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A Theory of Multi-Tier Ecolabel Competition

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Abstract

We model competing ecolabels sponsored by an industry trade association and an environmental group. For either sponsor in autarky, multi-tier labels are more attractive when there are many producers with high cost of quality, and the cost gap between low-cost and high-cost firms is large. When the two sponsors compete using binary ecolabels, multiple equilibria exist, and either sponsor may offer the more ambitious label; competition may increase environmental protection. When sponsors compete using multi-tier labels, however, there exists a unique equilibrium and competition produces less environmental protection than would the NGO in autarky.

1 Introduction

Global environmental issues such as biodiversity and climate change are increasingly important to citizens around the world, but are extremely difficult for governments to address with standard policy tools. The globalization of trade and the need for international coordination on global issues make harmonized world standards for environmental problems unlikely in the foreseeable future. Global trade law also makes it difficult for governments to attempt to regulate attributes of production processes beyond their borders. In response, many groups (both industry trade associations and environmental advocacy groups) have put increasing effort into international market mechanisms involving ecolabeling (Steering Committee, 2012).

Ecolabels can be of two types: binary or multi-tiered. Binary labels establish a threshold of performance and award a label to any product that meets or exceeds it. Binary labels include Forest Stewardship Certification (FSC) for forest products and Rainforest Alliance certification for coffee. Multi-tier labels establish a "ladder" of graduated performance levels, and award different labels depending on a product's performance. Perhaps the best-known multi-tier label is Leadership in Energy and Environmental Design (LEED) certification for buildings, which offers Certified, Silver, Gold, and Platinum levels.

Ecolabels also differ according to the sponsor of the label, with some offered by non-governmental organizations (NGOs) with a mission of environmental advocacy, and others offered by industry trade associations. NGO labels include FSC and Rainforest Alliance, while industry labels include Sustainable Forestry Initiative (SFI) certification for forest products and Green Globes for buildings.

Although there is a substantial theoretical literature on ecolabels, it has largely ignored the possibility of multi-tiered labels, the possibility of strategic competition between labels, and the different objectives of NGO and industry sponsors. Fischer and Lyon (2014) was the first paper to study strategic competition between labels, and to allow different objectives for NGO and industry sponsors. The present paper examines when each of these types of sponsors prefers to offer a binary label as opposed to a multi-tier label, and goes on to explore the nature of equilibrium when labels from both types of sponsors compete. We seek to characterize the nature of the ecolabels that are offered by each type of sponsor in equilibrium, and to assess the impact of multi-tiered labels and of label competition on overall environmental protection.[1]

We study credence goods, for which consumers cannot discern product quality on their own, even after consumption, and hence rely on labels to provide information about quality. We build on the standard duopolistic model of vertical product differentiation, in which all consumers prefer

[1] Li and van't Veld (2015) explore similar issues under a quite different set of assumptions, as we explain in more detail below.

higher-quality products, but differ in their willingness to pay for quality. However, because markets in which ecolabeling is common typically have many small producers rather than a duopoly, we allow for two classes of price-taking firms, some with low costs of improving quality and some with high costs of doing so. A multi-tier label creates incentive compatibility constraints that require label sponsors to distort environmental standards if they wish to induce low-cost firms to choose higher levels of performance. Consequently, from the perspective of either industry profits or environmental performance, binary labels may be preferred to multi-tier labels.

Two different types of organization may sponsor labels: an NGO seeks to maximize environmental benefits, while an industry trade association seeks to maximize the aggregate profits of the industry. For either type of sponsor, labels can take one of three basic forms. First, a single stringent standard can be set that can only be achieved by low-cost firms. Second, a single weak standard can be set that can be met by all firms. Third, two separate standards can be set, with the standard for low-cost firms distorted by the need to ensure that they do not pool with the high-cost firms.

For either sponsor in autarky, the optimal label format depends upon the mix of high-cost and low-cost firms, and the magnitude of the cost gap between them. When NGO and industry labels compete using binary labels, multiple equilibria exist, and environmental protection may be enhanced by competition. When the labels compete using multi-tier labels, however, there exists a unique equilibrium pair of standards, and competition always provides less environmental protection than would the NGO in autarky.

The remainder of the paper is organized as follows. Section 2 presents the basic model, its context within the literature, and the necessary and sufficient conditions for the existence of binary and multitiered labels. Section 3 characterizes binary ecolabels, considering first the binary label for the NGO in autarky, then the industry's optimal binary label, and finally the equilibrium when they compete. Section 4 characterizes multi-tier ecolabels, again considering first the optimal label for each entity in autarky, and then the equilibrium under competition. Section 5 discusses our results in the context of the stylized facts about ecolabel proliferation, and section 6 concludes.

2 Model Specifications and Context

We formulate a model with heterogeneous consumer preferences for ecolabel characteristics and heterogeneous costs for meeting ecolabel standards, depending on a firm's type. The demand side of our model uses the standard vertical product differentiation framework, in which all consumers

prefer greener products, but differ in their willingness to pay for environmental quality.[2] The supply side of our model, however, makes some novel assumptions that depart from the standard vertical differentiation model. In the canonical model, there are two firms with different costs of increasing product quality; the firms differentiate, with the high-cost firm offering a low-quality product and the low-cost firm offering a high-quality product and earning higher profits (e.g., Lehmann-Grube 1997). However, the actual markets in which ecolabeling is common—such as agriculture, forestry, and fisheries—typically have many small producers rather than a duopoly. Thus, in our model we allow for two classes of firms, some with low costs of improving environmental performance ("quality") and some with high costs of quality, but with many small price-taking firms in each class. The number of firms within each class is exogenously given, and we study the implications of varying the mix of these two classes of firms. The fixed industry size can reflect a short-run timeframe or be motivated by an (unmodeled) fixed cost of entry for each type.

Like many other papers, we treat environmental quality as a credence good, so consumers are unable to discern the environmental attributes of a product on their own, even after consumption. Hence they rely on ecolabels to provide information about these attributes. Two different types of organization may offer ecolabels: an NGO seeks to maximize environmental benefits, while an industry trade association seeks to maximize the aggregate profits of the industry.

Our focus on strategic ecolabel competition motivates some assumptions regarding the certification industry that depart from some related strands of the literature. One strand of the literature follows Lizzeri (1999), who assumes certification bodies seek to maximize their own profits, which leads them to set low standards and extract all industry rents through high certification fees. In the case of ecolabels, however, this seems to be sharply at odds with reality, where certification bodies are often non-profit organizations and chronically close to bankruptcy. Instead of assuming certification bodies maximize profits, we assume they costlessly set standards that serve the objectives of either NGOs or industry members. Another strand of the literature focuses on the imperfect nature of certification, allowing for Type I errors (incorrect rejection of a product that is truly green) and/or Type II errors (failure to reject a product that is not truly green). Hamilton and Zilberman (2006) pursue this approach in a setting with a monopolistic certification body and two quality options (green and brown) where sellers may engage in fraud, i.e. they allow for Type II errors. Mason (2011) pursues the noisy certification approach in a setting with a monopolistic certification body and two quality options (green and brown), and allows for both Type I and Type II errors. Harbaugh et al. (2012) study competition between exogenously set standards enforced

[2] Mussa and Rosen (1978) originated this modeling framework. Unlike a representative consumer model (Fischer and Lyon 2014), this structure implies that the demand for higher-quality products depends on both their own price and the price of lower-quality substitutes.

by error-prone auditors. While we believe it would be of interest to model the certification industry in more detail, including the possiblity of certification errors and the agency relationship between certification bodies and auditors (as in Lerner and Tirole 2006), we leave this task for future work, opting instead to focus on the implications of strategic competition between standard-setting bodies that have differing objectives in a setting where there is a continuum of possible quality options.

This paper builds on our own previous work (Fischer and Lyon 2014), which was the first paper to study strategic competition between two certification bodies with differing objectives. That paper, however, allowed each certification body to set only binary standards, so it assumed away the issue that takes center stage here, namely the incentives of certification bodies to choose between binary and multi-tiered standards. It also employed rather different models of demand and supply, using a simple representative consumer model based on that in Heyes and Maxwell (2004) and a continuum of firms with differing costs of quality. We believe the modeling choices we make in the present paper provide a better setting for exploring multi-tiered labels. The simpler treatment of the supply side of the model (two types instead of a continuum) allows us to obtain explicit results for strategic multi-tier competition in a more nuanced model of demand. At the same time, we maintain our focus on the competition between NGO-led and industry-led ecolabels.

The only other paper that examines similar issues is Li and van't Veld (2015), who also study strategic competition between NGO and industry ecolabels in a context with heterogeneous consumer preferences. However, they make some very different assumptions that lead to very different results. Most importantly, they assume all firms have the same marginal production cost of producing an environmentally-friendly product. As a result, all firms are indifferent between labels of varying stringency, and the industry association has no preferences regarding competition or the number of tiers offered by labeling schemes as long as at least one standard is set at the level that maximizes the green market's size. In addition, when they study competition between labels, they limit themselves to binary labels, as in Fischer and Lyon (2014). Thus, our paper is the first to obtain results on competition between certifiers setting multi-tiered labels.

2.1 Consumers

We consider two quality levels for the ecolabel standards: a basic level, s^B and a more ambitious level $s^A > s^B$. To represent the demand for ecolabel stringency, let consumers have utility $u = \mu s - p$, with $\mu \in [0, 1]$ distributed according to density function $f(\mu)$. Then we can find the consumer at μ^B who is indifferent between buying the product with the basic ecolabel and not buying at all:

$$\mu^B s^B - p^B = 0.$$

Next we identify the consumer at μ^A who is indifferent between the two qualities:

$$\mu^A s^A - p^A = \mu^A s^B - p^B.$$

Solving for these preference levels we have

$$\mu^B = \frac{p^B}{s^B}$$

and

$$\mu^A = \frac{p^A - p^B}{s^A - s^B}.$$

Assuming $f(\mu)$ is uniform on $[0, 1]$, then $f(\mu) = 1$, and as shown in Figure 1 there are three groups of consumers. Consumers with the lowest taste for quality do not buy an ecolabeled product, and their aggregate demand is

$$D^0 = \frac{p^B}{s^B}.$$

Consumers with the highest taste for quality purchase the high-quality product, and their aggregate demand is

$$D^A = 1 - \frac{p^A - p^B}{s^A - s^B}.$$

Finally, consumers with moderate taste for quality purchase the low-quality product, and their aggregate demand is

$$D^B = \frac{p^A - p^B}{s^A - s^B} - \frac{p^B}{s^B} = \frac{s^B p^A - p^B s^A}{s^B(s^A - s^B)}.$$

Note that in the case of a single, binary label with standard s^U and price p^U, consumer demand is

$$D^U = 1 - \frac{p^U}{s^U}.$$

[Insert Figure 1 about here]

2.2 Firms

On the supplier side of the market, there are N price-taking firms, each producing one unit of the product with environmental damage Z. Firms can take measures to reduce their environmental damages, with damages falling to $Z - s$ if the firm undertakes measures of stringency s. We will limit our analysis to cases where $s \geq 0$. The firms can be divided into two types, based on their costs of meeting the label requirements. For a firm of type i, the cost of adopting a label of stringency s^j is $\theta^i \left(s^j\right)^2$. Thus, costs are quadratic in label stringency and the marginal cost of quality is $2\theta^i$.

Profits for firm i pursuing label j are the revenues p^j minus these costs:

$$\pi^i = p^j - \theta^i \left(s^j\right)^2.$$

There are N^A firms with low cost parameter θ^A that are better suited to pursue the ambitious standard and N^B firms (having higher costs $\theta^B > \theta^A$) that are better suited for the basic label. (We make the matching between firms and standards precise below.) Let $N = N^A + N^B$. Our market scale is such that $N < 1$, since the distribution of consumers sums to 1.

2.3 Price Determination

If standards are set in such a way that the two types of firms prefer different labels, then in equilibrium supply equals demand, so that $N^A = D^A$ and $N^B = D^B$. We can then work backwards to solve for prices as a function of the standards. First, we obtain the price for the basic standard. From $N = D^A + D^B = 1 - p^B/s^B$, we obtain

$$p^B = s^B(1 - N).$$

Note that this price is a function of the basic standard alone and does not depend on the ambitious standard.

Next, we solve for the price of the ambitious standard. Setting $N^A = D^A$ and substituting in for p^B we obtain

$$p^A = s^A(1 - N^A) - s^B N^B.$$

Now we can compute profits. The profit of a low-quality firm meeting standard s^B is

$$\pi^B(s^B) = p^B - \theta^B \left(s^B\right)^2 = s^B(1 - N) - \theta^B \left(s^B\right)^2$$

and the profit of a high-quality firm meeting standard s^A is

$$\pi^A(s^A) = p^A - \theta^A \left(s^A\right)^2 = s^A(1 - N^A) - s^B N^B - \theta^A \left(s^A\right)^2.$$

Environmental gains from the industry's choices are

$$G = s^A D^A + s^B D^B.$$

2.4 Conditions for a Multi-Tier Equilibrium

The foregoing discussion assumes that the standards are such that a separating equilibrium exists in which the two types of firms prefer different labels. To characterize when this occurs, let us define the maximum *single* standard (i.e., when the other standard is absent; subscript "E" indicates this is the most environmentally friendly standard possible) that generates non-negative profits for each firm type:

$$\begin{aligned} s_E^B &\equiv (1-N)/\theta^B; \\ s_E^A &\equiv (1-N^A)/\theta^A > s_E^B. \end{aligned}$$

Other useful points of reference are the single standards that maximize profits for each *individual* type (subscript "π" indicates profit maximization):

$$\begin{aligned} s_\pi^B &\equiv s_E^B/2; \\ s_\pi^A &\equiv s_E^A/2 > s_\pi^B. \end{aligned}$$

For each firm type we have two constraints: 1) *Individual Rationality* (IR), which requires that profits be non-negative, and 2) *Incentive Compatibility* (IC), which requires that profits be higher with the firm's own standard than with the other type's standard, given the prevailing prices.

In a multi-tier equilibrium, for low-cost firms to prefer the ambitious standard, the IR constraint requires $\pi^A(s^A) \geq 0$, or $s^A \leq s_E^A$, and the IC constraint for an individual type-A firm ("ICA constraint") requires $\pi^A(s^A) \geq \pi^A(s^B) = p^B - \theta^A(s^B)^2$, which reduces to

$$s^A \leq s_{\text{ICA}}^A(s^B) \equiv s_E^A - s^B,$$

implying a one-to-one tradeoff as s^B is increased.

In a similar fashion, in order for high-cost firms to prefer the basic standard, the IR constraint requires $\pi^B(s^B) \geq 0$, or $s^B \leq s_E^B$, and the IC constraint for an individual type-B firm ("ICB constraint") requires $\pi^B(s^B) \geq p^A - \theta^B\left(s^A\right)^2$, which reduces to

$$s^B \geq s_{\text{ICB}}^B(s^A) \equiv (1-N^A)/\theta^B - s^A$$

Note that as long as the ambitious standard is above the profit-maximizing standard for the high-cost firms (which we will see can be safely assumed), the incentive-compatible basic standard that would generate the same profits as deviating to s^A will not be higher than that type's profit-

maximizing standard ($s^B_{\text{ICB}} \leq s^B_\pi$).

We also define an exclusionary standard $s^A_x(s^B)$ that is just high enough to exclude a high-cost firm from opting for the ambitious standard, given s^B:

$$s^A \geq s^A_x(s^B) \equiv (1 - N^A)/\theta^B - s^B.$$

Our basic notation is illustrated in Figure 2, which shows profits for each firm type as a function of s. Profits for Type B firms following the basic standard do not depend on the ambitious standard. Profits for the ambitious firms, however, do depend on the level of the basic standard, and in Figure 2 we illustrate type-A profits only for the case where $s^B = 0$. In addition, we graph the profits of an individual type-B firm should it deviate to s^A, which also depend on the level of the basic standard to which the other high-cost firms are adhering, and we again illustrate the case of $s^B = 0$. In the case shown, an ambitious standard set at s^A_π would fail to exclude a high-cost firm, since $s^A_\pi < s^A_x(0)$. Put differently, the standard s^A_π would entice a high-cost firm to adopt it if no basic standard were available, because $s^B = 0 < s^B_{\text{ICB}}(s^A_\pi)$. If, however, the cost difference between the firm types were larger, we could have $s^A_x(0) < s^A_\pi$, in which case the high-cost firm types would be excluded from the ambitious standard.

[Insert Figure 2 about here]

Note that if the high-cost firms have non-negative profits with the basic standard, then *a fortiori* the low-cost firms would have positive profits with that standard ($\pi^A(s^B) > \pi^B(s^B) \geq 0$); thus if the incentive compatibility constraint is met for the low-cost firms, then their individual rationality constraint is automatically satisfied, that is, $\pi^A(s^A) \geq \pi^A(s^B) > \pi^B(s^B) \geq 0$. Thus, in an equilibrium with two standards, four constraints must be met:

1. $0 \leq s^B \leq s^A$
2. $s^B \leq s^B_E$
3. $s^B \geq s^B_{\text{ICB}}(s^A)$
4. $s^A \leq s^A_{\text{ICA}}(s^B)$.

Together, these imply that s^B satisfies

$$\max\{s^B_{\text{ICB}}, 0\} \leq s^B \leq \min\{s^B_E, s^A_E - s^A_{\text{ICA}}\}.$$

3 Autarky Policies

We begin our analysis by characterizing the preferred labeling standards when each certifying body can set them on their own, without threat of competition. First, we consider the selection of binary

labels, as has been assumed in most of the prior literature on ecolabeling. Then we analyze behavior when a single labeling body has the option to set two tiers of standards.

3.1 Binary Labels

3.1.1 NGO

The NGO objective is to maximize total environmental gains:

$$G = N^A s^A + N^B s^B.$$

These gains are strictly increasing in each standard, so if the NGO can set only one standard, in autarky it chooses between s_E^A, the ambitious standard to which only the low-cost firms would adhere, and s_E^B, the single basic standard to which both types would adhere. It is straightforward to establish the conditions under which the ambitious option is preferred, namely

$$\theta^A/\theta^B < \Theta_N^{binary} \equiv \frac{N^A(1-N^A)}{N(1-N)}. \tag{1}$$

Proposition 1 *In autarky with binary labels, the NGO chooses a single ambitious standard of s_E^A when $\theta^A/\theta^B < \Theta_N^{binary}$, and chooses a single basic standard of s_E^B otherwise.*

Proof. The NGO simply chooses between s_E^A and s_E^B based on which offers more environmental protection, that is, on whether $N^A s_E^A > N s_E^B$. Some algebraic manipulation shows that this can be reduced to the condition $\theta^A/\theta^B < \Theta_N^{binary}$. ■

Figure 3 illustrates the NGO's choice of binary standard, based on the relative costs and market share of the low-cost types. The shaded areas indicate where the ambitious standard is preferred, and they depend on N. Together, the overlapping shaded areas reveal that the preference for an ambitious standard is more likely (i) the greater is the cost advantage of the low-cost firms over the high-cost firms, (ii) the greater is the number of low-cost firms relative to the the total number of firms, and (iii) the larger is the share of the certified market overall.

[Insert Figure 3 about here]

3.1.2 Industry

We assume the objective of the industry trade association in setting its standards is to maximize the total profits of all firms:

$$\Pi = N^A(s^A(1-N^A) - s^B N^B - \theta^A \left(s^A\right)^2) + N^B(s^B(1-N) - \theta^B \left(s^B\right)^2).$$

When it is limited to binary labels, the industry must choose between an ambitious standard and a basic standard. Let s^B_Π be the basic standard that maximizes joint profits with both types participating. These joint profits are

$$\Pi_B = N\left(s^B(1-N) - \overline{\theta}\left(s^B\right)^2\right),$$

where $\overline{\theta} \equiv (N^A\theta^A + N^B\theta^B)/N$. Taking the first-order condition, we solve for s^B_Π:

$$s^B_\Pi = \frac{(1-N)}{2\overline{\theta}}. \tag{2}$$

Note that since $\overline{\theta} \in (\theta^A, \theta^B)$, it is necessarily the case that $s^B_\Pi \in (s^B_\pi, s^A_\pi)$. In other words, if the industry chooses a basic standard, it is higher than the profit-maximizing standard for the high-cost firms and lower than the profit-maximizing standard for the low-cost firms. In addition, if s^B_Π is chosen, it must be that $s^B_\Pi < s^B_E$, since if $s^B_\Pi \geq s^B_E$, then by definition the high-cost firms have no profits while the low-cost firms have lower profits than they would with s^A_π, and hence s^B_Π cannnot be optimal.

Alternatively, the industry can choose an ambitious standard that cannot be met by the type B firms and maximizes the profits of the low-cost firms,

$$\Pi_A = N^A(s^A(1-N^A) - \theta^A \left(s^A\right)^2).$$

For a high-cost firm to be unwilling to participate in the ambitious standard, it must be that $p^A - \theta^B \left(s^A\right)^2 < 0$. If this condition holds for s^A_π (and the associated $p^A = s^A_\pi(1-N^A)$ that would obtain if no B's participated), then if the industry opts for the ambitious standard it will simply choose s^A_π. On the other hand, if $s^A_\pi(1-N^A) - \theta^B \left(s^A_\pi\right)^2 > 0$, then the industry must raise the the ambitious standard above s^A_π if it wants to exclude participation by high-cost firms. In the absence of a basic standard, the ambitious standard that just leaves the profit of a high-cost firm at zero (given that $s^B = 0$) is

$$s^A_x(0) = \frac{(1-N^A)}{\theta^B}.$$

We further note that $s^A_x(0) = (1-N^A)/\theta^B > (1-N)/\theta^B = s^B_E$. The difference exists because s^B_E is the standard at which high-cost firms earn zero profits if *all* of them certify to the standard, whereas $s^A_x(s^B)$ is the standard at which a single high-cost firm earns zero profits if it is the *only one* to certify

to the ambitious firms' standard. It is easy to see that $s_x^A(0) > s_\pi^A$ if $(1-N^A)/\theta^B > (1-N^A)/2\theta^A$, or $\theta^A/\theta^B > 1/2$.

We can now establish the conditions under which s_π^A is preferred to the basic label, which some algebra reveals to be

$$\frac{\theta^A}{\theta^B} < \Theta_I^{binary} \equiv \frac{N^A(1-N^A)^2}{(N+N^A)((N^A)^2+(1-N)^2)-2(N^A)^2}. \tag{3}$$

Similarly, we solve for the conditions under which $s_x^A(0)$ is preferred to s_Π^B:

$$\frac{\theta^A}{\theta^B} < \Theta_I^{exclude} \equiv \frac{1}{2} + \frac{N\sqrt{(2-N^A-N)\,N^B} - \sqrt{(N^B)^2\,(1-N^A)^2}}{2N^A(1-N^A)}$$

If $s_x^A(0)$ is chosen, the relative costs must lie in a window between 1/2 and $\Theta_I^{exclude} < \Theta_I^{binary}$, since a larger cost difference is required for the even more ambitious label to be preferred to the joint-profit-maximizing basic label.[3] We summarize this analysis in the following proposition.

Proposition 2 *In autarky with binary labels, industry chooses between* $\max[s_\pi^A, s_x^A(0)]$ *and* s_Π^B *based on which offers greater industry profits. It chooses a single ambitious standard of* s_π^A *if* $\theta^A/\theta^B < \Theta_I^{binary}$ *and* $\theta^A/\theta^B < 1/2$*; it chooses* $s_x^A(0)$ *if* $1/2 < \theta^A/\theta^B < \Theta_I^{exclude}$*; and it chooses a single basic standard of* s_Π^B *otherwise.*

Thus, much like the NGO, the industry chooses the ambitious label if the low-cost firms have a substantial cost advantage relative to the cost of the average firm. However, its response to the presence of a large number of firms is quite different. Intuitively, since total revenues are quadratic in the number of firms certifying, if N is large (i.e., $N > 0.5$) then it can be worthwhile to restrict the number of firms in the certified market by setting the ambitious standard and driving up the certified price.

Figure 4 illustrates the industry's choice of binary standard when $N = 1/2$. The shaded areas indicate where the single ambitious standard is preferred. The darker area reveals that when Type A costs are more than half those of Type B, the ICB constraint binds at s_π^A, and the industry must raise the standard to s_x^A. As a result, the tradeoff between binary standards is not monotonic in N^A/N. This is because as the low-cost market share increases, the cost of the exclusionary ambitious standard becomes higher, while s_Π^B approaches s_π^A, and their prices converge as well.

[Insert Figure 4 about here]

[3] Note that $\Theta_I^{exclude} < 1/2$ for small enough values of N^A, in which case $s_x^A(0)$ is not profit-maximizing.

The following proposition compares the industry and NGO binary standards in autarky.

Proposition 3 *In autarky with binary labels, the industry's binary standard may be higher than the NGO's binary standard but always offers less environmental protection.*

Proof. The industry chooses between $\max[s_\pi^A, s_x^A]$ and s_Π^B, and the NGO chooses between s_E^A and s_E^B. We showed above that $s_\Pi^B < s_\pi^A$ and $s_\Pi^B < s_E^B$, so whenever the industry chooses the basic label it is less stringent than the NGO's. For the ambitious label, any viable standard that will attract participation, including $\max[s_\pi^A, s_x^A]$ can be no stricter than the NGO's ambitious standard s_E^A. Yet, a range of parameters exists under which the industry chooses $s_x^A > s_E^B$ or chooses $s_\pi^A > s_E^B$ when the NGO would choose s_E^B over s_E^A, preferring greater participation. However, by definition, since the NGO maximizes environmental protection, any other choice of binary standard offers less. ■

Figure 5 overlays the binary standard choices for the industry and NGO when $N = 1/2$. Here we clearly see the regions where (i) both types would prefer a basic or ambitious standard, in which case the NGO always has a more stringent one; (ii) the NGO pursues an ambitious standard while the industry sets a basic one; and (iii) the industry sets an ambitious standard while the NGO chooses a basic one.

[Insert Figure 5 about here]

3.2 Multi-Tier Labels

We turn now to characterizing multi-tier labels. We show that, for both the NGO and the industry, a multi-tiered label is not always preferred to a single label. Furthermore, the nature of the circumstances under which a multi-tiered or binary label is preferred differs greatly across the label sponsors.

3.2.1 NGO Standards

First, consider the NGO incentives for a multi-tier standard in the absence of competition from the industry standard-setting organization. To maximize environmental gains, G, the NGO wants to set both standards as high as possible, subject to the individual rationality and incentive compatibility constraints (that $s^B \leq s_E^B$ and $s^A \leq s_{\text{ICA}}^A = s_E^A - s^B$). Thus, there are three options for the pair $\{s^A, s^B\}$:[4]

[4] Note that the NGO would be happy to have the high-cost firm want to adopt the more ambitious standard, so the s_{ICB}^B constraint is not a concern. Note also that the gains are linear in abatement and recall that $\partial s_{\text{ICA}}^A / \partial s^B = -1$, so there can be no interior solution with $0 < s^B < s_E^B$ and $s^A = s_{\text{ICA}}^A$.

1. $\{s_E^A, 0\}$, a single ambitious standard that can only be met by low-cost firms;
2. $\{s_E^A - s_E^B, s_E^B\}$, a multi-tier standard; or
3. $\{s_E^B, s_E^B\}$, a single basic standard in which both types participate.

Intuitively, the first strategy occurs when the NGO does not wish to dilute the ambitious standard (which is necessary to meet the ICA constraint) by offering a lower-tiered standard. The second, multi-tier strategy requires market conditions that support a differentiated standard (namely, a large enough cost differential). The third strategy of a single basic standard occurs when the multi-tier standard is not supported and the NGO prefers this binary standard over the ambitious one.

Formally, from the NGO's perspective, the multi-tier standard dominates the single ambitious standard when $N^A(s_E^A - s_E^B) + N^B s_E^B > N^A s_E^A$, or simply when $N^A < N/2$. Thus, when the low-cost firms have more than half of the labelled market share, the NGO does not wish to water down the ambitious standard to accomodate a positive basic standard.

The multi-tier standard dominates the single basic one when $N^A(s_E^A - s_E^B) + N^B s_E^B > N s_E^B$, or $s_E^A - s_E^B > s_E^B$. Note that this is equivalent to $s_\pi^A > s_E^B$. This means that the cost gap between the two types of firms is sufficiently large, i.e.

$$s_\pi^A > s_E^B \rightarrow \theta^A/\theta^B < \Theta_{ICA} \equiv (1 - N^A)/2(1 - N). \tag{4}$$

In this case, with the basic standard at s_E^B, the NGO can always find a higher standard that the low-cost firms will accept.[5]

The single ambitious standard dominates the single basic one when $N^A s_E^A > N s_E^B$, or when $\theta^A/\theta^B < \Theta_N^{binary}$, as in the previous section. Thus when the low-cost firms have more than half of the certified market, and the cost gap is large enough, the single ambitious standard dominates both the multi-tier and the single basic standard. Note that $\Theta_N^{binary} > 1/2$ when $N^A/N > 1/2$, and $s_E^B > s_\pi^A$ was the condition for the basic standard to dominate the multitiered one, so $s_E^B > s_\pi^A$ is a necessary condition to warrant a single basic standard.[6]

[5] Note that when $N > 1/2$, the right-hand side of this condition is greater than unity for small values of N^A, which means that the multi-tier standard is preferred to the single basic standard regardless of the cost gap when the number of low-cost firms is small enough.

[6] Note that Θ_N^{binary} is concave in N^A, is equal to unity at $N^A = N$ and $N^A = 1 - N$, and is strictly greater than unity for N^A between $1 - N$ and N. Thus, if $N < 1 - N$, i.e., if $N > 1/2$, then $\theta^A/\theta^B < \Theta_N^{binary}$ for all $N^A > 1 - N$. (Since $N^A \leq N$, there are two cases to consider. If $N < 1 - N$, i.e., if $N < 1/2$, then the right-hand side rises monotonically in N^A, reaching a maximum of unity when $N^A = N$. On the other hand, if $N < 1 - N$, i.e., if $N > 1/2$, then as N^A increases from zero, the right-hand side rises monotonically from zero to unity at $N^A = 1 - N$ and remains greater than unity for all $N^A \in (1 - N, N)$. In this case, $\theta^A/\theta^B < N^A(1 - N^A)/(N(1 - N))$ for all $N^A > 1 - N$.)

Market Shares	$\mathbf{N}^A/\mathbf{N} > \mathbf{1/2}$		$\mathbf{N}^A/\mathbf{N} < \mathbf{1/2}$	
Relative Costs	$\frac{\theta^A}{\theta^B} < \Theta_N^{binary}$	$\frac{\theta^A}{\theta^B} > \Theta_N^{binary}$	$\frac{\theta^A}{\theta^B} < \Theta_{ICA}$	$\frac{\theta^A}{\theta^B} > \Theta_{ICA}$
$\mathbf{s}_N^A$	s_E^A	s_E^B	s_{ICA}^A	s_E^B
$\mathbf{s}_N^B$	0	s_E^B	s_E^B	s_E^B

Table 1: Characterization of the NGO Label in Autarky

The possible equilibria are summarized in Table 1 and illustrated graphically in Figures 6a and 6b, which show how the set of equilibria changes as N increases. In particular, we illustrate separately the cases with three equilibria (we show the example of $N = 1/2$, but the figure is qualitatively similar for $N < 2/3$) and with two equilibria (when $N \geq 2/3$). The reason for the dependence on N is that the boundary conditions on θ^A/θ^B determining when a single basic standard is preferred to the alternatives change with N, as discussed above. In general, the equilibria can be characterized as follows, although the details depend upon N. When there are more low-cost firms than high-cost firms, and costs are sufficiently different, the NGO sets a single ambitious standard targeted at the efficient firms. When the high-cost firms are more numerous, and costs are sufficiently different, the NGO offers a multi-tier label in which the basic standard is at its maximum level and the ambitious standard is distorted downwards to accomodate the low-cost firms' IC condition. However, if the cost gap between the two types of firms is small, given the market shares, the NGO offers a single basic label that all firms can meet, and that pushes the high-cost firms up against their IR constraint. The NGO label for the case where $N = 1/2$ is illustrated below.

[Insert Figure 6a about here]

As mentioned above, if overall industry size is large enough, the NGO's strategy changes distinctly. We characterize this change in the following Lemma.

Lemma 1 *For $N \geq 2/3$, it is never optimal for the NGO to set the single basic standard.*
Proof. See the Appendix. ■

As the number of firms in the certification market grows, the value to the NGO of setting the single basic standard diminishes until at $N \geq 2/3$, it is dominated by one of the two other options. This case is illustrated in Figure 6b below.

[Figure 6b about here]

Thus, when $N \geq 2/3$, the NGO chooses between $(s_E^A, 0)$ and $(s_E^A - s_E^B, s_E^B)$. The multi-tier standard dominates the single ambitious standard when $N^A < N/2$.[7]

We summarize the foregoing analysis in the next proposition.

Proposition 4 *When multitier labels are possible, the NGO's optimal standard in autarky is as follows. If $N < 2/3$ and $N^A/N > 1/2$, then the optimal standard is $(s_E^A, 0)$ if $\theta^A/\theta^B < \Theta_N^{binary}$ and (s_E^B, s_E^B) if $\theta^A/\theta^B > \Theta_N^{binary}$. If $N < 2/3$ and $N^A/N < 1/2$, then the optimal standard is $(s_E^A - s_E^B, s_E^B)$ if $\theta^A/\theta^B < \Theta_{ICA}$ and (s_E^B, s_E^B) if $\theta^A/\theta^B > \Theta_{ICA}$. If $N > 2/3$, then the optimal standard is $(s_E^A, 0)$ if $N^A/N > 1/2$ and $(s_E^A - s_E^B, s_E^B)$ if $N^A/N < 1/2$.*

3.2.2 Industry Standards

Consider now the industry's behavior when it is free to set its own standards without competition from the NGO. The industry trade association wants to set its standards to maximize the total profits of all firms. We first show that the industry always prefers to avoid having all firms certify to a single standard.

Proposition 5 *In autarky with multitier labels, the industry never prefers an equilibrium in which both firm types certify to the same standard.*

Proof. The profit-maximizing joint standard is $s_\Pi^B \in (s_\pi^B, s_\pi^A)$. The industry can necessarily raise profits for both types of firms if it offers $\{s_\pi^A, s_\pi^B\}$. High-cost firms prefer s_π^B to s_Π^B, and their profits are unaffected by the ambitious standard. Low-cost firms prefer $s_\pi^A > s_\Pi^B$, and they also prefer that high-cost firms face a standard $s_\pi^B < s_\Pi^B$, since a lower standard for the B firms raises prices for A firms. To the extent that the industry then deviates from $\{s_\pi^A, s_\pi^B\}$, it must be that it further raises joint profits. ■

Thus, the industry always chooses either a single ambitious standard that excludes the high-cost firms, or a multi-tier standard. Interestingly, the combination of individually profit-maximizing standards is never the optimal multi-tier strategy for the industry. To see how the industry deviates from from this option, form the Lagrangian consisting of the industry objective function plus the two important constraints: the ICB constraint (assigned the shadow value λ), and the constraint that the basic standard cannot be negative (shadow value γ):

[7] The reader might wonder why Table 1 does not require that $N < 2/3$. The reason is shown in Lemma 1. When $N > 2/3$, $N^A/N > 1/2$ implies $\Theta_N^{binary} > 1$, so it is impossible to have $\theta^A/\theta^B > \Theta_N^{binary}$. Likewise, when $N > 2/3$, $N^A/N < 1/2$ implies that $N^A < 1/3$, which means that $\Theta_{ICA} > 1$ so it is impossible to have $\theta^A/\theta^B > \Theta_{ICA}$.

$$\begin{aligned}\mathcal{L} &= N^A(s^A(1-N^A) - s^B N^B - \theta^A\left(s^A\right)^2) + N^B(s^B(1-N) - \theta^B\left(s^B\right)^2) \\ &\quad -\lambda((1-N^A)/\theta^B - s^A - s^B) + \gamma s^B.\end{aligned}$$

The first-order condition with respect to the ambitious standard is

$$\frac{\partial \mathcal{L}}{\partial s^A} = N^A\left((1-N^A) - 2\theta^A s^A\right) + \lambda = 0.$$

Solving, we see the ambitious standard is independent of the basic standard, unless the ICB constraint is binding. (Although the ambitious standard does not affect the profits of the high-cost firms, it does affect their ICB constraint.) Thus,

$$s_I^A = s_\pi^A + \frac{\lambda}{2\theta^A N^A} \geq 0.$$

The industry always sets a positive standard for the low-cost producers that is at or above their profit-maximizing standard s_π^A, with the equality holding only when the ICB constraint does not bind. Under these conditions, the ICA constraint is always met.

The first-order condition with respect to the basic standard is independent of the ambitious standard, but not of the size of the ambitious market segment, since a higher s^B drives down prices and profits for the A firms:

$$\frac{\partial \mathcal{L}}{\partial s^B} = N^B((1-N) - 2\theta^B s^B) - N^A N^B + \lambda + \gamma = 0.$$

At the constrained optimum, the basic industry standard is defined by

$$s_I^B = \frac{1 - N - N^A + (\lambda+\gamma)/N^B}{2\theta^B} = s_\pi^B - \frac{N^A}{2\theta^B} + \frac{(\lambda+\gamma)}{2\theta^B N^B}.$$

Note that the shadow value of the ICB constraint raises both standards. It drives them further apart if $\theta^A N^A < \theta^B N^B$, or $\theta^A/\theta^B < N^B/N^A$, and brings them closer together otherwise.

Proposition 6 characterizes the industry's optimal strategy in autarky, making use of the notation $\Theta_I^{multi1} = (1-N^A)/(1+N^B)$ and $\Theta_I^{multi2} = 1 - N(1-N)/(2(1-N^A)N^A)$.

Proposition 6 *When multitier labels are possible, the industry's optimal standard in autarky is given by the following. If $N^A > 1-N$ and $\theta^A/\theta^B < 1/2$, the optimal standard is $\left(s_\pi^A, 0\right)$. If $N^A > 1-N$ and $\theta^A/\theta^B > 1/2$, the optimal standard is $\left(s_\pi^A + \frac{\lambda}{2N^A\theta^A}, s_{ICB}^B\right)$ if $\frac{\theta^A}{\theta^B} > \Theta_I^{multi2}$ and $\left(s_x^A, 0\right)$ otherwise. If $N^A < 1-N$ and $\theta^A/\theta^B > \Theta_I^{multi1}$, then the optimal standard is $\left(s_\pi^A + \frac{\lambda}{2N^A\theta^A}, s_{ICB}^B\right)$.*

Finally if $N^A < 1 - N$ *and* $\theta^A/\theta^B < \Theta_I^{multi1}$*, then the optimal standard is* $(s_\pi^A, s_\pi^B - \frac{N^A}{2\theta^B})$.

Proof. See the Appendix. ■

As Proposition 5 states, the industry association never wants to set a single standard to which both types would adhere. However, if costs are sufficiently dispersed, it may choose to set only a single ambitious standard, to avoid eroding *any* profits for the low-cost firms, even with a modest basic standard for the high-cost firms.

To better visualize these possibilities, we summarize the industry's optimal standard in Table 2 and illustrate them in Figures 7a and 7b. Note that the ambitious standard is always set at or above its autarkic profit-maximizing level, while the basic standard is always distorted downwards from its individually profit-maximizing level in order to reduce competition with the ambitious firms.

Market Shares	$\mathbf{N^A < 1 - N}$ (possible interior solution)		$\mathbf{N^A > 1 - N}$ (no interior solution possible)		
Relative Costs	$\frac{\theta^A}{\theta^B} < \Theta_I^{multi1}$ (if $\lambda = 0$)	$\frac{\theta^A}{\theta^B} > \Theta_I^{multi1}$	$\frac{\theta^A}{\theta^B} < \frac{1}{2}$	$\Theta_I^{multi2} > \frac{\theta^A}{\theta^B} > \frac{1}{2}$	$\frac{\theta^A}{\theta^B} > \Theta_I^{multi2}$
$\mathbf{s}_I^A$	s_π^A	$s_\pi^A + \frac{\lambda}{2N^A\theta^A}$	s_π^A	s_x^A	$s_\pi^A + \frac{\lambda}{2N^A\theta^A}$
$\mathbf{s}_I^B$	$s_\pi^B - \frac{N^A}{2\theta^B}$	s_{ICB}^B	0	0	s_{ICB}^B

Table 2: Characterization of the Industry Label in Autarky

This solution is presented graphically in Figure 7a for the case of $N = 2/3$, so $N^A = (1 - N)$ at $N^A/N = 1/2$. If the ambitious market segment is larger than the uncertified segment, and the A firms have substantially lower costs than the B firms, then the industry sets a single ambitious standard that only the A firms can meet. When $\theta^A/\theta^B < 1/2$, this is s_π^A; for a small range where $\theta^A/\theta^B > 1/2$, the industry raises the ambitious standard above s_π^A to exclude the high-cost firms. Otherwise the industry always offers a multi-tier label. When costs are more similar, the industry is constrained by the ICB requirement. If the ambitious segment is smaller than the uncertified segment but costs are sufficiently different, then the basic standard is $s^B = s_\pi^B - \frac{N^A}{2\theta^B}$.

[Insert Figure 7a about here]

Figure 7b presents the case of $N = 1/2$, so $N^A = (1 - N)$ at $N^A/N = 1$. In this case (and for any $N < 1/2$), the industry always chooses a multi-tier standard, and the only question is whether the ICB constraint it binding.

[Insert Figure 7b about here]

3.3 Comparing the NGO and Industry Schemes

The labeling schemes offered by the NGO differ from those of the industry in terms of the structure of the label, the number of firms that choose to label, and the stringency of standards.

In terms of label structure, the NGO offers a binary label for a wider range of parameter values than does the industry. For large enough values of N^A, both the NGO and the industry will set a binary standard. More specifically, the NGO chooses a single ambitious label whenever $N^A > N^B$ (or $N^A > N/2$) and $\theta^A/\theta^B < N^A(1-N^A)/(N(1-N))$, and the industry does so when $N^A > 1-N$ and $\theta^A/\theta^B < 1/2$. The NGO will also set a binary label when $N^A < N/2$ and $\theta^A/\theta^B > (1-N^A)/\left(2(1-N)\right)$, this time at a level s_E^B that both types of firm can meet. The industry never offers a binary label that attracts both types of firm.

The foregoing implies that there are many cases when the industry association would offer a multi-tiered label, but the NGO would not. If $N^A > N/2$, and either $N^A < 1-N$, and/or $\theta^A/\theta^B > \Theta_I^{multi2}$, then the NGO would set an ambitious binary label and the industry would offer a multi-tiered label. In this case, the industry label attracts greater participation than the NGO label. Alternatively, when $N^A < \min\{N/2, 1-N\}$ and $\theta^A/\theta^B > (1-N^A)/[2(1-N)]$, the NGO sets a basic binary label and the industry offers a multi-tier label.

In terms of stringency, the NGO's ambitious standard is always higher than the industry's ambitious standard when $s_N^A = s_E^A$. Furthermore, since the NGO only chooses a multi-tier label when $s_\pi^A > s_E^B$, that implies that $s_N^A = s_E^A - s_E^B > s_E^A - s_\pi^A > s_\pi^A$. However, the following lemma shows that the industry can set a higher ambitious standard.

Lemma 2 *The industry may set a more stringent ambitious standard than the NGO.*

Proof. This possibility occurs when both organizations want a multi-tier standard and $\lambda/(2N^A\theta^A) > s_E^A - s_E^B - s_\pi^A$. Since the stringency of the ICB constraint increases monotonically in θ^A/θ^B, we evaluate the standards at $\theta^A/\theta^B = 1$ and find $s_I^{A*} - (s_E^A - s_E^B) = (1-N)/2\theta^B > 0$. Such an outcome is also possible when the NGO sets a basic standard and $\lambda/(2N^A\theta^A) > s_E^B - s_\pi^A$. Consider the case where $s_E^B = s_\pi^A$, so the NGO is indifferent between the basic and multi-tier standard. If the ICB constraint is binding, then the industry will set a more stringent standard. ■

Thus, as the cost differences get small, the NGO may set a lower ambitious standard than the industry, in order to maintain a higher basic standard, while industry sets a higher ambitious standard in order to keep its basic standard low. These possibilities can be observed in Figures 6 and 7; the borderline between the basic and multi-tier standards for the NGO when $N = .5$ lies within the constrained multi-tier standards for the industry.

On the other hand, whenever the industry is not constrained, or the NGO prefers a single

ambitious standard, the industry standard is never higher than the NGO's.

It is also worth noting that the industry may set a more stringent standard for the high-cost firms than does the NGO. For example, there are parameter values for which the NGO sets an ambitious binary label (which implicitly sets $s_N^B = 0$) but the industry sets a multi-tiered label with $s_I^B > 0$. Thus, the industry tends to attract a greater number of firms to participate in labeling than does the NGO. However, as the following lemma shows, this is not always the case.

Lemma 3 *In autarky with multi-tier labels, the NGO may attract more participation than the industry if the total certified market size is large enough.*

Proof. The industry always garners as much or more participation except in the case where the industry wants a single ambitious label, while the NGO prefers a multi-tier label. The industry has a single ambitious label when $N^A > 1 - N$ and $\frac{\theta^A}{\theta^B} < \frac{1}{2}$ or $\frac{\theta^A}{\theta^B} < \Theta_I^{multi2}$. The NGO sets a multi-tier or single basic label if $N^A < N/2$ or $\frac{\theta^A}{\theta^B} > \Theta_N^{binary}$. These two situations can thus occur if $N/2 > N^A > 1 - N$, which requires $N > 2/3$. By Lemma 1, the NGO will not set a single basic standard in this range, but rather the multi-tier standard. Thus, when $N > 2/3$ and $\frac{\theta^A}{\theta^B} < \max[\frac{1}{2}, \Theta_I^{multi2}]$, the NGO has full participation and separate standards, while the industry only certifies the low-cost firms. ■

When the certified market is large and low-cost firms have both a big cost advantage and a large market share, the industry may prefer to set a single ambitious standard that yields a high price. The NGO would be willing to introduce more competition into the certified market, and would offer a multi-tier label instead. Thus, there exist situations in which the NGO will attract more participation than the industry in autarky.

4 Label Competition

We now consider what happens if the two organizations compete. We first analyze binary label competition, in which each can offer only one standard, and then competition with multi-tier standards.

4.1 Binary Label Competition

In binary label competition, each organization is restricted to offering a single standard. If two labels emerge as a result, we have two possible equilibria: in a "Normal" equilibrium, the NGO focuses on the ambitious firms and the industry takes the basic label; in a "Reverse" equilibrium, the opposite occurs, and the industry sets the ambitious label. Thus, for each best response function, we consider separately the cases where the organization chooses s^A and where it chooses s^B.

4.1.1 NGO Best Response

The NGO wants to maximize environmental gains $G = N^A s^A + N^B s^B$. Because its objective function is linear in the standards, the NGO's best response never involves an interior solution, and instead is always at a corner solution defined by a constraint. The two constraints from the NGO's binary label problem are still relevant: $s^B \leq s_E^B$ and $s^A \leq s_{\text{ICA}}^A = s_E^A - s^B$.

If the industry sets the ambitious standard, the NGO responds with $s_N^B = s_E^B$ unless $s_E^B > s_I^A$, in which case the NGO sets $s_N^B = s_I^A$ and leaves the high-cost firms indifferent between the two standards.

If the industry sets the basic standard, then the NGO maximizes its standard subject to the IC constraint for the low-cost firms, namely $s_N^A = s_{\text{ICA}}^A \equiv s_E^A - s_I$.[8] The NGO then chooses whichever gives the largest environmental gain. The latter is chosen if $N(s_E^B - s_I) > N^A(s_E^A - s_I)$, or if $N^B(s_E^B - s_I) > N^A(s_E^A - s_E^B)$.

4.1.2 Industry Best Response

If NGO sets the ambitious standard, then the industry has two options. It can set a standard that attracts only the high-cost firms, in which case it follows similar criteria for its choice of s^B in the multi-tier setting, so $s_I = \max\{0, s_{Int}^B, s_{\text{ICB}}^B\}$. Alternatively, it can set a basic standard that attracts both types of firms, i.e., $s_I = s_{\Pi}^B$.

If the NGO sets the basic standard, the industry's best response is given by the same first-order condition for s^A as in its autarky multi-tier problem, so $s_I = \max[s_\pi^A, s_{\text{ICB}}^A]$. (Recall that this condition does not depend on the level of s^B unless the ICB constraint is binding and the industry wants to avoid a multitier equilibrium).

4.1.3 Binary Label Equilibrium

We will consider the potential equilibria in turn. Importantly, for many relevant viable options, the industry's best response is not a function of the NGO's standard, or vice-versa, which greatly simplifies the analysis of the equilbrium in binary label competition.

Normal equilibrium In the "Normal" equilibrium the industry sets the basic standard, and the NGO determines the ambitious standard. In this case, the NGO maximizes its standard subject to the IC constraint for the low-cost firms, namely $s_N \leq s_{\text{ICA}}^A \equiv s_E^A - s_I$. As noted above, there are only four possible options for the industry: $0, s_{Int}^B$, s_{ICB}^B, or s_{Π}^B. However, we cannot have

[8] If $s_I < s_\pi^B$, the NGO could offer a higher standard that also attracts the high-cost firms while giving them the same profits, or $s_E^B - s_I$. However, as shown below, this never occurs in equilibrium.

an equilibrium with $(s_E^A, 0)$, since profits would be zero, which is obviously sub-optimal for the industry. Furthermore, both incentive compatibility constraints cannot bind simultaneously, so we cannot have an equilibrium with $(s_{\text{ICA}}^A, s_{\text{ICB}}^B)$. Thus, if this first type of equilibrium exists, it must be either $(s_E^A - s_{Int}^B, s_{Int}^B)$ or $(s_E^A - s_\Pi^B, s_\Pi^B)$.

Which is more profitable for the industry? One might think s_{Int}^B would be more profitable, since it derives from the industry's optimization problem. But it turns out that s_Π^B is more profitable. We know from Proposition 2 that the most profitable standard the industry can set and attract both types of firms is s_Π^B. Furthermore, whichever choice the industry makes, the NGO's standard is constructed to be just as profitable for the low-cost firms as the industry standard (and does not change the profits of high-cost firms). Therefore,

$$\Pi(s_E^A - s_\Pi^B, s_\Pi^B) = \Pi(s_\Pi^B, s_\Pi^B) > \Pi(s_{Int}^B, s_{Int}^B) = \Pi(s_E^A - s_{Int}^B, s_{Int}^B)$$

Thus, the Normal equilibrium takes the form $(s_E^A - s_\Pi^B, s_\Pi^B)$.[9]

Reverse equilibrium In the "Reverse" equilibrium, the industry sets the ambitious standard, while the NGO stakes out the basic standard. We know from above that the industry chooses $s_I = \max[s_\pi^A, s_{\text{ICB}}^A]$. However, since s_{ICB}^A is only necessary to maintain separation if $s^B < s_\pi^B$, and the NGO will never choose such a low standard, we thus have $s_I = s_\pi^A$. Since the low-cost firms will not be deterred from their profit-maximizing standard, the NGO will ask the most of the high-cost firms that it can. If $s_E^B < s_\pi^A$, its best response is s_E^B; if $s_E^B > s_\pi^A$, the NGO cannot attract any participation if it attempts to set a standard above the industry standard, so it opts to set the same standard ($s_N = s_\pi^A$) or, equivalently, not to set a standard at all ($s_N = 0$) and let the high-cost firms adhere to the ambitious label.[10]

Thus, the Reverse equilibrium takes the form $(s_\pi^A, \min\{s_E^B, s_\pi^A\})$.

Global stability As shown above, we have two potential equilibria, each involving a local best response to the other. For each potential equilibrium, however, we must also check its global stability, i.e. we must check that each player is willing to target its assigned group of firms, rather than defect and attempt to draw away the firms assigned to the other.

It turns out the NGO never has an incentive to deviate. For the Normal equilibrium, the NGO would only deviate if offering a basic standard instead would encourage more environmental gains from the high-cost firms than would be lost among the low-cost firms. Since $s_I^B = s_\Pi^B > s_\pi^B$, the

[9] Note that since $s_\pi^B < s_\Pi^B < s_\pi^A$, $s_E^A - s_\Pi^B > s_\pi^A$ and $s_\Pi^B > s_{\text{ICB}}^B$.

[10] Note that this result contrasts with Li and van't Veldt (2015), who find that the NGO always wants to enter against an Industry standard.

NGO could only attract the high-cost firms by offering a weaker standard, which it has no incentive to do. Furthermore, the low-cost firms would certify to a lower standard (s_{Π}^{B} instead of $s_{E}^{A} - s_{\Pi}^{B}$) if the NGO deviates to become the basic standard. Hence, the NGO would not want to deviate from the Normal equilibrium. Nor will the NGO deviate from the Reverse equilibrium, since it cannot ask for any more environmental gains from either kind of firm, given the industry sets s_{π}^{A}.

Thus, stability depends on whether the industry will deviate. To assess this, we explore two cases, depending on whether $s_{E}^{B} > s_{\pi}^{A}$. (This condition depends on the relative costs and relative market shares of the two types of firms: $\theta^{A}/\theta^{B} > \Theta_{ICA} = (1 - N^{A})/(2(1 - N))$. For it to hold, the low-cost firms cannot have costs that are less than half those of the high-cost firms; this threshold falls the larger is the market share of the low-cost firms.)

Narrow cost differential ($s_{E}^{B} > s_{\pi}^{A}$) If the industry deviates from the Normal equilibrium to set the ambitious standard instead, it would deviate to s_{π}^{A}. In this case, the NGO's standard of $s_{E}^{A} - s_{\Pi}^{B}$ will attract no participation, since $s_{E}^{A} - s_{\Pi}^{B} > s_{\pi}^{A}$. If $s_{E}^{B} > s_{\pi}^{A}$, deviating to s_{π}^{A} would attract the high-cost firms as well, who have no weaker option, but the industry would not prefer this, since by definition, the single basic standard that maximizes profits is s_{Π}^{B}, so $\Pi(s_{\Pi}^{B}, s_{\Pi}^{B}) > \Pi(s_{\pi}^{A}, s_{\pi}^{A})$. Thus, the Normal equilibrium is globally stable if $s_{E}^{B} > s_{\pi}^{A}$.

In contrast, the industry will deviate from the Reverse equilibrium if $s_{E}^{B} > s_{\pi}^{A}$. If the NGO sets no standard, then deviating to s_{Π}^{B} raises profits, since $\Pi(s_{\Pi}^{B}, s_{\Pi}^{B}) > \Pi(s_{\pi}^{A}, s_{\pi}^{A})$. If the NGO offers s_{π}^{A}, the industry would want to deviate to s_{int}^{B}, since doing so raises profits. Therefore, we cannot have a Reverse equilibrium if $s_{E}^{B} > s_{\pi}^{A}$.

Wide cost differential ($s_{E}^{B} < s_{\pi}^{A}$) This situation is more complicated. In the Normal equilibrium, if the industry deviates to set the ambitious standard s_{π}^{A}, the low-cost firms will certainly prefer that, and the high-cost firms will find both that and $s_{E}^{A} - s_{\Pi}^{B}$ out of their reach. Thus, the Normal equilibrium is stable as long as the industry prefers the joint basic standard to the single ambitious standard in autarky. Otherwise, if $\Pi(s_{\Pi}^{B}, s_{\Pi}^{B}) < \Pi(s_{\pi}^{A}, 0)$, the industry would deviate.

In the Reverse equilibrium, the NGO is offering $s_{E}^{B} < s_{\pi}^{A}$, so the industry will deviate if $\Pi(s_{E}^{B}, \max\{0, s_{Int}^{B}\}) > \Pi(s_{\pi}^{A}, s_{E}^{B})$. We know from profit maximization that $\Pi(s_{E}^{B}, \max\{0, s_{Int}^{B}\}) > \Pi(s_{E}^{B}, s_{\Pi}^{B})$. Furthermore, $\Pi(s_{E}^{B}, s_{\Pi}^{B}) > \Pi(s_{\Pi}^{B}, s_{\Pi}^{B})$; since $s_{\Pi}^{B} < s_{E}^{B} < s_{\pi}^{A}$, total profits are higher with this differentiation, because the high-cost firms have the same profits while the low-cost firms benefit from having a higher standard, closer to their profit-maximizing one. By definition, $\Pi(s_{\Pi}^{B}, s_{\Pi}^{B}) > \Pi(s_{\pi}^{A}, 0)$ if the industry prefers a single basic standard in autarky. Finally, $\Pi(s_{\pi}^{A}, 0) > \Pi(s_{\pi}^{A}, s_{E}^{B})$, since the high cost firms have no profits in either case, but the low-cost

firms' profits are lower with the positive basic standard. Thus, a sufficient condition for the industry to deviate from the Reverse standard is that in autarky it would prefer the single basic standard.[11]

Stability is not guaranteed if the industry prefers the ambitious standard in autarky, i.e. if $\Pi(s_\pi^A, 0) > \Pi(s_\Pi^B, s_\Pi^B)$. With this autarky preference, however, if s_E^B is very close to 0, it is clear that the industry would not want to deviate to leave the low-cost firms with a much weaker label. Thus, there exist some parameters with $s_E^B < s_\pi^A$ such that the industry would not want to deviate. More precisely, the Reverse equilibrium is stable if $s_E^B < s_\pi^A$ and $\Pi(s_E^B, \max\{0, s_{Int}^B\}) < \Pi(s_\pi^A, s_E^B)$.

The possibility remains that neither equilibrium is stable, which occurs if $s_E^B < s_\pi^A$, $\Pi(s_\Pi^B, s_\Pi^B) < \Pi(s_\pi^A, 0)$, and $\Pi(s_\pi^A, s_E^B) < \Pi(s_E^B, \max\{0, s_{Int}^B\})$.

In summary, we have demonstrated the following proposition.

Proposition 7 *When the two sponsors compete using binary labels, two types of local equilibria exist. (a) In the Normal equilibrium, the NGO sets an ambitious standard and the industry sets a basic standard; standards take the form* $(s_E^A - s_\Pi^B, s_\Pi^B)$ *where* $s_\Pi^B = (1-N)/2\overline{\theta}$. *This equilibrium is globally stable if and only if* $s_E^B > s_\pi^A$. *(b) In the Reverse equilibrium, the industry sets an ambitious standard of* s_π^A *and the NGO sets a standard of* $\min\{s_E^B, s_\pi^A\}$. *This equilibrium is globally stable if and only if* $s_E^B < s_\pi^A$, *the industry would prefer a single ambitious label in autarky, and* $\Pi(s_E^B, \max\{0, s_{Int}^B\}) < \Pi(s_\pi^A, s_E^B)$.

Thus, there are two kinds of globally stable equilibria, each of which applies for a specific set of parameter values. If the cost differential between firms is narrow, the NGO sets the ambitious standard, and the industry sets the basic standard it would choose in autarky. If, on the other hand, the cost differential is wide and the industry in autarky would prefer the single ambitious label, a Reverse equilibrium can be supported, where the industry sets the profit-maximizing standard for the low-cost firms, and the NGO asks for the most it can from the high-cost firms.[12]

Outcomes Notably, with the Normal equilibrium, the industry profit outcomes under competition are identical to what they would be under industry autarky. With the Reverse equilibrium, however, they are lower, because the industry would have preferred a single ambitious standard, but the NGO offers the high-cost firms a positive standard that keeps their profits the same but erodes the profits of the low-cost firms. Thus, we can state the following proposition:

[11] This autarky preference and the previously proven relationships ensure that $\Pi(s_E^B, \max\{0, s_{Int}^B\}) > \Pi(s_E^B, s_\Pi^B) > \Pi(s_\Pi^B, s_\Pi^B) > \Pi(s_\pi^A, 0) > \Pi(s_\pi^A, s_E^B)$.

[12] The possible existence of each of these types of binary equilibria parallels the findings in Fischer and Lyon (2014).

Proposition 8 *Suppose the two sponsors compete using binary labels. A globally stable equilibrium never raises profits relative to an industry binary label in autarky.*

Next, consider the environmental outcomes. Because the NGO only enters into label competition to increase environmental benefits relative to industry autarky, the interesting question is whether competition improves over NGO autarky.

Proposition 9 *Suppose the two sponsors compete using binary labels. Label competition erodes environmental gains relative to NGO autarky when $s_E^B > s_\pi^A$ ($\theta^A/\theta^B > \Theta_{ICA}$). Label competition can only improve environmental outcomes relative to NGO autarky if $s_E^B < s_\pi^A$ and $N^A < N^B$ and either 1) competition yields a Normal equilibrium ($\Theta_{ICA} > \theta^A/\theta^B > \Theta_I^{binary}$); or 2) competition yields a Reverse equilibrium and the NGO would set a basic standard in autarky (i.e., if $\Theta_{ICA} > \theta^A/\theta^B > \Theta_N^{binary}$).*

Proof. See the Appendix. ■

In other words, for label competition with a Normal equilibrium to offer better environmental protection than NGO autarky, one must have some special conditions. First, costs must be sufficiently differentiated ($s_E^B < s_\pi^A$), but not too differentiated, since the industry must prefer a single basic standard in autarky ($\theta^A/\theta^B > \Theta_I^{binary}$). At the same time, there must be more high-cost than low-cost firms ($N^B > N^A$). Alternatively, one could have the conditions for a Reverse equilibrium to hold while the NGO would prefer a single basic label in autarky, since the availability of the profit-maximizing standard for low-cost firms would allow them to certify to a higher standard.

We end this section by comparing our results with the results of Fischer and Lyon (2014), who study competition between binary labels under a different set of assumptions. The earlier paper differs from this one in two important ways. First, the previous paper used a representative consumer framework for the demand side of the model, while the present paper uses a vertical-differentiation framework based on heterogeneous consumers, as in Mussa and Rosen (1978). Second, the previous paper had a continuum of firms with varying costs of compliance, while the present paper has two types of firms differentiated by their cost of compliance. Despite the differences in assumptions, the basic results are qualitatively similar. First, there are two types of equilibria, a Normal one in which the NGO offers a more ambitious standard than does the industry, and a Reverse equilibrium in which the industry offers the more ambitious standard. Second, label competition sometimes offers better environmental performance than NGO autarky, especially if there is a large cost gap between high-cost and low-cost firms and there is a large number of high-cost firms. Under these conditions, a standard-setting entity faces a stark tradeoff between extracting substantial improvements from low-cost firms and inducing participation by high-cost firms. Because it is impossible to

accomplish both goals at once, label competition may be beneficial by setting a separate standard for each group of firms. An important difference between the two analyses, however, is that in the earlier paper, a Normal equilibrium always exists, while in the present paper its existence depends upon parameter values.

4.2 Equilibrium with Two Multi-Tier Labels

We turn now to label competition when both sponsors can offer multi-tiered labels. The fact that the NGO and the industry association have not only different preferences but also different situations in which they would not on their own offer a second label leaves room for label competition. Given the complexity of the results for the autarky cases, one might expect multi-tier label competition to produce extremely complicated results. However, exactly the opposite turns out to be the case. Unlike autarky, where each organization's labeling scheme depends upon details of the parameters, and unlike binary label competition, where many local equilibria are unstable, we are able to show the striking result that under multi-tier label competition there is a single perfect equilibrium regardless of bparameter values.

Proposition 10 *Under multi-tier label competition, the unique trembling-hand perfect equilibrium involves each player offering a multi-tier label of the form* (s_π^A, s_π^B).

Proof. See the Appendix. ■

Proposition 10 provides the remarkable result that there is a unique equilibrium pair of standards under label competition, with each sponsor offering a multi-tier label, each tier of which maximizes profits for one industry segment or the other. With multi-tier label competition between an NGO and industry association, the only outcome that satsfies trembling-hand perfection is identical multi-tier labels set at the same levels as if there were two separate industry groups! This outcome is illustrated in Figure 8 below.

[Figure 8 about here]

This result is surely counterintuitive at first blush, at least for readers familiar with the certification industry. The fact that the equilibrium is driven almost entirely by industry profit-maximization considerations, rather than environmental protection, seems to run counter to casual empirical evidence that NGOs set tough standards that go beyond what industry prefers. However the logic is clear and has two distinct components. First, the industry always sets its ambitious standard at the profit-maximizing level for the low-cost firms so it is impossible for the NGO to

induce these firms to adopt any more stringent label. Second, the industry prefers to distort downward the basic standard in order to increase overall industry profits, a result familiar from the vertical differentiation literature (Shaked and Sutton 1982). Thus, competition from the NGO can raise the basic standard and improve environmental performance and it is impossible for the industry to induce these firms to adopt a weaker standard. In effect, the NGO sets a minimum quality standard that reduces the excessive product differentiation desired by the industry.[13] The fact that each sponsor offers a multi-tier label is then simply a response to the possibility of trembles by the other player. We discuss the implications of this result further below.

5 Pareto-Improving Cooperative Solutions

To this point we have focused solely on non-cooperative solutions to the ecolabel game. Here we explore whether there may be cooperative outcomes that would be preferred by both players to the multi-tier equilibrium.

The question is whether there exists a $s_C^A \neq s_\pi^A$ and $s_C^B \neq s_\pi^B$ such that $\Pi(s_C^A, s_C^B) > \Pi(s_\pi^A, s_\pi^B)$ and $G(s_C^A, s_C^B) > G(s_\pi^A, s_\pi^B)$. Consider an adjustment that holds environmental benefits constant: $N^A s_\pi^A + (N - N^A)s_\pi^B = N^A s_C^A + (N - N^A)s_C^B$. Thus, we solve for this s_C^B as a function of s_C^A :

$$s_C^B = \frac{(1-N)(N-N^A)\frac{\theta^A}{\theta^B} + (1-N^A)N^A}{2(N-N^A)\theta^A} - \frac{N^A}{(N-N^A)}s_C^A$$

Maximizing profits $\Pi(s_C^A, s_C^B(s_C^A))$ with respect to s_C^A, we get

$$s_C^A = \frac{(N-N^A)\frac{\theta^A}{\theta^B} + (1-N^A)N^A}{2(N^A + (N-N^A)\frac{\theta^A}{\theta^B})\theta^A}.$$

Furthermore,

$$s_C^A - s_\pi^A = \frac{(N-N^A)N^A}{2(N^A + (N-N^A)\frac{\theta^A}{\theta^B})\theta^B} > 0$$

and

$$s_\pi^B - s_C^B = \frac{(N-N^A)N^A}{2(N^A + (N-N^A)\frac{\theta^A}{\theta^B})\theta^B} > 0.$$

Because we have held environmental benefits constant, we know that $s_C^B < s_\pi^B$.

Therefore, there is room to raise profits without lessening environmental gains (and vice-versa). Both parties can do better by coordinating than engaging in a non-cooperative multi-tier equilib-

[13] This result is similar to the analysis of minimum quality standards in Ronnen (1991).

rium. The result is more product differentiation than would occur in the noncooperative equilibrium, and more environmental effort by the low-cost firms. We leave the details of a cooperative analysis for future research.

6 Discussion

Our model yields a rich set of testable predictions, along with some normative implications. We first analyzed the labeling strategies of NGO and industry label sponsors in autarky, and showed that they differ substantially in their ecolabeling preferences. First, the NGO sets more stringent binary standards than does the industry. Second, the industry prefers multi-tier labels in a wider range of situations than does the NGO. Third, the industry never sets a binary standard that can be met by all firms, but the NGO does so when the cost differential between firms is narrow and there are roughly the same number of high-cost and low-cost firms. We then turned to label competion, and developed a series of results. First, when the cost differential between firms is narrow, binary label competition takes the Normal form, with the NGO setting the ambitious standard, and the industry setting the basic standard it would choose in autarky. Second, if the cost differential is wide and the industry in autarky would prefer the single ambitious label, a Reverse binary equilibrium can be supported, where the industry sets the profit-maximizing standard for the low-cost firms, and the NGO asks for the most it can from the high-cost firms. Third, binary label competition only improves environmental outcomes when there is a wide cost differential between firms and there are more high-cost than low-cost firms. Fourth, multi-tier label competition takes a unique, robust form that is largely determined by industry preferences. Finally, we showed that there is room for cooperative agreements between NGO and industry sponsors that can simultaneously raise profits and improve environmental gains. In this section, we discuss how these results map onto stylized facts about label competition.

As described by Conroy (2007), many certification systems sprang from campaigns by NGOs that attacked existing corporate practices and demanded higher standards. As first movers, these NGOs possessed market power in setting standards, as described by our analysis of NGO autarky. As our analysis of label competition demonstrates, however, these first movers lose considerable market power when confronted with entry by industry associations. Thus, theoretical models of ecolabels that ignore the role of competition are likely to provide quite an unrealistic picture that exaggerates the power of certification to shift markets.

Our results for Normal equilibria under binary label competition are consistent with the conventional wisdom that NGOs generally set tougher standards than industry associations. Consider, for example, the forest products sector, where Forest Stewardship Council (FSC) certification was

created in 1993 by a coalition of NGOs, including Greenpeace and the World Wildlife Fund, which were disappointed when nations failed to sign a global forest convention at the Rio Earth Summit (Sasser et al. 2006). The Sustainable Forestry Initiative (SFI), in turn, was created a year later by the American Forest and Paper Association, an industry trade group, as an alternative that gave industry members greater flexibility than the FSC system. Angered by the emergence of the SFI, which they clearly considered a weak alternative, NGOs supportive of FSC have continually blasted the SFI alternative as a sham. In fact, on May 20, 2005, a group of NGOs took out a full-page ad in the New York Times that said:

> "How can you trust the timber industry to measure its own environmental sustainability? Isn't that like the fox guarding the henhouse? Simply stated, the Sustainable Forestry Initiative program is a historic greenwashing effort to blur the public's trust in ecolabeling, helping loggers appear "sustainable" when it's really just the Same-old Forest industry."

One way our results may appear to depart from conventional wisdom, however, is that in practice many ecolabels take a binary form, which our model shows is dominated by a multi-tier structure under competition. There are several possible explanations for this. First, it could be that there is little variation in costs among industry members, so that there is no need for multiple tiers. Second, the use of binary labels may stem from the fact that many ecolabels are consumer-facing, and consumers are easily overwhelmed by choice complexity. Interestingly, the European appliance market uses ecolabels with multiple tiers. However, these are sponsored by the European Union, rather than being the outcome of competition between NGOs and an industry association. One might then think of them as being the outcome of a cooperative bargaining process such as that suggested in section 5 above. Third, the use of binary labels could derive from transaction costs in the creation and maintenance of complex, multi-tier labels. Fourth, it could be that in particular sectors, there is no consumer willingness to pay for greener products. In this case, ecolabels can only be supported by anti-corporate campaigns by NGOs, as in Baron's (2011) interesting model. Such campaigns may need to keep the focus on a simple binary ecolabel in order to maximize the strength of its campaign. We believe future research into these various rationales for the use of binary ecolabels would be a promising avenue of investigation.

An interesting possibility is that current outcomes in the ecolabel market are not consistent with being in a long-run equilibrium. In fact, it turns out that there are good reasons to suspect that the current ecolabel market is not in long-run equilibrium. According to www.ecolabelindex.com, the number of ecolabels on offer has grown sharply over time, with 444 currently available in 197 countries and 25 industry sectors. Many commentators have decried this proliferation of labels,

fearing that it leads to consumer confusion and a loss of faith in the whole ecolabeling enterprise. For example, the Organization for Economic Cooperation and Development (OECD) has held a series of meetings devoted to exploring solutions to the problems created by ecolabel proliferation.[14] Many observers expect there will ultimately be consolidation in the ecolabel industry, just as there often is in other industries, but they have been at a loss to predict the form of the industry shakeout.[15] One reason that consolidation and equilibrium seem to be so slow in the ecolabel industry is that many label sponsors are non-profits, whose motivations may lie more in maintaining their position in the market rather than seeking out profitable or efficient outcomes.

Although our analysis is not explicitly dynamic, it provides some intriguing indications of how the ecolabel market may evolve over time. As shown in Proposition 8, the unique multi-tier equilibrium in our model involves two standards, each set at the level that is profit-maximizing for one class of firms. These are very much industry-driven outcomes, the only wrinkle being that there is somewhat more intense label competition than would be profit-maximizing for the industry as a whole. We also showed that a cooperative arrangement can be Pareto-improving, suggesting that consolidation and multi-stakeholder governance structures are likely to be part of any ultimate equilibrium. Interestingly, the apparel industry appears to have already evolved from a situation dominated by NGO labels to one dominated by business-led labels (Marques 2013). Concerns about sweatshop labor in the apparel industry were initially voiced in 1989 by an activist NGO, Clean Clothes Campaign (CCC). Over time, more and more organizations, both non-profit and industry-driven, entered the space, to the point that by 2005 the CCC was stating publicly its concern that there were "too many multi-stakeholder initiatives" (Marques, 2013, p. 26). In 2007, the Global Social Compliance Program (GSCP) was launched in an effort to harmonize the growing set of standards, and in 2013 Wal-Mart's Sustainability Consortium launched a Clothing, Textiles and Footwear working group to help drive convergence across standards in a way that was consistent with Wal-Mart's goals, which can be assumed to be largely market-driven.

There are signs of movement towards greater business domination within the realm of sustainability labels, as well. The U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED), which offers Certified, Silver, Gold and Platinum tiers, long held a monopoly position in building certification. It has recently attracted competition from the new Green Globes certification scheme, an industry-led alternative that offers faster and less expensive certification than LEED (Alter 2013), and that is supported by U.S. timber companies because it does not

[14] The OECD has also commissioned a series of white papers on ecolabel proliferation (Gruère, 2013; Lyon, 2014).

[15] Heyes and Martin (forthcoming) offer an interesting model in which ecolabels are differentiated both horizontally and vertically, which allows them to address the question of the equilibrium number of labels. Each label is binary and occupies a unique horizontal niche, however, so the issue of multi-tier competition does not arise in their model.

require FSC certification for lumber used in construction (Bach 2013). Within the timber sector, there is some evidence that the standards of the FSC and the SFI have gradually been converging, as FSC has become more market-friendly and SFI has attempted to incorporate more conservation concerns (Cashore et al., 2004). Surprisingly, however, recent work suggests that the standards of both sponsors have been tightening over time, perhaps due to changes in preferences among consumers (Lord et al., 2015). In the coffee sector, there appears to be convergence among multiple different labels in terms of core criteria, but with some level of differentiation remaining as labels go after consumer groups with differing preferences (Reinecke et al., 2012).

Although it would be premature to claim that labeling schemes for any of these sectors have reached equilibrium, our results suggest that a plausible long-run outcome will be convergence toward business-led harmonized certification schemes, perhaps followed by a cooperative bargaining process that results in a single multi-stakeholder label.

7 Conclusions

We have developed the first theoretical model of competitive multi-tier ecolabels, and characterized such labels for the case of autarky with an NGO or an industry association choosing the standards, as well as for competition between these two types of standard-setting organizations. This is an important theoretical step, since although the literature has focused on labels that are binary in structure, some prominent labels, such as the US Green Building Council's LEED certification, have multiple tiers instead and all labels could potentially choose to have multiple tiers. We present a theory explaining how standard-setting organizations choose between these two forms, and compare the differing incentives of industry trade associations and non-governmental organizations (NGOs) in setting standards. We show that for either type of organization in autarky, multi-tier labels are more attractive when the number of low-cost producers is small and the cost gap between low-cost and high-cost firms is large. When the two types of organization compete using binary ecolabels, multiple equilibria may exist and the NGO may offer either the more ambitious label or the basic label; competition may provide either more or less environmental protection depending upon industry structure. When competition occurs using multi-tier labels, however, there exists a unique equilibrium pair of standards, and competition always provides less environmental protection than would the NGO in autarky. Our results suggest that competition between ecolabels may involve mergers or cooperation between NGO and industry labels, but that in equilibrium the standards reflected in these labels will be dominated by considerations of profitability as opposed to environmental protection.

8 Appendix

Proof of Lemma 1: The proof is by contradiction. Consider first the case where $N^A/N > 1/2$. The single basic standard is optimal for $\theta^A/\theta^B > N^A(1-N^A)/(N(1-N))$. The right-hand side of this expression is greater than unity for $N^A \in (1-N, N)$ so in order for the single basic standard to be optimal we must have $N^A < 1-N$. However, we are in the case where $N^A/N > 1/2$. Furthermore, $1-N > N/2$ is equivalent to $N < 2/3$. Hence $N > 2/3$ contradicts the assumption that $N^A/N > 1/2$. Now consider the case where $N^A/N < 1/2$. The single basic standard is optimal for $\theta^A/\theta^B > (1-N^A)/(2(1-N))$. The right-hand side of this expression is greater than unity for $N^A < 2N-1$, so in order for the single basic standard to be optimal we must have $N^A > 2N-1$. For $N > 2/3$, this requires $N^A > 1/3$. However, we are in the case where $N^A/N < 1/2$ or $N^A < 1/3$. Hence it is impossible for the NGO to prefer the single basic standard when $N > 2/3$.■

Proof of Proposition 6: First, consider the case where the ICB constraint is not binding, so $\lambda = 0$. Then the basic standard is set lower than would be profit-maximizing just for the high-cost firms, because raising it lowers prices for the low-cost types. Let us define the basic standard that would prevail in an interior solution ($\gamma = 0$ and $\lambda = 0$) as

$$s^B_{Int} \equiv s^B_\pi - N^A/2\theta^B.$$

If $N^A < 1-N$ (that is, if the type A market share is smaller than the share of consumers not purchasing a labeled product), $s^B_{Int} > 0$. However, if $N^A > 1-N$, then $s^B_\pi - N^A/2\theta^B < 0$ which means that $\gamma > 0$, and $s^B = 0$.

Now, consider the case where the incentive compatibility constraint is binding for the high-cost firms, so $\lambda > 0$ and $s^B = s^B_{\text{ICB}}$. Since $s^B_{\text{ICB}} \leq s^B_\pi$, we know now that in all cases the industry wants to hold the high-cost firms to a lower standard than would maximize their individual type profits.

Next, we analyze the conditions under which the ICB constraint binds. To solve for the shadow value of the constraint, we set the optimal basic standard equal to the incentive-compatible basic standard, evaluated at the optimal ambitious standard: $s^B_I = s^B_{\text{ICB}}(s^A_\pi + \frac{\lambda}{2N^A\theta^A})$, or $s^B_\pi - \frac{N^A}{2\theta^B} + \frac{(\lambda-\gamma)}{2\theta^B N^B} = (1-N^A)/\theta^B - s^A_\pi - \frac{\lambda}{2\theta^A N^A}$, which leads to

$$\lambda = \frac{N^A N^B}{N^B\theta^B + N^A\theta^A}((1+N^B)\theta^A - (1-N^A)\theta^B) + \frac{N^A\theta^B}{N^B\theta^B + N^A\theta^A}\gamma.$$

We noted above that if $N^A < 1-N$, then the industry offers the high-cost firms a positive

standard. Solving for $\lambda = 0$ when $\gamma = 0$, we find that the ICB constraint binds if

$$\frac{\theta^A}{\theta^B} > \Theta_I^{multi1} \equiv \frac{1 - N^A}{1 + N^B}. \tag{5}$$

In this case, inequality (5) simply determines whether or not the multi-tiered standard adds the shadow value of the ICB constraint to the interior solution.

However, if $N^A > 1 - N$, then $s_{Int}^B < 0$, and the constraint that $s^B \geq 0$ will bind if the shadow value λ is not large enough on its own. In this case, as with the binary standard problem, as long as $\gamma > 0$, the industry chooses $\max[s_\pi^A, s_x^A]$. To explore this range of possibilities, recall that the ICB constraint binds if at s_π^A, $s_{\text{ICB}}^B > 0$. Substituting, we obtain

$$s_{\text{ICB}}^B(s_\pi^A) = (1 - N^A)/\theta^B - s_\pi^A = \left(\frac{\theta^A}{\theta^B} - \frac{1}{2}\right) s_E^A.$$

We see immediately that if the ambitious firms have very low relative costs ($\theta^A/\theta^B < 1/2$), then $s_{\text{ICB}}^B < 0$ and the constraint that $s^B \geq 0$ is the only one binding; in this case, the industry chooses a single standard of s_π^A. On the other hand, if the costs of the two firm types are more similar ($\theta^A/\theta^B > 1/2$), then the ICB constraint binds; however, the constraint that $s^B \geq 0$ may also bind. Even with a positive λ, the industry may still want a negative s^B to create more separation between the standards; if it is constrained from doing so, it will choose instead to raise s^A alone to meet the ICB requirement, before offering multi-tiered standards. In this case, the industry chooses s_x^A.

Finally, as the ICB constraint becomes more binding and the shadow value λ rises, we arrive again in the region where $s^B > 0$, so $\gamma = 0$, and we have the multi-tier solution $\{s_I^A, s_{ICB}^B\}$. To solve for this border, we set $s_x^A = s_I^A$, evaluated at the equilibrium value of λ; i.e., $(1 - N^A)/\theta^B = s_\pi^A + \frac{\lambda}{2N^A\theta^A} = \frac{N(1-2N^A+N)}{2(N^A\theta^A+N^B\theta^B)}$. Solving for the cost ratio, we find that (for $N^A > 1 - N$) the multi-tier solution occurs when

$$\frac{\theta^A}{\theta^B} > \Theta_I^{multi2} \equiv 1 - \frac{N(1-N)}{2(1-N^A)N^A}. \tag{6}$$

Note that $\Theta_I^{multi2} > \Theta_I^{multi}$ only when $N^A > 1 - N$. ■

Proof of Proposition 9: Start with the case where $s_E^B > s_\pi^A$, in which case a stable Normal equilibrium is assured. Suppose that in autarky the NGO would choose a single basic standard of s_E^B. Environmental gains are then eroded by Normal label competition if $N^A(s_E^A - s_\Pi^B) + N^B s_\Pi^B - N s_E^B < 0$. Since by assumption $s_E^A < 2s_E^B$, we have $N^A(s_E^A - s_\Pi^B) + N^B s_\Pi^B - N s_E^B < N^A(2s_E^B - s_\Pi^B) + N^B s_\Pi^B - N s_E^B = (N^A - N^B)(s_E^B - s_\Pi^B)$. Thus, $N^A < N^B$ is a sufficient condition for environmental losses. If instead $N^A > N^B$, but the NGO would still choose a basic standard in autarky, then

$N^A(s_E^A - s_\Pi^B) + N^B s_\Pi^B - N s_E^B < N^A(s_E^A - s_\Pi^B) + N^A s_\Pi^B - N s_E^B = N^A s_E^A - N s_E^B < 0$, by revealed preference for the basic standard. Alternatively, suppose the NGO would choose the ambitious label in autarky, for which $N^A > N^B$ is a necessary condition.[16] Then label competition also erodes environmental improvements because $N^A(s_E^A - s_\Pi^B) + N^B s_\Pi^B - N^A s_E^A = (N^B - N^A)s_\Pi^B < 0$. Thus, when $s_E^B > s_\pi^A$ Normal label competition is bad for the environment.

Now consider the case where $s_E^B < s_\pi^A$ and a Normal equilibrium exists. (This requires $\Theta_{ICA} > \theta^A/\theta^B > \Theta_I^{binary}$.)[17] As in the previous analysis, if $N^A > N^B$ then competition lowers environmental outcomes, regardless of the NGO's autarky preference. If $N^A < N^B$, on the other hand, then environmental gains are higher with label competition. If the NGO would set the basic standard in autarky, then $N^A(s_E^A - s_\Pi^B) + N^B s_\Pi^B - N s_E^B = N^A 2 s_\pi^A + (N^B - N^A)s_\Pi^B - N s_E^B > N^A 2 s_\pi^A + (N^B - N^A)s_\pi^A - N s_E^B = N(s_\pi^A - s_E^B) > 0$. If instead the NGO would set an ambitious standard in autarky (this requires $\Theta_{ICA} > \Theta_N^{binary} > \theta^A/\theta^B > \Theta_I^{binary}$), then $N^A(s_E^A - s_\Pi^B) + N^B s_\Pi^B - N^A s_E^A = (N^B - N^A)s_\Pi^B > 0$.

Finally consider the case where $s_E^B < s_\pi^A$ and a Reverse equilibrium exists. In this case, environmental gains are higher under competition if the NGO would set a basic standard in autarky: $N^A s_\pi^A + N^B s_E^B - N s_E^B = N^A(s_\pi^A - s_E^B) > 0$. If instead the NGO would set an ambitious standard in autarky, then environmental gains are lower under competition: $N^A s_\pi^A + N^B s_E^B - N^A s_E^A = N^B s_E^B - N^A s_\pi^A < N s_E^B - N^A s_\pi^A < 0$. ■

Proof of Proposition 10: Proposition 1 shows that $s_N^A > s_I^A = s_\pi^A$. Since s_π^A maximizes the profits of the low-cost firms, the industry will always undercut the NGO's ambitious standard with s_π^A, and the NGO will not be able to attract the low-cost firms away; were the NGO to offer the label, s_π^A is the best it can do. When it comes to the basic label, Table 2 shows that if the industry offers a basic standard, it is always distorted below s_π^B to maintain profits for the low-cost firms. Thus, the NGO can raise the standard for the high-cost firms to at least s_π^B, and the industry can do nothing to attract those firms away. Nor can the NGO go higher than s_π^B, because then the industry could attract the high-cost firms away with a lower standard. Furthermore, since s_π^A is the profit-maximizing standard for the low-cost firms regardless of s^B, even with a higher s^B than the industry would like, the industry has no incentive to further raise s^A to differentiate the products. How the outcome is implemented—that is, exactly which label each sponsor offers—is less clear. One possibility is that the two sponsors offer identical multi-tier labels. This equilibrium is robust to "trembles" in the sense of Selten (1975). If the industry makes a small deviation from $s_I = (s_\pi^A, s_\pi^B)$ to play $(s_\pi^A - \varepsilon, s_\pi^B - \mu)$, the NGO's best response for $\varepsilon > 0$ and/or $\mu > 0$ is

[16] If $N^A < N/2$ and $s_E^B > s_\pi^A$, then the NGO prefers a single basic standard, as shown earlier.
[17] This requires $\Theta^{sep} > \theta^A/\theta^B > \Theta_I^{binary}$.

to offer $s_N = (s_\pi^A + \varepsilon, s_\pi^B + \mu)$ and for $\varepsilon < 0$ and/or $\mu < 0$ the NGO's best response is to offer $s_N = (s_\pi^A + |\varepsilon|, s_\pi^B + |\mu|)$. Either way, as $\varepsilon \to 0$ and $\mu \to 0$, the NGO's best response converges to the equilibrium value.

Similar logic applies for the industry's best response. If the NGO makes a small deviation from $s_I = (s_\pi^A, s_\pi^B)$ to play $(s_\pi^A - \varepsilon, s_\pi^B - \mu)$, the industry's best response for $\varepsilon > 0$ and/or $\mu > 0$ is to offer $s_N = (s_\pi^A, s_\pi^B - \mu)$ and for $\varepsilon < 0$ and/or $\mu < 0$ the industry's best response is to offer $s_N = (s_\pi^A, s_\pi^B + \mu)$. Either way, as $\varepsilon \to 0$ and $\mu \to 0$, the industry's best response converges to the equilibrium value.

An alternative is that the industry offers only the ambitious standard and the NGO offers the basic standard, but this equilibrium is not robust to trembles. If the industry makes a small deviation from $s_I = (s_\pi^A, 0)$ to play $(s_\pi^A - \varepsilon, 0)$, the NGO's best response is to offer $s_N = (s_\pi^A + \varepsilon, s_E^B\})$. As $\varepsilon \to 0$, the NGO's best response does not converge to $s_N = (0, s_\pi^B)$. Similar logic applies for the industry's best response.

One might also think that it would be an equilibrium for the NGO to set the ambitious standard s_π^A and the industry to set the basic standard s_π^B, but this also does not survive the equilibrium refinement of trembling-hand perfection. Suppose the NGO makes a small deviation from playing $s_N = (s_\pi^A, 0)$ to play $(s_\pi^A + \varepsilon, 0)$ The industry's best response is to offer $s_I = (s_\pi^A, \max\{0, s_{Int}^B, s_{\text{ICB}}^B)$. Furthermore, even as $\varepsilon \to 0$, the industry's best response remains $(s_\pi^A, \max\{0, s_{Int}^B, s_{\text{ICB}}^B)$, and never converges to $(0, s_\pi^B)$. On the other hand, if the industry makes a small deviation from $s_I = (0, s_\pi^B)$ to play $(0, s_\pi^B - \varepsilon)$, the NGO's best response is to offer $s_N = (s_{\text{ICA}}^A, s_\pi^B + \varepsilon)$. Again, the NGO's best response does not converge to $(s_\pi^A, 0)$ even as $\varepsilon \to 0$.■

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Figure 1: Consumer Demand

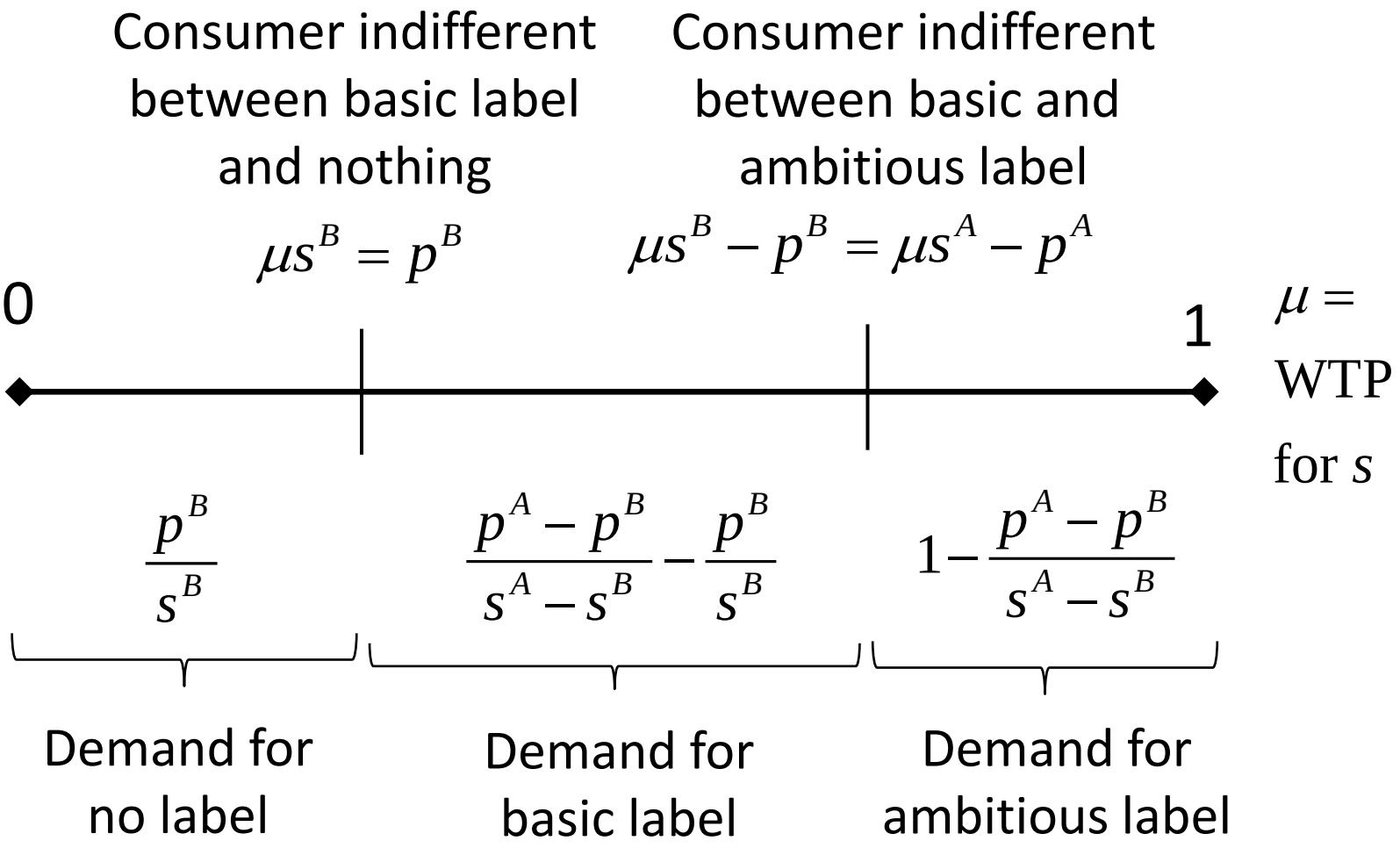

Figure 2: Profit functions by firm type with a single standard

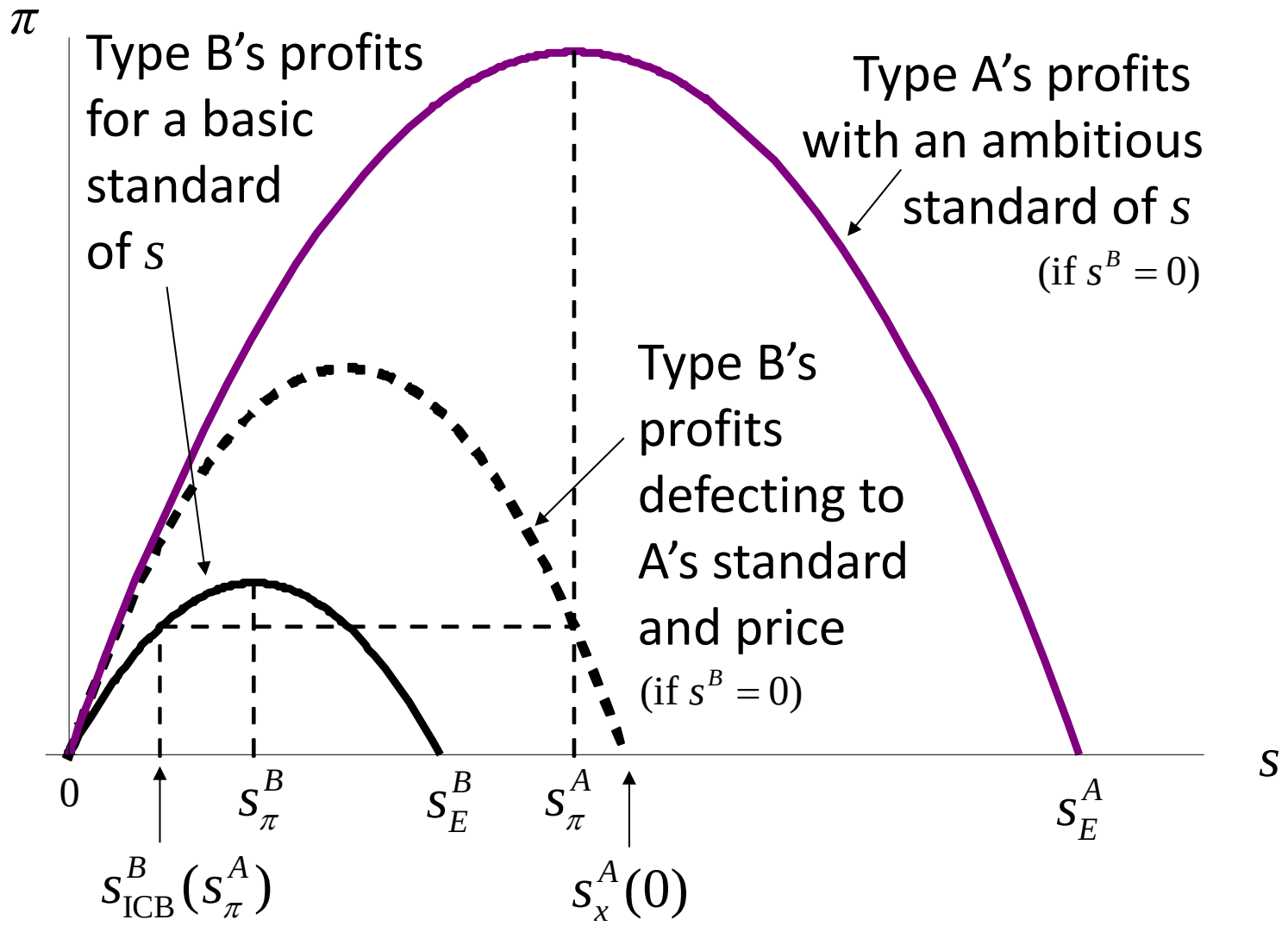

Figure 3: NGO binary strategy as a function of *N*

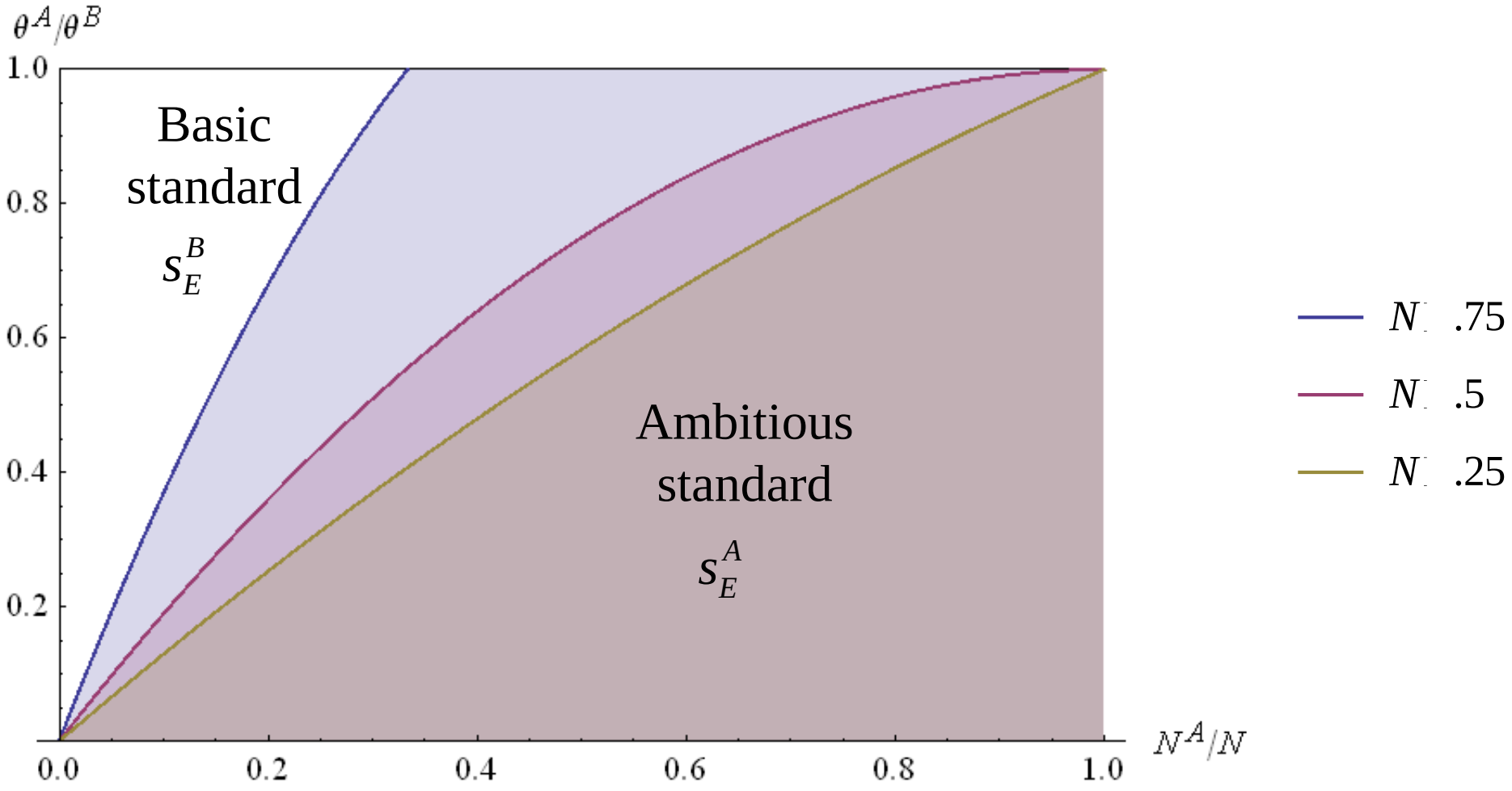

Figure 4: Industry Binary Strategy (N = 1/2)

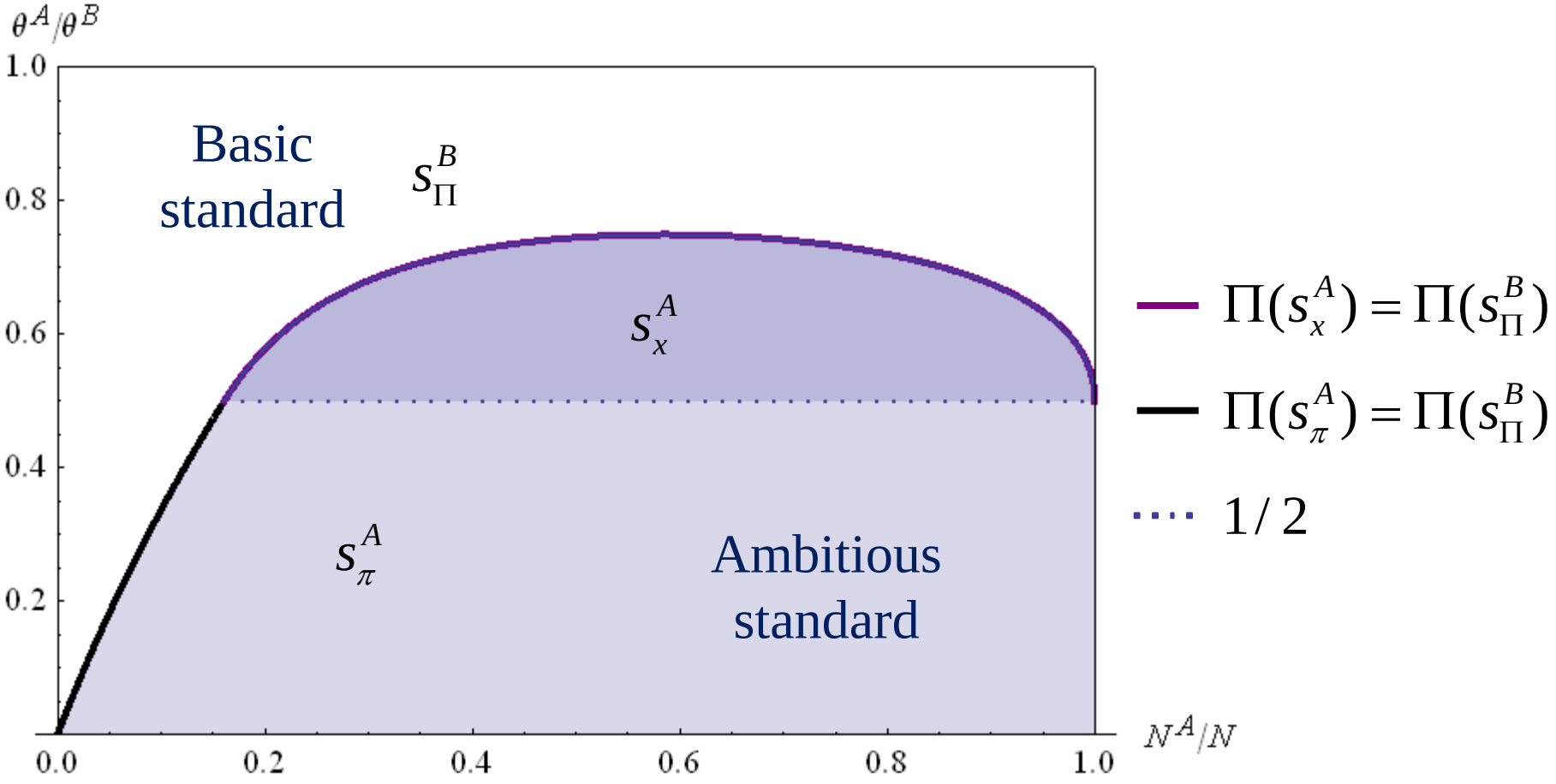

Figure 5: Binary Strategies (N = 1/2)

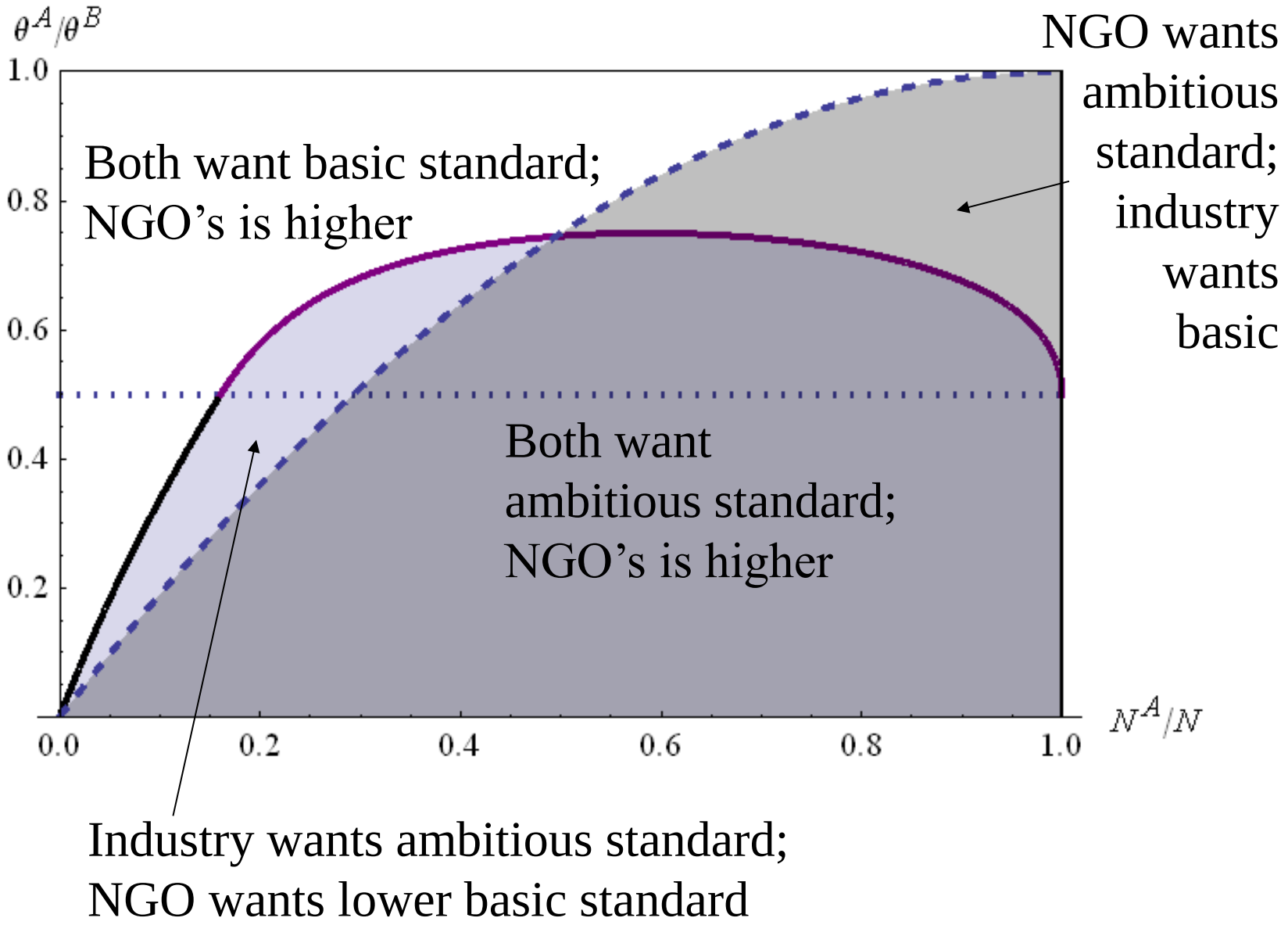

Figure 6a: NGO Optimum (N = 1/2)

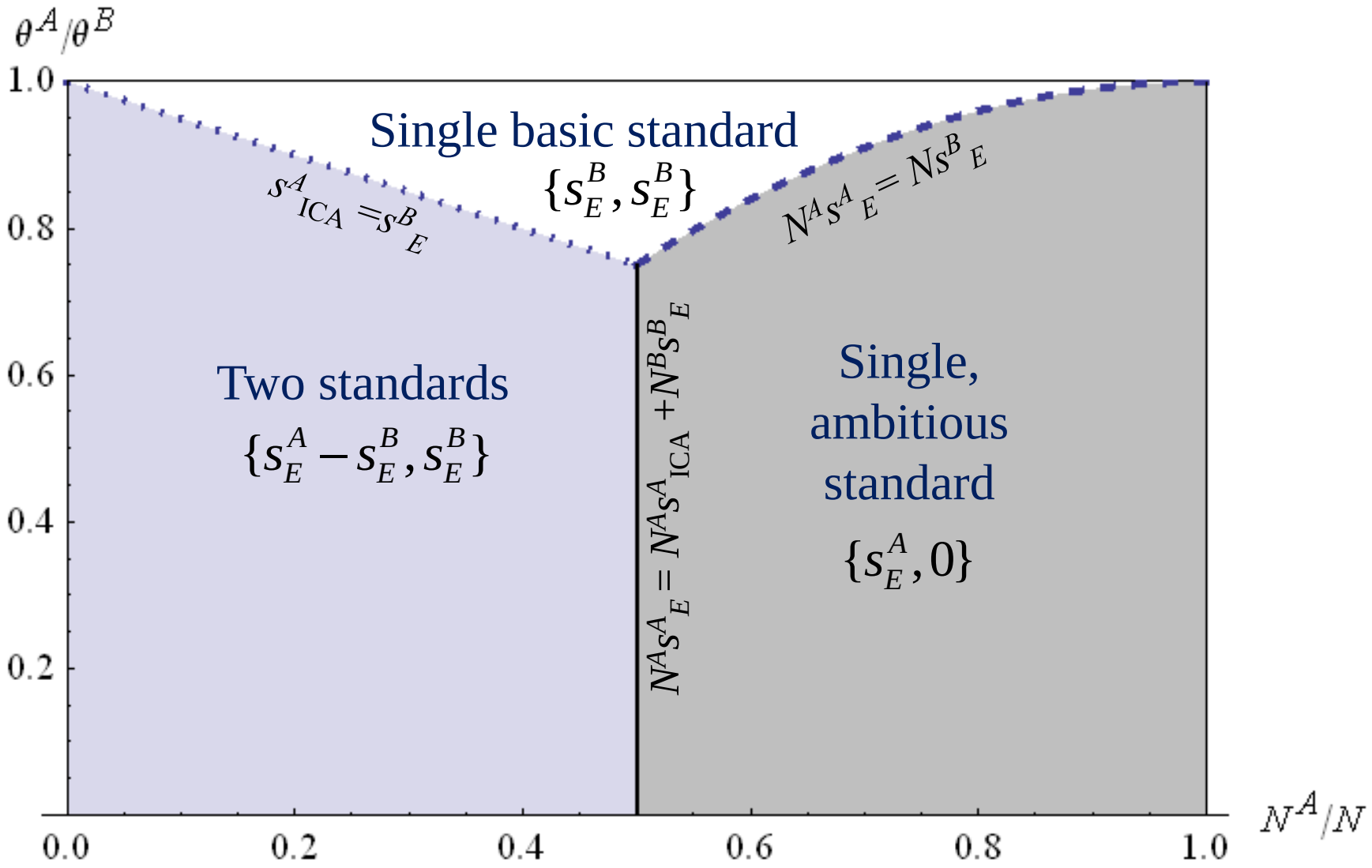

Figure 6b: NGO Optimum ($N \geq 2/3$)

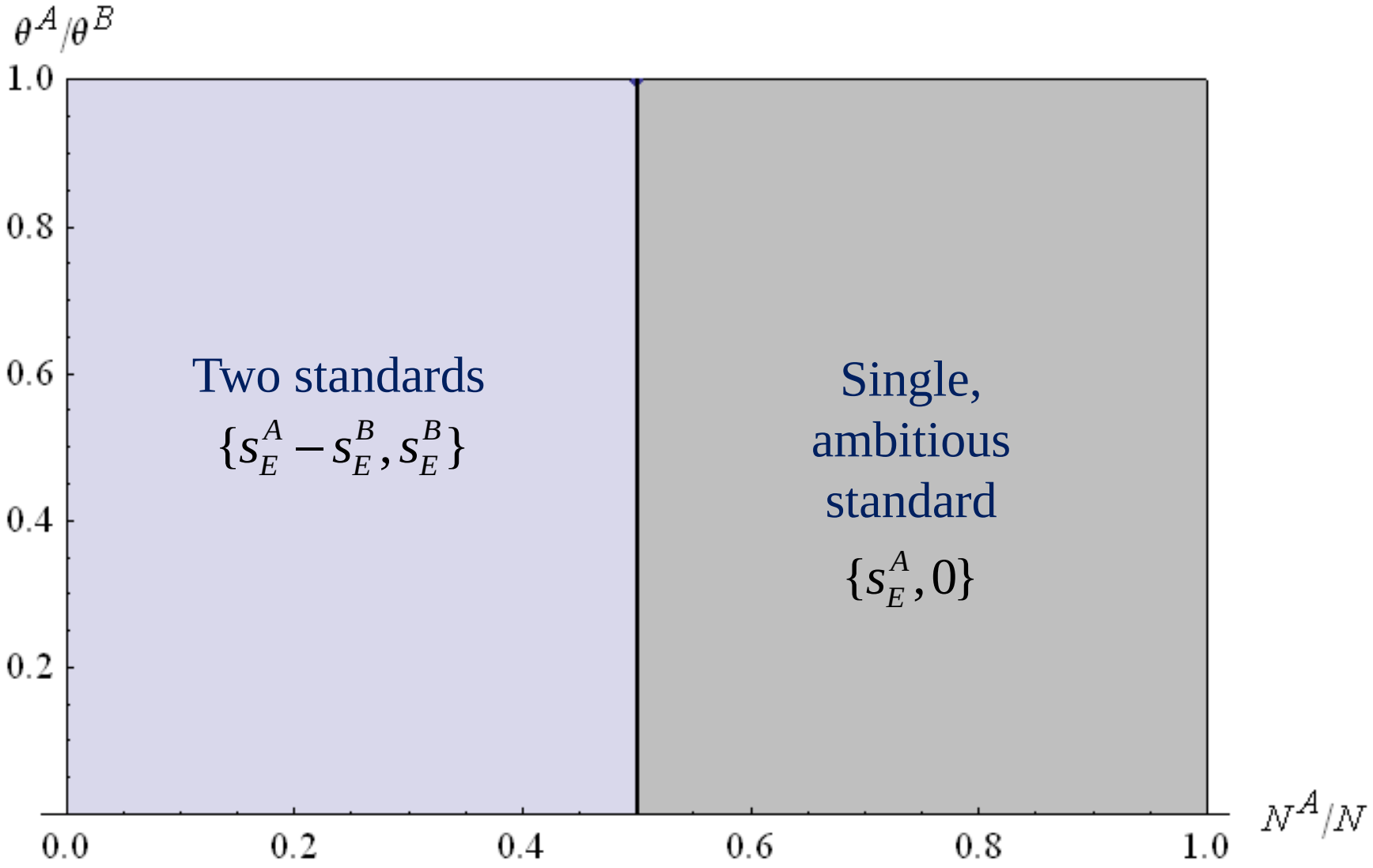

Figure 7a: Industry Optimum (N = 2/3)

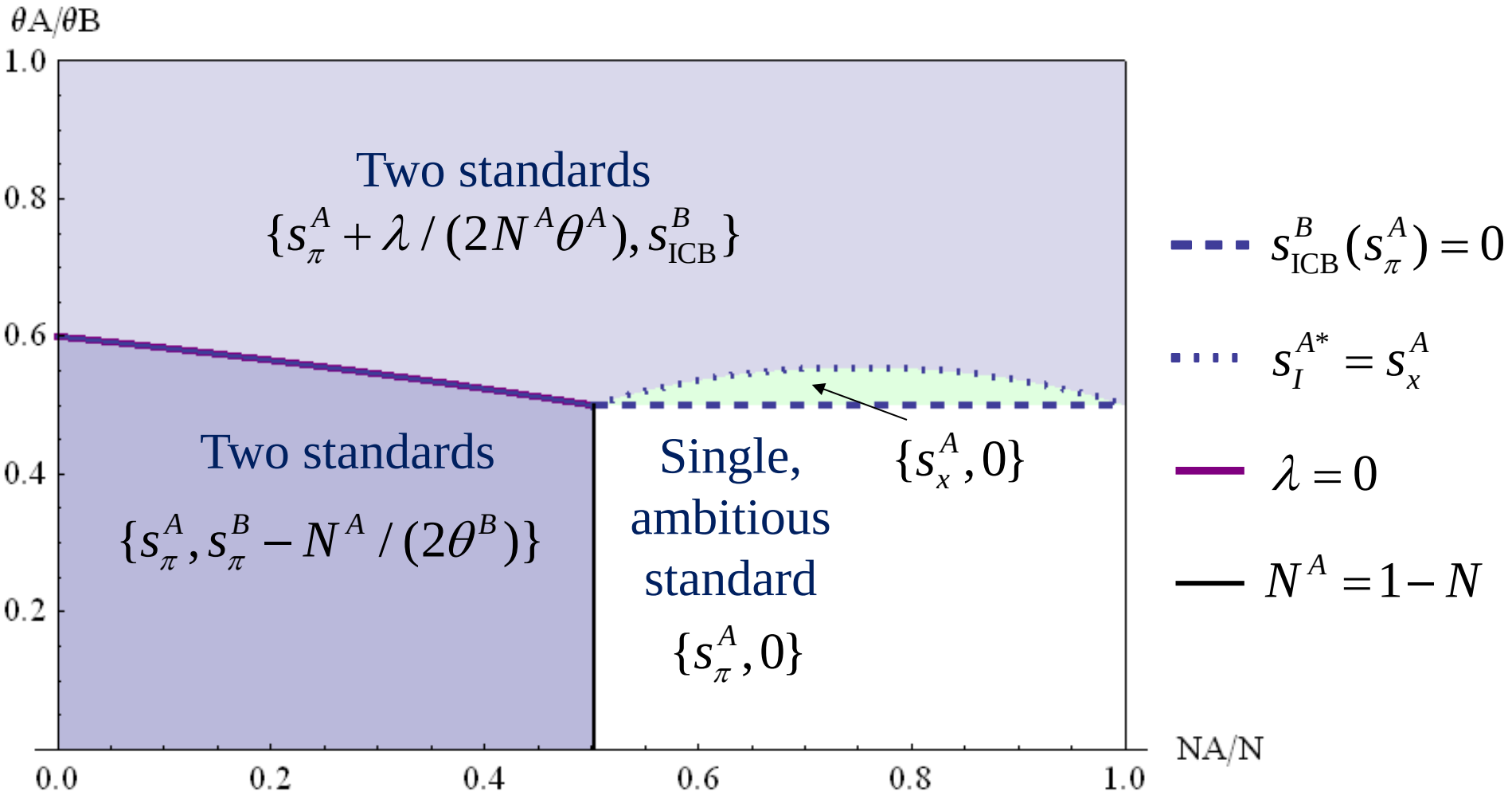

Figure 7b: Industry Optimum (N = 1/2)

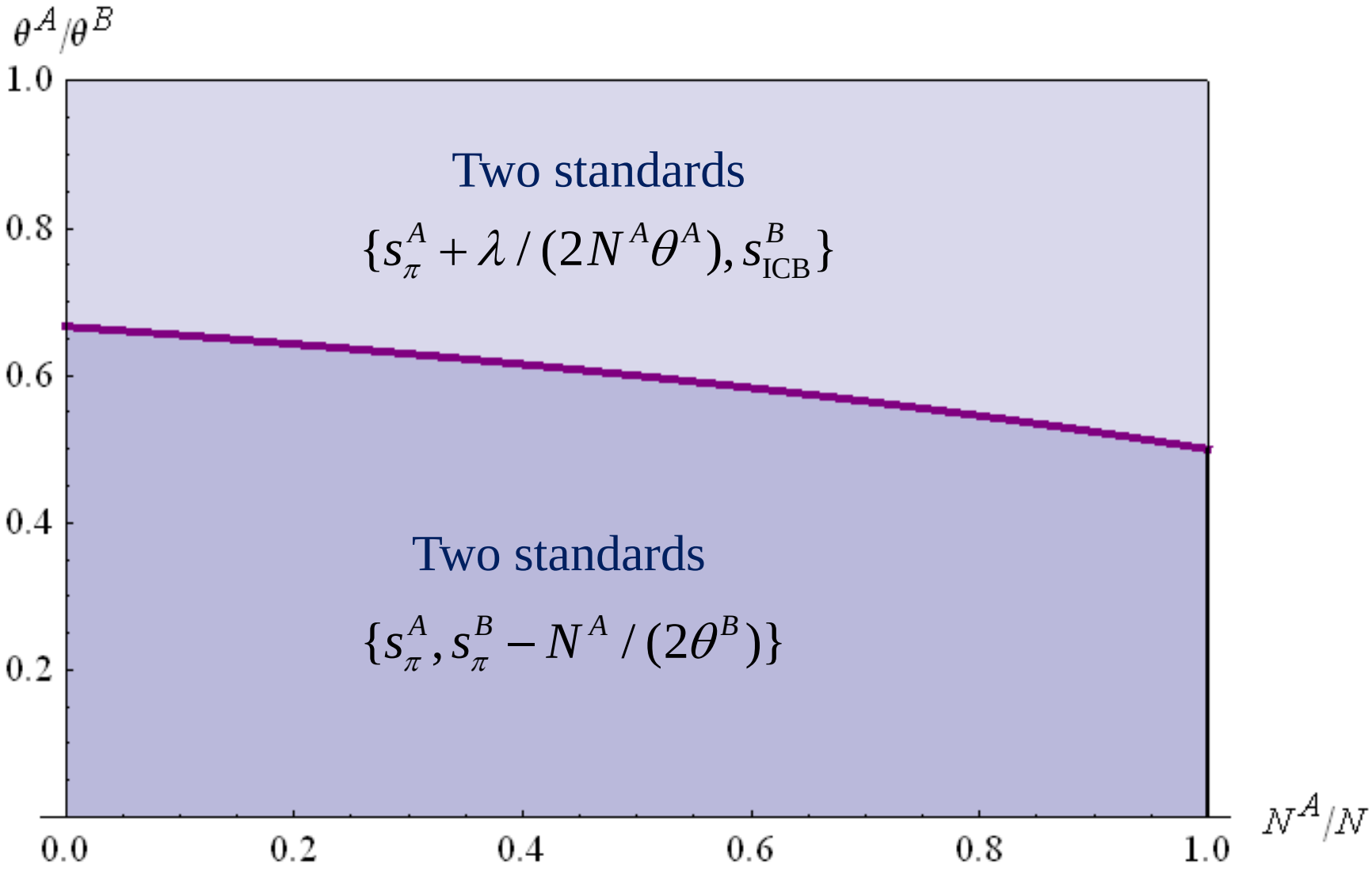

Figure 8: Unique Equilibrium in Multi-Tier Competition