q^e_{3un}. Based on these values, the volume sold in country S, and the corresponding equilibrium price, are

$$Q^e_S = (1 - \mu_1)Q^e_{S1} + Q^e_{2un},$$
$$P^e_S = P_S(Q^e_S).$$

In country N, the amounts sold in the certified segment of the market and in the unlabeled segment of the market are:

$$Q^e_c = Q^e_{2c} + Q^e_{3c},$$
$$Q^e_u = Q^e_1 + Q^e_{3un},$$

where

$$Q^e_1 = Q^e_{N1} + \mu_1 Q^e_{S1}.$$

The total quantity of green units sold in country N, and the corresponding equilibrium certified price, are

$$Q^e_G = Q^e_c + Q^e_{3un},$$
$$P^e_c = P_G(Q^e_G).$$

The value consumers in country N would place on a product they knew to be brown is based on the equilibrium volume of such units on offer:

$$P_1^e = P_B(Q_1^e).$$

The equilibrium price in the unlabeled segment of the market in country N is a weighted average of this price and the certified price, P_c^e, where the weights reflect the equilibrium fractions of brown and green units on offer, respectively. The equilibrium fraction of green units in the unlabeled segment of the market in country N is

$$\theta^e = \frac{Q_{Gun}^e}{Q_{Gun}^e + Q_1^e},$$

and so the equilibrium unlabeled price is

$$P_{un}^e = \theta^e P_c^e + (1 - \theta^e) P_1^e.$$

Finally, the arbitrage condition governing behavior of type 1 firms in country S implies

$$\mu_1 (P_S^e - P_{un}^e + \tau) = 0.$$

Let λ equal the fraction of type 3 units that are placed in the unlabeled segment of the market in country N, and let μ_2 equal the fraction of type 2 units that are exported to country N and certified. As the number of type 2 and type 3 sellers are fixed at n_2 and n_3, respectively, and since all sellers within a particular cohort produce the same output, one may express the various prices in terms of these fractions. Accordingly, characterization of the possible equilibria boils down to a determination of the equilibrium combinations of λ, μ_1 and μ_2. Towards that end, I write the certified price that would obtain for a given combination of these fractions as $P_c(\lambda, \mu_1, \mu_2)$, the fraction of green units in the uncertified market as $\theta(\lambda, \mu_1, \mu_2)$, the underlying price paid for brown units as $P_1(\lambda, \mu_1, \mu_2)$, and the price in country S as $P_S(\lambda, \mu_1, \mu_2)$. For a given value of μ, it is straightforward to determine the market supply in country S: $P_S((\lambda, \mu_1, \mu_2)$ balances that supply with demand in S. Similarly, the market clearing combination of prices $P_c(\lambda, \mu_1, \mu_2)$ and $P_1(\lambda, \mu_1, \mu_2)$ is determined by the quantity of green units on offer in country N and the supply of type 1 units in country N. Associated with the determination of these prices are levels of output for both unlabeled type 3 firms and type 1 firms in country N; these may also be regarded as functions of the fractions λ, μ_1 and μ_2, and so I write them as $q_3^{**}(\lambda, \mu_1, \mu_2)$ and $q_1^{**}(\lambda, \mu_1, \mu_2)$, respectively. Using these outputs together with the specified value of λ it is straightforward to determine θ in terms of λ, μ_1 and μ_2:

$$\theta(\lambda, \mu_1, \mu_2) = \frac{\lambda n_3 q_3^{**}(\lambda, \mu_1, \mu_2)}{\lambda n_3 q_3^{**}(\lambda, \mu_1, \mu_2) + n_1 q_1^{*}(\lambda, \mu_1, \mu_2)}. \tag{8}$$

Based on the above prices, one may express the potential profit for a typical type 3 firm from obtaining certification or from entering the unlabeled segment of the market as $\Pi_3^*(\lambda, \mu_1, \mu_2)$ and $\pi_3^*(\lambda, \mu_1, \mu_2)$, respectively. Similarly, the potential profit a typical type 2 firm can earn from obtaining certification and exporting to country N on the one hand, or from leaving its product in country S on the other, can be expressed as $\Pi_2^*(\lambda, \mu_1, \mu_2)$ and $\pi_2^*(\lambda, \mu_1, \mu_2)$, respectively. In turn, these values can be used to write the potential increase in operating profits the typical type 3 seller would realize by obtaining the eco-label as

$$\Omega_3(\lambda, \mu_1, \mu_2) = [P_c^e - b] q_3^*(\lambda, \mu_1, \mu_2) - c_3\left(q_3^*(\lambda, \mu_1, \mu_2)\right) - \left[P_{un}^e q_3^{**}(\lambda, \mu_1, \mu_2) - c_3\left(q_3^{**}(\lambda, \mu_1, \mu_2)\right)\right]. \tag{9}$$

Likewise, the potential increase in operating profits the typical type 2 seller would realize by obtaining the eco-label are

$$\Omega_2(\lambda, \mu) = [P_c^e - b] q_2^*(\lambda, \mu) - [c_2\left(q_2^*(\lambda, \mu)\right) + (\beta + \tau) q_2^*(\lambda, \mu)] - [P_S^e q_2^{**}(\lambda, \mu) - c_2\left(q_2^{**}(\lambda, \mu)\right). \tag{10}$$

By virtue of the continuity of the underlying supply and demand curves, both Ω_2 and Ω_3 are continuous functions of λ, μ_1 and μ_2. A key feature of the model is that[10]

$$\Omega_2 < \Omega_3. \tag{11}$$

This remark has clear implications for the possible equilibrium values of λ and μ_2. In particular, if $\mu_2 > 0$ then $\lambda = 0$, while $\lambda > 0$ then $\mu_2 = 0$; accordingly, $\lambda \mu_2 = 0$.

4.2.1 Equilibrium types

To say more about the possible equilibrium combinations of λ and μ_2, I consider a hypothetical normal form game between two players, one who is representative of actions taken by type 3 sellers and one who is representative of actions taken by type 2 sellers. The actions available to the former player are "obtain the eco-label" and "enter the unlabeled segment", while the actions available to the latter player are "export to country N and obtain the eco-label" and "leave the product in country S." These actions correspond to values of $\lambda = 0$ or 1 on the one hand, and $\mu_2 = 1$ or 0 on the other. The potential payoffs for each player are then determined by the four possible combinations of λ and μ_2. Since $\lambda\mu_2 = 0$, the continuity of Ω_2 and Ω_3 in terms of λ and μ_2 implies that in equilibrium either: a) $\lambda = 1$ and $\mu_2 = 0$; b) $\lambda = 0$ and $\mu_2 = 1$; c) $\lambda \in (0,1)$ and $\mu_2 = 0$; or d) $\lambda = 0$ and $\mu_2 \in (0,1)$. In a class a) equilibrium no firms are certified, so that the "no-information" equilibrium described above would obtain. In a class b) equilibrium, all green sellers (*i.e.*, all type 2 sellers and all type 3 sellers) certify. Evidently, this class of equilibrium can only obtain if the certification fees and adaptations costs are quite small. While it is conceivable that the various parameters might be consistent with one of these two equilibria, each equilibrium is only consistent with a narrow range of parameter combinations. Accordingly, I focus on equilibrium classes c) and d) in the following discussion.

4.2.2 Characteristics of type c) equilibrium

In the equilibrium class c), type 3 sellers are indifferent between certifying and not, while type 2 sellers prefer to sell in country S. Since $\mu = 0$ in this type of equilibrium, $P_c = P_G(Q_3^e)$; accordingly, the gain to certification for type 3 sellers is:

$$\Omega_3 = [P_c^e - b]q_3^* - c_3(q_3^*) - \left[P_{un}^e q_3^{**} - c_3(q_3^{**})\right]. \tag{12}$$

In this context, an increase in λ has two conflicting impacts upon the volume of type 3 units sold in country N: the volume of certified units falls, while the volume of uncertified units rises. The net effect on aggregate production by type 3 firms is $-n_3(q_3^* - q_3^{**})$, which is negative since the parenthetical term is positive. As a result, an increase in λ leads to an increase in P_c, which in turn causes an increase in the operating profit from certification; thus, $\Omega_3'(\lambda) > 0$.[11]

The defining characteristic of this class of equilibrium is $\Omega_3 = C$. Let $\underline{C}_3$ represent the value the left-hand side of eq. (12) takes when $\lambda = 0$; likewise, let $\overline{C}_3$ represent the value the left-hand side of eq. (12) takes when $\lambda = 1$. When certification costs fall between these two values (*i.e.*, $\overline{C}_3 > C > \underline{C}_3$), there is a positive value of λ strictly smaller than one such that eq. (12) holds; this is the equilibrium fraction of type 3 units that are placed in the unlabeled segment. For values of C that exceed $\overline{C}_3$, no green sellers certify; in this case, the equilibrium is the no-information equilibrium described above. For values of C smaller than $\underline{C}_3$, all type 3 units certify: $\lambda = 0$.

Three comparative statics hold in any class c) equilibrium. First, depending on the various parameters, combined welfare can rise or fall with the introduction of the eco-label. It is readily apparent that the fraction of green units sold as unlabeled in country N is smaller than the fraction of green units sold there in the no-information equilibrium. Accordingly, the unlabeled price in country N is smaller than the no-information price, $P^e_{un} < P_0$, which leads to a reduction in the volume of type 1 units on offer in country N. Some of this decrease is due to a decrease in the volume of type 1 units imported from country S, and some comes from a decrease in type 1 production within country N. Moreover, since a smaller fraction of green units are sold as generic units in the eco-labeling equilibrium, there is a reduction in the welfare loss associated with misaligned production in country N. At the same time, many type 3 producers realize a larger price, which induces them to increase their production. Since there was a general under-production of green units in the no-information equilibrium, this response is also socially beneficial. Thus, the introduction of a labeling scheme does generate benefits from better-aligned production. Even so, these benefits may not exceed the cost of labeling. In country S, the equilibrium price balances domestic demand with that supply associated with sellers who do not export. While this is an attractive outcome for market participants in S, the resultant price is surely smaller than the certified price in country N, by an amount in excess of the transaction cost τ. If the export cost represents real economic costs (as opposed to artificial costs associated with trade barriers), it would be socially beneficial to reallocate some of the green production from country S to country N. This mis-allocation is due to the per-unit adaptation cost, β; the larger is this cost, the larger is the fraction of type 2 sellers who eschew the certified segment of the market in country N. While the net impact on total welfare is ambiguous, two things seem clear: first, any potential welfare gains are diminished by the cost of acquiring information (*i.e.*, the certification cost C); second, welfare gains are further diminished by the presence of adaptation costs (*i.e.*, β). On balance, then, welfare in either country – and indeed, combined welfare – can either go up or down.

Second, an increase in the one-time certification cost raises profits for all sellers in country N. Note that an increase in C must induce some type 3 sellers to switch from the certified to the unlabeled segments of the market in country N. With the increase in type 3 sellers that place their products in the unlabeled segment, the unlabeled price must rise. In turn, this pushes up equilibrium profits for any seller in the unlabeled segment – both type 1 and type 3 sellers. But the in profits a type 3 seller can earn in the unlabeled segment forces up equilibrium profits in the certified segment, by an amount sufficient to balance those profits less the one-time cost against the available profits in the unlabeled segment. As the latter increases, so must the former; it follows that all type 3 sellers are better off following the increase in C.

Third, an increase in b raises profits for all sellers in country N. The argument follows similar lines to the second result. Following the increase in b, some type 3 sellers switch from the certified segment to the unlabeled segment, pushing up the unlabeled price and unlabeled profits. To keep type 3 sellers indifferent, certified profits (taking both types of eco-labeling costs into account) must rise by a like amount. The result is that all sellers in country N are better off.

While these last two results may seem somewhat counter-intuitive at first blush, they are readily explained by the nature of the class of equilibrium. Increases in either form of certification cost initially induce type 3 sellers to favor the unlabeled segment. Since increases in the number of green sellers in the unlabeled cohort tend to raise the unlabeled price, equilibrium profits must rise as well. When type 3 sellers are indifferent between the two market segments, as is true in the second class of equilibrium, anything that increases unlabeled profits must indirectly lead to adjustments that increase certified profits. But if type 3 sellers were not indifferent, as in the next class I discuss, this sort of arguments fails to go through; in that case, the impact of such increases in certification cost are ambiguous.

Because $\mu = 0$, type 2 sellers strictly prefer not to certify. Accordingly, anything that lowers the payoff a type 2 seller would obtain from certification does not affect their behavior. In particular, small changes in either β or τ have no effect on the equilibrium prices or payoffs in this class of equilibrium.

4.2.3 Characteristics of type d) equilibrium

In the equilibrium class d), all type 3 sellers strictly prefer to certify while type 2 sellers are indifferent. The defining characteristic of this class of equilibrium is $\Omega_2 = C$. In light of the remarks above, and noting that $\lambda = 0$ in this type of equilibrium, the gain from certification is

$$\Omega_2 = [P_c^e - b - \beta - \tau]q_2^* - [c_2(q_2^*)q_2^*] - [P_S^e q_2^{**} - c_2(q_2^{**})]. \tag{13}$$

A small increase in μ will raise Q_{2c}, and hence lower P_c, while decreasing Q_{2un} and hence raising P_S.[12] It follows that $\Omega_2'(\mu) < 0$. Define $\underline{C}_2 = \Omega_2(1)$ and $\overline{C}_2 = \Omega_2(0)$. For a class d) equilibrium to exist, the various exogenous parameters must be such that $\underline{C}_2 < C < \overline{C}_2$.

The effects of an increase in the test cost are more complex in a class d) equilibrium than in a class c) equilibrium. Here, an increase in certification costs lowers the equilibrium profit available to a type 2 seller that obtains the eco-label. Accordingly, more of these sellers leave their products in country S. But consumers in country S do not care about environmental friendliness, and so this increase in the volume of type 2 products in country S must lower the price in country S. In turn, profits available in country S go down. For type 2 sellers to remain indifferent, certification profits (net of all labeling costs) must fall as well. On the other hand, the certified price in country N rises, due to the reduction in the quantity of certified units. While this increase in price is too small to cover the increased certification costs for type 2 firms, the impact on type 3 firms is less clear.

To better understand this ambiguity, consider the effect of an increase of C on Ω_2. As $\Omega_2 = C$ in this class of equilibrium, it follows that $\mathrm{d}\Omega_2 = \mathrm{d}C$. From eq. (13), and applying the envelope theorem, one has

$$\mathrm{d}C = \mathrm{d}\Omega_2 = q_2^* \mathrm{d}P_c^e - q_2^{**} \mathrm{d}P_S^e, \tag{14}$$

The impact of the increase in C upon type 3 firms can be measured through the effect on Π_3^*; from eq. (5), and bearing in mind the envelope theorem, the first-order effect of an increase in C on the typical type 3 firm is $\mathrm{d}\Pi_3^* = q_3^* \mathrm{d}P_c^e - \mathrm{d}C$. Using eq. (14), one then infers that

$$\mathrm{d}\Omega_3 - \mathrm{d}C = \left(q_3^* - q_2^*\right)\mathrm{d}P_c^e - q_2^{**}\mathrm{d}P_S^e. \tag{15}$$

The first term on the right side of eq. (15) is positive because of assumption **A2**, though the second term need not be. That point noted, if the cost advantage type 3 firms obtain from the labeling (β) is sufficiently large, or demand in country S is sufficiently elastic, the first term will outweigh the second and type 3 firms' profits will rise. By contrast, if β is sufficiently small and demand in S is sufficiently inelastic, type 3 firms' profits can fall.

The potential for increased certification costs to raise type 3 firms' equilibrium profitst is related to the notion of raising rivals' costs, though not in the usual way. Type 3 firms do not gain because increased marginal costs hurt type 2 firms more than type 3 firms; rather, because the labeling scheme induces a cost advantage, type 3 firms are better able to bear the increased test cost. The increase in test cost leads to a lager certified price; this increased price benefits firms with lower costs more than firms with higher costs. When type 3 firms have a sufficient cost advantage, this added benefit that obtains from the higher certified price can more than offset the increase in test cost.

In contrast to the effect of a change in C, the effect of an increase in b in equilibrium class d) is similar to that in class c). Because an increase in b must lower type 3 sellers' profits, the impact on the typical type 2 seller's profit is

$$\mathrm{d}\Omega_2 = q_2^* \mathrm{d}\left[(P_c^e - b)\right] - q_2^{**} \mathrm{d}P_S^e. \tag{16}$$

As with an increase in test costs, the result of an increase in the variable component of certification costs must lead to an increase in μ_2, which in turn would lower the price in country S. It is apparent from eq. (16) that the impact on the wedge between certified price and variable certification cost is of the same sign as the impact on P_S^e. Accordingly, $P_c^e - b$ must fall when b rises. It follows that certification profits for type 3 sellers must then also fall.

Finally, I note that an increase in either β or τ must make all type 3 sellers better off. Such increases will lower the net price that type 2 sellers obtain from obtaining the eco-label and exporting into country N; accordingly, μ_2 must fall. But then P_c^e would rise, with no offsetting increase in costs to type 3 sellers. Hence, their profits must rise.

5 Heterogeneous Costs

In the basic model I assumed that all firms within a cohort face the same cost function. If, however, there are differences in abilities, access to other inputs, transportation costs to market, and so on across firms, then one would not expect all type k firms to have the same costs. To capture this effect, suppose that each firm i is described by a parameter α_i; production costs are $c_k(q;\alpha_i)$ for a type k firm. I interpret larger values of the parameter α_i as reflecting higher costs and higher marginal costs. For any particular parameter value, however, costs are increasing and convex in own output. As in the basic model, each firm's production costs are private knowledge, as is its output. The latter precludes consumers from drawing inferences about a firm's technology on the basis of its output, which greatly simplifies the discussion.

The probability distribution functions for cost parameters are $f_k(\alpha_j)$, where k indexes the country and j indexes the type of firm. Associated with each of these probability distribution functions is a cumulative distribution function, $F_k(\alpha_j)$. These probability distributions are defined on the intervals $[\underline{\alpha}_{kj}, \overline{\alpha}_{kj}]$. To capture the notion that it is generally more costly to use the green technology, all else equal, I assume that F_{S1} first-order stochastically dominates F_{S2}: for any α, $F_{S1}(\alpha) \geq F_{S2}(\alpha)$, with strict inequality arising when $F_{S1} > 0$ and $F_{S2} < 1$. Likewise, F_{N1} first-order stochastically dominates F_{N3}. Accordingly, the boundaries of the various supports satisfy the restrictions

$$\underline{\alpha}_{S1} < \underline{\alpha}_{S2};\ \underline{\alpha}_{N1} \leq \underline{\alpha}_{N3};\ \overline{\alpha}_{S2} \geq \overline{\alpha}_{S1};\ \overline{\alpha}_{N3} \geq \overline{\alpha}_{N1}.$$

It is easy to see that increases in costs will reduce profit to a larger degree the greater is the net price; it follows that type 3 firms with a cost parameter above some cutoff level eschew labeling. As in the basic model, I use q^*_{i3} to represent the profit-maximizing output, and $\Pi_3(q^*_{i3};\alpha_i, P_c - b)$ the resultant profit earned, in the certified segment; the corresponding values are q^{**}_{i3} and $\pi_3(q^*_{i3};\alpha_i, P_{un})$ in the unlabeled segment. A firm with cost parameter equal to this cutoff value, which I define as $\tilde{\alpha}_3$, would be just indifferent between entering the labeled and unlabeled segments of the market.

Thus, the cutoff value $\tilde{\alpha}_3$ is implicitly defined by

$$\Pi_3(q^*_{i3};\tilde{\alpha}_3,P_c-b)-C=\pi_3(q^{**}_{i3};\tilde{\alpha}_3,P_{un}). \tag{17}$$

Type 3 firms with cost parameters $\alpha_i<\tilde{\alpha}_3$ strictly prefer certification. Similarly, there is a cutoff value of the cost parameter for type 2 firms, which I denote by $\tilde{\alpha}_2$, at which type 2 sellers are indifferent between leaving their product in country S or adapting it and then entering the labeled segment of country N. Denoting the profit earned by a type 2 seller that enters the certified market in country N as $\Pi_2(q^*_{i2};\alpha_i,P_c-b-\tau-\beta)$, and the profit earned by a type 2 seller that sells in market S as $\pi_2(q^*_{i2};\alpha_i,P_S)$, the cutoff value $\tilde{\alpha}_2$ is implicitly defined by

$$\Pi_2(q^*_{i2};\tilde{\alpha}_2,P_c-b-\tau-\beta)-C=\pi_2(q^{**}_{i2};\tilde{\alpha}_2,P_S). \tag{18}$$

Type 2 sellers with cost parameters $\alpha_i<\tilde{\alpha}_2$ strictly prefer entering the certified segment in country N, while type 2 sellers with larger cost parameters strictly prefer to sell their product in country S. It is straightforward to show that $\tilde{\alpha}_2<\tilde{\alpha}_3$ for any given pair of prices (P_c,P_{un}).

To simplify the discussion, I shall proceed on the assumption that $P^e_S>P^e_{un}-\tau$. It follows that all type 2 sellers with cost parameters that are larger than $\tilde{\alpha}_2$, and all type 1 sellers located in country S, would sell their products in country S. As in the basic model, depending on the various parameters, the equilibrium with eco-labeling can have no sellers, some green sellers, or all green sellers obtaining the eco-label. Also as in the basic story, the welfare effects of introducing an eco-label are ambiguous.

With respect to the impact of eco-labeling upon the amount of type 1 and type 2 units produced in country S, I first note that for any combination of C and τ there is a critical value of β such that all type 2 sellers elect to not obtain the eco-label. This value may be inferred from eq. (18) when $\alpha_2 = \tilde{\alpha}_{S2}$. On the other hand, unless C and τ are quite large, it is easy to see that the volume of type 2 units exported to country N will increase with the introduction of eco-labeling when $\beta = 0$. Since no type 1 units are exported in the equilibrium with eco-labeling, the price in country S is generally lower in this equilibrium. Since all type 1 units wind up sold as unlabeled this reduction leads to a decrease in the quantity of type 1 units produced in country S. Accordingly, for sufficiently small values of β, eco-labeling leads to a shift in production patterns that is environmentally desirable. On the other hand, when β is sufficiently large, most type 2 units remain in country S. In this case, the ultimate composition of production will depend on the elasticities of the two supply curves; it is unclear that eco-labeling would lead to the desired shift in production within country S in this case.

It is instructive to compare this equilibrium against the first-best outcome. In this latter regime, all green units – be they type 3 or type 2 – would be sold in country N. All type 1 units would be sold within their country of origin. I note that the first-best price available to type 1 sellers in country N is lower than the unlabeled price, indicating that there is excess production of type 1 units in N in the eco-labeling equilibrium. On the other hand, the first-best price in S exceeds the equilibrium price with eco-labeling, since some type 2 sellers elect not to become certified in the eco-labeling equilibrium.

Reallocating these units from country S to country N would shift in the supply curve in country S, yielding a higher price. Accordingly, quantity demanded in country S would fall, so that fewer units would trade there; note that these would be type 1 units. All type 2 units would be exported, and at higher net price; it follows that production of type 2 units would rise. Similarly, a lower volume of type 1 units would be produced in country N, while a larger volume of type 3 units would be produced. Taking these points together, the welfare costs in the equilibrium with eco-labeling are due in part to the over-production of brown units, and in part to the under-production of green units.

I close this section by briefly discussing the impact of changes in the various parameters upon the equilibrium and sellers' profits. An increase in either form of certification cost (C or b) will reduce $\tilde{\alpha}_3$, while an increase in C, b, β or τ will reduce $\tilde{\alpha}_2$. As in the basic model, starting from an equilibrium where some type 3 sellers certify and some do not, increases in either C or b will induce some type 3 sellers to leave the certified segment for the unlabeled segment, raising the unlabeled price and hence unlabeled profits. As such, all type 3 sellers who were in the unlabeled segment prior to the change are better off. Those type 3 sellers who were in the certified segment prior to the change need not be better off. While the volume of green units on offer in country N falls, so that the certified price rises, the associated increase in revenues will only offset the higher certification costs for those sellers with sufficiently small cost parameter. An increase in any of the relevant parameters confronting type 2 sellers will lead to a decrease in the volume of type 2 products that obtain the eco-label, thereby lowering the volume of green products in country N and raising the volume sold in country S. As in the basic model, the increase in quantity trade in country S causes a reduction in price, which in turn lowers profits earned by any type 2 seller that leaves its product in country S. Similar to the effect on type 3 sellers that remain certified, the increase in the certified price is insufficient to cover the extra costs unless the firm?s cost parameter is sufficiently small. On balance, then, an increase in C or b will make most (perhaps all) type 2 sellers worse off, but will benefit many type 3 sellers. An increase in either β or τ will make most (perhaps all) type 2 sellers worse off, while benefiting all type 3 sellers.

6 Discussion

One particularly intriguing application of eco-labeling is in the market for wood products. Timber certification is a labeling process that awards an eco-label to companies that use "environmentally sound" production methods (Varangis et al., 1995). Consumers in developed countries often express an interest in promoting environmentally-friendly timber harvesting techniques, whether it be the protection of old-growth forests, movement away from clear-cutting, or other approaches that are less likely to adversely impact speciation (Baharuddin et al., 1997; Winterhalter and Cassels, 1993). In response to this sentiment, a variety of timber certification programs have emerged over the last decade or so (Baharuddin et al., 1997; Varangis et al., 1995). Many of these focus on production methods, and several of the programs are based in developed countries where it is believed that the great majority of environmentally conscious consumers reside (Dubois et al., 1995). While a considerable amount of timber trade is found in developed countries, a significant amount comes from developing countries.

With many of these programs the seller will bear two types of cost: direct costs (associated with the certification process itself) and indirect costs (associated with converting their production technology). The indirect costs appear to vary greatly across firms, from around 25% of current production costs for firms in temperate zones to around 100% of current production costs for firms in tropical zones (Dubois et al., 1995; Varangis et al., 1995). This anecdotal evidence is consistent with the set-up in my model. It is also worth reiterating that these adaptation costs could be very large. With this in mind, it seems unlikely that harvesters in tropical areas will be able to take advantage of timber certification on a large scale. It is worth reiterating that my model describes the evolution of a market with incomplete information regarding harvest technology. Accordingly, the market imperfections are tied to the information structure; there is little in the analysis regarding the impact of various technologies on species composition, the ability to sustain a particular eco-system in the face of harvesting pressures, or the impact on biodiversity. But these elements are implicit in the stylized nature of the production processes: if we think of types 2 and 3 as being similar in terms of sustainability and biodiversity, the message of my model is that eco-labeling will have limited ability to promote desired ecological ends. More specifically, in under-developed countries – often the source of tropical timber, for example – it appears that there is a very real concern that eco-labeling will indirectly yield market conditions that are more conducive to brown firms than to green firms. This unfortunate result is mitigated somewhat by the tendency to promote green production in developed countries. To the extent that deforestation is a larger concern in tropical than temperate regions, this offset is of little comfort.

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7 Appendix 1: Example

In this section I illustrate the workings of the labeling equilibrium for an example that combines specific functional forms. I choose these forms for analytical convenience.[13] The particular forms I choose are iso-elastic in nature: costs are $c_1(q) = q^\delta, c_2(q) = \alpha_2 q^\delta$

and $c_3(q) = \alpha_3 q^\delta$, with $\alpha_2, \alpha_3 > 1$ and $\delta > 1$. Demand is also iso-elastic: in country N, the inverse demand curve for green units is given by $P_G(Q) = A_G Q^{-\eta_G}$ while the inverse demand curve for brown units is given by $P_B(Q) = A_B Q^{-\eta_B}$; the demand curve in country S is $P_S(Q) = A_S Q^{-\eta_S}$. Reflecting the fact that green units are more valuable than brown units in country N, I impost the parameter restriction $A_G > A_B$. To focus the discussion, I also suppose $b = 0$, *i.e.*, there are no variable licensing costs associated with eco-labeling.

With this structure, marginal costs for a type $k = 2,3$ firm are $\alpha_k \delta q^{\delta-1}$. If such a firm entered the labeled market in country N it would receive the net price NP_k, where $NP_3 = P_c$ and $NP_2 = P_c - \beta - \tau$, and so choose the output

$$q_k^* = \left(\frac{NP_k}{\alpha_k \delta}\right)^{\frac{1}{\delta-1}}.$$

Its profits would then equal

$$\Pi_k^* = NP_k q_k^* - c_k(q_k^*) = \alpha_k(\delta-1)(q_k^*)^\delta.$$

Alternatively, were the firm to eschew labeling, it would receive the unlabeled price in its country; for type 2 firms that would be P_S while for type 3 firms that would be P_{un}. To focus the discussion on the tension between labeling and exporting, I restrict attention to parameter combinations that support the class d) equilibrium, so that some but not all type 2 firms export to country N and obtain the eco-label. Accordingly, all type 3 firms enter the labeled market, and so $P_{un} = P_B$ (and plays no further role of significance in this example). As all certified sellers are green, $P_c = P_G$ – and so is determined by the quantity of units sold in that segment of the market, Q_G.

The key element to be determined in this equilibrium is the fraction μ of type 2 sellers that choose to obtain the eco-label and export to country N. This fraction winds up determining the price in country S, since Q_S is inversely related to μ, and the certified price in country N, since Q_G is positively related to μ.

The equilibrium value of μ is determined by equating the cost of labeling with difference in profits earned by a type 2 seller in the two markets of interest. The profits earned by a type 2 seller that obtains the eco-label and exports are described above. The profit-maximizing output for any type 2 firms that elect to sell in country S is

$$q_2^{**} = \left(\frac{P_S}{\alpha_2 \delta}\right)^{\frac{1}{\delta-1}};$$

referring back to eq. (6), the corresponding profits are

$$\pi_2^* = \alpha_2(\delta - 1)(q_2^{**})^{\delta}.$$

Thus, the condition describing a type d) equilibrium in this example can be expressed as

$$\alpha_2(\delta-1)\left\{\left(\frac{P_G-\beta-\tau}{\alpha_2\delta}\right)^{\frac{\delta}{\delta-1}} - \left(\frac{P_S}{\alpha_2\delta}\right)^{\frac{\delta}{\delta-1}}\right\} = C, \quad \text{or}$$

$$P_G - \beta - \tau = \left[\left(\frac{P_S}{\alpha_2\delta}\right)^{\frac{\delta}{\delta-1}} + \left(\frac{\delta}{\delta-1}\right)(\alpha_2\delta)^{\frac{1}{\delta-1}}C\right]^{\frac{\delta-1}{\delta}}. \tag{19}$$

The equilibrium prices P_G and P_S are determined by μ.

In country S, the equilibrium price is $P_S^e = A_S(Q_S^e)^{-\eta_S}$, where

$$\begin{aligned} Q_S^e &= n_{S1}\left(\frac{P_S^e}{\delta}\right)^{\frac{1}{\delta-1}} + (1-\mu)n_2\left(\frac{P_S^e}{\delta}\right)^{\frac{1}{\delta-1}} \\ &= (n_{S1} + (1-\mu)n_2)\left(\frac{P_S^e}{\delta}\right)^{\frac{1}{\delta-1}}. \end{aligned}$$

In country N, the equilibrium price received by all certified units is $P_G^e = A_S(Q_G^e)^{-\eta_N}$, where

$$Q_G^e = n_3\left(\frac{P_G^e}{\alpha_3\delta}\right)^{\frac{1}{\delta-1}} + \mu n_2\left(\frac{P_G^e - \beta - \tau}{\alpha_2\delta}\right)^{\frac{1}{\delta-1}}.$$

8 Appendix 2: details of the example from section 7

With the iso-elastic cost structure adopted in the example, marginal costs for a type $k = 2,3$ firm are $\alpha_k \delta q^{\delta-1}$. If such a firm entered the labeled market in country N it would receive the net price NP_{kc}, where $NP_{3c} = P_c$ and $NP_{2c} = P_c - \beta - \tau$.The profit-maiximizing output, and corresponding profits, are then

$$q_k^* = \left(\frac{NP_{kc}}{\alpha_k \delta}\right)^{\frac{1}{\delta-1}},$$

$$\Pi_k^* = NP_{kc} q_k^* - c_k(q_k^*) = \alpha_k(\delta-1)(q_k^*)^{\delta}.$$

Similarly, were the firm to eschew labeling, it would receive the unlabeled price in its country, NP_{ku}; for type 2 firms that would be P_S while for type 3 firms that would be P_{un}. The profit-maiximizing output, and corresponding profits, are then

$$q_k^{**} = \left(\frac{NP_{ku}}{\alpha_k \delta}\right)^{\frac{1}{\delta-1}},$$

$$\pi_k^* = \alpha_k(\delta-1)(q_k^{**})^{\delta}.$$

In a class d) equilibrium, $\Pi_2^* - \pi_2^* = C$:

$$\alpha_2(\delta-1)\left\{\left(\frac{P_G-\beta-\tau}{\alpha_2\delta}\right)^{\frac{\delta}{\delta-1}} - \left(\frac{P_S}{\alpha_2\delta}\right)^{\frac{\delta}{\delta-1}}\right\} = C, \quad \text{or}$$

$$P_G - \beta - \tau = \left[\left(\frac{P_S}{\alpha_2\delta}\right)^{\frac{\delta}{\delta-1}} + \left(\frac{\delta}{\delta-1}\right)(\alpha_2\delta)^{\frac{1}{\delta-1}} C\right]^{\frac{\delta-1}{\delta}}. \tag{20}$$

The equilibrium price in country S is determined by the equilibrium quantity of units on offer:

$$Q_S^e = n_{S1}\left(\frac{P_S^e}{\delta}\right)^{\frac{1}{\delta-1}} + (1-\mu)n_2\left(\frac{P_S^e}{\delta}\right)^{\frac{1}{\delta-1}}$$
$$= (n_{S1} + (1-\mu)n_2)\left(\frac{P_S^e}{\delta}\right)^{\frac{1}{\delta-1}}. \tag{21}$$

This quantity dictates the equilibrium price via the inverse demand curve: $P_S^e = A_S(Q_S^e)^{-\eta_S}$. Equivalently, one can use the demand curve to determine quantity demanded in terms of price: $Q_S^e = (P_S^e/A_S)^{\eta_S}$. Combining with eq. (21) allows the determination of the equilibrium price in country S:

$$P_S^{e\,(\eta_S - \frac{1}{\delta-1})} = \left(\frac{A_S^{\eta_S}}{\delta^{\frac{1}{\delta-1}}}\right)\left(n_{S1} + (1-\mu)n_2\right)^{\left(\frac{\delta-1}{\delta-1-\eta_S}\right)}.$$

In country N, the equilibrium price received by all certified units is $P_G^e = A_S(Q_G^e)^{-\eta_N}$, where The key element to be determined in this equilibrium is the fraction μ of type 2 sellers that choose to obtain the eco-label and export to country N. This fraction winds up determining the price in country S, since Q_S is inversely related to μ, and the certified price in country N, since Q_G is positively related to μ.

The equilibrium value of μ is determined by equating the cost of labeling with difference in profits earned by a type 2 seller in the two markets of interest. The profits earned by a type 2 seller that obtains the eco-label and exports are described above. The profit-maximizing output for any type 2 firms that elect to sell in country S is

$$q_2^{**} = \left(\frac{P_S}{\alpha_2 \delta}\right)^{\frac{1}{\delta-1}};$$

referring back to eq. (6), the corresponding profits are

$$\pi_2^* = \alpha_2(\delta - 1)(q_2^{**})^{\delta}.$$

The equilibrium prices P_G and P_S are determined by μ.

Notes

[1] A number of surveys have reported that consumers claim to be willing to pay a price premium for more environmentally-friendly products (Amacher et al., 2004; Arda, 1997; Bjorner et al., 2004; Blend and van Ravensway, 1999; Cairncross, 1992; Cason and Gangadharan, 2001; Haji-Gazali and Simula, 1997; Levin, 1990; Wasik, 1996; Wessels et al., 1999; Winterhalter and Cassels, 1993). Experimental evidence corroborates these results (Cason and Gangadharan, 2001), as does field work based on cotton apparel (Nimon and Beghin, 1999a) and canned tuna (Teisl et al., 2002).

[2] The quote is from Deere (1999); see also discussions in (Henry, 1997; Salzman, 1998) and (Vossenaar, 1997). Such biases need not be accidental nor innocuous; indeed, Austria passed a law in 1992 that would have required all wood products imported from the tropics to be labeled as "made of tropical timber." This law was not at all popular in the international community, which may explain why the Austrian parliament rescinded the law the following year.

[3] For example, Salzman (1998) has been argued that Brazilian producers of paper products would have difficulty satisfying the eco-label criteria proposed by the European Union that required a certain minimum level of recycled content "despite the fact that Brazil's pulp came from sustainably harvested plantations and was processed using hydroelectric power."

[4] This aspect of my model contrasts with Nimon and Beghin (1999b), who assume

green products from the importing country are objectively of higher quality than imported green products. While this may be a fair characterization of some aspects of product quality, as I observed above there is anecdotal evidence that production techniques in exporting countries such as Brazil are at least as environmentally friendly as techniques in importing countries.

[5] It is important to note that the certification cost is different from the increases in production costs that may naturally occur if a firm switches from brown to green technology. I am assuming in this paper that firms' technologies are exogenously given, and hence their production costs do not change if they obtain the eco-label.

[6] Mason (2006) contains a discussion allowing for endogenous type choice, though not in a trade context.

[7] Downward-sloping demand could result because consumers with heterogeneous tastes over environmental friendliness buy zero or one units of a good (Bureau et al., 1998; Nimon and Beghin, 1999b). Alternatively, each individual consumer could have a downward-sloping demand curve, so that market demand is downward-sloping for both brown and green goods.

[8] Virtually all existing eco-labeling programs charge an application fee, and most also assess further charges based on volume of sales. The labeling process I have in mind is able to perfectly identify those firms that are environmentally friendly (Mattoo and Singh, 1994; Swallow and Sedjo, 2000). Unlike these earlier articles, I explicitly

account for the screening effect associated with costly acquisition of the eco-label. There is some doubt as to whether the certification process embodied in eco-labeling is capable of perfectly identifying environmentally friendly firms (Morris, 1997). For a discussion of imperfect certification in models such as the one considered in this paper, see Mason and Sterbenz (1994).

[9] There is considerable interest in "harmonizing" standards across countries, presumably to avoid this sort of effect. Even so, any standards that are agreed to are bound to favor some sellers over others because the notion of "environmentally friendly" harvesting techniques is ill-defined, and because production techniques are bound to vary with species composition, geographical effects, and the relative input price of labor to capital, all of which differ dramatically between developed and developing countries. Indeed, many schemes for certifying timber production are based on indicators that completely ignore fundamental underlying economic conditions such as relative input prices (Baharuddin et al., 1997). Since the lion's share of the pressure for eco-labeling comes from developed countries, one can perhaps anticipate that any harmonized standards favor the developed countries, for which country N plays the role in my model.

[10] In any scenario of interest, the net price available to type 2 sellers from certifying will exceed the domestic price in country S; accordingly, $q_2^* > q_2^{**}$. Because type 1 firms in country S have the option to export to country N, $P_S + \tau \geq P_{un}$. It follows that $\Omega_2 < (P_c - b)q_2^* - [c_2(q_2^*) + \beta q_2^*] - [P_{un}q_2^{**} - c_2(q_2^{**})]$. By virtue of assumption **A2**, $q_2^{**} \geq q_3^{**}$,

so the last braced term in the expression on the right-hand side of eq. (10) can not be smaller than $P_{un}q_3^{**} - c_2(q_3^{**}) = \pi_3*$. By virtue of assumption **A1**, the middle term in the expression on the right-hand side of eq. (10) – the production cost plus adaptation costs borne by a type 2 firm – are larger than the production costs born by a typical type 3 firm. It follows that $q_3^* > q_2^*$; moreover, it must then be true that $(P_c - b)q_3^* - c_3(q_3^*)$ exceeds the difference in the first two terms on the right-hand side of eq. (10). Combining these observations, one infers that

$$\Omega_2 < (P_c - b)q_3^* - [P_{un}q_3^{**} - c_3(q_3^{**})] = \Omega_3.$$

11 It is also true that the fraction of unlabeled units that are green will go up, so that P_{un} rises as well. Hence, the operating profit from the unlabeled segment will increase. But this effect is constrained by the arbitrage condition governing type 1 firms in country S. In any event, if demand for green products is more elastic than demand for brown products, which one expects to hold, and if the marginal cost curve for type 3 units is weakly convex, one can show that P_c will rise faster than P_{un}, which induces an increase in Ω_3.

12 There are also indirect effects manifested through changes in q_2^*, multiplied by the induced effect on certified profits, and q_2^{**}, multiplied by the the induced effect on profits in country S. By the envelope theorem, these induced effects on profits are zero, and so can be ignored.

[13] While the analytical derivations are relatively straightforward, they are nonetheless somewhat tedious. Accordingly, I relegate many of the derivations to the Appendix.