Competing eco-labels and product market competition

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Abstract

I analyze a green product market in which eco-labeling programs compete—programs certifying the environmental quality of the product to their respective standards. Specifically, I examine the strategic competition between an industry-sponsored program and a program sponsored by nongovernmental organization (NGO) in a duopoly product market where eco-labels are strategic variables for firms. In particular, I analyze the effects of such eco-label competition on environmental benefit and social welfare. I show that the eco-label competition may generate the same environmental benefit and generally increase social welfare relative to a single NGO label.

1 Introduction

Claims that products are environment-friendly cannot be verified by individual consumers either from search or consumption. One method to address this asymmetric information problem is the use of eco-labeling. Typically, an eco-labeling program certifies that the environmental quality of a product meets a voluntary quality standard chosen by the program, and the certified product receives the label.

In some markets, the number of eco-labels has increased gradually, as multiple eco-labeling programs enter the marketplace and set their respective standards according to differing objectives – I refer to this as eco-label competition. In many situations, the competition is between a program sponsored by a non-governmental organization (NGO) and a program sponsored by an industry association. A prominent example comes from the forest-products market, where the industry Sustainable Forestry Initiative (SFI) program introduces its own label and establishes alternative quality standard in response to the NGO label developed by the Forest Stewardship Council (FSC) program. While the NGOs often worry that the industry eco-label is merely an effort of "green-washing", there is surprisingly little consensus on the effectiveness of industry eco-labels aimed at environmental aspect of product quality. More importantly, there is no clear answer about the effect of such competition between the industry and NGO labels on product market structure, environmental benefit and, in particular, social welfare. This paper attempts to shed some new light on this issue.

In particular, this paper examines whether in an imperfectly competitive industry where eco-labels are potentially strategic variables for firms, the introduction of an industry label alongside an NGO one, with both labeling programs choosing their standards strategically, results in higher provision of environmental quality and increases social welfare, as compared to the case in which there is NGO label alone. In fact, such competition among eco-labeling programs provides firms with more options of differentiating products and affects the extent of vertical product differentiation. This, in turn, affects the intensity of product market competition, consumer and producer welfare, as well as aggregate provision of environmental quality; on the other hand, the anticipating competition in the product market and, in particular, firm choices on eco-labels influence the programs' decisions concerning setting quality standards. This argument is developed in this paper to show that eco-label competition may generate the same environmental benefit and, furthermore, increase social welfare relative to the case of a single NGO label.

I consider a Bertrand duopoly where initially there is no eco-label available and the products of the two identical firms are homogenous and have the same basic environmental quality. In the first stage, an NGO-sponsored eco-labeling program develops its label and announces the corresponding quality standard with the objective to maximize the aggregate environmental quality on the market. In the second stage, an industry-sponsored program creates its own label and standard, whose objective is to maximize industry profits. In the next stage, firms simultaneously choose whether to adopt a label and which one to adopt. Finally, firms engage in price competition. Firm adopting either label has to incur a fixed improvement cost (w.r.t. quantity) to upgrade its basic environmental quality up to the corresponding program's quality standard.

When the NGO program is alone in the market, in equilibrium the optimal NGO standard is always set at such a high level that the firm adopting the label earns zero profit while the other unlabeled firm produces the basic quality. On the other hand, in the presence of both labels, the industry program always responds to the NGO label with a standard set at the industry's profit-maximizing level, provided that the NGO program chooses a different standard in the first stage. The equilibrium continues to feature a vertical-differentiation outcome, but with one firm producing the basic quality and the other firm matching the industry's optimal standard.

I find that such an industry's optimal standard in the presence of eco-label competition is equal to the NGO's optimal standard in the single NGO label case, and furthermore, the environmental benefit is the same under both cases, if the marginal cost increases sufficiently fast in environmental quality. The intuition is as follows. The optimal level of the industry standard depends on the relative sizes of two effects: a "differentiation effect" and a "fixed cost effect". Increasing the standard increases the fixed improvement cost, which decreases industry profit. This is the fixed cost effect. On the other hand, increasing the standard increases the extent of vertical differentiation which, in turn, softens price competition and allows higher industry profit. This is the differentiation effect. The differentiation effect dominates when the marginal cost increases sufficiently fast in environmental quality, which is due to the fact that now the cost of environmental quality is borne largely by the marginal cost rather than the fixed cost; therefore, the industry program will end up setting a stringent standard such that it is equal to the optimal NGO standard in the single NGO label case.

I also show that relative to the single NGO label case eco-label competition may lead to higher social welfare. The determining factor here is the relative weight that the social

planner places on the private benefit (the sum of consumer surplus and industry profit) vs. the environmental benefit. In particular, when the private benefit dominates, eco-label competition raises social welfare.

There is a significant literature on labeling that studies under different product market structure firm strategic incentive to adopt an eco-label or other types of labels that communicate certain credence attributes (e.g., organically produced food or genetically modified organism-free food). However, this vast literature has generally ignored the phenomenon of eco-label competition and considered only settings in which there exists a single labeling program that provides certification (see, for instance, Amacher et al., 2004, Ben Youssef and Lahmandi-Ayed, 2008, Ibanez and Grolleau, 2008, and Bonroy and Constantatos, 2015).

Few papers formally model eco-label competition between labeling programs that set quality standards strategically: Fischer and Lyon (2014) and Li and van 't Veld (2015). However, in both papers, firms are modeled as being nonstrategic. For example, Fischer and Lyon (2014) assume that a firm will adopt a label with high standard instead of the one with lower standard as long as the quality premium consumers are willing to pay for exceeds the cost difference. But, unlike the previous papers, in my framework, competing firms strategically choose whether to adopt a label or which one to adopt, and I show that such strategic interaction will affect the standards chosen by the labeling programs.

This paper is an attempt to bring together these two strands of literature. To the best of my knowledge, this is the first paper that explicitly includes the strategic interaction between firms and eco-labeling programs in the analysis of the effect of eco-label competition on environmental benefit and social welfare.

The paper is organized as follows. Section 2 describes the model. In Section 3, I present a benchmark model in which the NGO program is alone in the market. Section 4 extends the analysis to consider eco-label competition and presents the major findings of this paper. Section 5 contains the welfare analysis. Section 6 concludes.

2 The model

I consider a duopoly model with vertical differentiation. The two identical firms indexed by i$\in \{1, 2\}$ produce a product that can be vertically differentiated in terms of environmental quality. Following Mussa and Rosen (1978), I assume that the indirect utility of a consumer who purchases a product of environmental quality q_i at price p_i from firm i is given by

$$V = \theta q_i - p_i, \tag{1}$$

where θ measures consumer's willingness to pay for the environmental quality, which is uniformly distributed on $[\underline{\theta},\overline{\theta}]$ with $\underline{\theta}>0$. Consumers have unit demand, and I assume that the market is fully covered.

Firm produces at constant unit cost that depends only on its own environmental quality, i.e.,

$$c_i = \alpha q_i. \tag{2}$$

The environmental quality provided by each firm is required to be at least equal to $\underline{s}$ (i.e., $q_i \geq \underline{s}$), where $\underline{s}>0$ is exogenously given. Hereafter, I refer to $\underline{s}$ as the minimum environmental quality standard.[1]

I consider a multi-stage game. Initially, there is no eco-label available on the marketplace. In the first stage, an NGO-sponsored eco-labeling program develops a label and chooses the corresponding quality standard $s_N \geq \underline{s}$. The program will certify product that meets this standard and the certified product receives the label. In the second stage, likewise, an industry-sponsored program creates its own label and sets a standard $s_I \geq \underline{s}$. In the next stage, firms simultaneously decide whether to adopt a label and which one to adopt. Finally, firms engage in price competition.

Consumers understand that the presence of an eco-label on a product means the environmental quality of this product meets or exceeds some given threshold such that s_N in the case of NGO label and s_I in the case of industry label. Thus, from the perspective of consumers, a labeled firm has a priori a quality $q \geq s_N$ or $q \geq s_I$, depending on which label it adopts, and an unlabeled firm has a quality $\underline{s} \leq q < \min\{s_N, s_I\}$. The simplest beliefs consumers have about the firms' qualities satisfying the above inequalities are such that an unlabeled firm provides the minimal environmental quality $q = \underline{s}$ and a firm adopting the NGO (industry) label has the quality which is exactly equal to $s_N(s_I)$, i.e., $q = s_N(s_I)$.

Given such consumer beliefs, once the labeling standards are set, it is never profitable for

[1] For example, in United States, antibiotics residues in beef products are required by law to be below certain thresholds; however, in Europe, the beef products may be required to be antibiotics-free. In fact, the minimum environmental quality standard may be set by different government agencies with differing objectives, such as to protect national consumers or promote market development, which results in differences in minimum standard across countries. Hence, I do not ask the normative question of optimal minimum quality standard and take the value of $\underline{s}$ as exogenously given.

a firm to provide an environmental quality other than $\underline{s}$ if it chooses to adopt neither label; similarly, a firm adopting the NGO (industry) label will never provide quality different from $s_N(s_I)$. This seems reasonable if consumers are not able to distinguish an unlabeled product of quality $\underline{s}$ from another unlabeled one of quality $\underline{s} \leq q < \min\{s_N, s_I\}$, nor an NGO labeled (industry labeled) product of quality $s_N(s_I)$ from another one of even higher quality. In other words, under this model setup, consumers cannot verify the exact environmental quality but they are perfectly informed about whether firms are labeled or not, the standard choices of labeling programs (i.e., s_N and s_I) as well as the level of $\underline{s}$. Therefore, firm choices are consistent with consumer beliefs.

If a firm decides to adopt an NGO (industry) label and therefore improve its quality to $s_N(s_I)$, it has to incur a fixed improvement cost (w.r.t. quantity), i.e.,

$$f_i = \beta(s_N - \underline{s})^2 (\text{or } f_i = \beta(s_I - \underline{s})^2). \tag{3}$$

In the remainder of this paper, the following parameter restriction is maintained:

Assumption 1. $2\underline{\theta}\text{-}\overline{\theta} < \alpha < 2\overline{\theta} - \underline{\theta}$.

Assumption 1 implies that the marginal cost increases neither too fast nor slowly in environmental quality, which ensures firms of all possible qualities will have strictly positive demand in price competition.

3 Benchmark: a single NGO label

In this section, I present a benchmark case in which only NGO label is available. The benchmark is useful for comparisons with the full model of competition between the NGO label and the industry label, from which I can determine the effects of such eco-label competition on this green market.

Suppose the NGO-sponsored program is on its own in creating an eco-label with a quality standard s_N^{NA} (where superscript NA denotes the case where the NGO program is alone in the market), whose objective I assume is to maximize E^{NA}, the aggregate environmental quality on the market.

First, I describe the equilibrium of the third stage pricing game after the firms' label decisions are made. Specifically, when no firm chooses the label, both firms provide quality $\underline{s}$, involve in competition "à la Bertrand", charge a price equal to the marginal cost $\alpha\underline{s}$, and earn zero profit. When both firms adopt the NGO label and provide quality s_N^{NA}, they still

engage in aggressive price competition, charge a price equal to αs_N^{NA}, and make a negative profit equal to -$\beta(s_N^{NA} - \underline{s})^2$.

When only one firm adopts the NGO label, the following lemma characterizes the pricing equilibrium.

Lemma 1 *Suppose that one firm is unlabeled and the other firm is labeled with* $s_N^{NA} \geq \underline{s}$. *In the unique price equilibrium, the prices charged by the labeled firm and the unlabeled firm, are* $p_N^{NA} = \frac{1}{3}[\alpha\underline{s} + 2\alpha s_N^{NA} + (2\overline{\theta} - \underline{\theta})(s_N^{NA} - \underline{s})]$ *and* $\underline{p}^{NA} = \frac{1}{3}[\alpha s_N^{NA} + 2\alpha\underline{s} + (\overline{\theta} - 2\underline{\theta})(s_N^{NA} - \underline{s})]$, *respectively.*

Consumers with $\theta \in [\widehat{\theta}, \overline{\theta}]$ *buy from the labeled firm and those with* $[\underline{\theta}, \widehat{\theta})$ *buy from the unlabeled firm, where* $\widehat{\theta} = \frac{\alpha + \overline{\theta} + \underline{\theta}}{3}$.

Proof. *See Appendix A.* ■

In the second stage, the duopolists determine whether to adopt the NGO label, taking into account the consequences of this decision for the third stage. The normal form of the second stage subgame is represented in Table 1:

	No label	NGO-label
No label	0,0	$\frac{(\overline{\theta} + \alpha - 2\underline{\theta})^2}{9(\overline{\theta} - \underline{\theta})}(s_N^{NA} - \underline{s}), \frac{(2\overline{\theta} - \alpha - \underline{\theta})^2}{9(\overline{\theta} - \underline{\theta})}(s_N^{NA} - \underline{s}) - \beta(s_N^{NA} - \underline{s})^2$
NGO-label	$\frac{(2\overline{\theta} - \alpha - \underline{\theta})^2}{9(\overline{\theta} - \underline{\theta})}(s_N^{NA} - \underline{s}) - \beta(s_N^{NA} - \underline{s})^2, \frac{(\overline{\theta} + \alpha - 2\underline{\theta})^2}{9(\overline{\theta} - \underline{\theta})}(s_N^{NA} - \underline{s})$	$-\beta(s_N^{NA} - \underline{s})^2, -\beta(s_N^{NA} - \underline{s})^2$

It is clear to see that the pure-strategy equilibria in the second stage game are as follows.

Lemma 2 *Suppose there exists only the NGO label. Then the equilibrium outcome in firm label choices is:*

(1) No firm adopts the NGO label, if $s_N^{NA} > \underline{s} + \frac{(2\overline{\theta} - \alpha - \underline{\theta})^2}{9\beta(\overline{\theta} - \underline{\theta})}$.

(2) One firm adopts the NGO label and the other firm does not, if $\underline{s} \leq s_N^{NA} \leq \underline{s} + \frac{(2\overline{\theta} - \alpha - \underline{\theta})^2}{9\beta(\overline{\theta} - \underline{\theta})}$.

The explanation behind this result is straightforward. If the NGO standard s_N^{NA} is very stringent i.e., $s_N^{NA} > \underline{s} + \frac{(2\overline{\theta} - \alpha - \underline{\theta})^2}{9\beta(\overline{\theta} - \underline{\theta})}$ then the benefit of selling vertically differentiated products cannot cover the fixed improvement cost and, therefore, neither firm adopts the label. On the other hand, if the NGO standard s_N^{NA} is less stringent, i.e., $\underline{s} \leq s_N^{NA} \leq \underline{s} + \frac{(2\overline{\theta} - \alpha - \underline{\theta})^2}{9\beta(\overline{\theta} - \underline{\theta})}$ then the benefit from selling differentiated products will be higher than or equal to the fixed improvement cost; since the adoption of the same eco-label by both firms eliminates

all the product differentiation, the equilibrium outcome in this case is that only one firm adopts the NGO label.

Now I turn to the first stage, where the NGO-sponsored program chooses s_N^{NA} that maximizes E^{NA}, the aggregate environmental quality on the market, taking into account the labeling behavior of firms.

If choosing a less stringent standard such that $\underline{s} \leq s_N^{NA} \leq \underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})}$ then the NGO-sponsored program solves the following optimization problem:

$$\max_{s_N^{NA}} E^{NA} = \int_{\underline{\theta}}^{\widehat{\theta}} \underline{s} f(\theta) d\theta + \int_{\widehat{\theta}}^{\overline{\theta}} s_N^{NA} f(\theta) d\theta. \tag{4}$$

The first term in (4) is the environmental quality provision of the unlabeled firm, and the second term is the quality provision of the labeled firm. I obtain the following solution:

$$s_N^{NA} = \underline{s} + \frac{(2\overline{\theta} - \alpha - \underline{\theta})^2}{9\beta(\overline{\theta} - \underline{\theta})} \equiv \widehat{s}. \tag{5}$$

The corresponding aggregate environmental quality and industry profit are respectively given by:

$$E^{NA} = \underline{s} + \frac{(2\overline{\theta} - \alpha - \underline{\theta})^3}{27\beta(\overline{\theta} - \underline{\theta})^2} \equiv \widehat{E}, \tag{6}$$

$$\Pi^{NA} = \frac{(\overline{\theta} + \alpha - 2\underline{\theta})^2 (2\overline{\theta} - \alpha - \underline{\theta})^2}{81\beta(\overline{\theta} - \underline{\theta})^2} \equiv \widehat{\Pi}. \tag{7}$$

On the other hand, if the program sets a very stringent standard i.e., $s_N^{NA} > \underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})}$ no firm adopts the label and the market provision of environmental quality is exactly the same as if there was no label at all, which is equal to $\int_{\underline{\theta}}^{\overline{\theta}} \underline{s} f(\theta) d\theta = \underline{s}$.

Now, I can establish the main result of this benchmark case.

Proposition 1 *Suppose there exists only the NGO label. The NGO-sponsored program always sets a quality standard that satisfies $s_N^{NA} = \widehat{s}$, where $\widehat{s}$ is given by (5).*

Further, in equilibrium, one firm produces environmental quality $\underline{s}$ whereas the other firm produces environmental quality $\widehat{s}$; the equilibrium aggregate environmental quality and industry profit are equal to $\widehat{E}$ and $\widehat{\Pi}$, which are given by (6) and (7), respectively.

Proposition 1 indicates that in order to achieve the highest level of market provision

of environmental quality, the NGO-sponsored program will always choose a high enough standard such that the fixed cost required for improving the quality just offsets the gain from label adoption, and the firm adopting the label thus makes zero profit.

4 Competition between NGO and industry labels

In this section, I turn my attention to the full model where the NGO-sponsored program competes with the industry-sponsored program. Specifically, the NGO program creates its label with standard s_N in the first stage, and the industry program responds with a label of standard s_I in the next stage whose objective is to maximize industry profit.

4.1 Label choice game

Now in the third stage, each firm faces a choice between three options: to choose no label, to choose the NGO label or the industry label, taking into account the consequences of this decision for the pricing game. Which label (or no label) a firm signs up for will depend on the relative stringency of the different standards.

First, consider the case where in the second stage the industry-sponsored program responds to the NGO standard by setting a lower standard (i.e., $\underline{s} \leq s_I < s_N$). The firm decisions can be summarized in the following normal form:

	No label	NGO label	Industry label
No label	0,0	$\frac{(\bar{\theta}+\alpha-2\underline{\theta})^2}{9(\bar{\theta}-\underline{\theta})}(s_N-\underline{s}), \frac{(2\bar{\theta}-\alpha-\underline{\theta})^2}{9(\bar{\theta}-\underline{\theta})}(s_N-\underline{s})-\beta(s_N-\underline{s})^2$	$\frac{(\bar{\theta}+\alpha-2\underline{\theta})^2}{9(\bar{\theta}-\underline{\theta})}(s_I-\underline{s}), \frac{(2\bar{\theta}-\alpha-\underline{\theta})^2}{9(\bar{\theta}-\underline{\theta})}(s_I-\underline{s})-\beta(s_I-\underline{s})^2$
NGO label	$\frac{(2\bar{\theta}-\alpha-\underline{\theta})^2}{9(\bar{\theta}-\underline{\theta})}(s_N-\underline{s})-\beta(s_N-\underline{s})^2, \frac{(\bar{\theta}+\alpha-2\underline{\theta})^2}{9(\bar{\theta}-\underline{\theta})}(s_N-\underline{s})$	$-\beta(s_N-\underline{s})^2, -\beta(s_N-\underline{s})^2$	$\frac{(2\bar{\theta}-\alpha-\underline{\theta})^2}{9(\bar{\theta}-\underline{\theta})}(s_N-s_I)-\beta(s_N-\underline{s})^2, \frac{(\bar{\theta}+\alpha-2\underline{\theta})^2}{9(\bar{\theta}-\underline{\theta})}(s_N-s_I)-\beta(s_I-\underline{s})^2$
Industry label	$\frac{(2\bar{\theta}-\alpha-\underline{\theta})^2}{9(\bar{\theta}-\underline{\theta})}(s_I-\underline{s})-\beta(s_I-\underline{s})^2, \frac{(\bar{\theta}+\alpha-2\underline{\theta})^2}{9(\bar{\theta}-\underline{\theta})}(s_I-\underline{s})$	$\frac{(\bar{\theta}+\alpha-2\underline{\theta})^2}{9(\bar{\theta}-\underline{\theta})}(s_N-s_I)-\beta(s_I-\underline{s})^2, \frac{(2\bar{\theta}-\alpha-\underline{\theta})^2}{9(\bar{\theta}-\underline{\theta})}(s_N-s_I)-\beta(s_N-\underline{s})^2$	$-\beta(s_I-\underline{s})^2, -\beta(s_I-\underline{s})^2$

Simple computations reveal that this game always possesses pure-strategy Nash equilibria, as follows.

Lemma 3 *If the industry-sponsored program responds to the NGO label by setting a lower standard (i.e., $\underline{s} \leq s_I < s_N$), then the equilibrium set in firm label choices is:*

(1) (NGO label, Industry label) and (Industry label, NGO label) if $s_I = \underline{s}$ and $s_I < s_N \leq \underline{s} + \frac{(2\bar{\theta}-\alpha-\underline{\theta})^2}{9\beta(\bar{\theta}-\underline{\theta})}$.

(2) (NGO label, No label) and (No label, NGO label) if $\underline{s} < s_I < s_N < 2\underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})} - s_I$.

(3) (Industry label, No label) and (No label, industry label) if $\max\{\underline{s}, 2\underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})} - s_N\} \leq s_I \leq \underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})}$ *and* $s_N > s_I$.

Proof. *See Appendix B.* ■

It is interesting to note that the firm providing the lower quality will in fact provide the minimal environmental quality (i.e., $q_i = \underline{s}$), which may either result from this firm choosing no label at all or this firm choosing the industry label when $s_I = \underline{s}$ and $s_I < s_N \leq \underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})}$. The intuition behind this result is as follows. The profit for the lower-quality firm decreases as it increases quality. Increasing quality raises the fixed improvement cost and intensifies price competition. Further, in a covered market where all consumers make a purchase, increasing quality never pulls more consumers into the market. Therefore, the equilibrium always has the lower-quality firm producing quality $\underline{s}$ and the higher-quality firm matching either s_N or s_I.

Similarly, I can obtain the equilibrium outcome in the label choice stage in the case where industry-sponsored program responds to the NGO label by setting a higher standard (i.e., $\underline{s} \leq s_N < s_I$), which is described in the following lemma.

Lemma 4 *If the industry-sponsored program responds to the NGO label by setting a higher standard (i.e.,* $\underline{s} \leq s_N < s_I$*), then the equilibrium set in firm label choices is:*

(1) (NGO label, Industry label) and (Industry label, NGO label) if $s_N = \underline{s}$ *and* $s_N < s_I \leq \underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})}$.

(2) (NGO label, No label) and (No label, NGO label) if $\max\{\underline{s}, 2\underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})} - s_I\} < s_N \leq \underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})}$ *and* $s_I > s_N$.

(3) (Industry label, No label) and (No label, industry label) if $\underline{s} < s_N < s_I \leq 2\underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})} - s_N$.

Proof. *See Appendix B.* ■

4.2 The equilibrium industry and NGO standard

Having described the equilibria of the third-stage games, I move back to earlier stages in which the industry-sponsored program chooses its standard s_I in the second stage and the NGO-sponsored program sets its standard s_N in the first stage.

To do this, I will have two scenarios. A first scenario arises when firms' marginal cost increases slowly in environmental quality (i.e., $2\underline{\theta}$-$\overline{\theta} < \alpha < \frac{1}{2}(\underline{\theta}+\overline{\theta})$), where α can also be interpreted as marginal cost of quality per unit. I will refer to this as the low marginal cost of quality scenario. The second scenario is one where firms' marginal cost increases fast in environmental quality (i.e., $\frac{1}{2}(\underline{\theta}+\overline{\theta}) \leq \alpha < 2\overline{\theta}-\underline{\theta}$), and I will refer to this as high marginal cost of quality scenario.

4.2.1 Low marginal cost of quality

Here I focus on when the marginal cost of quality per unit is low: $2\underline{\theta}$-$\overline{\theta} < \alpha < \frac{1}{2}(\underline{\theta}+\overline{\theta})$, the optimal behaviors of the industry-sponsored and the NGO-sponsored programs, as well as the equilibrium outcomes.

First, I obtain the best-response of the industry-sponsored program, whose objective is to maximize industry profit. I will show that the industry-sponsored program has incentives to differentiate its standard from that set by the NGO program. As a result, a high NGO standard in the first stage may induce the industry program to set a low standard, whereas a low NGO standard may induce a high industry one.

For instance, suppose that the industry program observes a sufficiently low NGO standard, i.e., $\underline{s} < s_N < \widetilde{s}$.[2] Then the industry program knows that if it responds with a higher standard such that $s_N < s_I \leq 2\underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})} - s_N$, in the next stage, one firm will choose no label and the other firm will choose the industry label (see Lemma 4).

Hence, in this case, the industry program's optimal choice of standard is such a s_I that maximizes the following industry profit:

$$\Pi = \frac{(\overline{\theta}+\alpha-2\underline{\theta})^2}{9(\overline{\theta}-\underline{\theta})}(s_I-\underline{s}) + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9(\overline{\theta}-\underline{\theta})}(s_I-\underline{s}) - \beta(s_I-\underline{s})^2, \tag{8}$$

which gives

$$s_I = \underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2 + (\overline{\theta}+\alpha-2\underline{\theta})^2}{18\beta(\overline{\theta}-\underline{\theta})} \equiv s^*,^{3} \tag{9}$$

and the corresponding industry profit is simply:

[2] $\widetilde{s} = \underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2 - (\overline{\theta}+\alpha-2\underline{\theta})^2}{18\beta(\overline{\theta}-\underline{\theta})}$.

[3] It can be checked that $s_N < s^* < 2\underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})} - s_N$, for any $s_N \in (\underline{s}, \widetilde{s})$.

$$\Pi^* = \frac{[(\overline{\theta} + \alpha - 2\underline{\theta})^2 + (2\overline{\theta} - \alpha - \underline{\theta})^2]^2}{324\beta(\overline{\theta} - \underline{\theta})^2}. \quad (10)$$

On the other hand, if the industry program responds with a lower standard such that $s_I < s_N$ or a very high one (above $2\underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})} - s_N$), then in the next stage, one firm will choose no label and the other firm will choose the NGO label (see Lemma 3 and Lemma 4), and the industry profit becomes $\Pi = \frac{(\overline{\theta}+\alpha-2\underline{\theta})^2}{9(\overline{\theta}-\underline{\theta})}(s_N - \underline{s}) + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9(\overline{\theta}-\underline{\theta})}(s_N - \underline{s}) - \beta(s_N - \underline{s})^2$. It is straightforward to check that the industry profit in this case is strictly lower than Π^* for any $s_N \in (\underline{s}, \widetilde{s})$. Thus, when faced with any $s_N \in (\underline{s}, \widetilde{s})$, the industry program's unique best response is to set $s_I = s^*$.

Similarly, I can characterize the industry program's best response when faced with a s_N in other remaining ranges, which are described in the following lemma.

Lemma 5 *When $2\underline{\theta}$-$\overline{\theta} < \alpha < \frac{1}{2}(\underline{\theta}+\overline{\theta})$, the best response of the industry-sponsored program is given by:*

(1) $s_I = s^*$, if $s_N = \underline{s}$ or $\underline{s} < s_N < \widetilde{s}$;
(2) $s_I = 2\underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})} - s_N$, if $\widetilde{s} \leq s_N < s'$;[4]
(3) $s_I = \underline{s}$ or $s_I > s_N$, if $s' \leq s_N \leq s^*$;
(4) $s_I = s^*$, if $s_N > s^*$.

I now turn to the first stage, where the NGO-sponsored program chooses s_N to maximize the aggregate environmental quality on the market, anticipating the reaction of the industry-sponsored program to s_N.

If the NGO program chooses either a very high standard (i.e., $s_N > s^*$) or a very low one (i.e., $s_N = \underline{s}$ or $\underline{s} < s_N < \widetilde{s}$), the industry program will always set $s_I = s^*$ in the next stage (see Lemma 5); furthermore, in equilibrium, one firm will provide quality $\underline{s}$, and the other firm will provide quality s^*. The resulting aggregate environmental quality on the market is:

$$\int_{\underline{\theta}}^{\widehat{\theta}} \underline{s} f(\theta)d\theta + \int_{\widehat{\theta}}^{\overline{\theta}} s^* f(\theta)d\theta = \underline{s} + \frac{(2\overline{\theta} - \alpha - \underline{\theta})[(\overline{\theta} + \alpha - 2\underline{\theta})^2 + (2\overline{\theta} - \alpha - \underline{\theta})^2]}{54\beta(\overline{\theta} - \underline{\theta})^2} \equiv E^* \quad (11)$$

I now argue that in this low marginal cost of quality scenario, no matter what standard

[4] $s' = \underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{18\beta(\overline{\theta}-\underline{\theta})}$.

the NGO program chooses in the first stage, the maximum of the aggregate environmental quality that can be reached is exactly E^*.

To see this, suppose that the NGO program instead sets an intermediate standard in the first stage (i.e., $\widetilde{s} \leq s_N < s^{'}$), and then the industry program's best response becomes $s_I = 2\underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})} - s_N$. Moreover, in equilibrium, one firm provides quality $\underline{s}$, and the other firm provides quality $(2\underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})} - s_N)$. In this case, the aggregate environmental quality on the market is:

$$E = \int_{\underline{\theta}}^{\widehat{\theta}} \underline{s} f(\theta) d\theta + \int_{\widehat{\theta}}^{\overline{\theta}} (2\underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})} - s_N) f(\theta) d\theta.$$

It can be shown that this expression is strictly decreasing in s_N. Since the NGO program's objective is to maximize the aggregate environmental quality, this implies that the NGO program should choose a standard as low as possible, which is $\widetilde{s}$ in this case and this, in turn, indicates that the industry program will set $s_I = 2\underline{s} + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})} - \widetilde{s} = s^*$ in the following stage, with resulting aggregate environmental quality equal to E^*.[5]

The following proposition presents the equilibrium outcome in this low marginal cost of quality scenario.

Proposition 2 *Suppose that* $2\underline{\theta}\text{-}\overline{\theta} < \alpha < \frac{1}{2}(\underline{\theta}+\overline{\theta})$*, i.e., the marginal cost of quality per unit is low. Then, the following equilibria exist:*

(1) $s_N = \underline{s}$ *and* $s_I = s^*$*; one firm adopts the NGO label and the other firm adopts the industry label.*

(2) $\underline{s} < s_N < \widetilde{s}$ *and* $s_I = s^*$*; one firm is unlabeled and the other firm adopts the industry label.*

(3) $s_N = \widetilde{s}$ *and* $s_I = s^*$*; one firm is unlabeled and the other firm adopts the industry label.*

(4) $s_N = s^*$ *and* $s_I > s^*$*; one firm is unlabeled and the other firm adopts the NGO label.*

(5) $s_N = s^*$ *and* $s_I = \underline{s}$*; one firm adopts the industry label and the other firm adopts the NGO label.*

(6) $s_N > s^*$ *and* $s_I = s^*$*; one firm is unlabeled and the other firm adopts the industry label.*

[5] Similar arguments show that the optimal NGO standard will be exactly $s_N = s^*$ if the NGO program considers to choose a standard between $s^{'}$ and s^*, and the industry program will respond with a higher standard (i.e., $s_I > s_N$) or a very low one (i.e., $s_I = \underline{s}$), with resulting aggregate environmental quality still equal to E^*

Further, in all equilibria, one firm produces environmental quality $\underline{s}$ whereas the other firm produces environmental quality s^*, which is given by (9); the equilibrium aggregate environmental quality and industry profit are equal to E^* and Π^*, which are given by (11) and (10), respectively.

It turns out that, in the situation where both NGO and industry labels are adopted, the equilibrium industry standard (NGO standard) would be exactly equal to $\underline{s}$, the lowest possible quality standard. The explanation is straightforward. As explained earlier, the lower-quality firm will always provide the minimal environmental quality $\underline{s}$ and the rival higher-quality firm match either s_N or s_I. Therefore, the only circumstance under which each program takes a segment of the market is when either $s_I = \underline{s}$ and $s_N = s^*$ or $s_N = \underline{s}$ and $s_I = s^*$. This implies that in this situation the environmental quality a labeled firm produces may be just what it would provide if it adopts no label at all.

Another interesting observation is that when faced with any $s_N \neq s^*$ (either $s_N < s^*$ or $s_N > s^*$) the industry program will set $s_I = s^*$ in the next stage. On the other hand, when faced with $s_N = s^*$, the industry program will respond by choosing either a low or high-dominated standard, which are $s_I = \underline{s}$ and $s_I > s^*$, respectively. In fact, the industry program may even choose to not enter into the market if the NGO program indeed sets $s_N = s^*$ in the first stage. Intuitively, the industry program cares only about the aggregate industry profit irrespective of what label firms adopt. As mentioned earlier, the equilibrium industry profit will always takes the form, $\Pi = \frac{(\bar{\theta}+\alpha-2\underline{\theta})^2}{9(\bar{\theta}-\underline{\theta})}(s-\underline{s}) + \frac{(2\bar{\theta}-\alpha-\underline{\theta})^2}{9(\bar{\theta}-\underline{\theta})}(s-\underline{s}) - \beta(s-\underline{s})^2$, and it is clear to see that the standard maximizing this expression is exactly s^*. Therefore, as long as the NGO standard is at level s^*, the industry program becomes indifferent between setting a standard that will not be adopted (i.e., $s_I > s^*$) or even staying out; however, if this is not the case, the industry program will enter the market with a standard equal to s^*.

These findings are broadly consistent with empirical evidence. One prediction this framework yields is that when the NGO and industry programs compete, the industry program is likely to choose the lowest possible standard, with the result that firm adopting such an industry label hardly improves its environmental performance as compared to its past performance when it adopted no label at all. This is consistent with the empirical finding of Rivera et al. (2004, 2006), who found no evidence that ski resorts which participated in the industry Sustainable Slopes Program improved their environmental performance over time; meanwhile this industry Sustainable Slopes Program is competing

with the NGO-sponsored Ski Area Citizens' Coalition (SACC) Program on the ski-resort market.

A second prediction is concerned with the dynamics of the labeling marketplace. For instance, the model predicts that the industry program will stay out if the NGO standard is set at a rather high level (i.e., $s_N = s^*$); however, if the NGO program lowers its standard (i.e., $s_N < s^*$), the industry program will enter the market with its own quality standard. This might explain why the Alaska salmon industry which used to participate in the NGO-sponsored Marine Stewardship Council (MSC), ended its partnership with MSC and initiated its own labeling program, due to the concern that the MSC sustainability standard had been slackened.[6]

4.2.2 High marginal cost of quality

Here, I find the equilibrium outcomes when the marginal cost of quality per unit is high: $\frac{1}{2}(\underline{\theta}+\overline{\theta}) \leq \alpha < 2\overline{\theta}-\underline{\theta}$.

The argument for this scenario is similar to that used in analyzing the low marginal cost of quality scenario, which leads to the following result.

Proposition 3 *Suppose that* $\frac{1}{2}(\underline{\theta}+\overline{\theta}) \leq \alpha < 2\overline{\theta}-\underline{\theta}$*, i.e., the marginal cost of quality per unit is high. Then, the following equilibria exist:*

(1) $s_N = \underline{s}$ *and* $s_I = \widehat{s}$*; one firm adopts the NGO label and the other firm adopts the industry label.*

(2) $s_N = \widehat{s}$ *and* $s_I = \underline{s}$*; one firm adopts the industry label and the other firm adopts the NGO label.*

(3) $s_N = \widehat{s}$ *and* $s_I > \widehat{s}$*; one firm is unlabeled and the other firm adopts the NGO label.*

(4) $s_N > \widehat{s}$ *and* $s_I = \widehat{s}$*; one firm is unlabeled and the other firm adopts the industry label.*

Further, in all equilibria, one firm produces environmental quality $\underline{s}$ *whereas the other firm produces environmental quality* $\widehat{s}$*, which is given by (5); the equilibrium aggregate environmental quality and industry profit are equal to* $\widehat{E}$ *and* $\widehat{\Pi}$*, which are given by (6) and (7), respectively.*

Proof. *See Appendix B.* ■

[6] In fact, there is controversy on whether MSC standard is weak. For instance according to Ward (2008), the link between the MSC certification standard and improvement in the conservation of dolphins is weak and, further, the lack of clarity in the standard is another challenge to MSC.

Proposition 3 indicates that when the marginal cost of quality per unit is high (i.e., $\frac{1}{2}(\underline{\theta}+\overline{\theta}) \leq \alpha < 2\overline{\theta}-\underline{\theta}$), the equilibrium outcome in the presence of eco-label competition is identical to that under the single NGO label case. In particular, the equilibrium features the same combination of quality that can be offered as well as the same industry profit and, more importantly, the same aggregate provision of environmental quality as the single NGO label equilibrium outcome does (see Proposition 1).

Interestingly, the industry program may find it optimal to set a sufficiently stringent standard (i.e., $s_I = \widehat{s}$) such that in equilibrium the firm adopting such an industry label makes exactly zero profit, where $\widehat{s}$ is also the optimal level of NGO standard if the program can freely choose its own standard. In other words, the two standards set by the two programs with conflicting interests may coincide. This somewhat surprising result is due to the fact that the optimal level of the industry standard depends on the relative sizes of two effects: a "differentiation effect" and a "fixed cost effect". Increasing the standard increases the fixed improvement cost, which decreases industry profits. This is the fixed cost effect. On the other hand, increasing the standard increases the extent of vertical differentiation which, in turn, softens price competition and allows higher industry profits. This is the differentiation effect. The differentiation effect dominates when the marginal cost increases fast in environmental quality (i.e., $\frac{1}{2}(\underline{\theta}+\overline{\theta}) \leq \alpha < 2\overline{\theta}-\underline{\theta}$), so that the cost of environmental quality is borne largely by the marginal cost instead of the fixed improvement cost. Therefore, in the high marginal cost of quality scenario, the industry standard is set at level $\widehat{s}$, the highest possible standard level.

5 Welfare analysis

In this section, I analyze the effects of eco-label competition on social welfare. To do this, I examine the social welfare in the situation where the industry and NGO program compete and compare this to the welfare when the NGO program is alone in the market.

Welfare is defined as the sum of consumer surplus, industry profit and the aggregate environmental quality weighted by γ, where the parameter $\gamma \geq 0$ measures the weight the social planner places on environmental benefit:

$$W = CS + \Pi + \gamma E. \tag{12}$$

Table 2 gives the components of welfare—consumer surplus, industry profit, and the ag-

gregate environmental quality—depending on the value of α and whether the two programs compete or the NGO program is alone in the market.

	CS	Π	E
Single NGO-label and $2\underline{\theta}-\overline{\theta}<\alpha<2\overline{\theta}-\underline{\theta}$	$\widehat{CS}$	$\hat{\Pi}$	$\hat{E}$
Eco-label competition and $\frac{1}{2}(\underline{\theta}+\overline{\theta})\leq\alpha<2\overline{\theta}-\underline{\theta}$	$\widehat{CS}$	$\hat{\Pi}$	$\hat{E}$
Eco-label competition and $2\underline{\theta}-\overline{\theta}<\alpha<\frac{1}{2}(\overline{\theta}+\underline{\theta})$	CS^*	Π^*	E^*

It is noteworthy that for any given $\alpha\in[\frac{1}{2}(\underline{\theta}+\overline{\theta}),2\overline{\theta}-\underline{\theta})$, each welfare component is the same under eco-label competition as under a single NGO-label, as shown in the first two rows of Table 2.[7] However, if $2\underline{\theta}\text{-}\overline{\theta}<\alpha<\frac{1}{2}(\underline{\theta}+\overline{\theta})$, each welfare component is markedly different under label competition and a single NGO-label.

The following lemma presents when $2\underline{\theta}\text{-}\overline{\theta}<\alpha<\frac{1}{2}(\underline{\theta}+\overline{\theta})$ the relationships between each pair of welfare component.

Lemma 6 *When $2\underline{\theta}\text{-}\overline{\theta}<\alpha<\frac{1}{2}(\underline{\theta}+\overline{\theta})$ (i.e., the marginal cost of quality per unit is low), the following holds:*

(1) For all $\alpha\in(2\underline{\theta}\text{-}\overline{\theta},\frac{1}{2}(\underline{\theta}+\overline{\theta}))$, $\widehat{E}>E^*$ and $\Pi^*>\widehat{\Pi}$.

(2) $\widehat{CS}\geq CS^*$ when $2\underline{\theta}\text{-}\overline{\theta}<\alpha\leq\underline{\alpha}$, where $\underline{\alpha}=(5\text{-}3\sqrt{3})\overline{\theta}+(3\sqrt{3}-4)\underline{\theta}$; on the other hand, $\widehat{CS}<CS^*$ when $\underline{\alpha}<\alpha<\frac{1}{2}(\underline{\theta}+\overline{\theta})$.

(3) Further, $\Pi^*+CS^*>\widehat{\Pi}+\widehat{CS}$ for all $\alpha\in(2\underline{\theta}\text{-}\overline{\theta},\frac{1}{2}(\underline{\theta}+\overline{\theta}))$.

Proof. *See Appendix C.* ■

The above lemma implies that when $2\underline{\theta}\text{-}\overline{\theta}<\alpha<\frac{1}{2}(\underline{\theta}+\overline{\theta})$ (i.e., the marginal cost of quality per unit is low), the environmental benefit is always higher under a single NGO-label (i.e., $\widehat{E}>E^*$); meanwhile, the private benefit (the sum of industry profit and consumer surplus) is strictly lower, i.e., $\Pi^*+CS^*>\widehat{\Pi}+\widehat{CS}$.

Intuitively, there are two major sources of gains in private benefit from eco-label competition. One stems from the fact that when the two programs compete and $2\underline{\theta}\text{-}$

[7] The expressions for $\widehat{\Pi},\Pi^*,\widehat{E}$,and E^* are given by (7), (10), (6), and (11), respectively. The expressions for $\widehat{CS}$ and CS^* are provided in the Appendix C.

$\overline{\theta} < \alpha < \frac{1}{2}(\underline{\theta}+\overline{\theta})$, the equilibrium always has some standard equal to s^* appearing in the market, which is the industry-profit maximizing standard (see Proposition 2). In contrast, in the case of a single NGO-label, the optimal NGO standard is set at a level that substantially deviates from the industry's preferred quality standard. This therefore explains why the industry profit is always higher under eco-label competition, i.e., $\Pi^* > \widehat{\Pi}$. Secondly, eco-label competition always improves the welfare of consumers who purchase from the lower-quality firm (the firm producing quality $\underline{s}$), as the price they pay decreases but the quality does not. Meanwhile, to those who purchase from the higher-quality firm, they benefit from higher quality in the single NGO-label case as compared to the case of eco-label competition, but suffer from higher price. This negative effect on consumer surplus stemming from the price rise outweighs the positive one in terms of environmental quality when α is relatively large, i.e., $\underline{\alpha}<\alpha < \frac{1}{2}(\underline{\theta}+\overline{\theta})$. As a result, consumers may also be better off under eco-label competition.

The following proposition summarizes the above discussion and shows that such competition between industry and NGO label may improve social welfare.

Proposition 4 *(1) If the marginal cost of quality per unit is high (i.e., $\frac{1}{2}(\underline{\theta}+\overline{\theta}) \leq \alpha < 2\overline{\theta}-\underline{\theta}$), both eco-label competition and a single NGO-label lead to the same level of welfare.*

(2) If, on the other hand, the marginal cost of quality per unit is low (i.e., $2\underline{\theta}$-$\overline{\theta} < \alpha < \frac{1}{2}(\underline{\theta}+\overline{\theta})$), eco-label competition leads to higher welfare when the social planner places relatively low weight on environmental benefit, i.e., $0\leq \gamma <\underline{\gamma}$, where

$$\underline{\gamma} = \frac{(\overline{\theta} + \alpha - 2\underline{\theta})(5\overline{\theta} - \alpha - 4\underline{\theta})}{6(2\overline{\theta} - \alpha - \underline{\theta})}. \tag{13}$$

Proof. *See Appendix C.* ■

The intuition behind this result is straightforward. When $\frac{1}{2}(\underline{\theta}+\overline{\theta}) \leq \alpha < 2\overline{\theta}-\underline{\theta}$, consumer surplus, industry profit, and the weighted aggregate environmental quality under eco-label competition are identical to their levels under a single NGO-label. This, in turn, implies that the social welfare remains the same in both cases. On the other hand, when $2\underline{\theta}$-$\overline{\theta} < \alpha < \frac{1}{2}(\underline{\theta}+\overline{\theta})$, the private benefit is always higher under eco-label competition whereas the environmental benefit is strictly lower. Thus, whether eco-label competition increases social welfare depends on γ, the welfare weight on environmental benefit, and it is clear that eco-label competition enhances welfare as long as γ is relatively small, i.e., $0\leq \gamma <\underline{\gamma}$.

6 Conclusion

This paper examines the effects of the strategic competition between NGO- and industry-sponsored eco-labeling programs on environmental benefit and social welfare in a green market where eco-labels are potentially strategic variables for competing firms. I find that the introduction of an industry label alongside an existing NGO one may generate the same environmental benefit and improve social welfare, compared to a single NGO label.

This result has implications for the debate over the effectiveness of industry-sponsored eco-labels. The introduction of industry eco-labels has long been criticized by NGOs, citing them as an effort of "green-washing" and representing weak standards. This paper shows that this is not necessarily the case. In fact, if the NGO-sponsored program chooses a low standard in the first place, there is always room for the industry-sponsored program to enter and respond with a higher standard.

The public policy implication is that when both NGO and industry labels are reliable and perfectly understood by consumers, the competition between the two labels should be promoted particularly when the welfare weight that the social planner places on private benefit is relatively high. Otherwise, the authority may want to discourage such eco-label competition.

A Appendix A

Proof of Lemma 1.

The demand for the unlabeled firm is simply: $\underline{D}=(\frac{p_N^{NA}-\underline{p}^{NA}}{s_N^{NA}-\underline{s}}-\underline{\theta})/(\overline{\theta}-\underline{\theta})$, and demand for the NGO-labeled firm is: $D_N^{NA}=(\overline{\theta}-\frac{p_N^{NA}-\underline{p}^{NA}}{s_N^{NA}-\underline{s}})/(\overline{\theta}-\underline{\theta})$.Therefore, the profits obtained from the product market are:

$\underline{\pi}=(\underline{p}^{NA}-\alpha\underline{s})\underline{D}$,

$\pi_N^{NA}=(p_N^{NA}-\alpha)D_N^{NA}$.

It is straightforward to see that the optimal prices are: $p_N^{NA}=\frac{1}{3}[\alpha\underline{s}+2\alpha s_N^{NA}+(2\overline{\theta}-\underline{\theta})(s_N^{NA}-\underline{s})]$, $\underline{p}^{NA}=\frac{1}{3}[\alpha s_N^{NA}+2\alpha\underline{s}+(\overline{\theta}-2\underline{\theta})(s_N^{NA}-\underline{s})]$.

B Appendix B

Proof of Lemma 3.

I will write the conditions for (NGO label, Industry label) and (Industry label, NGO label) to be the equilibrium set in firm label choice:

$\frac{(\overline{\theta}+\alpha-2\underline{\theta})^2}{9(\overline{\theta}-\underline{\theta})}(s_N-s_I)$-$\beta(s_I-\underline{s})^2\geq 0$

$\frac{(\overline{\theta}+\alpha-2\underline{\theta})^2}{9(\overline{\theta}-\underline{\theta})}(s_N-s_I)$-$\beta(s_I-\underline{s})^2\geq\frac{(\overline{\theta}+\alpha-2\underline{\theta})^2}{9(\overline{\theta}-\underline{\theta})}(s_N-\underline{s})$

$\frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9(\overline{\theta}-\underline{\theta})}(s_N-s_I)-\beta(s_N-\underline{s})^2\geq 0$

$\frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9(\overline{\theta}-\underline{\theta})}(s_N-s_I)-\beta(s_N-\underline{s})^2\geq\frac{(\overline{\theta}+\alpha-2\underline{\theta})^2}{9(\overline{\theta}-\underline{\theta})}(s_I-\underline{s})$.

It is clear to see that in order to simultaneously satisfy the above four inequalities, the condition must be: $s_I=\underline{s}$ and $s_I<s_N\leq\underline{s}+\frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})}$.

Similarly, I can derive the conditions for other equilibrium set in firm label choice.

Proof of Lemma 4.

The argument is identical to that used to prove Lemma 3 and the only difference is that now $\underline{s}\leq s_N<s_I$. I will write down the conditions for (Industry label, No label) and (No label, industry label) to be the equilibrium set in firm label choice:

$\frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9(\overline{\theta}-\underline{\theta})}(s_I-\underline{s})-\beta(s_I-\underline{s})^2\geq 0$

$\frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9(\overline{\theta}-\underline{\theta})}(s_I-\underline{s})-\beta(s_I-\underline{s})^2\geq\frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9(\overline{\theta}-\underline{\theta})}(s_N-\underline{s})-\beta(s_N-\underline{s})^2$

$\frac{(\overline{\theta}+\alpha-2\underline{\theta})^2}{9(\overline{\theta}-\underline{\theta})}(s_I-\underline{s})\geq\frac{(\overline{\theta}+\alpha-2\underline{\theta})^2}{9(\overline{\theta}-\underline{\theta})}(s_I-s_N)$-$\beta(s_N-\underline{s})^2$

It is clear to see that in order to simultaneously satisfy the above four inequalities, the condition must be: $\underline{s}<s_N<s_I\leq 2\underline{s}+\frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9\beta(\overline{\theta}-\underline{\theta})}-s_N$.

Similarly, I can derive the conditions for other equilibrium set in firm label choice.

Proof of Proposition 3.

In order to understand Proposition 3, it is important to note that when $\frac{1}{2}(\underline{\theta}+\overline{\theta}) \leq \alpha < 2\overline{\theta}-\underline{\theta}$, the industry's optimal standard is no longer s^*. The reason is that when $\frac{1}{2}(\underline{\theta}+\overline{\theta}) \leq \alpha < 2\overline{\theta}-\underline{\theta}$, s^* exceeds $\widehat{s}$, which means if a firm provides quality s^*, it will make strictly negative profit.

Since in all equilibria, one firm produces environmental quality $\underline{s}$ whereas the other firm matches either s_N or s_I. The industry profit function can always be written as $\Pi = \frac{(\overline{\theta}+\alpha-2\underline{\theta})^2}{9(\overline{\theta}-\underline{\theta})}(s-\underline{s}) + \frac{(2\overline{\theta}-\alpha-\underline{\theta})^2}{9(\overline{\theta}-\underline{\theta})}(s-\underline{s}) - \beta(s-\underline{s})^2$. When $\frac{1}{2}(\underline{\theta}+\overline{\theta}) \leq \alpha < 2\overline{\theta}-\underline{\theta}$, which implies $\underline{s}<\widehat{s} < s^*$, Π is an increasing function in s. Therefore, the optimal industry standard is equal to $\widehat{s}$ in this case.

Once we have determined that the optimal industry standard becomes $\widehat{s}$ when $\frac{1}{2}(\underline{\theta}+\overline{\theta}) \leq \alpha < 2\overline{\theta}-\underline{\theta}$. The rest of the proof is identical to the analysis for deriving Proposition 2.

C Appendix C

Proof of Lemma 6.

First, I will compare $\widehat{E}$ and E^*. Define $\Delta E = \widehat{E}$-E^*.

$\Delta E = [\underline{s}+\frac{(2\overline{\theta}-\alpha-\underline{\theta})^3}{27\beta(\overline{\theta}-\underline{\theta})^2}] - [\underline{s}+\frac{(2\overline{\theta}-\alpha-\underline{\theta})[(\overline{\theta}+\alpha-2\underline{\theta})^2+(2\overline{\theta}-\alpha-\underline{\theta})^2]}{54\beta(\overline{\theta}-\underline{\theta})^2}] = \frac{(2\overline{\theta}-\alpha-\underline{\theta})(\overline{\theta}+\underline{\theta}-2\alpha)}{18\beta(\overline{\theta}-\underline{\theta})}$.

Since I consider the situation in which $2\underline{\theta}$-$\overline{\theta} < \alpha < \frac{1}{2}(\underline{\theta}+\overline{\theta}) < 2\overline{\theta}-\underline{\theta}$, $\Delta E > 0$ always holds.

Similarly, $\Delta\Pi = \widehat{\Pi} - \Pi^* = -\frac{(\overline{\theta}+\underline{\theta}-2\alpha)^2}{36\beta} < 0$ for all $\alpha \in (2\underline{\theta}$-$\overline{\theta}, \frac{1}{2}(\underline{\theta}+\overline{\theta}))$.

$\Delta CS = \widehat{CS} - CS^* = \frac{(\overline{\theta}+\underline{\theta}-2\alpha)}{54\beta(\overline{\theta}-\underline{\theta})}[0.5\alpha^2 + (4\underline{\theta}$-$5\overline{\theta})\alpha + (7\underline{\theta}\overline{\theta} - (\overline{\theta})^2 - 5.5(\underline{\theta})^2]$.

Therefore, $\Delta CS > 0$ is equivalent to $[0.5\alpha^2 + (4\underline{\theta}$-$5\overline{\theta})\alpha + (7\underline{\theta}\overline{\theta} - (\overline{\theta})^2 - 5.5(\underline{\theta})^2] > 0$.

Solving the inequality, I have:

$\widehat{CS} \geq CS^*$ when $2\underline{\theta}$-$\overline{\theta} < \alpha \leq \underline{\alpha}$, where $\underline{\alpha}$=(5-3$\sqrt{3}$)$\overline{\theta}$ + (3$\sqrt{3}$ − 4)$\underline{\theta}$; $\widehat{CS} < CS^*$ when $\underline{\alpha}<\alpha < \frac{1}{2}(\underline{\theta}+\overline{\theta})$.

Furthermore, in order to compare the private benefit (the sum of consumer surplus and industry profit) under the two cases, I need to determine whether $\Delta\Pi + \Delta CS$ is greater than 0. If $\Delta\Pi + \Delta CS > 0$, which implies that $\widehat{\Pi} + \widehat{CS} > \Pi^*+CS^*$, then the private benefit is higher under a single NGO label.

However, $\Delta\Pi + \Delta CS > 0$ if and only if $\alpha < 2\underline{\theta}$-$\overline{\theta}$ or $\alpha > 5\overline{\theta} - 4\underline{\theta}$, which contradicts to Assumption 1. Hence, the private benefit is higher under eco-label competition.

Proof of Proposition 4.

Suppose that the marginal cost of quality per unit is low (i.e., $2\underline{\theta}\text{-}\overline{\theta} < \alpha < \frac{1}{2}(\underline{\theta}+\overline{\theta})$). I define W^{NA} as the welfare level under a single NGO label, and W^{EC} as the welfare level under eco-label competition.

Further, $\Delta W = W^{NA} - W^{EC}$.

Clearly, by Lemma 6, we have

$\Delta W = \gamma \Delta E + \Delta \Pi + \Delta CS.$

$\Delta W > 0$ is equivalent to:

$\frac{\gamma(2\overline{\theta}-\alpha-\underline{\theta})}{3\beta(\overline{\theta}-\underline{\theta})} + \frac{(\overline{\theta}+\alpha-2\underline{\theta})(\alpha+4\underline{\theta}-5\overline{\theta})}{18\beta(\overline{\theta}-\underline{\theta})} > 0.$

Solving the inequality, I have $\Delta W > 0$ if $\gamma > \frac{(\overline{\theta}+\alpha-2\underline{\theta})(5\overline{\theta}-\alpha-4\underline{\theta})}{6(2\overline{\theta}-\alpha-\underline{\theta})} \equiv \underline{\gamma}$.

In other words, eco-label competition improves welfare if $0 \leq \gamma < \underline{\gamma}$.

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