Harmonization Versus Mutual Recognition of National Eco-labels*

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Abstract

This paper formalizes a welfare-comparison between two suggestions to correct for the market failures arising from multiple eco-labels in international markets. In an asymmetric information environment, where the goods' environmental quality is a credence attribute, firms with different labeling standards cannot implement a separating equilibrium through price signaling. The difference between the standards generates an information-rent in the export market increasing the number of labeled firms complying with lower standards. This pro-competitive spillover implies that when labels with different requirements are treated equally on the markets (mutual recognition), the outcome is welfare superior to the case of harmonized labeling standards, insofar as the difference between the standards is relatively small.

Keywords: Labeling, Environmental-quality uncertainty, duopoly signaling
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1 Introduction

Eco-labeling has become a standard practice in most countries (Vossenaar 1997).[1] A market-based reason for their existence is a signal of higher environmental quality which might not be fully assessed on behalf of the customers willing to pay for the products' environmental attributes. In theory, labeling therefore constitutes an efficient, non-mandatory, instrument of environmental policy. While the positive environmental benefits of credible eco-labeling schemes are clear, some argue that these programs have become an important factor in market access generating pressures for the producers to apply for a label. This has contributed to a several trade-disputes as national eco-labeling schemes are often perceived discriminating and generating distortional effects on trade. These distortions have fueled a public debate about an appropriate level of differentiation between regional labeling standards in the global markets.[2]

There are two suggested remedies for the problem of multiple country-specific labels. *Harmonization* of labeling standards has certain benefits. It helps the exporters sell their products without having to comply with different regulations in each country, and increases market transparency by ensuring the consumers that imported goods comply with the same standards. The second remedy is *mutual recognition* of existing labeling schemes. This means that if a product is eligible for a label granted by a national labeling program, it would automatically receive an equal treatment with any other label in the importing countries. Mutual recognition arguably provides flexibility from the viewpoint of the producing countries for it allows them for more leverage to consider country-specific characteristics in the design of labeling standards.[3]

The economic trade-off between these policy schemes is linked to an old issue in competition policy debate; namely, market transparency. Less transparency on the consumer side, so that consumers are uninformed about the product characteristics, usually diminishes the producers'

[1] These programs are designed by an independent intermediary, which imposes and monitors certain criteria that producers must meet in order to receive a certification for their environmental performance. Third-party labeling tend to perform better than industry-led programs in correcting for the problem of asymmetric information between producers and consumers. See, e.g. Kirchhoff (2000) and Cason and Gangadharan (2002).

[2] For example, Germany requires companies not participating in its Green Dot scheme to take back their packaging and bear the cost of recycling themselves. The cost is naturally greater for foreign companies, which therefore have claimed that the for Green Dot label places imported goods at a market disadvantage.

[3] It is implausible to presume that countries have identical environmental characteristics or social preferences on which the labeling standards should be based. For instance, Scandinavian countries and Canada are by far more sensitive to acid rain generated by the release of oxides of nitrogen (NOx) and sulphur dioxide (SO2) than countries in Central Europe and US.

incentives for product differentiation (see e.g. Bester 1998 and Akerlof 1970). This is arguably a problem under mutual recognition, as goods with higher environmental standards might not survive the competition in the markets.[4] To prevent the collapse of markets for goods with high environmental quality, it is therefore plausible to think that the optimal coordination of eco-labeling schemes calls for harmonization.

This paper explains why, despite the potential lack of market transparency, mutual recognition of labeling standards in the international markets could be welfare superior to harmonization. In a specific example involving vertically differentiated industry and asymmetric information about the environmental quality of the products, this means that a small market failure generated by the lack of transparency induces more producers to apply for a label. The positive welfare effect of mutual recognition is that tougher competition between producers makes the labeled goods more affordable to consumers, improving the overall quality in the market.

Essentially, the model combines several features in the literature on industrial organization, signaling games and international trade. The main contributions of this paper will be derived in three steps. The first step presents a benchmark involving closed markets and full information. The market is segmented by consumer types with different willingness to pay for the products' environmental quality and a price competition between firms induces a market outcome involving different qualities.[5] The second step introduces asymmetric information to the model. This reflects the usual property that sellers are often better informed about the production related environmental attributes of the goods than consumers; hence, the extent to which they can capitalize on the consumers' willingness to pay depends on their ability to signal the improvements in their environmental performance to consumers.[6]

[4] A dispute, which is at least partly driven by this trade-off, is between the dominant forest certificates in Europe, Pan European Forest Certificate (PEFC) and Forest Stewardship Council (FSC). Each side has a strong nationally divided group of representatives. For instance, most Finnish forest owners are certified by PEFC while the Swedish forests belong dominantly to FSC program. The representatives of PEFC argue that FSC requirements do not consider the regional differences between forests' ecological characteristics and the ownership structure. PEFC thus claims that both certificates should be treated equally as there is only minor differences between the actual requirements. However, FSC and some environmental organizations argue that any labeling program, which does not meet FSC standards, is insufficient to guarantee environmentally sound forest management and consumers should question the environmental attributes of PEFC-labeled products. See, e.g. "Anything Goes" (2001) by Greenpeace and The Finnish Nature League.

[5] See e.g. Arora and Gangopadhyay (1995). More recently, Cremer and Thisse (1999) employed a similar vertical product differentiation framework and show that environmental quality competition improves the overall quality on the market, but in the absence of government intervention the equilibrium fails to satisfy the criteria for Pareto-efficiency.

[6] In a seminal article Akerlof (1970) established that under asymmetric information markets are ineffective in

The examination of the price-signaling game shows that producers cannot implement a separating equilibrium, in which consumers observe the differences between the environmental qualities in the market. This results in a collapse of markets for goods with high environmental quality, unless there is a labeling program monitored by an independent third party.[7] Labeling enhances the quality distribution in the market, but the market outcome fails to satisfy the criteria for Pareto-efficient allocation of environmental quality. This is because in a closed economy a labeling program does not provide incentives for new producers to enter the market, leaving the incumbent firms with market power which they can employ to price discriminate the consumers.

The analysis of the signaling game in a single market serves as building block for the third step of the analysis which considers two countries with two firms producing for the domestic and a third country export market. Within this framework the analysis shows that under mutual recognition between country specific labels, the signaling problem carries over to the export market: When the export market consists of producers with different labeling standards, the ones with higher standards cannot implement a separating equilibrium. This generates an information rent for the producers with lower labeling standards, inducing more producers to apply for this label. Tougher competition in the market for labeled goods depresses prices, but does not drive the higher quality out of the market, and thereby increases the market efficiency making higher environmental quality more affordable to consumers. By comparing the equilibrium outcomes, the analysis shows that a market failure in the form of lower market transparency has a pro-competitive spillover that implements an equilibrium which Pareto dominates harmonization.

Market transparency, product differentiation, eco-labeling and the signaling problem have been touched upon before in the economic literature. However, the analysis of the international dimensions of labeling and transparency in the presence of credence attributes has not been conclusive. Most of the literature on quality signaling examines the interaction between one firm and consumers, abstracting from signaling between competing senders.[8] The literature on oligopoly-signaling focuses on cost-signaling between competing firms and, as in the present

providing quality and only goods with lowest quality are sold to the market.

[7] There is a number of studies on asymmetric information and quality-signaling, but the most severe problem, namely, the case of goods' credence attributes has deserved less attention (see e.g. Shapiro 1982). This problem is particularly relevant for most internationally traded goods with production related environmental externalities, since the consumers may have diminished ability to learn the goods' environmental quality, because of the physical distance between the production and consumption sites.

[8] For instance Milgrom and Roberts (1986) examine the price and advertising signaling in monopoly.

study, quality-signaling between firms and consumers.[9] Included among these are Herzendorf and Overgaard (2000); Herzendorf and Overgaard (2001) and Fluet and Garella (2002), which examine price signaling behavior of firms without established reputation.[10]

Kirchhoff (2000) examines the role of third-party labels in producers' environmental quality decision, when a monopolist can build reputations and the qualities are revealed with a certain probability. The results establish that third-party labeling increases the likelihood that compliance to voluntary environmental standards is profitable for the monopolist. For the general case of labeling standards and trade, Jansen and Lincé de Faria (2002) compared mutual recognition and harmonization for two countries with different consumer preferences and cost differences. The study showed that harmonization, in most cases, leads to a better welfare outcome than mutual recognition.

The remainder of the paper is organized as follows. Next section describes the assumptions of the model. Section three establishes the criteria for welfare optimal distribution of environmental quality, and examines firms' quality decisions under full information and autarky. Section four analyzes the signaling game under asymmetric information, and compares the results with full information and Pareto efficient benchmarks. Section five analyzes how third-party labeling influences the industry-equilibrium in domestic and foreign markets. Conclusions follow.

2 The Model

We consider a partial equilibrium model, in which good x is produced in two countries, domestic and foreign. When needed, subscripts d and f are used as a mnemonic for domestic and foreign country. In each country there are two incumbent firms and n potential entrants. The incumbent firms are denoted by superscripts 1 and 2; and the entrants are denoted by superscript $N = (3, 4, ..., n)$. The firms produce good x for domestic and world market. The remaining assumptions of the model are comparable to those used in the literature on vertical product differentiation:

1. **Abatement**: Production of x generates an environmental externality (emissions), $e = (\underline{e} - a)$, where $\underline{e}$ denotes *laizzes faire* emission level, and $a \in (\underline{a}, \bar{a})$ denotes the abatement

[9] For information on signaling as a mechanism to deter entry, see, e.g. Bagwell and Ramey (1991).
[10] Herzendorf and Overgaard (2001) and Fluet and Garella (2002) also allow for advertising signals.

level, where $\underline{a} > 0$ is the minimum abatement requirement for an active firm. Abatement level $\bar{a}$ denotes the most efficient, technically feasible, abatement level.

2. **Production costs**: For each active firm, a short-term cost function takes the form $C(a) > 0$ $\forall a > \underline{a}$ and $C(a) = 0$ otherwise. The cost is constant in quantity, but convex in abatement: $C'(a) > 0$ and $C''(a) > 0$. In addition, each firm that upgrades its technology from, say a^i to a^j, and wishes to inform the consumers about it, incurs a fixed set-up and advertisement cost, $\eta^j(a^j) = \eta$, before the production stage.[11] The cost satisfies,

$$C(a^j) - C(a^i) \geq \eta^j(a^j) \quad for\ any \quad a^j > a^i \geq \underline{a} \tag{1}$$

reflecting that the unit-cost difference between a goods with different quality is higher than the set-up and advertisement cost. The incumbent firms have an initial abatement technology $\underline{a}$. Hence, they may produce with minimum quality level without additional costs. A representative entrant has an initial abatement level $a^N = 0$. Entry thus requires an upgrade to $\underline{a}$ and a cost equal to $\eta^N(\underline{a}) = \eta$.[12]

3. **Preferences and asymmetric information**: The description of consumer preferences is a version of Mussa and Rosen (1978). In each country there is a continuum of consumers uniformly distributed and ranked in the same interval in *decreasing order* of their intensity of preferences for goods' environmental quality $\theta \in [\overline{\theta}, \underline{\theta}] \equiv [0, 1]$. The density is given by $M > n + 2$, i.e. in each country there is less potential producers than consumers. When the quality of the goods is perfectly observable, the indirect utility of purchasing one unit of good x is conditional on consumer's type θ and can be formalized as

$$U(p; \theta) = [R + (\alpha - \theta)a - p(a)] \tag{2}$$

where R denotes the reservation value, which represents common willingness to pay for the good's basic physical characteristics with any given quality. Parameter $\alpha > 1$ is the

[11] Advertising in this context means announcements about the product quality, which are not verified by a third party.

[12] Condition (1) thus states that η is small enough to ensure non-negative payoff for the entrant that chooses quality a^i, provided that the rival firms' quality is higher and there is positive demand for the product variety.

common component in consumers preferences for environmental quality.[13] In a full information environment a denotes the environmental attribute of the good determined by the seller's abatement technology, and $p(a)$ is the price of the good. Thus, $(\alpha - \theta)a$ determines consumer-specific marginal willingness to pay for this quality.

The environmental quality is considered a credence attribute, which cannot be observed even after the purchase.[14] Consumers have, however, a prior idea about the initial distribution of qualities in the market and observe the cost-structure described in assumption (2). This gives a raise to a signaling game in which the firms can use prices to affect the consumers' beliefs about their environmental quality.

The signaling game has two stages. The consumers enter the market with a prior distribution of qualities in their minds. The firms set prices and the consumers update their beliefs about the goods' environmental qualities on the basis of the available information.[15] When a price-signal $p^*(a)$ is perceived credible by the consumer θ, her utility of the purchase coincides with (2), i.e. $U = U[p^*(a); \theta]$. However, in a market with different qualities and no credible price-signal, the consumer-specific marginal willingness to pay for the good's environmental quality is the same for any good in the market. Hence, the indirect utility in a pooling equilibrium can be described by the following von Neuman-Morgenstern utility function

$$U^e[p(\Delta^c); \theta)] = [R + (\alpha - \theta)\Delta^c - p(\Delta^c)],$$

where $\Delta^c = \sum_{i=1}^{N} \frac{a^i}{N}$ and N denotes the number of active firms.[16] This indicates that the perceived environmental quality in a pooling equilibrium is determined by the average quality in the market. From the specification of the utility function it follows immediately that although the consumers willingness to pay increases when a producer chooses to increase his quality, only the goods with the lowest price survive in the market. Hence, the market for high qualities will collapse, unless the producers can credibly signal their qualities through

[13] The role of parameter α is treated in more detail in assumption 5.

[14] This is a plausible assumption, especially in the case of internationally traded goods with long geographical distance between production and consumption locations. Firms cannot build reputations, as the quality is unobservable. For more information on reputation-building and product quality, see Shapiro (1982). For more information on credence attributes and signaling through labeling see Auriol and Schilizzi (2003).

[15] A more detailed description of the consumers' belief system is in subsection 2.1.

[16] See also Jansen and Lincé de Faria (2002).

labeling or price-signaling.

4. **Market coverage:** The preferences and the cost function have the following properties:

$$C(\bar{a}) \leq R \quad and \quad C'(\bar{a}) \leq (\alpha - \underline{\theta}), \tag{3}$$

Expression (3) states that if goods are priced at marginal cost, then all consumers buy the highest quality.[17] Furthermore, when the lowest quality in the market is priced at $C(\bar{a})$, all consumers buy a good regardless of the quality-distribution.

5. **Quality decision and asymmetric information**: The quality game between the firms is sequential: Nature chooses the incumbent that gets to choose its quality first. After the incumbents' quality decision, the entrants choose quality levels.[18] The quality levels are observable, but non-verifiable. Specifically, the existing qualities are observed by each agent, but they cannot be linked to a particular firm.[19]

6. **Labeling and mutual recognition:** Under third-party labeling, an independent intermediary monitors firms' performance and grants a label for a firm that meets the given labeling requirement. Consumers perceive the label as a credible signal of the goods' environmental quality. Mutual-recognition of labels implies that when the market consists of multiple labels, consumers observe the existing quality-requirements, but without further information they cannot ascertain the potential differences between environmental qualities indicated by the labels.

7. **The structure of the full game:** The structure of the game is depicted in Figure 1. First, the firms choose qualities as described above. This involves a decision about participation to the national labeling program and, by entrants' quality decisions, the number of active firms at the production stage of the game.[20] Second, the consumers and the firms form their prior beliefs about qualities in the market. Third, the firms set prices, on the basis

[17] This assumption ensures that so-called finiteness property holds, hence, the market is a natural oligopoly under full information. See Anderson et al. (1992).

[18] For a similar treatment of firms' entry decisions in a vertically differentiated oligopoly, see e.g. Peitz (2002).

[19] For instance, when firm 2 is the first-mover and incumbent 1 is the follower, firm 1 observes that quality distribution on the market is $\Delta^1(a^2) = a^2$. After the quality decision of firm 1, the first entrant N observes the existing qualities and based on a^2 and a^1, its assessment of overall quality on the market is $\Delta^N(a^2, a^1) = (a^2+a^1)/2$.

[20] That is, each entrant that chooses a quality $a^N > 0$ is considered an active firm.

which the consumers update their beliefs. Firms can set a single price within each country, but can price discriminate consumers across markets.

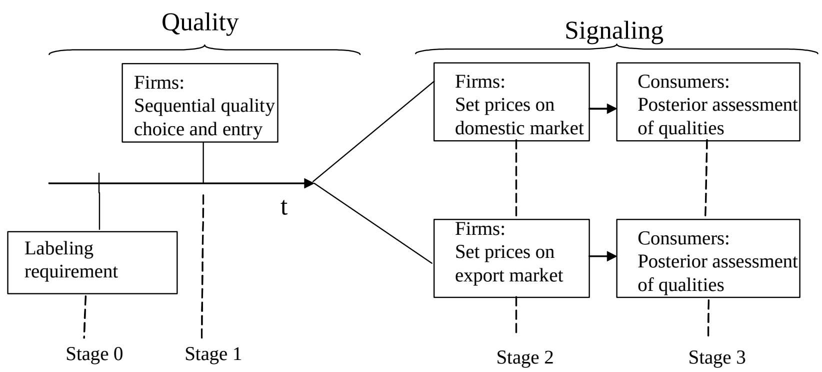

Figure 1: Timing of the game

3 Full-Information Benchmark

This section derives the equilibrium under full information and imperfect competition. Full information benchmark comes in useful as a starting point for the analysis of the quality competition under asymmetric information and welfare comparisons under different labeling schemes. To perform the welfare comparisons, we first establish a Pareto efficiency benchmark, which will be used when considering the welfare loss associated with market imperfections:

Definition 1 (Pareto efficiency) *Let $p(a)$ denote the market price of the good with quality a. A necessary requirement for Pareto-efficiency is given by*

$$p(\bar{a}) - p(a) \leq (\alpha - \theta)(\bar{a} - a) \quad \textit{for all } \theta \in [\bar{\theta}, \underline{\theta}] \quad \textit{and} \quad a \in [\underline{a}, \bar{a}]. \tag{4}$$

Pareto-efficiency thus requires that quality $\bar{a}$ is produced and each consumer buys this quality at a price that yields her a nonnegative surplus in comparison to other varieties in the market. For future reference it is worth noting that this allocation obtains when $\exists p(\overline{a}) : p(\bar{a}) = C(\bar{a})$.

3.1 Full-Information Benchmark

Suppose that the market consists of two firms, 1 and 2.[21] The firms produce goods x^1 and x^2 with environmental qualities a^1 and a^2, respectively. For the ease of exposition we assume that the qualities satisfy $a^1 < a^2$, and the market is fully covered.

Denote the customer who is indifferent between buying x^1 and x^2 at prices p^1 and p^2 as $\widehat{\theta}$. Since the ranking of preferences is inverse, each consumer with $\theta < \hat{\theta}$ buys the higher quality, and consumers $\theta > \hat{\theta}$ buy the lower quality. The demand for x^2 and x^1 can thus be formalized as $D^2 = M\widehat{\theta}$ and $D^1 = M(1 - \widehat{\theta})$, respectively. Using consumers' utility function we obtain $\widehat{\theta} = \alpha - (p^2 - p^1)/(a^2 - a^1)$; hence, the profits can be written as

$$\pi^2(p^2, p_l^1) = M\widehat{\theta}[p^2 - C(a^2)] - \eta^2(a^2),$$
$$\pi^1(p^2, p^1) = M(1 - \widehat{\theta})[p^1 - C(a^1)] - \eta^1(a^1),$$

where $\eta^2(a^2) = \eta$; and $\eta^1(a^1) = \eta$ for $a^1 > \underline{a}$ and $\eta^1(\underline{a}) = 0$. The firms choose prices taking the quality decisions and the associated sunk costs as given. The first-order conditions yield the following equilibrium price levels:

$$\hat{p}^2 = 1/3[(\alpha + 1)(a^2 - a^1) + 2C(a^2) + C(a^1)] \quad (5)$$
$$\hat{p}^1 = 1/3[(2 - \alpha)(a^2 - a^1) + 2C(a^1) + C(a^2)]. \quad (6)$$

It is easy to verify that (5) and (6) express the equilibrium prices.[22] Hence, we infer that

Lemma 1 *In a full-information equilibrium, qualities are such that* $\underline{a} \leq a^1 < a^2 \leq \bar{a}$ *and* $\widehat{\theta} < \underline{\theta}$. *The quality distribution in the market does not satisfy the criteria for Pareto-efficient allocation*

Proof. The first part of the proof is by contradiction. Assume $\underline{a} < a^1 = a^2 \leq \bar{a}$, by Bertrand argument the long-term profit is $\pi^i = -\eta < 0$; $i = 1, 2$. Hence, the equilibrium is strictly dominated by any quality distribution that involves $\underline{a} \leq a^1 < a^2 \leq \bar{a}$. Assume then that $\underline{a} = a^1 = a^2$. (1) together with (5) and (6) imply that for given $\underline{a} = a^1$, an increase in a^2 yields a

[21] Although the model allows for entry, we assume only two firms. This is for expositional purposes to illustrate the perfect information benchmark. A condition which determines the upper bound for active firms can be found in Cremer and Thisse (1999).

[22] For a similar analysis of the price game, see e.g. Cremer and Thisse (1999).

positive mark-up for each firm. Quality distribution $\underline{a} = a^1 = a^2$, in turn entails $\pi^i = 0$; $i = 1, 2$, hence, this distribution is strictly dominated by $\underline{a} \leq a^1 < a^2 \leq \bar{a}$.

The proof of the second part is a straightforward consequence of (4) and the first-part of Lemma 1. Since both firms are active in equilibrium, at least one consumer buys the good with quality $a^1 < \bar{a}$. Hence, the equilibrium does not satisfy (4). ■

This result establishes that both incumbent firms are active and produce differentiated goods with prices above their marginal cost. The quality difference depends on the parameters of the model. However, Lemma 1 unambiguously establishes the quality allocation is not welfare-optimal. The reason is that the firm producing higher quality can price-discriminate consumers with a lower willingness contributing to a inefficient market outcome as some consumers do not buy quality $\bar{a}$.[23]

4 Asymmetric-Information Benchmark in Autarky

When environmental quality of the goods is a credence attribute, the consumers know the distribution of qualities in the market, but the quality-differences cannot be verified without further information.[24] Since the consumers have information on the firms' cost function and on the prices posted on the market, but cannot link the qualities with the firms, the firms can use prices as a signal of quality. This signaling game is the focus of the analysis in this section. For the reasons of tractability we consider first a generic game played in a single market. The results will then be used as a stepping stone in the analysis of eco-labeling and international trade.

4.1 Consumer Beliefs and Demand

Suppose that the market consist of two active firms.[25] The firms first set prices and consumers then draw inferences about the actual qualities of goods in the market. The equilibrium of

[23] This result coincides with previous studies on vertical product differentiation. For example, Crampes and Hollander (1995) show that although high-quality producer could capture the entire market, it is more profitable to allow lower qualities exist on the market.

[24] This is arguably a rather extreme assumption, but it is widely used in models of oligopoly signaling. See e.g. Herzendorf and Overgaard (2000); Herzendorf and Overgaard (2001); and Fluet and Garella (2002). A good example which can be used to justify the assumption is the forest industry. In forest industry a consumer has an idea of differences in forest management practises, but cannot ascertain whether the wood inputs used to produce the final goods originate from sustainable sources known to exist.

[25] It will be shown that in equilibrium only two firms are active.

the signaling game is thus a pair of prices and a system of posterior beliefs about product qualities. The solution mechanism of the game is the following. Starting from the last stage, we determine the set of price-pairs that implement a belief system consistent with the definition of the separating equilibrium. This involves the analysis of the evolution of consumers' beliefs and corresponding demand functions. Given the consumers' belief system, the second step is to investigate firms' signaling strategies, which determines the equilibrium outcome for any given quality distribution. Finally, we examine the firms' quality and entry decisions.

Let $\mu^p = \mu(\check{p}^1, \check{p}^2, a^1, a^2)$ and $\mu^s = \mu(p^1, p^2, a^1, a^2)$ denote the beliefs when qualities are verifiable and unverifiable by consumers, respectively. Furthermore, given prices p^1 and p^2, let $\beta^1(p^1, p^2)$ denote the consumer's assessment that firm 1's quality is a^2. This belief system satisfies $\beta^1(p^1, p^2) = 1 - \beta^2(p^1, p^2)$, where $\beta^2(p^1, p^2)$ is the consumer's assessment that firm 2's quality is a^2.[26]

Consumers know the cost functions of the firms and infer that the price of a variety a^2 must yield a non-negative mark-up for the producer, i.e. $p^2 \geq C(a^2)$. Hence, the belief system exhibits the following properties:

Lemma 2 *Suppose that $a^2 > a^1$. Given qualities (a^1, a^2), prices (p^1, p^2) and costs $[C(a^1), C(a^2)]$; system $\mu(p^1, p^2, a^1, a^2)$ is such that*

(**i**) $\mu = \mu^p$, *i.e.* $\beta^1(p^1, p^2) = 1/2 \quad iff \quad p^1, p^2 \in [C(a^2), \overline{p}]$,

(**ii**) $\mu = \mu^s$, *i.e.* $\beta^1(p^1, p^2) = 0 \quad iff \quad p^1 \in [C(a^1), C(a^2))$, *where* $\overline{p} = R + \alpha a^2$.

Proof. Lemma 2 requires that all observed prices must be admissible. Hence,

(**i**) For prices $p^1, p^2 \in [C(a^2), \overline{p}]$, where $\overline{p} = R + \alpha a^2$ is the choke-off price, consumers infer that *any* firm charging $p \geq C(a^2)$ could be selling quality a^2. Hence, a consumer expects that any good in the market is of the higher quality with probability $1/2$.

(**ii**) The firms will not set prices below their marginal-cost. Thus, a price $p^1 < C(a^2)$ implies that the firm setting price p^1 is producing quality a^1, and leads the consumers to update their beliefs accordingly. ∎

Lemma 2 establishes that the consumers' beliefs are determined through the low-quality firm's pricing decision. Consequently, implementation of separating beliefs requires that firm 1

[26] Since the market consists of two product varieties, the beliefs are such that $\beta^1(p^1, p^2) + \beta^2(p^1, p^2) = 1$.

has an incentive reveal its true type. Otherwise, no separating equilibrium exists.[27]

Using Lemma 2 the demand system, $\mathbf{D} \equiv (\widehat{D}^2, \widehat{D}^1)$, can be written as

$$\mathbf{D} \equiv \begin{cases} (M\widehat{\theta}, M(1-\widehat{\theta})) & for \quad \mu = \mu^s \\ (M/2, M/2) & for \quad \mu = \mu^p : p^1 = p^2 < R + (\alpha - 1)\Delta^c(a^1, a^2) \\ (0, M) & for \quad \mu = \mu^p : p^1 < p^2 \leq R + (\alpha - 1)\Delta^c(a^1, a^2) \end{cases}$$

where $\Delta^c(a^1, a^2) = (a^1 + a^2)/2$ denotes the expected quality in the market. The system is derived using the consumers' assessments about qualities and responses to the observed price-differential. First, when consumers observe the actual qualities, the demand system coincides with the one under full information. Second, in a pooling equilibrium, the firms split the market with equal prices. Finally, when the consumer cannot link the firms and qualities, a firm with lower price captures the entire market, because consumers are willing to pay a single price for any good in the market.

4.2 Price Signaling

Having analyzed how consumers update their beliefs after realizing the prices in the market, we move on to the analysis of firms' pricing strategies. The analysis is in three steps. First, we show that full-information prices do not constitute an equilibrium under asymmetric information. Then we investigate the existence of price-pairs, which constitute separating equilibria. Finally, after the determination of the set of potential equilibrium price-pairs, we solve for an equilibrium that cannot be destabilized by one-stage deviations.

Consider firm 1's price decision when it conjectures that firm 2 has set its price equal to full-information level. Lemma 2 establishes that a separating equilibrium requires the firm with lower quality to reveal its type. In Appendix A we show that given the full-information price level $\hat{p}^2$, firm 1's optimal price-response is

$$\begin{aligned} p^1 &= \hat{p}^2 \quad for \quad \hat{p}^2 \leq R + (\alpha - 1)\Delta^c(a^1, a^2) \\ p^1 &\leq \hat{p}^2 \quad for \quad \hat{p}^2 > R + (\alpha - 1)\Delta^c(a^1, a^2), \end{aligned} \tag{7}$$

[27]It is important to note that Lemma 2 describes the basic belief system, which abstracts from refinements that rely on out-of-equilibrium prices. Out-of-equilibrium beliefs will be treated in more detail below.

where $\hat{p}^1$ and $\hat{p}^2$ denote full-information price levels. Hence, full-information prices do not constitute an equilibrium under asymmetric information. This is because firm 1 observes that for given $\hat{p}^2$, it can split the entire market for the goods by imitating firm 2. If $\hat{p}^2$ is high enough, so that pooling induces partial market-coverage, firm 1 captures the entire market and increases its profit by setting $p^1 = R + (\alpha - 1)\Delta^c(a^1, a^2)$, i.e. just the price for which it captures the entire market for the expected quality $\Delta^c(a^1, a^2)$.

In order to determine whether there is a price pair that constitutes a separating equilibrium, we need to consider firm 1's best-response to all admissible prices $p^2 \in [C(a^2), R+\alpha]$. To this end, consider firm 1's best-response correspondence, $p^1(p^2)$. A price p^2 that implements a separating equilibrium is such that firm 1 rather reveals its type by setting $p^1 < C(a^2)$ than imitates firm 2. In Appendix A we show that the best-response of firm 1 is always (weakly) higher than the marginal cost of the firm with higher quality:

Proposition 1 *Regardless of the differences between the firms' environmental quality, the firm producing higher environmental quality cannot induce the low-quality firm to reveal its actual quality to consumers. Hence, no separating equilibria exist.*

Proof. See Appendix A. ■

This proposition states that firm 2 cannot implement a separating equilibrium. The reason is that for $p^2 > C(a^2)$, by setting $p^1 = p^2 - \varepsilon$, firm 1 captures the entire market, where the consumers buy goods with expected quality $\Delta^c(a^1, a^2) \geq a^1$. For $p^2 = C(a^2)$, firm 1, in turn, imitates firm 2 and charges $p^1 = C(a^2)$ rather than reveals its type.

We have now determined the set of potential equilibria in the signaling game. To establish the strategically stable equilibrium, however, requires a brief look at how the consumers update their beliefs on the basis of observed out-of-equilibrium prices. Consider a candidate equilibrium: $\tilde{p}^1 = \tilde{p}^2 > C(a^2)$. The strict inequality implies that each firm can increase its profit by slightly cutting the price-level. A price-cut could be inferred as a defection by the low quality firm, but the consumer has no reason to rule out the possibility that the lower price is set by the one with quality a^2. Hence, when consumer observes prices $p^1 < p^2$, she updates her beliefs to $\beta^1(\cdot) = 0$, if and only if $p^1 < C(a^2)$.[28] This result gives raise to the following proposition:

[28] It is important to note that we abstract from equilibrium refinements that are consistent with another equilibrium. Mailath, Okuno-Fujiwara and Postlewaite (1993) argue that no defection should be considered in isolation. Their idea is that an equilibrium can be destabilized only by another equilibrium, not by an isolated defection.

Proposition 2 *Equilibrium prices equal the marginal cost of the high-quality firm* $C(a^2)$. *Although firm* 2 *makes zero short-term profit, it will not be driven out of the market. Firm* 1*'s mark-up equals the difference between the firms' marginal costs, i.e.*

$$\begin{aligned} \pi_h^1(a^1, a^2) &= (M/2)[C(a^2) - C(a^1)] > 0 \\ \pi_h^2(a^1, a^2) &= (M/2)[C(a^2) - C(a^2)] = 0. \end{aligned}$$

Proof. See Appendix A. ■

The result can be understood intuitively as follows. A candidate pooling equilibrium-candidate with a prior belief-system $\Delta^c(a^2, a^1) > a^1$ and prices $p^1 = p^2 > C(a^2)$, does not constitute an equilibrium. This is because the equilibrium is destabilized by a price-cut on behalf any of the two firms, insofar as consumers' beliefs about product quality are unaffected by such defection. For $p^1 = p^2 = C(a^2)$, a price-cut results in an update of consumer beliefs, so that a firm with price $p' < C(a^2)$ is producing lower quality with certainty.

Although the equilibrium outcome is driven by Bertrand-type argument, the characterization of the equilibrium is quite different. From the consumers' viewpoint, each good in the market has the same expected quality and the evolution of the belief system allows the firms to cut prices similarly as in a standard Bertrand game. However, the cost difference implies that, in equilibrium, both firms are active since no firm can feasibly set its price below $C(a^2)$. This is because by setting $p^1 < C(a^2)$, the firm 1 would induce a shift in consumer beliefs, which by condition (3) results in zero demand for its product.

4.3 Quality Game

The quality subgame involves three stages.[29] First, the incumbent 2 chooses its quality. Second, incumbent 1 observes that market consists of quality a^2 and chooses a^1. Finally, the entrants observe the quality distribution in the market and choose to enter, i.e. set $a^N \geq \underline{a}$ or remain passive.

The incumbents anticipate the potential entrants' quality decisions and observe that the price-premium generated by choosing a higher abatement level will be fully appropriated by the

[29] For a similar treatment of firms' quality decision under threat of entry, see e.g. Peitz (2002).

rivals. This implies negative payoff in the long-term, and thus, the optimal strategy for each incumbent is quality $\underline{a}$:

Proposition 3 *Under asymmetric information without labeling, the market consist of two incumbent firms producing at the minimum quality level,* $\underline{a}$.

Proof. Consider the incumbent 2's quality decision. Letting $a^N(a^2, a^1)$ denote the entrants' quality decision given the incumbents' qualities, the incumbent firm 2's program is given by

$$\begin{aligned} \max_{a^2} \pi^2[a^2, a^1, a^N(a^2, a^1)] &= (M/n)[p^2(a^2, a^1, a^N) - C(a^i)] - \eta^2(a^2), \\ & s.t. \\ p^2(a^2, a^1, a^N) &= C(a^2) \qquad for \qquad a^2 \geq \underline{a} \end{aligned}$$

where $a^N(a^2, a^1)$ is the entrant's best response function to incumbents' quality decisions and $\nu = n + 2$ for $a^N(a^2, a^1) \geq \underline{a}$; and $\nu = 2$ for $a^N(a^2, a^1) = \underline{a}$. It is sufficient to show that firm 2 always chooses $a^2 = \underline{a}$, for this induces $a^1 = \underline{a}$ and $a^N(a^2, a^1) = \underline{a}$. Suppose firm 2 chooses $a^2 > \underline{a}$. By Proposition 2, this implies that the firm 1 with lower quality can capture positive rent by choosing $a^1 = \underline{a}$. This yields a negative long-term profit for firm 2. Hence, an optimal strategy for firm 2 involves $a^2 = \underline{a}$, which implements $a^1 = \underline{a}$ and $a^N(a^1, a^2) = \underline{a}$. ■

A firm that chooses to abate more than the minimal requirement $\underline{a}$, raises the overall quality and the price level in the market. This generates an information rent for the firms producing lower quality. Anticipating this, the firms have diminished incentives to improve their quality for it yields a negative long-term profit. Hence, only the incumbent firms can feasibly produce for the market, but the quality level will be inefficiently low.[30] This result is typical in models with asymmetric information, like those in Akerlof (1970) and Leland (1979). However, unlike these papers, the present model allows for endogenous quality choice. The welfare implication of the result is nevertheless that provision of quality is minimal and therefore lower than under full information with two active firms.

[30] It is worth noting that raising the minimum quality standard would imply negative long-term profit as the competition would drive the price premium to zero for each active firm.

5 Third-Party Labeling and Trade

This section examines the role third-party labeling-programs in the domestic and export markets. The firms set a single price within each market, but can price discriminate between markets. It is thus convenient to analyze the market outcomes separately. In what follows, the first subsection introduces national labeling requirements and examines firms' quality decisions in autarky. The second subsection examines the industry equilibrium in the export market under mutual recognition of labels. Finally, we analyze whether the equilibrium properties in the export-market influence the domestic market, and compare the welfare implications under different presumptions about the labeling requirements.

5.1 Labeling in Autarky

Suppose that a domestic labeling intermediary imposes a requirement $a_d : \bar{a} \geq a_d > \underline{a}$, which the local firms must meet to be eligible for quality-certification, L_d. Consumers observe that any firm i with a label L_d is producing with quality $a^i \geq a_d$. It is however important to note that if the market consists of two labeled goods with qualities $a^j > a^i \geq a_d$, the label does not provide ranking between the goods in terms of their quality. Hence, the problem of asymmetric information is present in each sub-market with more than one product variety.

A feasible standard a_d must satisfy the following participation constraint for firm 2:

$$\pi^2[a^1(a^2), a^2, \mathbf{a}^N(a^1, a^2)] \geq 0 \quad for \quad a^2 \geq a_d, \tag{8}$$

where $\mathbf{a}^N(a^1, a^2) = [a^3(a^1, a^2), a^4(\cdot), ..., a^n(\cdot)]$ denotes the quality response of the entrants and $a^1(a^2)$ that of the incumbent 1. The constraint simply states that a successful program yields a non-negative long-term profit for the participating firms.

Consider then the firms' quality decisions. Starting from the last stage of the quality game, the first entrant takes the existing qualities in the market as given and chooses whether to enter the market. The optimal quality choice is the following:

$$a^N(a^1, a^2) \begin{cases} = a_d & for \quad a^i > a_d \quad and \quad a^j = \underline{a} \\ = \underline{a} & for \quad a^i = a_d \quad and \quad a^j > \underline{a} \\ = 0 & for \quad a^i = a_d \quad and \quad a^j = \underline{a}, \end{cases}$$

where $i, j = 1, 2$ denote the existing qualities in the market and $a^N = 0$ refers to the case of no entry. The solution for this problem is simple: The entrant N chooses to enter, when it observes quality levels higher than a_d or $\underline{a}$. This follows immediately from the previous results implying that the information rent in each sub-market can be fully appropriated by an entrant that has a lower quality-level than an incumbent firm. However, when the incumbents choose qualities a_d and $\underline{a}$, entry yields negative long-term profit for the entrant. As a result, such initial quality distribution discourages entry and leads to a duopoly outcome in the market.

Firm 1 anticipates the entrant's response to incumbents' quality-decisions. Hence, given incumbent 2's quality level a_d or $\underline{a}$, firm 1's quality-response becomes

$$a^1(a^2) \begin{cases} = a_d & for \quad a^2 = \underline{a} \\ = \underline{a} & for \quad a^2 = a_d. \end{cases}$$

The reason why firm 1's choice is involves just qualities a_d and $\underline{a}$, is that for any other quality level, either firm 2 or the entrants appropriate the rent associated with increase in firm 1's quality.

Given the followers' responses, a similar reasoning applies for firm 2, and its decision boils down to choosing between quality levels a_d and $\underline{a}$. Thus, when requirement is such that

$$\pi^2(a^2, a^1) = \pi^2[\hat{p}^2(a_d), \hat{p}^1(\underline{a})] > \pi^2[\hat{p}^2(\underline{a}), \hat{p}^1(a_d)], \tag{9}$$

where $\hat{p}^2(\cdot)$ and $\hat{p}^1(\cdot)$ denote the full information prices, firm 2 chooses $a^2 = a_d$. If the inequality is reversed, firm 2 chooses $a^2 = \underline{a}$ and firm 1's response is $a^1 = a_d$. In both cases, entry is deterred by the incumbents, because the entrants observe that entry with a higher quality level leads to a signaling game which yields negative long-term profit.

Hence, the resulting equilibrium can be characterized as follows:

Lemma 3 *In autarky, a labeling program implements an outcome that coincides with the full information equilibrium involving qualities $a^1 = \underline{a}$ and $a^2 = a_d$. Regardless of the standard a_d, the market equilibrium does not satisfy the criteria for Pareto-efficiency.*

Proof. The proof follows immediately from the analysis and the proof of Proposition 3. Lemma 1 ensures that the outcome is not welfare optimal. ■

Lemma 3 implies that only the incumbent firms with qualities a_d and $\underline{a}$ survive the competition. This, in turn, means that the high-quality firm can price discriminate the consumers with lower willingness to pay. Hence, the equilibrium does not satisfy the criteria for Pareto efficiency as there is a segment of consumers not buying the high quality good.

5.2 Equilibrium Pricing in the Export-Market

The importing country has no domestic production of x. Under mutual recognition of labels, the labeled sub-market involves two qualities, a_d and a_f, but the difference between the qualities indicated by the labels cannot be verified by the consumers. The consumer's prior belief about the quality of a good with a label is therefore $\Delta^c(a_d, a_f) > a_d$, when $a_d < a_f$. When the labeling standards are harmonized, there is a full information in the labeled sub-market, i.e. $\Delta^c(a_d, a_f) = a_d$.

When the consumers cannot observe the quality difference between the labels, the equilibrium in the export market has the following properties:

Lemma 4 *Suppose that each producing country has a labeling program that allows firms with quality a_d (a_f) carry a label L_d (L_f). In the export market:*

(**i**) *Harmonizing requirements (i.e. $a_f = a_d$) implies that only labeled goods are exported and sold at marginal cost.*

(**ii**) *Mutually recognized labels with qualities $a_f > a_d > \underline{a}$, induce a pooling equilibrium, where the consumers' beliefs about the qualities are given by $\Delta^c(a_f, a_d) > a_d$ and prices equal the marginal cost of the firm with higher quality, i.e. $p_d^2 = p_f^2 = C(a_f)$. Each firm with a label survives in the export market.*

(**iii**) *When the quality difference is small, each consumer rather buys a labeled good than an unlabeled one. Hence, the unlabeled goods will be driven out of the export market if*

$$(\alpha - \underline{\theta})[\Delta^c(a_f, a_d) - \underline{a}] \geq C(a_f) \qquad for \qquad a_f - a_d > \delta, \tag{10}$$

where δ is a critical parameter that determines the quality difference under which the consumers are just indifferent between buying a good with expected quality $\Delta^c(a_f, a_d)$ and a good with a certain quality $\underline{a}$ for a marginal cost prices $C(\underline{a})$ and $C(a_f)$.

Proof. Result (**i**) follows immediately from a Bertrand argument and condition (1). Part (**ii**) is a consequence of Lemma 3: When $a_d < a_f$ the labeled firms from country d prefer to pool rather than set their prices below $C(a_f)$, indicating that the optimal pricing strategy for the firms with a label L_d is $p_d^2 = p_f^2 = C(a_f)$. Part (**iii**) follows directly from comparisons consumers' surplus: For $p_d^2 = p_f^2 = C(a_f)$, the expected quality of a labeled good $\Delta^c(a_f, a_d)$ yields a higher surplus than the unlabeled variety, insofar as the quality difference is small enough. For instance, when $a_d \to a_f$, no consumer will purchase an unlabeled good, and the market for $\underline{a}$ does not exist. ■

The first part of the result is straightforward. In equilibrium, firms with identical costs and qualities end up setting marginal-cost prices. By condition (3) this drives the unlabeled variety out of the market. The second part argues that the labeled sub-market exhibits pooling, when the labeling requirements are not harmonized. The reasoning is similar to that of Proposition 2: For any given price p_f^2, a labeled firm from country d will not reveal its true type, and consequently, all labeled producers set their prices equal to marginal cost of the high-quality producer. These prices are just high enough to keep all firms active and sustain pooling beliefs.

The third part argues that the quality distribution in the export market depends on the steepness of the consumers' utility function and that of the cost function. When the consumers have strong preferences for environmental quality, they rather buy any good with a label than a good without one. This property holds locally when the quality-difference is small, i.e. $\Delta^c(a_f, a_d) \to a_f$, and globally when $a_d \to \underline{a}$, provided that the cost function is sufficiently flat.

Figure 3a describes a polar case which illustrates the third part of Lemma 4. In this case the cost function is relatively flat and $a_d \to \underline{a}$. Consumer $\underline{\theta}$ observes that the expected quality of labeled goods is lower than the highest quality available, but for a price equal to $C(a_f)$, she rather buys a labeled good than an unlabeled one, the low-quality firms split the unlabeled sub-market and make zero profit.[31] This is illustrated in Figure 3b, where consumers $\theta = \underline{\theta}$ purchase the unlabeled variety.

[31] In Figures 3a and 3b, $CS[\Delta^c(a_f, a_d)]$ denotes the difference between consumer surplus when buying labeled goods instead of unlabeled ones for marginal cost prices, $C(a_f)$ and $C(\underline{a})$, respectively.

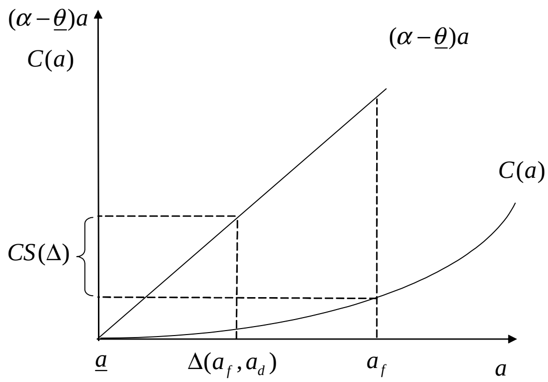

Figure 3a:

$(\alpha - \underline{\theta})[\Delta^c(a_f, a_d) - \underline{a}] > C(a_f)$

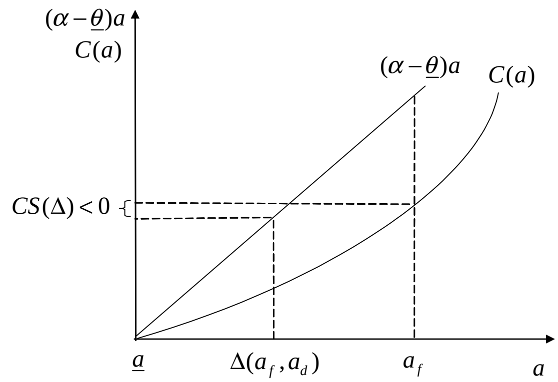

Figure 3b:

$(\alpha - \underline{\theta})[\Delta^c(a_f, a_d) - \underline{a}] < C(a_f)$

5.3 Welfare Analysis

This section derives the linkages between the markets of the model. In particular, we examine whether the information rent in the export market is sufficiently high to induce entry in the producing countries, and thereby influence the quality distribution and pricing in the markets of the producing countries.

When the firms have the option to produce for both domestic and export markets, the entry decision is driven by two effects. First, Lemma 3 implies that in autarky, entry induces zero short-term profit in the domestic market, regardless of the labeling requirements of the foreign country. Second, a difference between the labeling requirements generates a rent in the export market. When this rent is high enough, it outweighs the fixed cost of entry, and therefore, increases the number of labeled producers. The market implications of these effects are described in more detail in the following lemma:

Lemma 5 *Suppose that (10) holds. If $a_f > a_d$ the industry-equilibrium is such that*

(**i**) *Each domestic firm chooses quality a_d and makes positive profits in the export market:*

$$\pi_d^2(a_d, a_f) = [M/(n+3)][C(a_f) - C(a_d)] > 0.$$

Marginal-cost pricing implies zero-profit for the foreign firm.

(**ii**) *Domestic market consists of $n + 2$ labeled firms. Each firm produces quality a_d, and* *charges prices equal to* $C(a_d)$.

Under harmonized labeling requirements $a_f = a_d$, *the market outcome in the producing countries coincides with the full information benchmark with qualities* $\underline{a}$ *and* a_d. *Only labeled firms produce for the export market, in which prices equal marginal cost.*

Proof. See Appendix B. ■

Lemma 5 establishes that a difference between labeling requirements increases the number of firms with label L_d. In domestic market this induces tougher competition, and consequently, increases the market share of the labeled variety. Under harmonized labeling requirements, firms' profits in the export market are zero. Since the incumbent can deter entry in the domestic country, the lack of competition in the producing countries implies that the quality distribution coincides with the one under autarky.

The following result illustrates the welfare implications of this pro-competitive effect of mutual recognition of national eco-labels.

Proposition 4 *For any given* a_f, *a labeling schedule with requirement* $a_d^* = a_f - \varepsilon$, *where* $\varepsilon \to 0$, *is welfare-superior to harmonized labels,* $a_d = a_f$. *In particular, when* $a_f = \bar{a}$, *the property* $a_d^* = \bar{a} - \varepsilon$ *implements an outcome that approaches Pareto-efficient allocation of quality in country d and export market.*

When the standards are harmonized, the export market exhibits marginal-cost pricing, but the producing have only one labeled producer which can price-discriminate its customers with a lower willingness to pay for products environmental quality. This means that, in comparison to mutual recognition of labeling standards, the lack of competition in the labeled sub-market leads to Pareto-inferior outcome in the domestic markets.

Proposition 4 states that there is a positive spillover associated with mutual recognition which can correct for inefficiently low provision of quality in domestic market. To further emphasize this effect, suppose that $a_f = \bar{a}$. A small difference between the labeling requirements changes the market-structure through an information rent in the export-market, generating an incentive for new producers to apply for domestic label. An increase in the number labeled firms intensifies the price-competition in domestic market, and consequently, drives the prices down toward marginal-costs. Sufficiently low prices allow *all* domestic consumers to purchase the labeled variety, and unlabeled goods will be driven out of the market. It then follows that when labeling requirement of the foreign country is $\bar{a}$ and the difference between the requirements is small, the outcome in the domestic market satisfies the criteria for Pareto-efficiency.

While this result provides a stylized argument for mutual recognition of labels, it should be noted that such an outcome in all markets is unfeasible. This is because it requires that only quality $\bar{a}$ is produced and purchased by each individual in all countries. Based in the above considerations this cannot be implemented through labeling or by imposing minimum quality standards.

6 Conclusion

This paper examined the structure of an international vertically differentiated industry, and the welfare implications of harmonization and mutual recognition of national eco-labels. The analysis shows that a difference between labeling requirements induces a positive spillover in a country which applies lower standards to its producers. The effect is generated through an information rent in the export-market which increases the number of labeled producers, and thereby improves the aggregate environmental quality of goods.

More specifically, under full information, the overall quality in the market falls short of Pareto-efficiency. Second, asymmetric information drives all goods produced with higher abatement level out of the market, and consequently, only goods with minimal environmental quality will be produced. The problem of asymmetric information can be mitigated by establishing a labeling program. In autarky, the program improves quality provision, but yet the allocation of environmental quality is inefficient. This is because incumbent firms can deter entry in the labeled sub-market and then price-discriminate consumers with a lower willingness to pay for the goods' environmental quality.

Mutual recognition of labels with different standards generates an information rent in the export market for the firms with lower standards. The rent also yields positive profit for the entrants and thereby intensifies price-competition in domestic market as the number of the labeled firms increases. In other words, a small imperfection in the form of lower market transparency in the export market intensifies competition, and makes the high quality goods more affordable to consumers in the producing countries. This increases the consumers' surplus and diminishes the production related environmental externalities. Under harmonized labeling requirements the incumbent firms can deter entry, which diminishes the share of high quality products in domestic market. A welfare comparison between mutual recognition and harmonization thus reveals that under mutual recognition a small difference between labeling standards Pareto-dominates the full information outcome with harmonized labels.

Appendix A

Proof of (7). The proof involves two cases. (**a**) fully covered markets $\hat{p}^2 < R+(\alpha-1)\Delta^c(a^1,a^2)$ and (**b**) partially covered markets $\hat{p}^2 > R+(\alpha-1)\Delta^c(a^1,a^2)$.

(**a**) Full market coverage implies that when $p^1 = \hat{p}^2$ each consumer buys the good so that the firms split the demand. If the full information prices constitute an equilibrium, the following condition holds $\pi^1[p^1,\hat{p}^2;\mu^p] \geq \pi^1(\hat{p}^1,\hat{p}^2;\mu^s)$. This can be written as

$$\frac{1}{2}\left[\hat{p}^2 - C(a^1)\right] \geq \left[1-\alpha+\frac{(\hat{p}^2-p_l^1)}{(a^2-a^1)}\right][\hat{p}^1 - C(a^1)].$$

Substituting the closed form expression for $\hat{p}^2$ yields:

$$(\alpha+1)(a^2-a^1)+2C(a^2) \geq 2(1-\hat{\theta})\left[(\alpha-1)(a^2-a^1)+C(a^1)+C(a^2)\right].$$

Since $\alpha+1 > 2(1-\hat{\theta})(\alpha-1)$ and $2C(a^2) > C(a^1)+C(a^2)$, we conclude that full information prices do not constitute an equilibrium.

(**b**) Partial market coverage implies that some consumers refuse to buy the good at price $\hat{p}^2$. Observe first that $C(\bar{a}) \leq R$, hence, it is sufficient to show that by setting $p^1 = R+(\alpha-1)\Delta^c(a^1,a^2)$, firm 1 can capture the entire market, and the payoff is higher than in the case $p^1 < C(a^2)$. This condition can be written as

$$R+(\alpha-1)\Delta^c(a^1,a^2)-C(a^1) > (1-\hat{\theta})[\hat{p}^1 - C(a^1)].$$

The properties $1-\hat{\theta} < 1$ and $R+(\alpha-1)\Delta^c(a^1,a^2) > \hat{p}^1$ readily show that pooling is indeed optimal for firm 1. ■

Proof of Proposition 1. To show that firm 2 can induce firm 1 to reveal its true type, we must prove that there is p^2 that induces a response $p^1 < C(a^2)$. Formally, this requires

$$\tilde{p}^1 = \arg\max_{p^1} \pi^1(p^1, p^2, \mu^s) \tag{11}$$

$$\pi^1(\tilde{p}^1, p^2; \mu^s) \geq \pi^1(p^2, p^2; \mu^p) : \quad \tilde{p}^1 < C(a^2) \tag{12}$$

Expression (11) states that $\tilde{p}^1$ must be a profit maximizer for firm 1 given beliefs μ^s; (12) sates that in an equilibrium, firm 1 has no incentives to pool.

We have already showed that for $R + (\alpha - 1)\Delta^c(a^1, a^2) \geq p^2 > C(a^2)$ firm 1 can capture the entire market by setting $p^1 = p^2 - \varepsilon$.[32] Plugging this into (12) and evaluating at $\varepsilon \to 0$, the condition becomes:

$$(1 - \hat{\theta})[p^1 - C(a^1)] \geq \left[p^2 - C(a^1)\right].$$

This is obviously a contradiction since $(1 - \hat{\theta}) < 1$. For $p^2 = C(a^2)$, condition (3) states implies that firm 1 reveals its type if

$$0 \geq \frac{1}{2}\left[C(a^2) - C(a^1)\right].$$

This is a contradiction.[33] Hence, no separating equilibrium exists. ■

Proof of Proposition 2. The proof follows the same lines of reasoning as the proof of Proposition 1. Consider an equilibrium candidate $(\tilde{p}^1, \tilde{p}^2) : \tilde{p}^1 = \tilde{p}^2 > C(a^2)$. By Bertrand-argument we infer that each firm can destabilize the equilibrium by lowering its price marginally: e.g. $p^1 = \tilde{p}^2 - \varepsilon$, and capture the entire market.

Price-cutting is (weakly) beneficial for both firms insofar as the strategy profiles satisfy $\tilde{p}^2 - \varepsilon = C(a^2)$. Letting $\varepsilon \to 0$, the equilibrium price-pair thus becomes $(\tilde{p}^1, \tilde{p}^2) = [C(a^2), C(a^2)]$ with payoffs $\pi^1(a^1, a^2) = (M/2)\left[C(a^2) - C(a^1)\right] > 0$ and $\pi^2(a^1, a^2) = (M/2)\left[C(a^2) - C(a^2)\right] = 0$.

This equilibrium is strategically stable for the following reasons: (**a**) Since the firm with lower price captures the entire market, neither firm can increase its payoff by upward price-deviation. (**b**) Price-cutting implies negative profit for firm 2. In terms of price-cost margin per unit of output, firm 1 would make positive profit by cutting its price. However, since firm 1's

[32] For $p^2 > R + (\alpha - 1)\Delta^c(a^1, a^2)$, the optimal strategy for firm 1 is obviously $p^2 > p^1 \geq R + (\alpha - 1)\Delta^c(a^1, a^2)$.
[33] This follows immediately from that for a price $p^2 = C(a^2)$ induces all consumers to buy good x^2.

conjectures that the rival will keep its price fixed at $p^2 = C(a^2)$, it infers that when beliefs are updated according to the observed signal $p^1 < C(a^2)$, each consumer would buy the good with quality a^2, implying zero demand. ■

Appendix B

Proof of Lemma 5. The first part states that (**i**) all domestic firms produce with quality a_d and (**ii**) the foreign firm is active in the export market.

(**i**) Lemma 4 readily shows that export market exhibits pooling and the cost advantage for domestic firms is $C(a_f) - C(a_d)$ per unit of output. For the domestic entrants this implies positive payoff from entry. Hence, each entrant produces quality a_d. Condition (3) and a standard Bertrand argument ensures that domestic market with multiple firms with quality a_d induces marginal cost pricing in the labeled sub-market and thus zero demand for the unlabeled variety. Thus, all domestic firms choose quality a_d.

(**ii**) This follows immediately from that foreign country has positive mark-up in the local market which provides an incentive to participate the labeling program.

The second part argues that under identical labeling requirements, domestic market equilibrium coincides with the full information outcome with qualities a_d and $\underline{a}$. Bertrand argument ensures that market outcome in the export market involves marginal-cost pricing, and consequently, zero profit for all labeled firms. Thus, Lemma 4 ensures that entry yields negative profit in both in domestic and in the export market, indicating that the market in the producing countries involves only 2 firms producing qualities $\underline{a}$ and a_d. ■

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