Competing Environmental Labels*

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Suggested Running Head: Competing Eco-labels

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Abstract

We study markets in which consumers prefer green products but cannot determine the environmental quality of any given firm's product on their own. A non-governmental organization (NGO) can establish a voluntary standard and label products that comply with it. Alternatively, industry can create its own standard and label. We compare the stringency of these two types of labels, and study their strategic interaction when they co-exist. We find that even with error-free labels, environmental benefits may be smaller with two labels than with the NGO label alone, and we characterize when label competition is more likely to be environmentally beneficial.

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 anytime soon. Global trade law also makes it difficult for governments to attempt to regulate attributes of production processes outside their borders, as opposed to inherent product attributes.

In the absence of environmental standards for production behavior, many groups have put increasing effort into international market mechanisms such as ecolabeling. In some cases, industry takes the lead in developing labels, e.g. Starkist's move to dolphin-safe tuna (Reinhardt 2000, pp. 31-34) or the pulp and paper industry's "Totally Chlorine Free" label (US EPA 1998, p. B115). In other cases, non-governmental organizations (NGOs) sponsor labels, such as the "Good Environmental Choice" label created by the Swedish Society for the Conservation of Nature (US EPA, p. B99), or the Forest Stewardship Council (FSC) label, which was created by a coalition of groups. More recently, there has been a growing proliferation of labels, as multiple groups enter the labeling marketplace.[1] Of particular interest are situations in which industry has responded to an NGO label with its own certification standards that employ alternative criteria, which are typically less stringent than those used by the NGO. For example, a coalition of industry groups has attacked the well-known Leadership in Energy and Environmental Design (LEED) standard created by the non-profit US Green Buildings Council because it restricts the use of certain plastics and forest products; the coalition instead promotes the weaker Green Globes standard. (Makower 2012)

A vivid example of label competition comes from the forest products sector. As recounted by Sasser et al. (2006), the FSC was initiated 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

[1] Steering Committee of the State-of-Knowledge Assessment of Standards and Certification (2012) offers a thorough analysis of the global impact of ecolabels. The website www.ecolabelindex.com provides an up-to-date overview of the labels currently in existence, and as of this writing tracks 410 different ecolabels around the world.

convention at the Rio Earth Summit. The Sustainable Forestry Initiative (SFI), in turn, was created a year later by the American Forest and Paper Association (AF&PA), as an alternative that gave industry members greater flexibility than the FSC system. Angered by the emergence of the SFI, 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."

The emergence of label competition is not surprising. As Bernstein and Cashore (2007) point out, the initiators of a labeling regime face a dilemma: strict standards can only be met by a small fraction of firms in an industry, while standards achievable by most mainstream firms may be too loose to produce much overall environmental improvement. Whether the first label takes a stringent or a lax approach, there is room for a rival to enter and pursue the alternative strategy. Today, about 13% of the world's productive forests are certified, with 143 million hectares certified worldwide via FSC and 232 million hectares certified by SFI and other labels under the umbrella of the Programme for the Endorsement of Forest Certification (Cashore and Auld 2012). Whether such label competition is actually good for the environment, however, is unclear.

There exists a substantial theoretical literature on ecolabels, which addresses several sets of issues.[2] One strand of the literature emphasizes how firms respond to a labeling regime, building on the industrial organization literature on duopolistic vertical differentiation. For example, Amacher et al. (2004) extend this literature to allow a first stage in which firms can invest in a green

[2] There is also a literature on for-profit certification intermediaries, which includes such papers as Lizzeri (1995). In these models, the certifier investigates the firm and chooses what to disclose to the buying public, and is able to retain a substantial share of the surplus. Environmental certification is quite different. Certifiers typically set a standard *ex ante* that firms must meet in order to receive the label. NGO certifiers aim to maximize environmental benefits, and are typically close to bankruptcy. Industry-sponsored certifiers aim to maximize the benefits to the firms being certified rather than to the certifier itself. Thus, the for-profit certifier model does not seem appropriate for our purposes.

technology; they find that environmental performance is enhanced when the high-quality and low-quality firms have similar cost structures. In a similar setup, Ibanez and Grolleau (2008) allow for a "brown" firm to mimic a "green" firm by spending money to falsify a label; they show that this reduces the effectiveness of labeling. A second line of research explores the implications of imperfect certification processes. McCluskey (2000) demonstrates the importance of repeat purchases and third-party monitoring when certification is imperfect. Mahenc (2009) shows that if consumers do not consider the labeling agency trustworthy, then the agency may charge excessive prices in order to signal its credibility. Mason (2011) shows that when certification can distinguish a green firm from a brown firm only with a certain amount of noise, ecolabeling can either raise or lower welfare depending upon the cost and accuracy of the certification process.

Other papers explore the interaction of ecolabels with alternatives such as government regulation. Nimon and Beghin (1999) find that governments in the global "South" have greater incentives to harmonize national labels than do governments in the North. Heyes and Maxwell (2004) find that a voluntary NGO label may reduce welfare by undermining political support for a more socially desirable mandatory government standard; the two instruments together, however, are better than either one alone. Greaker (2006) shows that a government may prefer to eschew setting a domestic environmental standard, and instead introduce an ecolabel and induce both the domestic and the foreign firm to adopt it. Hamilton and Zilberman (2006) study the relationship between market structure, environmental policy and the amount of fraud in markets with eco-certification. Baksi and Bose (2007) find that costless self-labeling by individual firms often dominates a costly third-party label, but only if the government is willing to engage in costly monitoring of the self-labels. Ben Youssef and Lahmandi-Ayed (2008) show that a welfare-maximizing certification body that also cares about political support may opt not to offer a label at all. Bottega and DeFreitas (2009) find that if an NGO can advertise and convince consumers to pay for the environmental enhancements provided by labeled products, the need for government regulations aimed at substandard products may cease as that market dries up.

Few papers formally model label competition, and none of these allow standards to be set strategically. Lerner and Tirole (2006) consider how a firm that is unsure of the quality of its own product chooses from a continuum of non-strategic certifiers that vary in the stringency of their standards. Roe and Sheldon (2007) study a vertically-differented duopoly under a variety of government policies regarding the use of government or private labels, assuming the government standard is exogenously set, and the private label is always set at the firm's profit-maximizing level. Ben Youssef and Abderrazak (2009) study a duopoly in which each label can only be used by one firm; under complete information adding the second ecolabel always improves environmental protection, but if consumers cannot tell which label is more stringent, the firms use prices to signal qualities, and the second ecolabel actually reduces overall environmental protection. Harbaugh et al. (2011) assume firms' qualities and the stringency of labels are exogenous; they find that when consumers are unsure of the environmental standard conveyed by a given ecolabel, then label competition can produce consumer confusion that undermines the value of labeling.

Our analysis differs from previous work in several respects. Most importantly, we model rivalry between ecolabels, with the labeling organizations choosing their standards strategically to further their own objectives. In particular, we explore the impact of strategic competition between an NGO label and an industry-sponsored label; for simplicity, we limit each labeling organization to offering one standard. Our setting includes a large number of competing firms, whose costs of environmental improvement are unobservable to others but the distribution of which is common knowledge. We do not force a simple choice between "brown" and "green" production processes, but instead allow each firm to choose exactly how green it wants to be. Our key finding is that even when labels provide perfectly reliable information to consumers, environmental damages may be worse in the presence of both labels than with the NGO label alone; we also provide insight into the conditions under which welfare-reducing competition is likely.

The remainder of the paper is organized as follows. Section 2 lays out our basic model with a single label, and compares the NGO label to the industry label. Section 3 studies the nature of strategic interaction when the two labels coexist, and characterizes each group's best response to the other's label. Section 4 characterizes the Nash equilibrium of the game with competing labels, first analytically (for the case of a uniform distribution of firms' environmental improvement costs) and then using simulation results (for a Beta distribution with a range of parameter values).

Section 5 analyzes the impacts of label competition on industry profits and the environment, using simulation methods. Section 6 concludes. All proofs are relegated to the Appendix.

2 Basic Model with Single Label

The industry consists of a continuum of firms that supply a product sold in a global market. Each firm has an ecological footprint that can be improved, e.g. it emits pollutants that impose external costs or conducts activities that diminish habitat and ecosystem services. Firms differ according to their costs of environmental improvement, indexed by θ, which is distributed over $[\underline{\theta}, \overline{\theta}]$ with probability density $f(\theta)$ and cumulative distribution $F(\theta)$. The distribution $F(\theta)$ is common knowledge, but the efficiency of any given firm is not known to other firms or consumers.[3]

Each firm chooses its own environmental improvement level s, the cost of which is θs.[4] In order to make the analysis more tractable, we assume that each labeling organization offers exactly one standard, and that funding for each organization comes from exogenous sources such as foundation grants, citizen donations, or industry trade association dues. Although we do not model the costs of label development explicitly, our assumption on the number of labels can be interpreted as a restriction on the fixed costs of label development, with these costs being small enough that each organization is willing to offer one label, but large enough that neither organization is willing to offer more than one.

There is also a continuum of consumers, all of whom have "green" preferences. These are captured by assuming that the representative consumer has a willingness-to-pay $p(s)$ with $p'(s) > 0$ and $p''(s) < 0$. For simplicity, we will assume that $p(s)$ is also the price received by a firm offering a product of environmental quality level s, which can be interpreted as assuming that individual consumers have an inelastic demand for one unit of the good. We assume that $p'(0) > \underline{\theta}$, to ensure that at least the firm with lowest environmental improvement cost can profitably implement

[3] This basic structure follows that of Heyes and Maxwell (2004).

[4] This cost can be thought of as having two components, a certification cost that is common to all firms and a firm-specific cost of changing production technology. In particular, let $\theta = c + g\phi$, with ϕ distributed over some range with probability density $b(\phi)$ and cumulative distribution $B(\phi)$. Then $cs = s\underline{\theta}$ can be thought of as the common certification cost, and $sg\phi$ as the firm-specific cost of changing production technology.

a strictly positive level of environmental improvement.

If consumers know that a firm has undertaken environmental improvement level s, and the firm has environmental improvement cost θ, then its profits are $\pi(\theta, s) = p(s) - \theta s$. However, in the absence of any labels, consumers cannot distinguish the environmental improvement levels of any individual firms, so a firm has no incentive to undertake any environmental improvement, and aggregate environmental damages are unchanged.

We begin with the situation in which firms have only one labeling option, developed by institution i (either an NGO or an industry trade association) with standard s^i. That institution will certify all firms that meet or exceed this level, and allow them to display an ecolabel to consumers. A firm of type θ will mitigate to the level required to obtain certification if $p(s^i) - \theta s^i > p(0)$, that is, if its costs are lower than the corresponding cutoff level θ^i:

$$\theta < \theta^i \equiv \frac{p(s^i) - p(0)}{s^i}. \tag{1}$$

Thus an interval of low-cost firms will choose to be certified. Note that

$$\frac{\partial \theta^i}{\partial s^i} = \frac{s^i p'(s^i) - (p(s^i) - p(0))}{(s^i)^2} = \frac{s^i p'(s^i) - s^i \theta^i}{(s^i)^2} = \frac{p'(s^i) - \theta^i}{s^i} < 0. \tag{2}$$

Because the firm's profit function $p(s) - \theta s$ is concave in s, it has a unique maximum at which $p'(s) - \theta = 0$, which we denote by $s^*(\theta)$. By definition, for the firm at the cutoff level, profits are zero, hence marginal profits are negative, i.e. $p'(s^i) - \theta^i < 0$. Thus, as the standard becomes more stringent, fewer firms adopt the standard, because the cutoff cost rate falls. Note that (1) implicitly imposes an upper bound on the standard that can be imposed, namely $\overline{s}$ defined by $(p(\overline{s}) - p(0))/\overline{s} = \underline{\theta}$.

2.1 NGO Label in Autarky

Suppose the NGO is on its own in developing an ecolabel. The NGO is assumed to have as its objective the maximization of environmental improvements, $V(s)$, which are a function of the standard it selects.[5] The NGO chooses its standard s^N (and correspondingly θ^N) to maximize $V(s^N) = s^N F(\theta^N)$. The first-order condition is

$$\frac{\partial V(s^N)}{\partial s^N} = F(\theta^N) + \frac{\partial \theta^N}{\partial s^N} s^N f(\theta^N) = 0,$$

and substituting in from (2) and rearranging implies

$$p'(s^N) = \theta^N - \frac{F(\theta^N)}{f(\theta^N)}. \tag{3}$$

The NGO faces a tradeoff: increasing its standard by a small amount causes all inframarginal firms to increase their environmental improvement, but also causes some firms at the margin to abandon certification. The NGO continues increasing its standard until these two opposing effects exactly balance one another. We do not present second-order conditions, but they can be shown to hold if the price function is sufficiently concave.

2.2 Industry Label in Autarky

Suppose now that there is no NGO label, and the industry sets its own label instead. The industry sets a standard s^I and firms decide whether or not to mitigate to a level that complies with the standard. A firm of type θ will do so if $\theta < \theta^I$, as previously defined.

The industry is assumed to have as its objective the maximization of industry profits, so it chooses s^I to maximize the total profits of certifiers and non-certifiers,

$$\Pi(s^I) = \int_{\underline{\theta}}^{\theta^I} (p(s^I) - \theta s^I) f(\theta) d\theta + \int_{\theta^I}^{\overline{\theta}} p(0) f(\theta) d\theta.$$

The first-order condition is

$$\frac{\partial \Pi(s^I)}{\partial s^I} = \int_{\underline{\theta}}^{\theta^I} (p'(s^I) - \theta) f(\theta) d\theta + \frac{\partial \theta^I}{\partial s^I} (p(s^I) - \theta^I s^I - p(0)) f(\theta^I) = 0.$$

[5] We assume the NGO's valuation of environmental amenities is linear in s, while consumers have diminishing marginal utility of quality. The fact that the NGO's marginal valuation of environmental quality does not diminish is meant to capture the notion that the advocacy group has an objective that is not limited by consumers' current willingness to pay.

From the definition of θ^I we know that $p(s^I) - \theta^I s^I = p(0)$, so the above simplifies to

$$\frac{\partial \Pi(s^I)}{\partial s^I} = \int_{\underline{\theta}}^{\theta^I} (p'(s^I) - \theta) f(\theta) d\theta = 0. \tag{4}$$

Integrating by parts and rearranging terms allows us to rewrite the industry's FOC as

$$p'(s^I) = \theta^I - \frac{\int_{\underline{\theta}}^{\theta^I} F(\theta) d\theta}{F(\theta^I)}, \tag{5}$$

which will facilitate comparison between the industry label and the NGO label.

Industry profits clearly increase from the presence of the ecolabel, since $p(s^I) - \theta s^I > p(0)$ for all firms that adopt the ecolabel. Furthermore, since industry maximizes profits, industry profits must be at least as great as when the NGO sets the ecolabel.

2.3 Comparing Labels

Now we want to compare the degrees of stringency chosen for the two kinds of labels in autarky, that is, when there is only one label in existence. To do so we impose the relatively weak assumption that the density $f(\theta)$ is log-concave, which means the natural logarithm of $f(\theta)$ is concave. Bagnoli and Bergstrom (2005) show that this property is satisfied by such familiar distributions as the uniform, the normal, the exponential, the logistic and the Beta distributions.

Proposition 1 *If $f(\theta)$ is log-concave, then in autarky the NGO always sets a more stringent standard than does the industry.*

Proposition 1 shows that under quite general conditions the NGO will set a more stringent standard than the industry in autarky.[6] Nevertheless, while this result is very intuitive, it does not necessarily hold for all probability distributions. Note that a public standard, set by a government whose objective function is some weighted average of industry profits and environmental improvement, would be set at a level in between those chosen by the NGO and the industry.

[6] We thank Mark Bagnoli for his generous help with this proposition.

3 Combining NGO and Industry Labels

We turn next to the interaction between the two ecolabels when they coexist. Throughout we will use subscript "A" for "autarky" to denote standards when only one entity sets a standard, and the subscript "B" to denote the case where both labels coexist. For the moment, let us abstract from which label is stricter, and simply refer to a "High" and a "Low" standard, so that $s_B^H > s_B^L$, which implies that $\theta_B^H < \theta_B^L$ (i.e., the cut-off cost level for the higher standard is lower than for the lower standard). Now firms will sort themselves into three categories: certifying to the High standard, the Low standard, or none at all. We will have two conditions determining which label a firm signs up for, and the nature of the two conditions will depend upon which label is more stringent.

A firm of type θ certifies to the High standard if doing so is more profitable than certifying to the Low standard,[7] i.e., if $p(s_B^H) - \theta s_B^H > p(s_B^L) - \theta s_B^L$, or

$$\theta < \theta_B^H \equiv \frac{p(s_B^H) - p(s_B^L)}{s_B^H - s_B^L}. \tag{6}$$

A firm of type θ certifies to the Low standard if doing so is more profitable than not certifying to a standard at all, i.e. if $p(s_B^L) - \theta s_B^L > p(0)$, or

$$\theta < \theta_B^L \equiv \frac{p(s_B^L) - p(0)}{s_B^L}. \tag{7}$$

A firm of type θ opts not to certify at all if $\theta > \theta_B^L$.

To analyze how the cutoff values respond to changes in each standard, the following Lemma will be useful.

Lemma 2 $p'(s_B^L) - \theta_B^H > 0 > p'(s_B^H) - \theta_B^H$.

The Lemma allows us to establish how participation in the two labels varies with changes in

[7] It is straightforward to show that if the High standard is more profitable than the Low standard, it is also more profitable than not certifying at all.

their stringency. Differentiation shows that

$$\frac{d\theta_B^H}{ds_B^H} = \frac{p'(s_B^H) - \theta_B^H}{(s_B^H - s_B^L)} < 0 \tag{8}$$

$$\frac{d\theta_B^H}{ds_B^L} = -\frac{p'(s_B^L) - \theta_B^H}{s_B^H - s_B^L} < 0. \tag{9}$$

From Lemma 2, we know that since a firm of type θ_B^H is just indifferent between the High and Low standards, its marginal profits at the High standard are negative, so raising the High standard lowers its cutoff cost threshold. Furthermore, an increase in the Low standard also lowers the cutoff cost threshold for High standard participants, because the Low standard is now more attractive.

As in the autarky case, the cutoff cost for the Low standard is decreasing in the stringency of that standard; it is unaffected by the High standard.

$$\frac{d\theta_B^L}{ds_B^L} = \frac{p'(s_B^L) - \theta_B^L}{s_B^L} < 0 \tag{10}$$

$$\frac{d\theta_B^L}{ds_B^H} = 0. \tag{11}$$

Thus, tightening the High standard leads to reduced certification to the High label but has no effect on certification to the Low label. However, tightening the Low standard lowers both cutoff thresholds, which reduces certification overall and reduces certification to the High label, but can result in either increased or reduced certification to the Low label.

We turn now to establishing how each label responds to entry by the other. We begin with the case in which the industry responds to the standard set by the NGO, and then turn to the opposite case. As in the vertical differentiation literature (e.g., Ronnen 1991), we will see that the two organizations have incentives to differentiate themselves one from the other, so that a high standard by the initial party may elicit a low standard from the other, while a low standard from the initial party may elicit a high standard from the other. Throughout the analysis, we will assume that the second-order conditions for an interior optimum for both the NGO and the industry labels are satisfied for each case we consider; it can be shown that concavity of the objective functions is assured if the willingness-to-pay function is sufficiently concave.

3.1 Industry Best Response

Suppose the NGO has set a standard s^N and the industry chooses a best response. That best response may be above or below the NGO standard. Industry profits are then the maximum of the profits associated with the best response conditional on the industry standard being higher than the NGO standard ("BIH") and the best response conditional on the industry standard being lower than the NGO standard ("BIL"):

$$\Pi_B(s_B^I; s_B^N) = \max\left[\Pi_{BIL}(s_L^I; s_B^N), \Pi_{BIH}(s_H^I; s_B^N)\right]$$

where

$$\Pi_{BIL}(s_L^I; s_B^N) = \max_{s_B^I < s_B^N} \int_{\underline{\theta}}^{\theta_{BIL}^N} (p(s_B^N) - \theta s_B^N) f(\theta) d\theta + \int_{\theta_{BIL}^N}^{\theta_{BIL}^I} (p(s_L^I) - \theta s_B^I) f(\theta) d\theta + \int_{\theta_{BIL}^I}^{\overline{\theta}} p(0) f(\theta) d\theta,$$

and

$$\Pi_{BIH}(s_H^I; s_B^N) = \max_{s_B^I > s_B^N} \int_{\underline{\theta}}^{\theta_{BIH}^I} (p(s_H^I) - \theta s_H^I) f(\theta) d\theta + \int_{\theta_{BIH}^I}^{\theta_{BIH}^N} (p(s_B^N) - \theta s_B^N) f(\theta) d\theta + \int_{\theta_{BIH}^N}^{\overline{\theta}} p(0) f(\theta) d\theta.$$

We conduct the analysis by considering both the case where the industry response is below the NGO standard, and the opposite. Although Proposition 1 suggests that the former case is more likely to obtain, both are possible in theory and must be considered carefully. The following proposition characterizes how the industry association adjusts its standard in response to competition from the NGO standard.

Proposition 3 *Suppose the NGO sets a standard s_B^N and then industry responds with a standard s_B^I. If $s_B^I < s_B^N$, then it must be the case that $s_B^I < s_A^I$, and if $s_B^I > s_B^N$, then it must be the case that $s_B^I > s_A^I$.*

The proposition shows that, relative to autarky, the industry responds to the presence of an NGO standard by increasing the difference between its standard and that of the NGO. Thus, if the industry standard under label competition is weaker than the NGO standard, then it is even weaker than it would be under autarky. By weakening its standard, the industry association increases participation in its standard and raises profit margins of some high-cost firms (who had previously not certified at all and now certify to the low standard) at the expense of medium-cost firms (who were already willing to be certified to the low standard and now receive a lower price). However, if the industry standard under label competition is stricter than the NGO standard, then it is even stronger than it would be under autarky. By tightening its standard relative to its autarky level, the industry association raises profit margins of low-cost firms (who were already willing to certify to the highest standard available) while cutting those of some medium-cost firms (who are driven to switch from the high to the low standard). In either case, the presence of a competitor drives the industry to take a more extreme position than it would under autarky, a result reminiscent of the vertical differentiation literature. (Ronnen 1991)

The next proposition further characterizes the industry's best response function.

Proposition 4 *The industry's best-response function $s^I(s^N)$ is upward-sloping. There exists an $\widetilde{s}^N$ such that the industry best-response function is discontinuous at $s^N = \widetilde{s}^N$, with $s^I(s^N) > s^N$ for $s^N < \widetilde{s}^N$ and $s^I(s^N) < s^N$ for $s^N > \widetilde{s}^N$.*

The two foregoing propositions provide a detailed characterization of the industry's best-response function. We know it is everywhere upward sloping, with a downward jump at the point where $s^N = \widetilde{s}^N$. Furthermore, we know that $s^I(s^N) < s^I_A \ \forall s^I_B < s^N$ and $s^I(s^N) > s^I_A \ \forall s^I_B > s^N$. For future use, define $\overline{s}^I(\widetilde{s}^N)$ as the limit as s^N approaches $\widetilde{s}^N$ from below and $\underline{s}^I(\widetilde{s}^N)$ as the limit as s^N approaches $\widetilde{s}^N$ from above. Thus, the industry best-response function jumps downward from $\overline{s}^I(\widetilde{s}^N)$ to $\underline{s}^I(\widetilde{s}^N)$ at $\widetilde{s}^N$. The existence of discontinuous best-response functions means that the nature of equilibrium with competing ecolabels may be quite complex. Before turning to this discussion, however, we characterize the NGO's best-response function.

3.2 NGO Best Response

Now suppose industry sets a standard s_B^I and then the NGO responds with a standard s_B^N . Intuitively, the NGO can either loosen its standard relative to the autarky case, in order to draw in more participants, or tighten it so as to achieve inframarginal improvements from all the firms that would have certified to its standard anyway. We begin by demonstrating that the NGO never wishes to set $s_B^N = s_B^I$. We then go on to consider its best response in more detail.

Lemma 5 *Under label competition, the NGO chooses* $s_B^N \neq s_B^I$.

Lemma 5 shows that the NGO never wants to simply set a standard equal to that of the industry label. It can always do better by raising its standard above the industry standard. Doing so will not cause any of the firms that had been certifying to the industry standard to abandon certification, but it will induce some firms to switch to the more stringent NGO standard. Hence, total environmental improvement is greater. However, it may be able to achieve even greater environmental improvement by setting a standard below that of the industry standard. We consider each of these possibilities in more detail below. The next proposition summarizes how the NGO responds to the presence of an industry standard.

Proposition 6 *Suppose the industry sets a standard* s_B^I *and the NGO responds with a standard* s_B^N. *Then, it is possible for* $s_B^N \geq s_A^N$ *but also possible for* $s_B^N < s_A^N$.

The proposition shows that the NGO responds to an industry standard in a complex fashion. The NGO loses market share when the industry introduces a standard, and the appropriate response may either be to weaken its standard and recapture market share, or raise the standard and get more effort out of the remaining participants. Ultimately, whether the NGO standard is stronger or weaker under competition than under autarky depends upon parameter values.

The following proposition further characterizes the NGO's best-response function. It turns out to be more complex than the industry best-response function.

Proposition 7 *If* $f(\theta)$ *is monotonically increasing (decreasing), then the NGO's best-response function slopes upward (downward). Furthermore, for any density function that is single-peaked* *with mode θ^m, if $\theta_B^I < \theta^m$ ($\theta_B^I > \theta^m$), then the best-response function slopes upward (downward). There is a discontinuity in the NGO's best-response function at a point $s^I = \widetilde{s}^I$, with $s^N(s^I) > s^I$ for $s^I < \widetilde{s}^I$ and $s^N(s^I) < s^I$ for $s^I > \widetilde{s}^I$.*

Thus, unlike the industry's best-response function, the NGO's best-response function is not even guaranteed to be piecewise monotonic unless we place additional restrictions upon $f(\theta)$. Our simulation results in section 4 illustrate the potential for a non-monotonic NGO best-response function. For future use, define $\overline{s}^N(\widetilde{s}^I)$ as the limit as s^I approaches $\widetilde{s}^I$ from below and $\underline{s}^N(\widetilde{s}^I)$ as the limit as s^I approaches $\widetilde{s}^I$ from above Thus, the NGO best-response function jumps downward from $\overline{s}^N(\widetilde{s}^I)$ to $\underline{s}^N(\widetilde{s}^I)$ at $\widetilde{s}^I$.

4 Characterizing Nash Equilibria

The previous section showed that label competition can produce a complex set of responses from the institutions creating standards. The NGO's best-response function is particularly complex. The industry best-response slopes upwards, but has a discontinuity where it drops downward. Like the industry, the NGO has a discontinuity in its best-response function, but unlike the industry, the NGO's best-response function is only monotonic if additional restricitions are placed on the distribution function, e.g. if the underlying density function is monotonic. These features make it extremely difficult to fully characterize the Nash equilibrium retaining our general functional forms.

For a stable equilibrium with $s^N > s^I$ to exist, it must be the case that the industry best-response function is steeper than the NGO best-response function, that is, ds^N/ds^I is greater along the industry reaction function than the NGO reaction function. In addition, the discontinuity in the industry best-response function must allow for the reaction functions to cross, i.e., $\underline{s}^I(\widetilde{s}^N) < \widetilde{s}^I$.

A stable equilibrium with $s^N < s^I$ may also exist. Such an equilibrium would similarly require the industry response function to be steeper, as well as that the NGO reaction function has a discontinuity point that allows for the second equilibrium, i.e. $\underline{s}^N(\widetilde{s}^I) < \widetilde{s}^N$.

Since further analytical manipulation with the general functional forms is unlikely to be fruitful, we explore the Nash equilibria in the two-label game by employing additional assumptions. First, we study a commonly used distribution function—the uniform distribution—to derive more tractable analytical results and a transparent numerical solution. Second, to consider a wider variety of possibilities, we conduct simulations using a flexible Beta distribution, in combination with different cost ranges and price functions of different curvatures. In these simulations, we always find the existence of a stable equilibrium with $s^N > s^I$, and we also find some cases in which a second equilibrium with $s^N < s^I$ is possible.

4.1 Uniform Distribution

We begin our exploration of Nash equilibria by focusing on the uniform distribution. Let $p(s) = \ln(1+s)$ and let $f(\theta)$ be uniform on $[\underline{\theta}, \overline{\theta}]$. Thus, $f(\theta) = 1/(\overline{\theta} - \underline{\theta})$ and $F(\theta) = (\theta - \underline{\theta})/(\overline{\theta} - \underline{\theta})$. For simplicity, we will focus on the case where $\underline{\theta} = 0.1$ and $\overline{\theta} = 1.1$.[8]

Now the NGO's first-order condition under autarky simplifies to $p'(s^N) = \underline{\theta}$. For $p(s) = \ln(1+s)$, we have $p'(s) = 1/(1+s)$, so $s^N = (1-\underline{\theta})/\underline{\theta}$, $p(s^N) = -\ln\underline{\theta}$ and $\theta^N = [p(s^N) - p(0)]/s^N = -\underline{\theta}\ln\underline{\theta}/[1-\underline{\theta}]$. If $\underline{\theta}= .1$, then $s^N_A = 9$, $p(s^N_A) = 2.30259$, and $\theta^N_A = 0.256$.

The industry's first-order condition in autarky simplifies to $p'(s^I_A) = (\theta^I + \underline{\theta})/2$. It is easy to see that $p'(s^I_A) \geq p'(s^N_A)$. The concavity of $p(s)$ then implies that $s^I_A \leq s^N_A$. For $p(s) = \ln(1+s)$, the first-order condition implies $s^I_A = 2/(\theta^I_A + \underline{\theta}) - 1$, so substituting in for θ^I_A we obtain

$$s^I_A = \frac{(2-\underline{\theta})s^I_A - \ln(1+s^I_A)}{\ln(1+s^I_A) + s^I_A\underline{\theta}}.$$

There is no closed-form solution to this equality, but for $\underline{\theta} = .1$ the numerical solution is $s^I_A = 2.1624$, $p(s^I_A) = 1.1513$, and $\theta^I_A = \ln(3.1624)/2.1624 = 0.53243$.

When the labels compete, we must consider $s^N > s^I$ and $s^N < s^I$. In the first case, the NGO's first-order condition is the same as the autarky case, so the NGO continues to set $s^N = (1-\underline{\theta})/\underline{\theta}$. In the second case, it turns out that $\partial V(s^N_B; s^I_B)/\partial s^N = 0$, so changes in abatement under the NGO's

[8] Given this monotonically increasing price premium function and constant marginal abatement costs, in the limit as $\underline{\theta}\to 0$ the NGO's optimal standard goes to infinity, and the NGO relies on a single firm to costlessly produce an unlimited amount of abatement. To avoid this outcome, we assume a minimum cost, but other options would be to assume increasing marginal costs or to constrain abatement by an individual firm to be no larger than an initial level of pollution. Such settings would induce the NGO to set a lower standard and spread the burden of abatement across a larger group of firms, even when $\underline{\theta}= 0$.

standard are exactly offset by changes in abatement under the industry's standard. Thus, a best response for the NGO is simply to keep its standard at $s_B^N = (1-\underline{\theta})/\underline{\theta}$.

What is the industry's standard under label competition? Consider first Case 1, with $s^N > s^I$. The industry's first-order condition is $p'(s_B^I) = (\theta^I + \theta^N)/2 > (\theta^I + \underline{\theta})/2 = p'(s_A^I)$. The concavity of $p(s)$ implies that if $s_B^I < s_B^N$, then $s_B^I < s_A^I$. Numerical analysis shows s_B^I =1.5290 in Case 1. Note that this equilibrium is clearly stable, because the NGO's reaction function is flat, while the industry's reaction function is upward sloping. Direct calculation of the two cutoff costs shows $\theta_B^N = 0.184014$ and $\theta_B^I = 0.606821$, implying market shares of 42% for the industry label and 8% for the NGO label, with half of the firms opting to be unlabeled.

In Case 2, $s_B^I > s_B^N$. The industry's first-order condition is now $p'(s_B^I) = (\theta^I + \underline{\theta})/2 \geq \underline{\theta} = p'(s_B^N)$. Hence, the only solution has $s_B^I < s_B^N$, which is inconsistent with the assumption that $s_B^I > s_B^N$. Thus, for the uniform distribution there is no equilibrium with $s_B^I > s_B^N$.

In summary, as shown in Table 1, for the uniform distribution with a natural logarithmic price function, the NGO in autarky sets a much more stringent standard than the industry would in autarky, and achieves much greater environmental improvement. Under label competition, the NGO maintains the same standard as in autarky, but loses nearly half of its participation, while the industry greatly relaxes its standard and roughly maintains its market share.

	Standard	Price	Share of Market
NGO Autarky	9.000	2.303	15.6%
Industry Autarky	2.162	1.151	43.2%
NGO Both	9.000	2.303	8.4%
Industry Both	1.629	0.928	42.3%

Table 1: Results for Uniform Distribution with $\theta \in [0.1, 1.1]$ and $p(s) = \ln(1+s)$

4.2 Simulations with Other Cost Distributions

Our analysis thus far has yielded few general results about label competition. Our most robust result is that in autarky the NGO sets a more stringent label than does industry. Once the labels compete, however, many different outcomes are possible. Either label may strengthen or weaken its standard relative to the autarky level. As a result, it is possible that environmental damages will increase under label competition, relative to a case where only the NGO label is offered. To shed further light on how label competition performs, and when it is more likely to produce negative environmental results, we conduct a series of simulation analyses.

We use a Beta distribution to conduct a wide variety of simulations, varying the skewness and variance of the distribution function, the shape of the price premium, and the range of costs. We employ a logarithmic price function of the form $p(s) = h\ln(1+js)$, which results in a marginal price premium of $p'(s) = hj/(1+js)$. By varying h and j, we change the curvature of the price function. We consider three different price functions: a "regular" price function $p(s) = \ln(1+s)$, a "bowed" price function $p(s) = 0.5\ln(1+10s)$, and a "flat" price function $p(s) = 2\ln(1+s/4)$.

We assume the environmental improvement cost parameter $\theta = (c + g\phi)$, where ϕ is distributed over $[0,1]$ with probability density $f(\phi)$ and cumulative distribution $F(\phi)$. A common cost term is assumed to be nonnegative ($c \geq 0$), and forms the lower bound $\underline{\theta}$. The width of the distribution is determined by g. Thus, firm environmental improvement costs fall in the range $[c, c+g]$. For the density function $f(\phi)$, we use the Beta distribution, which is defined as

$$f(\phi; a, b) = \frac{\phi^{a-1}(1-\phi)^{b-1}}{\int_0^1 u^{a-1}(1-u)^{b-1}du} = \frac{\Gamma(a+b)}{\Gamma(a)\Gamma(b)}\phi^{a-1}(1-\phi)^{b-1},$$

where $\Gamma(u)$ is the gamma function.[9] The Beta distribution is defined on the interval $[0,1]$, has mean $E(\phi) = a/(a+b)$, and is log-concave if $a \geq 1$ and $b \geq 1$. (Bagnoli and Bergstrom 2005) The Beta distribution is convenient because it can take on a great variety of shapes depending upon the values of a and b. For example, if $a = b$, the density is unimodal with mean $1/2$, and if in addition $a = b = 1$, we have the uniform distribution. When $a > b$, the density skews to the left (i.e., more of the tail is at the low-cost end), while if $a < b$, the density skews to the right (with more of the tail toward the high-cost end).

Figure 1 displays three examples of reaction functions, generated using the three different price functions with the same cost distribution ($a = b = 5$, which is narrow and symmetric, with $c = 0$,

[9] There is no closed-form representation for the Beta distribution.

$g = 1$, meaning the cost distribution is identical to the beta distribution). As discussed in the previous section, in all cases the industry response rises from its autarky point until s^N reaches $\tilde{s}^N$, at which point it jumps below the 90-degree line and begins to rise again with the NGO standard, asymptoting back to the autarky level. The NGO reaction function also has a jump point, and in all cases we find that $\tilde{s}^I > s^I_A$. However, the shape of the NGO reaction function, and whether it crosses the industry function below the 90-degree line, depends on our parameter assumptions.

Figure 1(a) (using the "regular" price function) shows an example in which the NGO response rises monotonically with s^I until the jump point is reached, but here $\underline{s}^N(\tilde{s}^I) > \tilde{s}^N$, so there is a single Nash equilibrium in which the NGO tightens and industry loosens in response to label competition. Figure 1(b) (using the "bowed" price function) shows an example in which the NGO response initially declines with s^I before rising again until the jump point is reached, also beyond the industry jump point; again there is a single Nash equilibrium, but in this case the NGO has loosened in response to label competition. Figure 1(c) (using the "flat" price function) shows the NGO response rising monotonically with s^I until the jump point is reached, but this time $\underline{s}^N(\tilde{s}^I) < \tilde{s}^N$, and a second Nash equilibrium is possible in which the industry offers the higher standard (but not as high as the NGO's in the first Nash equilibrium) while the NGO has a lower standard (though not as low as the industry offers in the first Nash equilibrium). Indeed, both equilibria are stable, with the industry response function crossing from below. Furthermore, if we calculate the values of the objective functions, we find in this case the NGO would prefer the BIL equilibrium, while the industry prefers the BIH equilibrium.

[Figures 1(a), (b), and (c)]

More generally, these three classes of equilibria (single equilibrium in which the NGO tightens its standard relative to autarky; single equilibrium in which the NGO loosens its standard; and multiple equilibria, one with the NGO standard higher than the industry standard and one with the NGO standard lower) can also be generated with the "regular" price function by varying the cost distribution; while the precise levels change, the basic shapes are the same. In all cases we find the presence of a stable BIL equilibrium. In some cases, a BIH equilibrium is also possible, and sometimes the NGO may even prefer it, but in those cases the industry would prefer the BIL equilibrium. Thus, we do not see a necessary dominance of one equilibrium over the other; which equilibrium is arrived at may depend on starting points or which player is given the first move. Nevertheless, in the remainder of the paper we focus primarily on BIL equilibria, since we know of no examples of BIH equilibria in practice.

In the next set of figures, we explore some of the underlying drivers of these responses, but restricting ourselves to the BIL equilibria. The panels of Figure 2 show the cutoff costs and cumulative participation in each label. The darkest shade represents the participation in the NGO label under label competition. The medium shade represents additional participation in the NGO label under autarky that is lost to the industry under competition. The lighter shade represents additional participation garnered under competition relative to the NGO in autarky; the light and medium shades together thus represent total participation in the industry label when the two standards compete. Finally, the black line represents the cutoff cost level for participation in the industry label in autarky.

In Figure 2(a), the price premium takes the "regular" form, and we notice that the industry autarky cutoff is well past the mode of the distribution at 84% participation, while the NGO autarky cutoff is right by the mode at 53% participation. With label competition, the industry loosens its standard and expands total participation above the autarky standards, and takes two-thirds of the market share from the NGO standard (which we know is also higher from Figure 2(a)). Figure 2(b) shows the results with the bowed price function, which offers a higher premium at lower standards. In combination with the assumed distribution, the industry always garners 100% participation. Meanwhile, the NGO in autarky has a cutoff cost well past the peak in the distribution; since $f'(\theta) < 0$ at this point, we know that the NGO best-response function is initially downward sloping, so it loosens in response to label competition. Despite this easing, it still loses the bulk of its autarky market share to the industry, going from 80% to 20% participation. Figure 2(c) shows the case of the flat price premium; in this case, the labels are competing in a smaller range at the low end of the distribution, all to the left of the mode of the distribution. Since $f'(\theta) > 0$, we know the NGO tightens its standard in response to label competition; its market share falls from 16% in autarky to 5%. Meanwhile, the loosening of the industry standard causes the cutoff value to ride up the increasing portion of the distribution, with a net effect of increasing its market share slightly relative to autarky (from 23% to 24%).

[Figures 2(a), (b), and (c)]

In the next section, we discuss how these changes in the standards and participation rates with label competition affect the objectives of the two sponsors.

5 Impacts of Label Competition

It seems unlikely that industry would set a standard higher than that of the NGO, given that its autarky standard is lower and its response to an NGO standard is typically to further loosen its own standard. This presumption is supported in the numerical analysis, which always finds an equilibrium with the NGO standard higher than the industry standard; even in the cases where a second, "reverse", equilibrium may also exist, we have never found it to dominate for both parties. Therefore, we focus on cases in which $s_B^N > s_B^I$.

5.1 Profits

By definition, the addition of an industry-chosen label to a market with an NGO label must weakly raise profits. After all, industry could always set its standard equal to the NGO standard and maintain profits at the same level; any other choice must increase profits. The question is, how do profits compare to the situation in which the industry chooses the sole label? This is the subject of the next proposition.

Proposition 8 *Industry profits are higher when an industry label and an NGO label coexist than when there exists only the industry label.*

From the industry perspective, label competition is always a good thing. Industry can maintain the same standard it offered under autarky, and the NGO standard simply offers another option that is more profitable for low-cost firms. Alternatively, industry can adjust its standard somewhat if that would be even more profitable. Thus, having an NGO standard alongside the industry standard always raises profits.

5.2 Environment

It is easy to compare environmental improvements between the autarky systems; obviously, since the NGO maximizes environmental improvement, emissions will be lower with an NGO label than with an industry label. However, what happens to environmental improvement when the industry introduces its own label alongside the NGO label?

Suppose that $\theta_B^N < \theta_A^N < \theta_B^I$. (This does not require that $s_B^N \geq s_A^N$, but only that the NGO does not gain market share when the competing label enters). The change in environmental benefits can be decomposed into three parts:

$$
\begin{aligned}
& V(s_B^N; s_B^I) - V(s_A^N; 0) \\
= & \int_{\underline{\theta}}^{\theta_B^N} s_B^N f(\theta) d\theta + \int_{\theta_B^N}^{\theta_B^I} s_B^I f(\theta) d\theta - \int_{\underline{\theta}}^{\theta_A^N} s_A^N f(\theta) d\theta \\
= & \underbrace{(s_B^N - s_A^N) F(\theta_B^N)}_{\substack{\text{Change in Stringency} \\ ?}} + \underbrace{(s_B^I - s_A^N)\left(F(\theta_A^N) - F(\theta_B^N)\right)}_{\substack{\text{Lost Participation to Industry} \\ -}} + \underbrace{s_B^I \left(F(\theta_B^I) - F(\theta_A^N)\right)}_{\substack{\text{Additional Participation} \\ +}}
\end{aligned}
$$

Thus, the change in environmental improvement depends upon whether the changes in reductions among NGO label participants, plus the lost reductions from those firms who switch from the NGO label to the industry one, outweigh the additional reductions from former non-adopters who now adopt the industry standard.

Note that if $s_B^N < s_A^N$, then the first term is negative; when the NGO responds to competition by loosening its standard, overall environmental benefits may well be lower than with the NGO in autarky.

5.2.1 Uniform Distribution

With our example of the uniform distribution, we have already shown that $s_B^N = s_A^N > s_B^I$, and it can be shown that the change in damages is

$$V(s_A^N; s_B^I) - V(s_A^N; 0) = f\left(s_A^N(\theta_A^N - \theta_B^N) - s_B^I(\theta_B^I - \theta_B^N)\right) = 0 \tag{12}$$

Thus, in this particular case, adding the industry label to the NGO label does exactly as much good as harm, in terms of environmental benefits. This gives us the following proposition.

Proposition 9 *With a uniform distribution on costs, adding an industry label to an existing NGO label has no effect on environmental damages.*

5.2.2 Other Distribution Functions

For a wider range of distribution functions and price premia, environmental benefits may be higher or lower with label competition than with a single NGO label. We observe both of these outcomes in Figure 3, which displays the changes in environmental benefits for our earlier examples in Figure 2 ("VIA" indicates environmental benefits under industry autarky, "VNA" indicates environmental benefits under NGO autarky, and "VB" indicates environmental benefits when both labels are present.) As expected, benefits are always lowest under the industry autarky standard. Relative to NGO autarky, label competition increases benefits when the price premium is flat, while it decreases benefits for the other two cases. In particular, benefits are high under a single NGO label when the price premium is bowed, and they fall dramatically in label competition, due to the combination of loosening of the NGO standard and a large loss in market share.

[Figure 3]

We also conducted simulations for the other distribution functions using the regular price premium, but they are qualitatively similar to our results in Figure 3, so we do not present them in detail here. As expected, we found that $V_A^I < V_A^N$ in all cases. More interestingly, $V_B < V_A^N$ for distributions with $(a = 5, b = 5)$ and $(a = 2, b = 5)$, that is, competition was environmentally harmful for narrow distributions that were symmetric or skewed toward high costs. Competition was only beneficial for narrow distributions skewed toward low costs.

5.3 Broader Simulation Results

We conducted extensive simulations assuming different combinations of the three forms of the log price function, beta distribution functions and cost ranges for θ. Although we do not claim these simulations are exhaustive (or randomly generated), we selected a wide variety to investigate a range of effects. In terms of the reaction functions and effects of label competition on objectives, the results can be sorted into categories illustrated in Table 2.

Industry Response	Loosen			
Total Participation	Higher			
Industry Profits	Higher			
NGO Market Share	Lower			
NGO Response	Tighten			Loosen
Environmental Benefits	Higher		Lower	Lower
Industry Market Share	Higher	Lower	Lower	Lower
Reverse Equilibrium	Possible	Not Found	Not Found	Not Found

Table 2: Summary of Simulation Results:

Responses to Label Competition Compared to Autarky

In all cases, the industry responds to competition by loosening its standard, and label competition increases industry profits and overall participation (sometimes up to 100%). The NGO may tighten or loosen its standard in response. Whenever the NGO does respond by loosening its standard, environmental benefits are always lower under competition than NGO autarky. However, when the NGO responds by tightening the standard, environmental benefits are not always higher than under autarky. Interestingly, we only observe the presence of a BIH Nash equilibrium in situations in which participation in the industry standard is higher than under its autarky standard, which also coincides with environmental benefits being higher with label competition.

Our broad conclusion from the simulations is that the outcome of label competition is very sensitive to shifts in the distribution of firm costs, relative to the price premium. In terms of environmental performance, there are three important dimensions: the shape of the price premium, the variance of the distribution, and whether it is skewed to the left or the right. With narrow distributions, label competition tends to be less valuable for the environment, as the two labels are competing for the same set of firms, which tends to drive down standards. When the distribution is skewed toward high-cost firms, a single NGO label can capture most of the environmental benefits of certification, and competition from a second label serves mainly to drive down standards and reduce environmental performance. When the distribution is skewed toward low-cost firms, the NGO label in autarky faces a difficult tradeoff between maintaining a strict standard, and attracting few participants, or loosening standards to increase participation. As a result, the presence of a second label can reduce this tension by providing a chance for higher-cost firms to participate without undermining the performance of low-cost firms. When the distribution is narrow but symmetric, there is again intense competition between the labels, and standards are driven down by competition.

These conclusions suggest that the dynamic process of evolution in the ecolabel business will be important but complex. As mentioned in the Introduction, there has been a proliferation of labels in recent years. A plausible dynamic trajectory might start with an industry in which only a few specialty firms have developed a competitive advantage in cutting their environmental improvement costs; this would imply a distribution where firms' costs are skewed to the left. Label competition in the early stages of labeling may then be beneficial to the environment. As the high-cost firms learn how to reduce environmental improvement costs, the distribution is likely to become narrower and more symmetric. At this point, label competition is more likely to be bad for the environment. As cost-reducing innovations continue to diffuse through the industry, there will eventually be a large group of firms in an industry that have invested and reduced their environmental improvement costs, and a smaller set of laggard firms whose costs remain stubbornly high. The distribution will then be skewed to the right, and label competition will be detrimental for the environment. Thus, label competition may be useful in the early stages of an industry, but consolidation of labels over time may serve to improve the industry's environmental performance.[10]

6 Conclusions

We have presented a formal economic model of rivalry between ecolabels strategically developed by an environmental NGO and by industry association. We showed that an NGO label is more stringent than an industry ecolabel, assuming there is only one label present in the market at a time. When an NGO label is added to a market with an industry label, industry profits increase. Since the NGO only enters the market if it can reduce damages, environmental quality necessarily improves relative to the industry label alone. However, when an industry label is added to a market with an NGO label, the NGO may strengthen or weaken its label. Furthermore, environmental damages may rise or fall with two labels, relative to a situation with the NGO label by itself. These latter results are sensitive both to the distribution of environmental improvement costs among firms and to consumers' willingness to pay for increasingly stringent standards. However, simulation results indicate that label competition is more likely to be beneficial if the respective labels are targeting separate markets (as would occur if the distribution is wide), while a single NGO label provides greater benefits when that label would achieve broad, industry-wide coverage (as would occur with a narrow distribution of costs).

Our findings are testable, but to do so would require a substantial database on labels. An empirical analysis could use information on the size distribution of firms in a given industry as a proxy for the distribution of costs. It would also need to attempt to assess both demand-side effects on market share as the number of labels changes, as well as supply-side effects regarding the extent of process change induced by various labels. As Blackman and Rivera (2011) indicate, the knowledge base on ecolabels is currently too small to draw firm conclusions about how differences in industry structure affect ecolabel performance.

The broad policy lesson from our work is that governments cannot simply rely on the invisible hand to guide the market for ecolabels, even when the labels are reliable and perfectly under-

[10] Cashore (2002) offers a political science framework for future research on the evolution of certification systems.

stood by consumers. In some cases, industry-sponsored labels improve environmental performance relative to the case of a single ecolabel. In these cases, welfare is necessarily higher with label competition. In other cases, environmental protection would be enhanced if the government could stop industry-sponsored labels from entering the marketplace. However, given that profits are always higher with multiple labels, welfare maximization might allow some competition that reduces environmental benefits. Thus, providing general guidance regarding when label competition is beneficial is challenging. Policymakers must have a sophisticated understanding of demand-side information, market structure, and sustainable production processes in order to make astute calls that improve market performance. The U.S. Federal Trade Commission's recently revised Green Guides offer some hope that government is developing the capacity to make more sophisticated judgment calls regarding ecolabels and corporate green claims.[11]

Several simplifications in this analysis merit exploration in further research. We have assumed that consumer willingness to pay for one label depends only on the standard for that label; in reality, ecolabels may function as substitutes, meaning prices would depend on the qualities of the other labels as well. Adding this feature would create additional interactions between competing labeling schemes. It would also be interesting to allow the NGO to campaign against the industry label, thereby reducing the demand for the latter. We assume firms are not initially differentiated according to their environmental quality, that there is no exit or entry in the model, and no market power. Each labeling organization finds it too costly to offer more than one standard, and neither is offered by a government, whose objectives might differ from both the NGO's and the industry's. Extending the model to generalize these features would make our analysis more general. Exploring the possibility of a sequential move game, where the NGO (or the industry) sets a standard before the rival does, would also be interesting. We have also assumed that standards set targets for reductions in damages. While this assumption may be applicable for some voluntary programs, many environmental labels set absolute standards, in which case the labeling groups would face more complicated twin distributions of firms by costs and by emissions. We would expect that including these additional complications would tend to reinforce ambiguity in the environmental

[11] The new Green Guides can be accessed at http://www.ftc.gov/bcp/grnrule/guides980427.htm.

effectiveness of competing ecolabels. Finally, we have limited ourselves to the study of "binary" ecolabels, that is, labels that either approve or disapprove a product. Although this is certainly true for many labels, such as Nordic Swan, Energy Star, and the Marine Stewardship Council, there are other labels, such as Leadership in Energy and Environmental Design (LEED) that have multiple tiers. Incorporating competing multi-tiered labels would make an interesting extension of our analysis.

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7 Appendix: Proofs of Lemmas and Propositions

Proposition 1 *If $f(\theta)$ is log-concave, then in autarky the NGO always sets a more stringent standard than does the industry.*

Proof. From the two first-order conditions (3) and (5), $s^N > s^I$ if at s^I, $p'(s^I) - \theta^I + \frac{F(\theta^I)}{f(\theta^I)} > 0$, which means the NGO prefers to increase s. This implies that

$$\frac{F(\theta^I)}{f(\theta^I)} > \frac{\int_{\underline{\theta}}^{\theta^I} F(\theta)d\theta}{F(\theta^I)}.$$

Rearranging terms, this is equivalent to

$$\left(F(\theta^I)\right)^2 > f(\theta^I)\int_{\underline{\theta}}^{\theta^I} F(\theta)d\theta. \tag{13}$$

Now define

$$G(x) = \int_{\underline{\theta}}^{x} F(\theta)d\theta,$$

so that $G'(x) = F(x)$ and $G''(x) = f(x)$ for any x in the support of the random variable θ. Given this, we can rewrite (13) as

$$G''(x)G(x) - \left(G'(x)\right)^2 < 0. \tag{14}$$

Remark 3 in the Appendix of Bagnoli and Bergstrom (2005) shows that $G(x)$ is log-concave if and only if (14) holds. Furthermore, Theorem 1 of Bagnoli and Bergstrom (2004) establishes that log-concavity is inherited, that is, if $f(x)$ is log-concave, then so are $F(x)$ and $G(x)$. Hence, because $f(x)$ is log-concave, so is $G(x)$, which implies immediately that (14) holds. ■

Lemma 2 $p'(s_B^L) - \theta_B^H > 0 > p'(s_B^H) - \theta_B^H$.

Proof. Because the firm profit function $p(s) - \theta s$ is strictly concave, it has a unique maximum, which we denote by $s^*(\theta)$. Hence, the existence of a cutoff cost value θ_B^H such that $p(s_B^H) - \theta_B^H s_B^H = p(s_B^L) - \theta_B^H s_B^L$ implies that $s_B^L < s^*(\theta_B^H) < s_B^H$. ■

Proposition 3 *Suppose the NGO sets a standard* s_B^N *and then industry responds with a standard* s_B^I. *If* $s_B^I < s_B^N$, *then it must be the case that* $s_B^I < s_A^I$, *and if* $s_B^I > s_B^N$, *then it must be the case that* $s_B^I > s_A^I$.

Proof. There are two cases to consider. In Case 1, industry chooses a weaker standard than the NGO, so that $s_{BIL}^I < s_{BIL}^N$, then $\theta_{BIL}^I > \theta_{BIL}^N$. At the cutoff cost factor θ_{BIL}^I, the alternative to the industry label is still no label, so $\theta_{BIL}^I \equiv (p(s_B^I) - p(0))/s_B^I$ as before. The first-order condition is now

$$\frac{\partial \Pi_{BIL}}{\partial s_B^I} = \int_{\theta_{BIL}^N}^{\theta_{BIL}^I} (p'(s_B^I) - \theta)f(\theta)d\theta = 0.$$

Note that this has the same form as (4) except that the lower limit of the integral is now θ_{BIL}^N

instead of $\underline{\theta}$. If we evaluate the above condition at the autarky standard, so $\theta^I_{BIL} = \theta^I_A$, we see that:

$$\frac{\partial \Pi_{BIL}}{\partial s^I_B} = \int_{\theta^N_{BIL}}^{\theta^I_{BIL}} (p'(s^I_A) - \theta) f(\theta) d\theta < \int_{\underline{\theta}}^{\theta^I_A} (p'(s^I_A) - \theta) f(\theta) d\theta = 0.$$

Since the move from $\underline{\theta}$ to θ^N_{BIL} truncates the lower end of the cost distribution, it removes positive contributions to the integral, and hence reduces its value. Thus, marginal industry profits are negative at the autarky standard, because the existence of the NGO label causes some low-cost firms to switch to it. Since industry profits are concave in s^I, then in response the industry chooses a lower standard than it would in the absence of an NGO label. In Case 2, industry chooses a standard $s^I_B > s^N_B$ (and hence $\theta^I_{BIH} < \theta^N_{BIH}$), and industry profits are

$$\Pi(s^I_B; s^N_B) = \int_{\underline{\theta}}^{\theta^I_{BIH}} (p(s^I_B) - \theta s^I_B) f(\theta) d\theta + \int_{\theta^I_{BIH}}^{\theta^N_{BIH}} (p(s^N_B) - \theta s^N_B) f(\theta) d\theta + \int_{\theta^N_{BIH}}^{\overline{\theta}} p(0) f(\theta) d\theta.$$

Recall that $\partial \theta^H_B / \partial s^L_B < 0$, which in this case means that $\partial \theta^I_{BIH} / \partial s^N_B < 0$. If $s^N = 0$, then we would have $\theta^I_B = \theta^I_A$, the autarky level. Now, however, we have $s^N > 0$, so $\theta^I_{BIH} < \theta^I_A$ for any given levels of s^N and $s^I > s^N$. The industry's first-order condition is now

$$\frac{\partial \Pi}{\partial s^I_B} = \int_{\underline{\theta}}^{\theta^I_{BIH}} (p'(s^I_B) - \theta) f(\theta) d\theta = 0$$

This condition has exactly the same form as (4), so at first glance it appears as if industry wants to set the same standard as in the absence of the NGO standard. However, since $\theta^I_{BIH} < \theta^I_A$, marginal profits are higher than they would be in autarky; therefore, the industry will choose a stronger standard than in the absence of an NGO label. ■

Proposition 4 *The industry's best-response function $s^I(s^N)$ is upward-sloping. There exists an $\widetilde{s}^N$ such that the industry best-response function is discontinuous at $s^N = \widetilde{s}^N$, with $s^I(s^N) > s^N$ for $s^N < \widetilde{s}^N$ and $s^I(s^N) < s^N$ for $s^N > \widetilde{s}^N$.*

Proof. We consider the two cases in turn. Consider first Case 1, with $s^I_B < s^N_B$. Totally differentiating the first-order condition, recalling that $\partial \theta^I_B / \partial s^N = 0$ for this case, substituting in for

$\partial\theta_B^N/\partial s^N = [p'(s_B^N) - \theta_B^N]/[s_B^N - s_B^I]$, rearranging terms, and using Lemma 2 yields

$$\frac{ds^I}{ds^N} = \frac{\overbrace{[p'(s_B^N) - \theta_{BIL}^N]}^{-}\overbrace{[p'(s_B^I) - \theta_{BIL}^N]}^{+}\overbrace{f(\theta_{BIL}^N)}^{+}}{\underbrace{(s_B^N - s_B^I)}_{+}\underbrace{[SOC_{BIL}^I]}_{-}} > 0.$$

Hence, the best-response function is upward-sloping for Case 1. Consider next Case 2, with $s_B^I > s_B^N$. Applying virtually identical steps to those used in Case 1, we obtain

$$\frac{ds^I}{ds^N} = \frac{\overbrace{[p'(s_B^N) - \theta_{BIH}^I]}^{+}\overbrace{[p'(s_B^I) - \theta_{BIH}^I]}^{-}\overbrace{f(\theta_{BIH}^I)}^{+}}{\underbrace{(s_B^I - s_B^N)}_{+}\underbrace{[SOC_{BIH}^I]}_{-}} > 0.$$

Thus, regardless of whether $s_B^N \lesseqgtr s_B^I$, the industry's best-response function is upward-sloping. Finally, consider the continuity of the best-response function. From Proposition 3 we know that if $s_B^I < s_B^N$, then $s_B^I < s_A^I$, and if $s_B^I > s_B^N$, then $s_B^I > s_A^I$. Since the reaction function is everywhere upward-sloping, there must be a discontinuous jump downward in the industry reaction function at some $\widetilde{s}^N$. At $\widetilde{s}^N$, it must be the case that maximized industry profits are equal in Case 1 and Case 2. ■

Lemma 5 *Under label competition, the NGO chooses $s_B^N \neq s_B^I$.*

Proof. Suppose to the contrary that $s_B^N = s_B^I$. The level of environmental improvement achieved is $V(s_B^I; s_B^I) = s_B^I F(\theta_B^I)$. Alternatively, if the NGO sets $s_B^N > s_B^I$, its objective function is

$$V_{BIL}(s_B^N; s_B^I) = s_B^I F(\theta_{BIL}^I) + (s_B^N - s_B^I)F(\theta_{BIL}^N).$$

From 11, we know this change has no effect on $\theta_{BIL}^I = \theta_B^I$, so the first term on the right-hand side is unchanged. However, some low-cost firms elect to certify to the NGO standard, and hence the second term on the right-hand side is strictly positive. Thus $V_{BIL}(s_B^N; s^I) > V(s^I; s^I)$. ■

Proposition 6 *Suppose the industry sets a standard s_B^I and the NGO responds with a standard s_B^N. Then, it is possible for $s_B^N \geq s_A^N$ but also possible for $s_B^N < s_A^N$.*

Proof. In Case 1, the NGO chooses $s_B^N > s^I$ and $\theta_{BIL}^I > \theta_{BIL}^N$. Now the relevant comparison for the cut-off firm at θ_{BIL}^N is not being unlabeled, but rather adopting the lower industry standard. By the same logic as in the industry case, we can show that $\theta_{BIL}^N < \theta_A^N$. In other words, by offering another option besides no label, the industry label reduces participation in the NGO label and lowers the relevant threshold cost for adopting the NGO label. The NGO's objective function is now

$$V_{BIL}(s_B^N; s_B^I) = s_B^I F(\theta_{BIL}^I) + (s_B^N - s_B^I) F(\theta_{BIL}^N),$$

and the first-order condition is

$$\frac{\partial V_{BIL}}{\partial s_B^N} = F(\theta_{BIL}^N) + (s_B^N - s_B^I) f(\theta_{BIL}^N) \frac{d\theta_{BIL}^N}{ds_B^N} = F(\theta_{BIL}^N) + (p'(s_B^N) - \theta_{BIL}^N) f(\theta_{BIL}^N),$$

where we have made use of the fact that when the industry is the Low standard, $d\theta_{BIL}^I / ds_B^N = 0$. Thus, once again we appear to recover the same first-order condition as in autarky:

$$p'(s_B^N) = \theta_{BIL}^N - \frac{F(\theta_{BIL}^N)}{f(\theta_{BIL}^N)}.$$

However, recall that $\theta_{BIL}^N < \theta_A^N$ for a given s^N. This has a direct effect of reducing the first term on the right-hand side of this equation, but it also reduces the cumulative distribution and has an ambiguous impact on the density. Therefore, the NGO may respond to the industry standard by either tightening or loosening its standard, or not at all, depending on the relative size of these factors. Now consider Case 2, in which the industry sets a standard, and the NGO responds with a lower one such that $s_B^N < s_B^I$ and $\theta_{BIH}^I < \theta_{BIH}^N$. In this case, the NGO maximizes

$$V_{BIH}(s_B^N; s_B^I) = s_B^I F(\theta_{BIH}^I) + s_B^N \left(F(\theta_{BIH}^N) - F(\theta_{BIH}^I) \right),$$

leading to the first-order condition

$$\frac{\partial V_{BIH}}{\partial s_B^N} = F(\theta_{BIH}^N) - F(\theta_{BIH}^I) + (s_B^I - s_B^N) f(\theta_{BIH}^I) \frac{d\theta_{BIH}^I}{ds_B^N} + s_B^N f(\theta_{BIH}^N) \frac{d\theta_{BIH}^N}{ds_B^N} = 0$$

Substituting in for $d\theta^I_{BIH}/ds^N_B$ and rearranging terms, we get

$$p'(s^N_B) = \theta^N_{BIH} - \frac{F(\theta^N_{BIH}) - F(\theta^I_{BIH}) + f(\theta^I_{BIH})(\theta^I_{BIH} - \theta^N_{BIH})}{\left(f(\theta^N_{BIH}) - f(\theta^I_{BIH})\right)}.$$

The numerator of the second term on the right-hand side is smaller than in the case of autarky (and possibly negative), but so is the denominator. Thus, the NGO may respond to a higher industry standard by raising or lowering its standard, relative to autarky. It is also possible that $s^N_B = s^N_A$, which is easily demonstrated by considering the case of a uniform distribution, for which the NGO's best-response function is independent of s^I. Since the uniform distribution is analyzed in detail in section 4, we omit that analysis here. ■

Proposition 7 *If $f(\theta)$ is monotonically increasing (decreasing), then the NGO's best-response function slopes upward (downward). Furthermore, for any density function that is single-peaked with mode θ^m, if $\theta^I_B < \theta^m$ ($\theta^I_B > \theta^m$), then the best-response function slopes upward (downward). There is a discontinuity in the NGO's best-response function at a point $s^I = \widetilde{s}^I$ with $s^N(s^I) > s^I$ for $s^I < \widetilde{s}^I$ and $s^N(s^I) < s^I$ for $s^I > \widetilde{s}^I$.*

Proof. Consider first Case 1, with $s^I_B < s^N_B$. Totally differentiating the first-order condition, substituting in for $\partial\theta^N_B/\partial s^I = -[p'(s^I_B) - \theta^N_B]/[s^N_B - s^I_B]$, rearranging terms, and recalling Lemma 2, we see that

$$\frac{ds^N}{ds^I} = \frac{\overbrace{[p'(s^I_B) - \theta^N_B]}^{+}\overbrace{[p'(s^N_B) - \theta^N_B]}^{-}\overbrace{f'(\theta^N_B)}^{?}}{\underbrace{(s^N_B - s^I_B)}_{+}\underbrace{[SOC]}_{-}}.$$

Consider next Case 2, with $s^N_B < s^I_B$. Totally differentiating the first-order condition, substituting in for $\partial\theta^I_B/\partial s^I = [p'(s^I_B) - \theta^I_B]/[s^I_B - s^N_B]$ and $\partial\theta^N_B/\partial s^I = 0$, rearranging terms, and applying Lemma 2 yields

$$\frac{ds^N}{ds^I} = \frac{\overbrace{[p'(s^I_B) - \theta^I_B]}^{-}\overbrace{[p'(s^N_B) - \theta^I_B]}^{+}\overbrace{f'(\theta^I_B)}^{?}}{\underbrace{(s^I_B - s^N_B)}_{+}\underbrace{[SOC^N_{BIL}]}_{-}}.$$

In both cases, the sign of the best-response function depends on the shape of the density function $f(\theta)$. If $f'(\theta) < (>) 0$ for all θ, then the NGO's best-response is downward(upward)-sloping for

$s_B^N < s_B^I$. Also, for any unimodal density function with mode θ^m, if $\theta_B^I < \theta^m$ ($\theta_B^I > \theta^m$), then the best-response function slopes upward (downward). Now consider the continuity of the best-response function. By construction, $s^N(0) = s_A^N$. Furthermore, $s^N(\overline{s}+\varepsilon) = s_A^N$, since a standard of $\overline{s}+\varepsilon$ attracts no participation. This implies a non-monotonic best-response function. Hence, if $f(\theta)$ is monotonic, then there must be a jump in the best-response function at some $\widetilde{s}^I$. However, even if $f(\theta)$ is not monotonic, Lemma 5 shows that $s^N(s^I) \neq s^I$, so there must be a discontinuity at the 45-degree line. Furthermore, the NGO best-response function must cross the 45-degree line, since for low enough s^I, e.g. $s^I = 0$, the NGO prefers to set $s_A^N > 0$ and for high enough s^I, e.g. $s^I = \overline{s}$, the NGO will prefer to set $s^N < s^I$ since otherwise its standard has no impact on environmental improvement. Thus, there must be a discontinuity at $s^N = s^I$. ■

Figure 1: Reaction Function Examples
(Narrow, Symmetric Distribution)

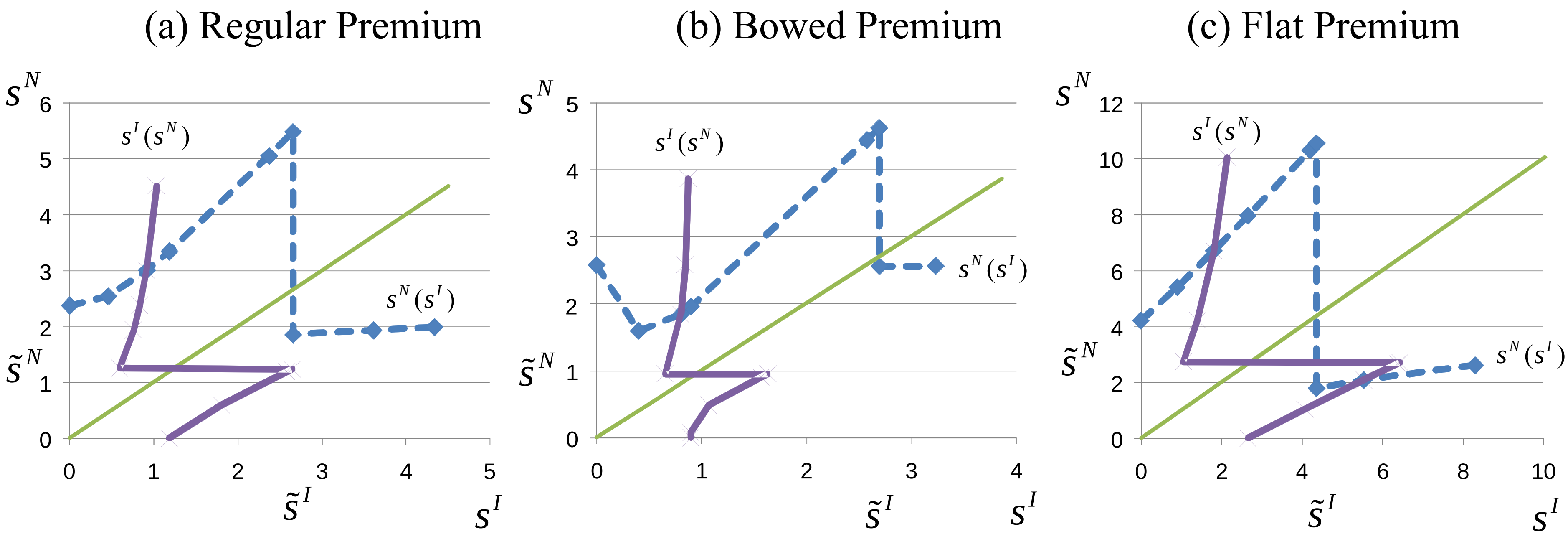

Figure 2 (a): Participation Shares with Regular Premium

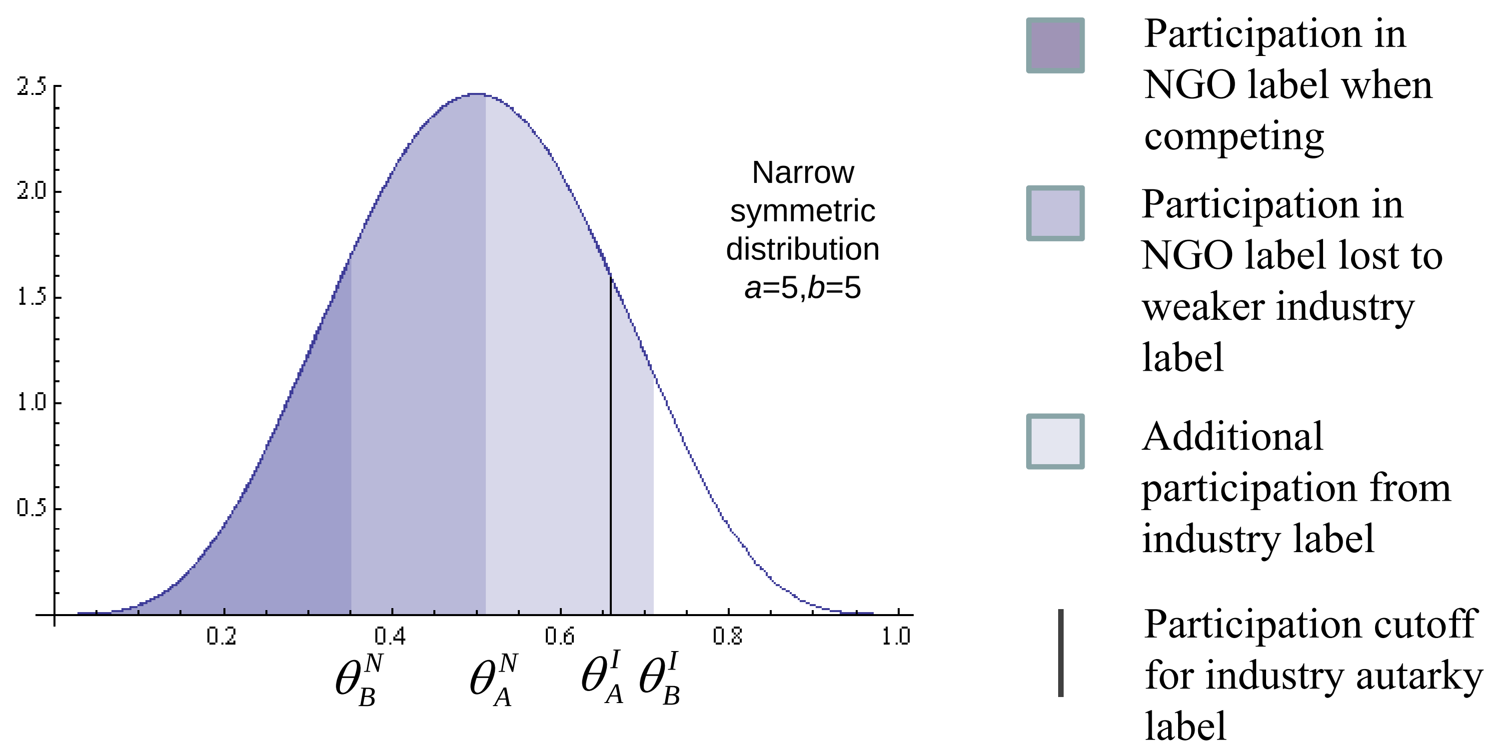

Figure 2 (b): Participation Shares with Bowed Premium

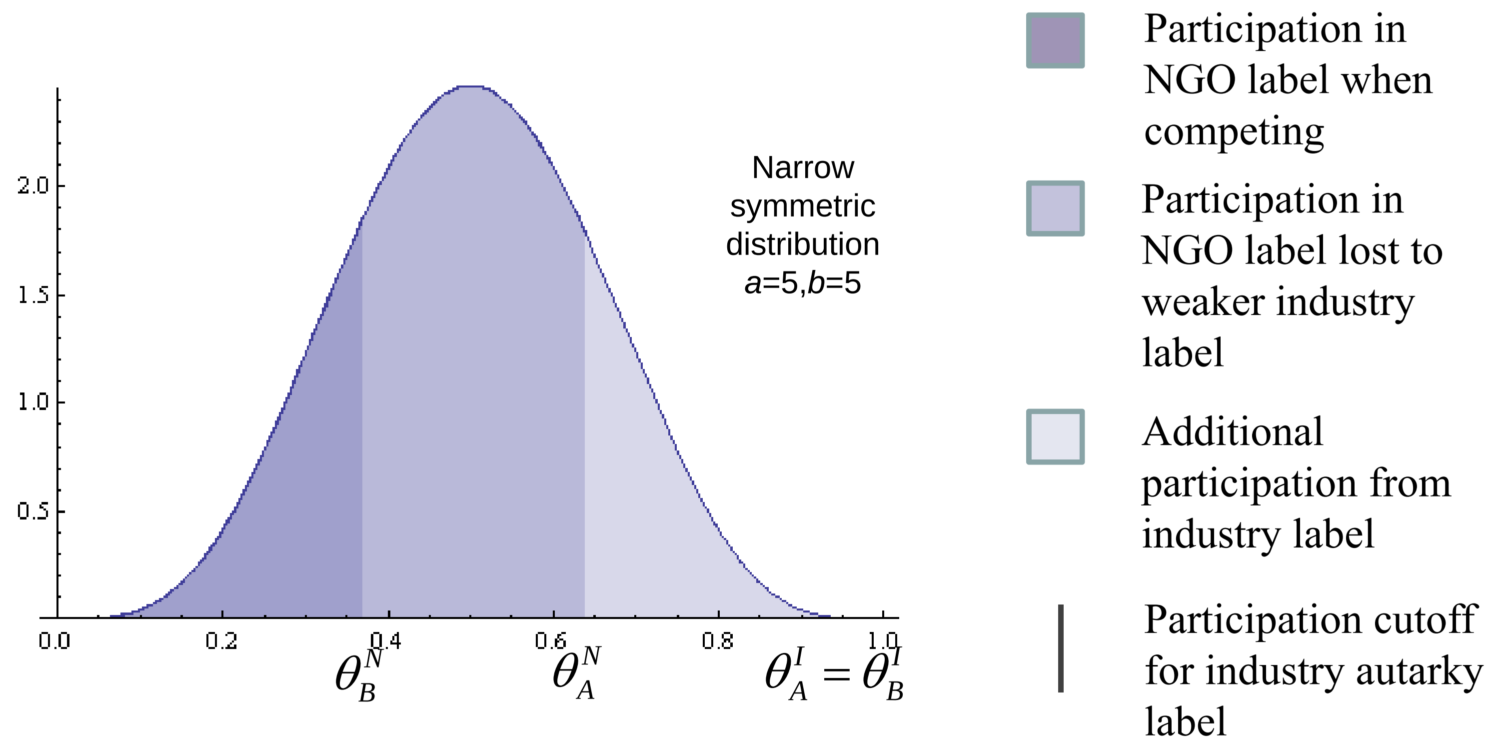

Figure 2 (c): Participation Shares with Flat Premium

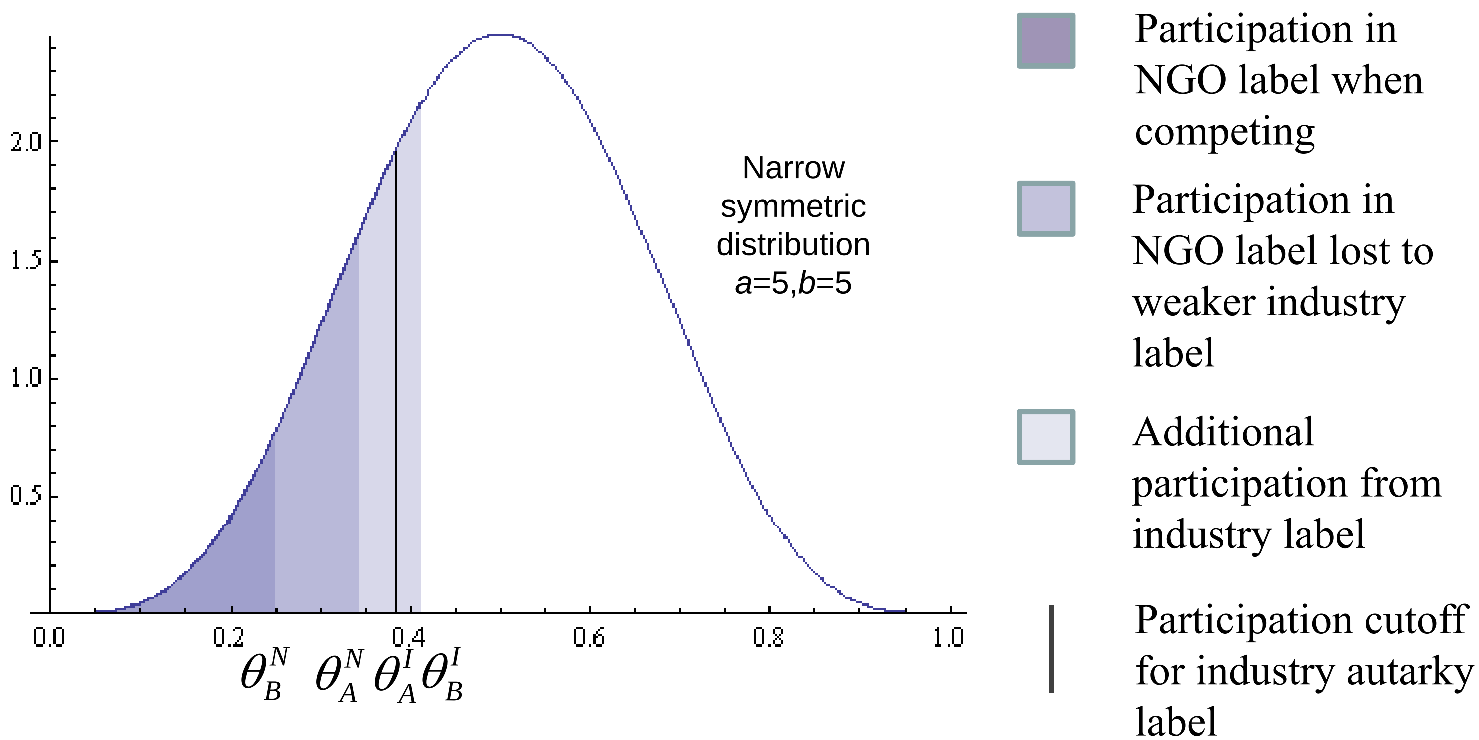

Figure 3: Environmental Benefits under Autarky and Label Competition, by Price Premium (for Narrow, Symmetric Distribution)