# Label Confusion:
## The Groucho Effect of Uncertain Standards*

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**Abstract**

Labels certify that a product meets some standard for quality, but often consumers are unsure of the exact standard that the label represents. Focusing on the case of eco-labels for environmental quality, we show how even small amounts of uncertainty can create consumer confusion that reduces or eliminates the value to firms of adopting voluntary labels. First, consumers are most suspicious of the standard for a label when a product with a bad reputation has it, so labels are often unpersuasive at showing that a seemingly bad product is actually good. Second, label proliferation multiplies the effect of uncertainty, causing the informativeness of labels to decrease rather than increase. Third, uncertainty makes labeling and non-labeling equilibria more likely to coexist as the number of labels increases, so consumers face greater strategic uncertainty over how to interpret the presence or absence of a label. Finally, a label can be either legitimitized or spoiled for use by other products when a product with a good or bad reputation displays it, so firms have an incentive to adopt labels strategically to manipulate such information spillovers, which further exacerbates label confusion. Managers can reduce label confusion by supporting mandatory labeling or by undertaking investments to make certain labels "focal".

JEL Classification Categories: L15, L21, D82

Key Words: Eco-labels, quality labels, disclosure, certification, persuasion, standard proliferation, self-regulation

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# 1 Introduction

When product quality is unobservable, quality labels are an important mechanism for firms to prove their quality to consumers. However, consumers are often unsure of the exact quality standard that a label represents – is it a relatively easy or difficult standard? This is particularly important for "eco-labels" for certifying environmental quality since environmental impact is often a credence good that consumers cannot directly observe and since there has been a proliferation of numerous different labels for firms to choose from.[1] Despite attempts by governments, industry groups, and NGOs to clarify label standards, confusion by consumers is widely blamed for undermining the credibility of eco-labels, thereby reducing the incentive for their adoption by firms.[2] We examine this issue of how consumer uncertainty about label standards affects the managerial decision to certify a product of given environmental quality with an eco-label.

When label standards are uncertain, consumers face a joint estimation problem. If they see a label on a product they must estimate whether the label is more indicative of a high quality product, or of an undemanding standard for the label. For instance, when a car buyer sees a Low Emission Vehicle label, she will update both her estimate of the car's environmental quality and of the meaning of the Low Emission Vehicle label. If the car is a large SUV then the updating on both dimensions is likely to be very different than if the car is a small hybrid. Just as an employer must jointly estimate the ability of a job applicant and the value of his degree, or a tourist must jointly estimate the quality of a hotel and the toughness of the local rating system, a consumer cannot rely on the mere presence of an eco-label to determine a product's environmental quality.

We investigate how this joint estimation problem affects the power of labels to reduce information asymmetries about product quality. We find that concern over the effects of uncertain labeling standards is well founded. In addition to the direct information loss due to the uncertainty, the optimal responses of consumers and firms lead to further information losses that can greatly undermine the value of voluntary labeling. First, labeling is most valuable when consumers think that a product is likely to be bad but in fact it is certifiably good. But when standards are uncertain, if a product is expected to be low quality then there is a "Groucho effect" in which consumers infer that the labeling standard is probably weak if such a product can meet it. Just as Groucho Marx famously joked that he did not want to join a club with standards so low as to accept him as a member, a firm with a bad reputation gains little from labeling. Therefore the incentive for labeling is undermined when the problem of information asymmetry, and hence the potential gain from labeling, is greatest.

[1] Ecolabelling.org lists over 300 eco-labels in use. Many of these apply to multiple product categories and use varying standards for the categories, e.g., only 11% of light fixtures are eligible for the U.S. EnergyStar Label for energy saving while 89% of televisions are eligible for the same label (Washington Post, February 22, 2010).

[2] As a report prepared for the World Bank noted, "The diversity of ecolabels (which reflect the multitude of certification schemes) can be confusing to consumers and weaken the credibility of all labels," (Fischer et al., 2005). See also "What do labels really tell you? As eco-labels proliferate, so do doubts," *Wall Street Journal*, April 2, 2009. The impact of label confusion on adoption incentives is seen for the E.U. Flower label where no products by major manufactures have been certified for some product categories (see *European Eco-label Catalogue* at www.eco-label.com) and surveys indicate that understanding of the label is far lower than of other regional and national eco-labels (Sto and Strandbakken, 2005).

Second, the presence of multiple labels with different standards should create more opportunity for firms of different quality levels to certify themselves and thereby reduce information asymmetries. But when standards are uncertain, the proliferation of labels has the opposite impact. Since consumers do not know which standards are easy and which are difficult, a label only proves that a firm has met the easiest of the different standards, even if the firm has met a higher standard. This both reduces the informativeness of labeling and also reduces the incentive to be certified. As the number of different standards rises, we find that the informativeness of labeling goes to zero and that a "non-labeling" equilibrium always exists for a sufficiently high number of standards.

Third, uncertain standards aggravate the problem of strategic uncertainty due to the coexistence of labeling and non-labeling equilibria. Multiple equilibria can arise with voluntary labeling because if consumers expect a firm to have a label then lack of one is particularly damaging to the firm's estimated quality, but if labeling is not expected then the firm loses less from not having a label and can save on certification costs. When standards are known, this multiplicity of equilibria disappears under a regularity condition as the number of standards increases. But with uncertain standards we find instead that the multiple equilibrium problem is aggravated by more labels and that labeling and non-labeling equilibria always coexist for a sufficiently large number of labels unless certification costs are so high that only non-labeling is an equilibrium.

Finally, we find that uncertainty over standards generates information externalities between firms that can lead to strategic behavior that further reduces the informativeness of labels. A firm can "legitimize" or "spoil" a label for use by other firms depending on whether the firm has a good or bad reputation. Consequently disreputable firms have an incentive to adopt the same label as reputable firms, while reputable firms instead have an incentive to avoid labels adopted by disreputable firms. Such managerial strategizing makes it difficult for consumers to rely on the existing reputations of firms as a simple way to learn about different standards, and gives certifiers an incentive to promote early adoption among firms of recognized high quality.[3]

A key factor in consumer uncertainty over labeling standards is that the source of a label or certificate is often unclear. For instance, the similar-appearing "FSC" and "SFI" labels are two of the main eco-labels for forest products, but one is controlled by an environmental NGO and the other by an industry-backed NGO. The potential for such confusion is widespread – of the 363 different labeling schemes tracked by ecolabelling.org, 209 are run by NGOs, 59 are run by industry groups, 53 are run by governments, and 42 are run by for-profit firms. Moreover, even when the source of a label is clear, the objectives of certifiers, and hence the likely difficulty of their standards, are often unclear.[4]

To capture these uncertainties, we model consumers as having a prior distribution of the labeling standard(s) that can be arbitrarily precise or diffuse, and arbitrarily skewed toward higher or lower

[3] An E.U. report on the difficulty of getting the E.U. Flower Label established in the laundry detergent market states, "Moreover, a real break-through calls for one or more of the multinationals to apply for the eco-label on their main products... it will probably have a snowball effect on the market." (Madsen et al., 2002).

[4] Shaked and Sutton (1981) discuss the varying objectives of industry groups, and Maxwell (2010) discusses the unclear objectives of NGOs.

levels. For instance, consumers might believe that an eco-label standard is likely to be easy or difficult, but be unsure of exactly how easy or difficult, or they might be completely uncertain of the difficulty. This distinguishes our approach from most of the literature in which the labeling standards are assumed to be common knowledge. Our model is most appropriate for consumer product markets where buyers are unlikely to be well-informed, rather than for markets for raw materials or intermediary products where buyers have strong incentives to acquire exact information on the source and meaning of different standards.

Since label confusion reduces the value of labeling as a strategy to inform consumers about product quality, firms with high environmental quality might want to take various managerial actions to reduce label confusion. Most directly, investments in clarifying label standards can enhance both the informativeness and likelihood of labeling, thereby allowing consumers to make more informed decisions.[5] Industry groups, governments, for-profit labelers, or NGOs interested in promoting label adoption can also try to make a particular standard "focal" in the sense of publicizing it and making consumers expect that firms will adopt the standard if they meet it. This can reduce or eliminate the information losses caused by label proliferation and by strategic uncertainty over which equilibria are being played by firms. For instance, "look for the label" campaigns can be interpreted as encouraging consumers to focus on particular labels among the multiplicity of possible labels. Government and industry attempts to reduce the number of labels or "harmonize" or standardize different voluntary standards also have this effect.[6]

These results on label confusion add to the literature on verifiable message "persuasion" or "disclosure" games (see the survey by Dranove and Jin, 2010),[7] and in particular to the debate on mandatory vs. voluntary disclosure. The classic "unravelling" result finds that mandatory disclosure is unnecessary since even those with bad information have an incentive to prove they do not have worse information.[8] However, as recognized early on, voluntary disclosure might be insufficient if

[5] Additional gains can arise from a quality response to labels as found by Jin and Leslie (2003), but we take quality as exogenous in our model and focus on the certification decision. Lerner and Tirole (2006) allow firms to adjust their quality in response to standards.

[6] In response to Canadian regulations enforcing a single definition for "organic", a spokesperson for the Organic Trade Association stated: "It's a consumer's dream. When they see an organic claim out in the marketplace, it has a very strict definition, the government is behind it, and everybody is meeting the same standards." (Montreal Gazette, February 17, 2009). More generally, the EU has been attempting to harmonize eco-labels across countries in the "Proposal for a Regulation of the European Parliament and of the Council on a Community Ecolabel Scheme," SEC(2008) 2118 and SEC(2008) 2119. Regarding private efforts, the ISEAL Alliance of certifiers has tried to make standards for eco-labels more transparent in order to reduce consumer confusion (http://isealalliance.org). Of course, not all firms prefer harmonization and transparency. Firms who cannot meet labeling standards or who prefer not to pay the costs can potentially benefit from more label confusion due to label proliferation.

[7] The restriction of messages to certain types, e.g., a firm cannot show a label it is not qualified for, distinguishes this literature from cheap talk games. Communication is still possible through pure cheap talk if there are multiple dimensions of quality (Chakraborty and Harbaugh, 2010), but in this paper we follow the standard assumption of a single dimension.

[8] Mandatory disclosure is distinct from the imposition of minimum quality standards that can exclude firms from the market (Leland, 1979). The application to environmental quality standards is considered by Arora and Gangopadhyay (1995) and Lutz, Lyon, and Maxwell (2000), and the application to eco-labeling is analyzed by Amacher, Koskela, and Ollikainen (2004) and Mattoo and Singh (1994).

disclosure is costly (Viscusi, 1978; Jovanovic, 1982; Verrecchia, 1983). Our analysis contributes to this debate by showing that the combination of costly disclosure and uncertainty is particularly disruptive to voluntary disclosure, and that the effects are exacerbated when there are multiple labels.

The idea that the imperfect nature of labels can have an important effect on disclosure strategies appears in other papers that differ from ours in other key respects. Sinclair-Desgagne and Gozlan (2003) consider binary tests of environmental quality that are known by consumers to vary in accuracy and allow firms to choose whether to take the more accurate or less accurate test. Lerner and Tirole (2006) and Farhi, Lerner, and Tirole (2008) consider standards that are known to be of differing difficulty and assume the firm is uncertain of its own quality, so that from the firm's perspective there is uncertainty over whether a particular standard will turn out to be too difficult. These papers focus on how firms can best "show off" their quality by choosing standards that are known to be either more or less difficult, and find that multiple standards increase the ability of firms to provide information about their quality. But for eco-labels we believe that our assumption that consumers are unaware of the underlying standard embodied in a certification label is more appropriate. Because of this difference in assumptions, other papers have not addressed the main issues that we examine, including confusion due to label proliferation, legitimizing and spoiling of labels, and the role for mandatory disclosure or "focal" equilibria in reducing confusion. As discussed later, the exception is Fishman and Hagerty (1990) who consider costless disclosure of one of multiple noisy signals of "high" or "low" quality and whose results are closely related to our findings regarding focal equilibria.

Our analysis is for the case where labels certify that a standard has been met and provide no more detailed information. Voluntary labels typically takes this "pass-fail" form in which a certificate or label is awarded or not, even in cases where more detailed information could be provided. For instance, of the 10 non-government eco-labels for carbon emissions listed at the ecolabelling.org website, all but one provides a simple label of approval without more detailed information about the product's carbon footprint. The prevalence of simple labels could reflect the need to reduce information processing by consumers. Or, consistent with the theoretical literature, it could reflect the incentive of certification intermediaries to withhold more detailed information when labeling is voluntary (Lizzeri, 1999). Given the prevalence of the pass-fail form and the multiple reasons for it, we take the form as given in our analysis.

We discuss our results in the context of eco-labeling, but they apply to any certification or labeling scheme about which uncertainty over a pass-fail standard exists. More broadly, the issues we investigate arise in any situation in which observers must jointly update their beliefs about an agent's quality and an uncertain quality standard. For instance, consistent with Groucho Marx's concerns, our analysis shows that a disreputable individual might indeed find little benefit from joining a club because the very fact of his membership downgrades the perceived standards of the club.

The paper proceeds as follows. In Section 2 we develop the basic model with one standard, define the conditions for the existence of both labeling and non-labeling equilibria, show the existence of the Groucho effect and analyze its impact on informativeness. In Section 3 we analyze the multi-standard case, showing that the qualitative results of Section 2 continue to hold, and that the impact of the Groucho effect is worsened. In Section 4 we consider strategic interactions between firms when there are multiple standards and information spillovers. In Section 5 we present our conclusions.

## 2 Base Model

We consider a firm's decision to have its product certified that it meets a quality standard for a eco-label. The product's exogenously given (environmental) quality $Q$ is distributed according to distribution $F$ with full support on $[0,1]$ and with corresponding density function $f$.[9] The firm knows the realized value $q$ of $Q$, but consumers only know its distribution $F$. There exists a label with standard $S$ which is distributed according to the distribution $G$ with full support on $[0,1]$ and with corresponding density function $g$. The firm knows the realized value $s$ of $S$. If consumers also know the realized value $s$ we say the standard is "certain" and if they only know the distribution $G$ we say the standard is "uncertain". For simplicity we assume $Q$ and $S$ are independent. In this section we assume that there is only one label.

If $q \geq s$ the firm has a choice to obtain a label or not, i.e., a firm that meets the labeling standard need not choose to be certified for the label. If $q < s$ the firm does not meet the standard so it has no choice. Certification has a fixed cost $c > 0$ that is independent of $q$ or $s$[10] and captures any fees to the certifier and any other costs, e.g., the expense of documenting quality control processes, auditing and testing costs by the certifier, and the opportunity cost of providing space on the product packaging for the label.[11] We assume the payoff to the firm is the expected quality of its product as estimated by consumers less the certification cost if it chooses to certify. Since we allow for general $F$, all of the results hold as long as the firm's payoff is a strictly increasing function of quality as estimated by consumers. Consumer concern for environmental quality could capture direct financial gains to the consumer, e.g., savings from lower energy use, or internalized social benefits, e.g., knowing that forests are protected.

[9] The exogeneity assumption applies best to quality features that are not so essential to consumers that the firm will immediately change its product in response to a label standard. While eco-labeling organizations typically hope for product changes over time, such hopes depend on the successful initial adoption of the eco-label for existing products. Our model is focused on this label adoption decision.

[10] Since quality $q$ is exogenous this cost is purely a certification cost rather than a cost to improve the product. We assume the certification cost is also independent of the standard $s$ but in some cases the testing component of certification costs might be more expensive when the standard is tougher. This would strengthen our result that consumers are suspicious that a label represents a low standard and aggravate the negative effect of standard uncertainty on labeling incentives.

[11] The costs of certification for eco-labels can be a substantial fraction of total costs (Vitalis, 2002). The main association of small and medium businesses in the E.U. lists its primary requested revision in eco-label policy as, "An overall reduction of the costs, in particular the costs of the technical tests required in order to show the respect of the criteria." (See "UEAPME's Position on the Revision of the Eco-label Regulation," UEAPME, November, 2008). Note that we are not differentiating between whether the manufacturer or retailer is paying the certification costs (Guo, 2009).

The expected quality of a product conditional on quality $Q$ exceeding the standard $S$, where the value of $S$ is distributed according to $G$, is

$$E[Q|Q \geq S] = \frac{\int_0^1 \int_s^1 q dF(q) dG(s)}{\int_0^1 \int_s^1 dF(q) dG(s)}, \tag{1}$$

and similarly the expected quality conditional on not meeting the standard is

$$E[Q|Q < S] = \frac{\int_0^1 \int_0^s q dF(q) dG(s)}{\int_0^1 \int_0^s dF(q) dG(s)}. \tag{2}$$

When $s$ is known these conditional expectations reduce to $E[Q|Q \geq s] = \int_s^1 q dF(q) / \int_s^1 dF(q)$ and $E[Q|Q < s] = \int_0^s q dF(q) / \int_0^s dF(q)$.

Before analyzing the equilibrium behavior of firms, first consider the effect of uncertainty about the standard on consumer information supposing that all firms meeting the standard obtain a label. Because the label provides information about both $Q$ and $S$, it provides less information about $Q$ alone than when $S$ is known. For instance, for the case of uniform $F$ and $G$, the expected mean-squared-error of consumer estimates of $Q$ falls from 1/12 to 1/24 when $S$ is certain but falls only to 1/18 when $S$ is uncertain. As the following proposition confirms, this pattern holds for general $F$ and $G$. For particular realizations $s$ of $S$, e.g., for very high or low $s$, certain standards can be less informative than uncertain standards, but on average a certain standard is more informative.

**Proposition 1** *Suppose all eligible firms are labeled. The expected informativeness of the label is lower if the standard is uncertain than if it is certain.*

**Proof.** All proofs are in the Appendix. ■

Clearly, if the objective of firms in affixing a label to their product is to convey information about quality to consumers, it is desirable that consumers understand the meaning of the label. Our objective in the present paper is to explore how the equilibrium labeling decisions of firms aggravate the uncertainty problem to create further confusion among consumers.

Our equilibrium concept is perfect Bayesian equilibrium subject to a belief-refinement introduced below. In a *labeling equilibrium* a firm whose product meets or exceeds the labeling standard always obtains a label, so the lack of a label implies failure to meet the standard. Consumer beliefs used to update product quality are consistent with this firm strategy in equilibrium, so the equilibrium condition is simply that the benefit from labeling is higher than the cost,[12]

$$E[Q|Q \geq S] - E[Q|Q < S] \geq c. \tag{3}$$

Since $E[Q|Q \geq S] > E[Q|Q < S]$ such an equilibrium exists for $c$ sufficiently small and does not exist for $c$ sufficiently large. In a *non-labeling equilibrium* a firm does not certify product quality

[12] If a labeling equilibrium exists a continuum of equilibria also exist where only types in some subset $X \subset [S, 1]$ obtain a label with the knife-edge result that $E[Q|Q \in X] - E[Q|Q \notin X] = c$. We do not analyze these equilibria in which all types are indifferent between labeling and non-labeling.

even if it can, so lack of a label represents no news at all, implying the prior estimate $E[Q]$ is unchanged. Labeling in the non-labeling equilibrium is an unexpected, out of equilibrium action. We refine the perfect Bayesian equilibrium set by assuming that consumers believe that such an action is equally likely to have been by any type that meets the standard, so an unexpected label is good news that generates the updated estimate $E[Q|Q \geq S]$.[13] Therefore the equilibrium condition for the non-labeling equilibrium is

$$E[Q|Q \geq S] - E[Q] \leq c. \tag{4}$$

Since $E[Q|Q \geq S] > E[Q]$ such an equilibrium does not exist for $c$ sufficiently small and does exist for $c$ sufficiently large. Comparing the two conditions, since $E[Q|Q < S] < E[Q]$ the left hand side of (3) is greater than the left hand side of (4), implying for any given $c$ one or the other of these two equilibria exists. Both conditions are satisfied simultaneously, indicating the existence of multiple equilibria, when

$$E[Q|Q \geq S] - E[Q] \leq c \leq E[Q|Q \geq S] - E[Q|Q < S], \tag{5}$$

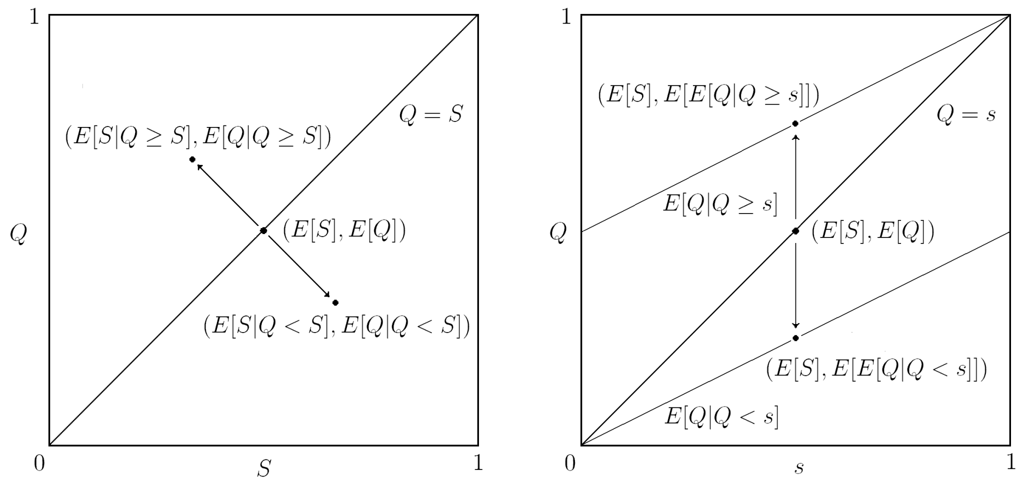
which is possible again by the fact that $E[Q|Q < S] < E[Q]$. Regarding when one of the equilibria is unique, the labeling condition (3) cannot be satisfied for $c$ sufficiently large and the non-labeling condition (4) cannot be satisfied for $c$ sufficiently small. We state these results as the following proposition where the proof verifies the inequalities stated above.

**Proposition 2** *With certain or uncertain labeling standards, there exists* $0 \leq \underline{c} < \overline{c} \leq 1$ *such that a non-labeling equilibrium exists iff* $c > \underline{c}$*, a labeling equilibrium exists iff* $c < \overline{c}$*, and both equilibria exist iff* $c \in [\underline{c}, \overline{c}]$*.*

To see the differential effects of certainty and uncertainty, first consider Figure 1(a) where $F$ and $G$ are uniform so that the priors are $(E[S], E[Q]) = (1/2, 1/2)$. The updated expectations of $S$ and $Q$ for $Q \geq S$ and $Q < S$ are given by the centers of mass of the upper and lower triangles respectively, so $E[Q|Q \geq S] = 2/3$ and $E[S|Q \geq S] = 1/3$, while $E[Q|Q < S] = 1/3$ and $E[S|Q < S] = 2/3$. Therefore meeting the standard is good news about $Q$ and bad news about $S$, while failing to meet the standard is the opposite. We term the downward adjustment of the estimate of $S$ due to a label the "Groucho effect" – achieving the goal diminishes the goal itself. And we term the upward adjustment to the estimate of $S$ due to lack of a label the "reverse Groucho effect" – failing to meet the goal enhances the goal itself. These adjustments lead to a moderating effect on the estimates of $Q$ where consumers are both less impressed by a label and less discouraged by lack of a label.

This can be seen by comparison with Figure 1(b) where $F$ and $G$ are still uniform and the realized value $s$ of the standard is known to consumers. The updated quality estimates based on meeting the standard or not, $E[Q|Q \geq s] = (1+s)/2$ and $E[Q|Q < s] = s/2$, are given respectively by the upper and lower lines in the figure. Integrating these estimates of $Q$ over the different values of $s$ we get the

[13] There is no variation in the incentives of different types to certify so, as discussed by Banks and Sobel (1987), standard forward-induction arguments do not indicate that one type or another is a more plausible source of the unexpected action.




a) Uncertain Standard $S$ b) Certain Standard $S = s$

Figure 1: Updated Quality and Standard Estimates

ex ante expected qualities for a certain standard of $E[E[Q|Q \geq s]] = 3/4$ and $E[E[Q|Q < s]] = 1/4$. These are the average expected qualities for the certain standard case where $s$ is known, and they are the expected qualities that would result for the uncertain standard case if the conditional distribution of $S$ did not become less favorable when $Q \geq S$ and more favorable when $Q < S$. Comparing these expectations with those in Figure 1(a), the example illustrates the general rule, verified in the proof of the following proposition, that

$$E[E[Q|Q < s]] < E[Q|Q < S] < E[Q] < E[Q|Q \geq S] < E[E[Q|Q \geq s]], \tag{6}$$

so meeting the labeling standard is better news on average if the standard is known for sure than if it is uncertain, and not meeting it is worse news on average if the standard is known for sure than if it is uncertain.

The relationship in (6) implies that condition (3) for a labeling equilibrium is more strict with an uncertain standard than it is on average for a certain standard, and that condition (4) for a non-labeling equilibrium is less strict with an uncertain standard than it is on average for a certain standard. Thus, the Groucho effect makes the condition for the labeling equilibrium harder to meet, and the reverse Groucho effect makes the condition for the non-labeling equilibrium easier to meet.

**Proposition 3** *The expected range of certification costs supporting a labeling (non-labeling) equilibrium is smaller (larger) if the standard is uncertain rather than certain.*

To gain further insight into these differences, consider Figure 2 where $G$ is uniform and $F$ follows the Beta distribution $B(q; a, b)$. For the figure we restrict either $a = 1$ and $b \geq 1$, or $a \geq 1$ and $b = 1$,

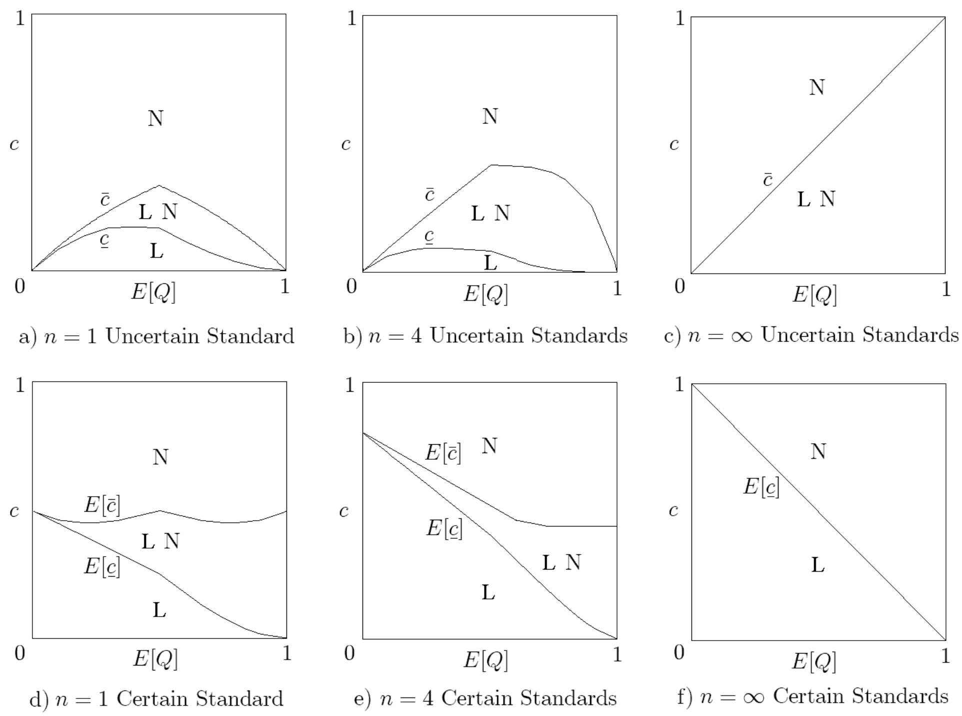



Figure 2: Labeling (L) and Non-Labeling (N) Equilibrium Regions

so that the distribution is respectively concave (a "bad reputation firm" with low expected quality) or convex (a "good reputation firm" with high expected quality) and is uniquely determined by its mean $E[Q] = a/(a+b)$.[14] Figure 2(a) shows the cost cutoff $\bar{c} = E[Q|Q \geq S] - E[Q|Q < S]$ for the boundary of the labeling region (L) from the equilibrium condition (3), and the cost cutoff $\underline{c} = E[Q|Q \geq S] - E[Q]$ for the boundary of the non-labeling region (N) from the equilibrium condition (4). Figure 2(d) shows the certain standard case where the corresponding regions are determined by the expected values $E[\bar{c}] = E[E[Q|Q \geq s]] - E[E[Q|Q < s]]$ and $E[\underline{c}] = E[E[Q|Q \geq s]] - E[Q]$ based on averaging out the exact values for different realizations of $S = s$. The figures illustrate the result from Proposition 2 that uncertainty over the standard makes label adoption less likely in that, relative to the case of certain standards, the equilibrium range for the labeling equilibrium is always smaller and the equilibrium range for the non-labeling equilibrium is always larger.

Consider the effect of prior expectations about firm quality on labeling incentives. The Groucho effect is strongest for firms with bad reputations because consumers are suspicious of any standard that such a firm can meet, and similarly the reverse Groucho effect is strongest for firms with good

[14] For instance, for integer values of $a$ and $b$, if $a = 1$ and $b \geq 1$ then $f(q) = b(1-q)^{b-1}$ and if the opposite then $f(q) = aq^{a-1}$. Therefore the Beta distribution reduces to the uniform distribution for $a = b = 1$, a falling triangle distribution for $a = 1$ and $b = 2$, and a rising triangle distribution for $a = 2$ and $b = 1$.

reputations since consumers infer that failure to obtain a label implies that the standard for the label was very difficult. Therefore the incentive to obtain a label is undermined the most for both good and bad reputation firms. Since the Groucho and reverse Groucho effects are weakest for intermediate firms whose quality is most uncertain, the impact of certification on expected quality is the strongest, and such firms have the most incentive to obtain a label.[15] This is seen in Figure 2(a) where the labeling region is at a minimum and the non-labeling region is at a maximum for $E[Q]$ approaching 0 or 1.

When standards are certain there is no joint updating about both quality and standards so bad reputation firms who are actually of high quality can effectively certify their quality, and good reputation firms who fail to certify their quality when expected to can be heavily penalized by consumers. Therefore, as seen in Figure 2(d) the labeling equilibrium region is comparably large for all firms. The non-labeling region is smallest for bad reputation firms because they have a strong incentive to certify their quality even when not expected to, while good reputation firms can rely on their good reputations and save the certification costs.

These results on the role of prior expectations imply that firms with bad reputations for environmental quality that can in fact meet relatively stringent standards have the most to gain from more transparent labeling standards. As will be seen in the following section, and as illustrated in the remaining panels of Figure 2, the divergence in labeling incentives between the certain and uncertain cases, and the differential effect on incentives based on prior expectations, becomes increasingly stark as the number of standards increases.

# 3 Multiple Labels

We now consider how label confusion is affected by the availability of multiple labels with different standards. As noted in the introduction, the proliferation of different labels for some products is quite extreme. For instance, the website ecolabelling.org lists over 30 different labels for forest products, over 40 different labels for textiles, and over 100 different labels for food products. It might seem that more options should offer firms more ways to show off their quality, so that label usage increases. But the proliferation of standards is often blamed for creating confusion among consumers that weakens the credibility of all labels and reduces label adoption (Fischer et al., 2005). This suggests that an increase in labels can aggravate the underlying problem of uncertain standards.

To gain insight into how the proliferation of labels interacts with standard uncertainty, we now assume that there are $n \geq 1$ labels with different standards drawn independently from the same distribution $G$ with the same cost $c$. Following standard notation for order statistics we denote the random variable representing the $i$th lowest realized standard by $S_{i:n}$ and its distribution by $G_{i:n}$, so that $G_{1:n}$ represents the distribution of the worst standard and $G_{n:n}$ represents the distribution

[15] The functional form of $F$ in the figure implies that $F$ is most diffuse for $E[Q] = 1/2$. Regarding mean-preserving spreads in $F$, for the case of uniform $G$ it can be shown that they increase the incentive to disclose both for certain and uncertain standards. From a sociological perspective, Phillips and Zuckerman (2001) find that middle status types have the most incentive to meet social norms given the uncertainty of their status.

of the best standard. The firm's quality and the realized difficulties of the different standards are only known by the firm, while $F$, $G$, $c$, and $n$ are also known by consumers.

For simplicity we assume that if a firm meets the standards for multiple different labels it can only adopt one of them. As long as attaining and displaying extra labels is costly, this assumption does not affect our main qualitative results.[16] We also restrict attention initially to a "symmetric" labeling strategy where the firm adopts the toughest label that it meets independent of any arbitrary properties of the ex ante identical standards. Any other equilibrium strategy that is similarly symmetric, such as always adopting the second toughest standard when possible, provides equivalent information about firm quality to consumers. For now we do not consider "focal" equilibrium strategies where it is assumed that a particular label will always be adopted if the standard for it is met.

Since consumers do not know which of the labels has a more difficult standard, a label under a symmetric labeling strategy only proves that a firm has met the easiest standard, even if the firm has in fact met the best standard. Hence the incentives to obtain a label or not are exactly the same as in the previous section, with the only exception that we replace the random variable $S$ with the random variable $S_{1:n}$ representing the weakest of the $n$ standards. Therefore, following conditions (3) and (4), for uncertain standards a *symmetric labeling equilibrium* exists if and only if

$$E[Q|Q \geq S_{1:n}] - E[Q|Q < S_{1:n}] \geq c \tag{7}$$

and a non-labeling equilibrium exists if and only if

$$E[Q|Q \geq S_{1:n}] - E[Q] \leq c. \tag{8}$$

For certain standards the conditions are quite different because consumers know the difficulty of the standard that was met, and also know the difficulty of standards that were not met. We define a labeling equilibrium for certain standards as an equilibrium in which any of the different labels are adopted. For instance, a firm might find a label with a high standard worth the certification cost, but not a label with a lower standard (e.g., Viscusi, 1978; Jovanovic, 1982). A labeling equilibrium exists if and only if some firm types find it more profitable to pay the certification cost and prove that they meet a particular standard (and none higher) than to be thought of as coming from the whole range below that standard,[17] i.e., if and only if

$$\max_{i=1,..,n} \{E[Q|s_{i:n} \leq Q \leq s_{i+1:n}] - E[Q|Q < s_{i:n}]\} \geq c, \tag{9}$$

[16] The restriction to displaying one label does not affect the conditions for existence of labeling and non-labeling equilibria if there are constant or diminishing returns to labels. This holds, for instance, for uniform $F$ and $G$. But if returns are increasing over some range, then it might be worthwhile to be certified by multiple labels even if it would not be worthwhile to be certified by one label, e.g., a restaurant might display multiple labels in its window. Since the marginal value of any label goes to 0 as the number of labels increases, the limiting results of this section are unaffected by the possibility of showing multiple labels.

[17] Given that firms meeting the label with standard $i$ adopt it, firms meeting a label with an even higher certain standard will also want to adopt that label, so the binding constraint is for the label with standard $i$.

where we define $s_{n+1:n} = 1$. The condition for a non-labeling equilibrium is simpler since lack of a label always gives a payoff of $E[Q]$, implying that the incentive to unexpectedly adopt a label is always highest for those meeting the highest standard. In particular, under our belief refinement a non-labeling equilibrium exists if and only if

$$E[Q|Q \geq s_{n:n}] - E[Q] \leq c. \tag{10}$$

As shown in Figure 2, these conditions imply that behavior with uncertain standards diverges dramatically from that with certain standards. As the number of labels $n$ increases consumers become increasingly suspicious of the value of a label and the expected quality conditional on having a label $E[Q|Q \geq S_{1:n}]$ falls. Therefore, comparing panel (a) with panels (b) and (c), as $n$ increases the non-labeling equilibrium region based on equation (8) expands. In the limit condition (8) converges to $E[Q] - E[Q] \leq c$ so a non-labeling equilibrium always exists for $c > 0$, which is particularly damaging to bad reputation firms who lose the opportunity to disprove consumer expectations. Regarding the labeling equilibrium, if consumers expect a firm to obtain a label and the firm does not, then the expected quality conditional on not having any label $E[Q|Q < S_{1:n}]$ also falls as the number of labels increases. Since both $E[Q|Q \geq S_{1:n}]$ and $E[Q|Q < S_{1:n}]$ are decreasing in $n$, the labeling equilibrium region based on (7) can expand or contract, and as seen in the figure in this example the region expands. In the limit condition (7) converges to $E[Q] - 0 \geq c$, so a labeling equilibrium only exists if firm reputations are sufficiently good.[18] This labeling equilibrium provides almost no information on firms, but good reputation firms still feel compelled to obtain a label to avoid being thought of as very low quality. In contrast, comparing panel (d) with panels (e) and (f), for certain standards as $n$ increases the labeling incentive for bad reputation firms becomes increasingly strong, while the labeling incentive for good reputation firms disappears.

The following proposition shows that these patterns hold generally for uncertain standards and, following Lizzeri (1999, Theorem 1), hold for certain standards as long as the distribution of $F$ is log-concave.[19]

**Proposition 4** *Suppose there are $n$ labels with i.i.d. standards. If standards are uncertain, (i) the support of a non-labeling equilibrium is increasing in $n$, and, in the limit as $n$ increases: (ii) non-labeling is an equilibrium for all $c > 0$, (iii) symmetric labeling is an equilibrium if and only if $E[Q] \geq c$, and (iv) the symmetric labeling equilibrium is uninformative. If standards are certain, in the limit as $n$ increases: (v) non-labeling is almost surely an equilibrium if and only if $E[Q] \geq 1 - c$, and (vi) for $F$ log-concave, labeling is almost surely an equilibrium if and only if $E[Q] \leq 1 - c$.*

[18] Note that at $E[Q] = 1$ the firm's quality is perfectly revealed and the incentive to label disappears, but our analysis assumes $Q$ has full support on $[0, 1]$ so the analytic results and the figure are for the range $E[Q] \in (0, 1)$.

[19] As a step in a more general analysis, Lizzeri (1999) analyzes the case where certification costs are given and each quality level can be certified. In our case in the limit as the number of labels increases there is essentially a different label for every quality level, so the problem converges to that analyzed by Lizzeri. Note that logconcavity is equivalent to a decreasing reverse hazard rate and is satisfied by most commonly used distributions including the Normal, Uniform and Beta distribution (Bagnoli and Bergstrom, 2005).

Recall that Proposition 1 showed that certification is always less informative when standards are uncertain. Proposition 4(iv) shows that for large $n$ this result is even stronger in that, even though labeling can still be an equilibrium for large $n$, the informativeness of a label when standards are uncertain goes to zero, i.e., estimates of $Q$ are no better than the prior estimates without a label. Managers find themselves in a labeling paradox. Labeling is completely wasteful since in equilibrium the firm proves that it is not of the lowest type, but the firm does not benefit relative to prior expectations and consumers do not learn any information since the firm being of the lowest type is a zero probability event anyway. This contrasts with the result for certain standards where as $n$ increases a label becomes highly informative and the only residual uncertainty arises from firms who do not have a label because of the certification costs. This suggests that as the number of labeling organizations expands organizations interested in promoting eco-labels should try to limit the number of labels or better educate consumers about label standards.

That labeling provides no new information as $n$ increases is related to the finding by Lizzeri (1999) that a certification intermediary who is interested in maximizing profits from certification will often choose the lowest possible standard with the result that there is no net gain in information to consumers. Since a firm that does not meet the standard will be thought of as extremely low quality, firms are willing to pay a high cost for the certificate, and since the certificate is so easy, almost all of them are able to pay for the certificate and receive it. Therefore a profit-maximizing certification intermediary uninterested in informing consumers benefits the most from a low standard. Our model differs in the assumption that there are multiple exogenous labeling standards rather than an endogenous standard chosen by a profit-maximizing certification intermediary, and that there is a fixed cost to certification rather than a profit-maximizing price set by the intermediary. Nevertheless we find the same result that as the number of labels grows consumers learn little from certification even as firms feel forced to expend substantial resources on it.

With multiple standards one standard is sometimes "focal" or "salient" in that consumers expect firms to adopt the standard if they are able to, even if they also meet another potentially more demanding standard. For instance, in many European countries regional or national eco-labels appear to be focal relative to the E.U. Flower Label, e.g., the Nordic Swan label and German Blue Angel labels are more widely adopted for almost all product categories. Given the focality of these labels and that consumers do not know which labeling standards are tougher, consumers might infer that a firm which displayed the E.U. Flower label was only able to attain it and not the focal label.

It might seem that information flows will decrease if firms are expected to choose a focal standard rather than the one they know to be toughest. To see how a focal standard can increase rather than decrease information flows, we now consider "focal labeling strategies" based on arbitrary properties of the labels that are unrelated to their difficulty. In such a strategy there is one label, say label $X$, that a firm is expected to adopt if it can. If the firm adopts another label, say label $Y$, then it is assumed that it could not meet label $X$ and that label $Y$ was the best of the other labels it did meet. For certain standards, a firm will clearly certify whichever label is toughest so any equilibrium based on focal strategies will break down. But for uncertain standards, consumers do not know which label is tougher so such a focal labeling equilibrium is possible. Such an equilibrium is more informative than a symmetric labeling equilibrium as the following proposition shows.[20]

**Proposition 5** *Suppose there are $n$ labels with i.i.d. standards. (i) If standards are uncertain and $c$ is sufficiently low there exists a focal labeling equilibrium that is more informative than the symmetric labeling equilibrium. ii) If standards are certain a focal labeling equilibrium cannot exist.*

The focality of a standard eliminates the problems caused by multiplicity of voluntary standards. The result is then similar to the $n = 1$ case in that there is no degradation of the expected difficulty of the standard, but it is actually better since firms who do not meet the focal standard can still provide information to consumers by meeting a different standard. As discussed in the introduction, this result provides a role for industry groups, governments, and NGOs in not just setting and clarifying standards, but in attempting to make particular standards focal. "Look for the label" campaigns can help induce an equilibrium where consumers expect a particular standard to be used, and look less favorably on adoption of other labels. The key is not necessarily that the focal label has a higher standard, or that the standard be certain, but simply that there is a single standard which consumers expect firms to try to attain.

This result has important implications for the debate over the role of industry-sponsored labels aimed at environmental and or social aspects of product quality. It is common for NGOs to criticize the introduction of industry-sponsored labels, often citing them as embodying lower quality standards than existing NGO labels. However, if the industry labels are introduced as a response to label proliferation, and if the industry succeeds in making its label focal, then there can be a gain in information to consumers. Therefore it might be strategic for NGOs to settle for less demanding labels that have a greater chance of becoming focal.

Our result on focal certification equilibria is closely related to a finding by Fishman and Hagerty (1990) who analyze a persuasion game with costless disclosure where there are multiple noisy signals about whether an investment project is profitable or not, and assume that a firm can only reveal one of them. Similar to our result they find that a "lexicographic" equilibrium is most informative in which a firm releases the first signal that is favorable in accordance with a set order that is anticipated by receivers, so that releasing another favorable signal is therefore evidence that the first signal was not favorable.[21]

An alternative to the use of campaigns to establish focal standards is to simply make it mandatory for a firm to disclose whether it meets a particular standard. In this case bad news regarding this

[20] The following proposition looks at the case where costs are sufficiently low that a firm will adopt another label if it cannot meet the standard for the focal label. It can also be an equilibrium for a firm to adopt the focal label if it can and otherwise not adopt any label. For sufficiently many standards such a strategy is also more informative than the symmetric disclosure equilibrium, but for low costs the firm has an incentive to deviate to the equilibrium strategy we examine. Note also that in a focal equilibrium fewer firms pay the certification cost than in a symmetric equilibrium.

[21] For more than two signals the lexicographic equilibrium they consider differs from our focal equilibrium because there is a backup second "focal" label, then a third, etc. Because our setup is complicated by allowing for a continuum of firm types and labeling standards, and because such a full degree of coordination appears unlikely for product labels, we do not evaluate such a lexicographic strategy.

mandatory disclosure on one standard can still be supplemented with good news on other standards, so the result is essentially the same as in the focal equilibrium if the certification costs for the mandatory standards are taken as sunk costs. Therefore the informativeness result of Proposition 5 also provides an argument for mandatory certification of a particular label, even if consumers do not know the exact standard for the label, and suggests that firms may benefit from partnering with government or dominant NGOs to promote a specific label as a marketing strategy.

# 4 Multiple Firms

We now consider how the presence of multiple firms affects label confusion. It might seem that, by observing which firms obtain which labels, consumers should be able to learn about different labeling standards, and thereby reduce the information problems analyzed above. Indeed, if there is only one label and all firms that can meet the label standard adopt it, then as the number of firms increases, the fraction of the firms obtaining the label is an increasingly precise estimate of the label standard. However, we find that two factors limit such learning. First, the non-labeling equilibrium is unaffected by an increase in the number of firms, so the potential for no learning, and also the potential for strategic uncertainty about how to interpret lack of a label, remains. Second, in the realistic case where there are both multiple firms and also multiple labels, we find that firms have an incentive to choose standards strategically in a way that interferes with consumer learning.

First consider the simpler case where $m$ firms with i.i.d. qualities $Q_1, ..., Q_m$ simultaneously choose whether to adopt a single label with standard $S$. Assume that firms know the realized values of their own and each other's qualities $q_1, ..., q_m$ and the realized difficulty of the standard $s$, but that consumers only know $F$, $G$, $c$, and $m$. The first part of the following proposition uses a standard Law of Large Numbers result to confirm that the fraction of firms obtaining the label can be an asymptotically precise estimate of the standard, so the situation for each firm is equivalent to that of a single firm facing a certain standard as examined in Section 2. The second part shows that this logic does not extend to the non-labeling equilibrium since the gain from deviating by a single firm is $E[Q_i|Q_i \geq S] - E[Q_i]$, so the condition for a nondisclosure equilibrium remains exactly the same as that of a single firm facing an uncertain standard. The third part confirms that for a certain standard the number of firms has no effect on the support of either equilibrium.

**Proposition 6** *Suppose $m$ i.i.d. firms face a single label. If the label standard is uncertain: (i) the expected support of a labeling equilibrium converges to that of a single firm facing a certain standard as $m$ increases, while (ii) the expected support of a non-labeling equilibrium is the same as for $m = 1$. (iii) If the label standard is certain the expected support of either equilibrium is the same as for $m = 1$.*

Looking back at Figure 2, this Proposition implies that the region where the labeling and non-labeling equilibria coexist expands from the "L,N" areas in the separate panels of (a) and (d) to encompass the area above $\underline{c}$ in panel (a) and underneath $E[\overline{c}]$ in panel (d). Therefore even though the presence of multiple firms can potentially reduce uncertainty over the standard by the first part of the proposition, it need not do so by the second part of the proposition, and the combination of these results implies that there is increased strategic uncertainty due to the larger range of $c$ that supports multiple equilibria.[22] Therefore this result reinforces the argument that firms and organizations interested in promoting eco-label adoption need to consider how to promote eco-labels in an environment where both labeling and non-labeling are equilibria. Similarly it also supports a role for mandatory labeling to avoid the multiple equilibrium problem.

Now considering the case where there are both multiple firms and multiple labels, learning about label standards is made more difficult because adoption of one label by a firm creates an information externality or spillover that can affect the incentives for other firms to certify. If a firm follows the strategy of adopting the toughest label that it meets, and if the firm is a good reputation firm, then adoption of a label might be good news about the label standard which counteracts the Groucho effect. Because of this selection effect a good reputation firm can "legitimize" a standard and make it more attractive to other firms, while because of the Groucho effect a bad reputation firm can "spoil" a standard and make it less attractive to other firms. Firms therefore have an incentive to choose standards strategically in a way that interferes with consumer learning.

To gain insight into this incentive, first suppose there are two labels with i.i.d. standards and two i.i.d. firms. If one firm follows the strategy of adopting the toughest label it meets and the prior $F$ is very favorable, then the label which it adopts is likely to be the better one. This gives the other firm an incentive to adopt the same label, regardless of whether the label is really the toughest. Conversely, if the prior $F$ is very unfavorable, then the label which is adopted is still likely to be the worse one. This gives the other firm an incentive to adopt the opposite label, regardless of whether it is really the toughest. Therefore in both cases firms have an incentive to deviate from the symmetric certification strategy of adopting the label with the toughest standard.[23]

This is seen in Figure 3(a) for two firms with i.i.d. quality given by the Beta distribution as before and for two standards with i.i.d. uniform distribution. Define $E[Q_i|\text{Same}]$ as the expected quality of firm $i$'s product when the toughest standard that each firm meets is the same,

$$E[Q_i|S_{1:2} \leq Q_1, Q_2 < S_{2:2} \cup S_{1:2} < S_{2:2} \leq Q_1, Q_2], \tag{11}$$

and $E[Q_i|\text{Different}]$ as the expected quality of firm $i$'s product when one firm meets a higher standard,

$$E[Q_i|S_{1:2} \leq Q_1 < S_{2:2} \leq Q_2 \cup S_{1:2} \leq Q_2 < S_{2:2} \leq Q_1]. \tag{12}$$

[22] This is seen for the E.U. Flower Label which has different standards for different product categories, and where label adoption rates for the categories vary greatly. For instance, consumers could interpret the absence of adoption by any major laundry detergent products either as reflecting a non-labeling equilibrium or as strong evidence that the labeling standard for detergents is very strict. In this case the former interpretation appears to be correct (Rubik and Frankl, 2005).

[23] Jovanovic (1982) notes in passing that the disclosure incentives of one firm can be affected by those of another if firm quality is correlated. Here firm quality is independent but conditional correlation is generated by the same uncertain standards being available to each firm.

Because the firms are i.i.d., $E[Q_1|\text{Same}] = E[Q_2|\text{Same}]$ and $E[Q_1|\text{Different}] = E[Q_2|\text{Different}]$, so if (11)>(12) both firms will prefer to adopt the same standard even if one meets a higher standard, and if (11)<(12) both firms will prefer to adopt a different standard even if they both meet the higher standard, so a pure strategy equilibrium cannot exist. Only in the knife-edge case where (11)=(12) and the firms are just indifferent is it an equilibrium for firms to always follow the symmetric labeling strategy. This is seen in the figure where, unless $E[Q_i] = 1/2$, firms have an incentive to either pool with each other or separate from each other by choosing standards strategically. Such strategic behavior aggravates label confusion and makes it more difficult for a firm with a bad reputation to prove itself to be good.

Now consider more generally $m$ firms with i.i.d. qualities choosing simultaneously whether to adopt one of $n$ labels with i.i.d. standards where again the realized qualities and standards are known by the firms but only $F$, $G$, $c$, $m$, and $n$ are known to consumers. Let $a = (a_1, ..., a_m)$ where $a_j$ equals the label 1 to $n$ adopted by firm $j$ with 0 representing no label. Then in a candidate symmetric labeling equilibrium $E[Q_i|a]$ is expected quality conditional on the observed $a$ and on the equilibrium strategy of adopting the toughest label attainable. If $E[Q_i|a]$ is constant for all $a$ that are attainable for a given realization of $(Q_1, ..., Q_m)$ then no firm has an incentive to deviate. But if this knife-edge condition does not hold then, as in the two-firm and two-label example above, at least one firm has an incentive to deviate by adopting a lower standard.

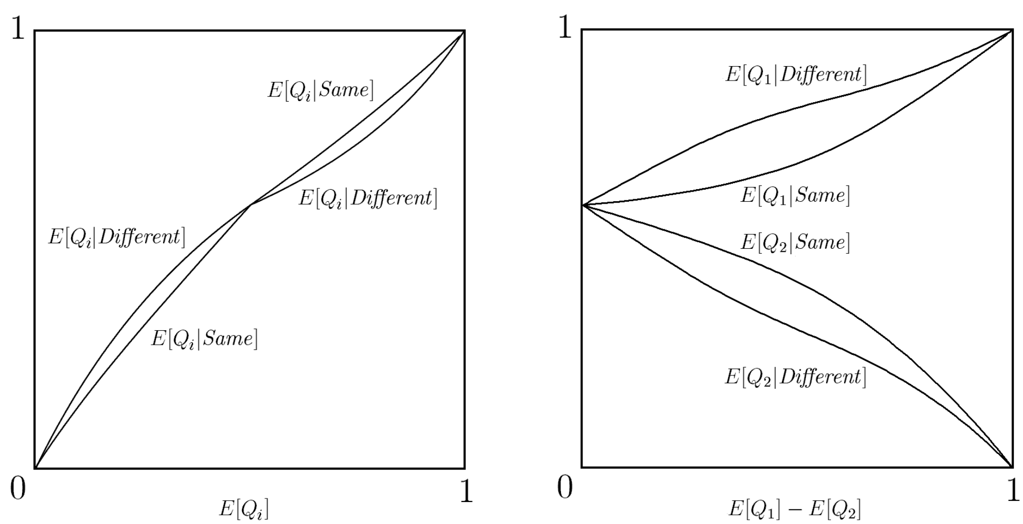
This problem does not arise for a focal equilibrium. Suppose that there is a particular label that each firm is expected to adopt or not if it meets the standard for it. Then the incentive to adopt the label is exactly the same as if there was only one label,[24] including the result from Proposition 6 that with many firms consumers will become increasingly certain of the standard for the focal label. Therefore the focal equilibrium can approximate the case of a mandatory label, allowing consumers to learn about the meaning of the standard for the label from their experiences with different products. Again this result supports a role for marketing efforts aimed at the development or adoption of a focal labeling standard.

The proof of the following proposition follows directly from the above arguments.

**Proposition 7** *Suppose $m > 1$ i.i.d. firms choose among $n > 1$ labels with i.i.d. standards. i) If the label standards are uncertain then a symmetric labeling equilibrium does not exist generically, but a focal labeling equilibrium always exists under the same condition as for $n = 1$. ii) If the label standards are certain then the support of any equilibrium is the same as for $m = 1$.*

This incentive to choose standards strategically can be aggravated if consumers have different priors about the different firms's products. Figure 3(b) shows the case where "good reputation" firm 1 has convex Beta distribution parameterized by $(\theta, 1)$ and "bad reputation" firm 2 has the symmetric concave independent Beta distribution parameterized by $(1, \theta)$ so $E[Q_1] - E[Q_2] = (\theta - 1)/(\theta + 1)$.

[24] If firms that do not meet the standard for the focal label adopt another label then this is good news that the firm at least meets the easiest standard. Which of the other labels firms choose depends on the same coordination issues regarding the symmetric labeling equilibrium, so generically there will be a mixed strategy equilibrium for the other labels, but this does not affect the incentive to adopt the focal label.




a) Two I.I.D. Firms b) Good and Bad Reputation Firms

Figure 3: Strategic Choice of Labels

When $\theta = 1$ both firms have uniformly distributed quality ($E[Q_1] = E[Q_2] = 1/2$ in the figure) there is no incentive to be strategic, but as soon as a gap emerges the good reputation firm always wants to choose a different label than the bad reputation firm, and the bad reputation firm always wants to choose the same label as the good reputation firm. If both firms adopt the same label, it is likely that only the weaker standard was met, which is bad news for the good reputation firm and good news or the bad reputation firm. If both firms adopt different labels, it is likely that the good reputation firm met the tougher standard and the bad reputation firm met the weaker standard, so the good reputation firm gains and the bad reputation firm loses. Hence there cannot be an equilibrium in which each firm always adopts the toughest label it meets. Instead, if both firms meet both standards, there must be a mixed strategy equilibrium where the bad reputation firm tries to choose the same label as the good reputation firm while the good reputation firm tries to avoid such an outcome.

The above analysis assumes that the choice of standards is simultaneous, but the analysis can also be applied to the case of sequential adoption. In the sequential case, a "labeling cascade" can emerge in which firms choose the same label strategically. For instance, in the two-firm and two-label example in Figure 3(a), if both firms have good reputations so that $E[Q_i|Same] > E[Q_i|Different]$ then the second firm raises its expected quality by herding with the first firm and adopting the same label even if it meets an even tougher standard for another label. Similarly, if both firms have good reputations so that $E[Q_i|Same] < E[Q_i|Different]$ then anti-herding can arise in which the second firm chooses a different label than the first firm. These effects are amplified if the firms have different reputations as in the example in Figure 3(b), in which case herding will arise if the good reputation firm goes first and anti-herding will arise if the bad reputation firm goes first. In each case, the uncertainty of standards creates interdependence in the perceived quality of products that leads to a strategic choice of labels.[25]

As mentioned in the introduction, a common strategy when introducing a new eco-label is to try to induce the most reputable companies to adopt the label with the hope that other companies will then adopt it. Similar strategies occur in many other contexts, e.g., new journals try to start with articles by respected authors. The above analysis implies that information spillovers may be one reason for this strategy. If a good reputation firm moves first then the bad reputation firm can always choose the same label if it is capable of doing so. Therefore the good reputation firm has no incentive to deliberately choose an easier label and, if it faces any uncertainty at all over whether the bad reputation firm will meet the tougher label, it has a strict incentive to choose the tougher label. However, since there is a second-mover advantage, a good firm needs to be given some incentive to move first.

We have assumed that firms do not care directly how other firms are regarded by consumers, but only care if the label itself is diminished or enhanced due to the actions of other firms. In many situations firms will be in the same industry and therefore have a competitive incentive to look good relative to other firms by undermining their competitors' perceived quality.[26] The above analysis shows that, even without such product market externalities, firms need to worry about the strategic effects of labeling decisions.

# 5 Conclusion

The literature on eco-labels and other quality certification schemes has long recognized that consumer confusion is a major hurdle to their adoption and effective use. Our analysis provides a theoretical basis for such concerns when consumers have even slight uncertainty about the difficulty of labeling standards. Since consumers must jointly update the estimated quality of the product and the estimated difficulty of the standard, there are not only direct information losses but also substantial indirect losses as firms decide whether it is worthwhile to be certified and, if so, which of multiple labels to adopt. We find that a "Groucho effect" due to uncertainty discourages labeling when it is most beneficial to consumers and firms, that the effects of uncertainty are aggravated by the proliferation of labels with different standards, that strategic uncertainty due to multiple equilibria becomes particularly problematic as the number of labels increases, and that information spillovers give firms an incentive to choose strategically among different labels so as to make learning about labeling standards more difficult for consumers.

[25] Note that we are focusing on choices between different labels, rather the choice to obtain a label at all. If choices are sequential and a firm unexpectedly deviates from the non-labeling equilibrium then consumer beliefs might reasonably change and other firms might face pressure to also deviate, but our belief refinement does not apply in this case.

[26] However, competition does not always lead to more disclosure. Guo and Zhao (2009) show that there is less disclosure in a competitive rather than monopolistic environment, though sequential disclosure can mitigate the problem. See also Hotz and Xiao (2006), Board (2009), and Levin, Peck and Ye (2009).

Mandatory adoption of eco-labels can also suffer from direct information losses due to uncertainty over certification standards, but precludes the additional indirect losses due to firm labeling decisions, and can also facilitate consumer learning about standards. Therefore these results provide an additional consideration in the debate over voluntary versus mandatory disclosure of product quality. We find that actions aimed at making one standard "focal" can also reduce the indirect information losses. "Look for the label" promotional campaigns that induce consumers and firms to focus on a particular label, even if the standard for it remains uncertain, can increase certification incentives, reduce the problem of strategic uncertainty due to multiple equilibria, and improve consumer learning by eliminating firm incentives to choose among labels strategically.

Our results assume that consumers are unsure of both the absolute and relative difficulty of different standards, but sometimes the relative difficulty of different standards is known even when the exact standards are not. For instance, consumers might know that one eco-label is an industry label while another is an NGO label, and infer that the latter represents a more difficult standard. Clearly, such relative information can reduce some of the problems identified in this paper. Therefore another strategy for organizations to reduce label confusion is to focus on providing a clear ranking of different labels, even if the exact standards remain difficult to communicate to consumers. One option is for a single certifier to provide multiple labels representing different ranked standards, e.g., gold, silver, and bronze labels for LEED certification of buildings. However, as discussed in the introduction, the vast majority of eco-labels take the simple pass-fail form analyzed in this paper, so better understanding of why certifiers do not provide richer information to consumers is an important area of future research.

# 6 Appendix

**Proof of Proposition 1:** Let $\underline{q} = E[Q|Q < S]$ and $\overline{q} = E[Q|Q \geq S]$, and, for the realized value $S = s$, let $\underline{q}(s) = E[Q|Q < s]$ and $\overline{q}(s) = E[Q|Q \geq s]$. Then the mean-squared error (MSE) for the uncertain case is

$$\begin{aligned}
& \int_0^1 \left( \int_0^s (q - \underline{q})^2 dF(q) + \int_s^1 (q - \overline{q})^2 dF(q) \right) dG(s) \\
= \; & \int_0^1 \left( \int_0^s (q^2 - 2q\underline{q} + \underline{q}^2) dF(q) + \int_s^1 (q^2 - 2q\overline{q} + \overline{q}^2) dF(q) \right) dG(s) \\
= \; & E[Q^2] + \int_0^1 \left( F(s) \left( \underline{q}^2 - 2\underline{q}\ \underline{q}(s) \right) + (1 - F(s)) \left( \overline{q}^2 - 2\overline{q}\ \overline{q}(s) \right) \right) dG(s) \qquad (13)
\end{aligned}$$

and the expected MSE for the certain case is

$$
\begin{aligned}
& \int_0^1 \left( \int_0^s (q-\underline{q}(s))^2 dF(q) + \int_s^1 (q-\overline{q}(s))^2 dF(q) \right) dG(s) \\
= \quad & E[Q^2] + \int_0^1 \left( F(s) \left( \underline{q}(s)^2 - 2\underline{q}(s)^2 \right) + (1-F(s)) \left( \overline{q}(s)^2 - 2\overline{q}(s)^2 \right) \right) dG(s) \\
= \quad & E[Q^2] - \int_0^1 \left( F(s)\underline{q}(s)^2 + (1-F(s))\overline{q}(s)^2 \right) dG(s). \qquad (14)
\end{aligned}
$$

Comparing, (13)–(14) equals

$$
\begin{aligned}
& \int_0^1 F(s) \left( \underline{q}^2 - 2\underline{q}\ \underline{q}(s) \right) + (1-F(s)) \left( \overline{q}^2 - 2\overline{q}\ \overline{q}(s) \right) dG(s) \\
& + \int_0^1 F(s)\underline{q}(s)^2 + (1-F(s))\overline{q}(s)^2 dG(s) \\
= \quad & \int_0^1 F(s) \left( \underline{q}^2 - 2\underline{q}\ \underline{q}(s) + \underline{q}(s)^2 \right) + (1-F(s)) \left( \overline{q}^2 - 2\overline{q}\ \overline{q}(s) + \overline{q}(s)^2 \right) dG(s) \\
= \quad & \int_0^1 F(s)(\underline{q} - \underline{q}(s))^2 + (1-F(s)) \left( \overline{q} - \overline{q}(s) \right)^2 dG(s) > 0, \qquad (15)
\end{aligned}
$$

so the MSE is larger for the uncertain case. ■

**Proof of Proposition 2:** Given that the support of $q$ is restricted to $[0,1]$ we just need to verify for the uncertain case that $E[Q|Q \geq S] > E[Q < S]$, $E[Q|Q \geq S] > E[Q]$, and $E[Q|Q < S] < E[Q]$ and for the certain case that $E[Q|Q \geq s] > E[Q < s]$, $E[Q|Q \geq s] \geq E[Q]$, and $E[Q|Q < s] \leq E[Q]$ for all $s$. The latter group of inequalities is standard for conditional expectations. Checking the first group of inequalities, note that $E[Q|Q \geq S] - E[Q]$ equals

$$
\begin{aligned}
& \int_0^1 \int_s^1 q dF(q) dG(s) - E[Q] \int_0^1 \int_s^1 dF(q) dG(s) \\
= \quad & \int_0^1 \left( \int_s^1 q dF(q) - \int_s^1 dF(q) E[Q] \right) dG(s) \\
\propto \quad & \int_0^1 \left( E[Q|Q \geq s] - E[Q] \right) dG(s) > 0, \qquad (16)
\end{aligned}
$$

where the inequality follows since $E[Q|Q \geq s] \geq E[Q]$ for all $s$ with strict inequality for $s > 0$. By similar calculations $E[Q|Q < S] < E[Q]$ also holds, so combining the two inequalities, $E[Q|Q \geq S] > E[Q < S]$. ■

**Proof of Proposition 3:** From (1), for the labeling equilibrium we need to show that

$$
\begin{aligned}
& \frac{\int_0^1 \int_s^1 q dF(q) dG(s)}{\int_0^1 \int_s^1 dF(q) dG(s)} - \frac{\int_0^1 \int_0^s q dF(q) dG(s)}{\int_0^1 \int_0^s dF(q) dG(s)} \\
\leq \quad & \int_0^1 \frac{\int_s^1 q dF(q)}{\int_s^1 dF(q)} dG(s) - \int_0^1 \frac{\int_0^s q dF(q)}{\int_0^s dF(q)} dG(s) \qquad (17)
\end{aligned}
$$

and, from (2), for the non-labeling equilibrium we need to show that

$$\frac{\int_0^1 \int_s^1 q dF(q) dG(s)}{\int_0^1 \int_s^1 dF(q) dG(s)} \leq \int_0^1 \frac{\int_s^1 q dF(q)}{\int_s^1 dF(q)} dG(s). \tag{18}$$

Considering the non-labeling equilibrium first, (18) is equivalent to

$$\begin{aligned}
& \int_0^1 \left( \frac{\int_s^1 q dF(q)}{\int_0^1 \left( \int_t^1 dF(q) \right) dG(t)} - \frac{\int_s^1 q dF(q)}{\int_s^1 dF(q)} \right) dG(s) \leq 0 \\
\iff \quad & \int_0^1 \left( \int_s^1 q dF(q) \right) \left( \frac{\int_0^1 F(t) dG(t) - F(s)}{\left(1 - \int_0^1 F(t) dG(t)\right)(1 - F(s))} \right) dG(s) \leq 0 \\
\iff \quad & \int_0^1 E[Q|Q \geq s] \left( \int_0^1 F(t) dG(t) - F(s) \right) dG(s) \leq 0 \\
\iff \quad & \int_0^1 E[Q|Q \geq s] \left( 1 - \frac{F(s)}{\int_0^1 F(t) dG(t)} \right) dG(s) \leq 0.
\end{aligned} \tag{19}$$

Letting $P(s) = \int_0^s F(t)dG(t) / \left( \int_0^1 F(t)dG(t) \right)$, then (19) is equivalent to $\int_0^1 E[Q|Q \geq s] dP(s) \geq \int_0^1 E[Q|Q \geq s] dG(s)$, or integrating by parts, $-\int_0^1 \left( \frac{d}{ds} E[Q|Q \geq s] \right) (P(s) - G(s)) ds \geq 0$. Therefore, since $\frac{d}{ds} E[Q|Q \geq s] > 0$, the inequality holds if $G(s) \geq P(s)$ for all $s$, i.e., if $P \succ_{FOSD} G$. Note that $G(s) \geq P(s)$ is equivalent to $\int_0^1 F(t)dG(t) \geq \left( \int_0^s F(t)dG(t) \right) / G(s)$. The RHS is an increasing function of $s$ and the inequality holds weakly for $s = 1$ so the inequality holds for all $s$.

Now considering the labeling equilibrium, given that (18) holds, (17) holds if

$$\frac{\int_0^1 \int_0^s q dF(q) dG(s)}{\int_0^1 \int_0^s dF(q) dG(s)} \geq \int_0^1 \frac{\int_0^s q dF(q)}{\int_0^s dF(q)} dG(s), \tag{20}$$

which always holds by the same arguments as above. ■

**Proof of Proposition 4:** (i) We first want to show that $G_{1:n} \succ_{MLR} G_{1:n+1}$, i.e., the distribution of the worst of $n$ standards MLR dominates the distribution of the worst of $n+1$ standards. Noting that

$$g_{k:n}(x) = \frac{n!}{(k-1)!(n-k)!} G(x)^{k-1} (1 - G(x))^{n-k} g(x), \tag{21}$$

by the definition of MLR dominance we need to show that, for all $x < y$,

$$\frac{g_{1:n}(x)}{g_{1:n+1}(x)} \leq \frac{g_{1:n}(y)}{g_{1:n+1}(y)}, \tag{22}$$

or

$$\frac{(n)(1 - G(x))^{n-1} g(x)}{(n+1)(1 - G(x))^n g(x)} \leq \frac{(n)(1 - G(y))^{n-1} g(y)}{(n+1)(1 - G(y))^n g(y)},$$

which simplifies to $G(x) \leq G(y)$ which holds for all $x < y$. Now we want to show that if $G \succ_{MLR} H$ for any two distributions $G$ and $H$ then it is better good news when the firm bears a standard with distribution $G$ than $H$. So we need to prove that

$$\frac{\int_0^1 \int_s^1 q dF(q) dG(s)}{\int_0^1 \int_s^1 dF(q) dG(s)} \geq \frac{\int_0^1 \int_s^1 q dF(q) dH(s)}{\int_0^1 \int_s^1 dF(q) dH(s)}, \tag{23}$$

which can be rewritten as

$$\frac{\int_0^1 E[q|q \geq s](1-F(s))g(s)ds}{\int_0^1 (1-F(s))g(s)ds} \geq \frac{\int_0^1 E[q|q \geq s](1-F(s))h(s)ds}{\int_0^1 (1-F(s))h(s)ds}. \tag{24}$$

Define the densities $p(s) = (1-F(s))g(s)/\int_0^1(1-F(t))g(t)dt$ and $q(s) = (1-F(s))h(s)/\int_0^1(1-F(t))h(t)dt$ and let $P(s)$ and $Q(s)$ represent the respective distributions. Since $E[q|q \geq s]$ is increasing in $s$, the above condition holds if $P \succ_{FOSD} Q$. By the assumption that $G \succ_{MLR} H$, for all $x < y$,

$$\begin{aligned}
& \frac{g(x)}{g(y)} \leq \frac{h(x)}{h(y)} \\
\iff \quad & \frac{(1-F(x))g(x)}{(1-F(y))g(y)} \leq \frac{(1-F(x))h(x)}{(1-F(y))h(y)} \\
\implies \quad & \frac{\int_0^y (1-F(x))g(x)dx}{(1-F(y))g(y)} \leq \frac{\int_0^y (1-F(x))h(x)dx}{(1-F(y))h(y)} \\
\iff \quad & \frac{\int_0^y (1-F(x))g(x)dx}{p(y)\int_0^1 (1-F(x))g(x)dx} \leq \frac{\int_0^y (1-F(x))h(x)dx}{q(y)\int_0^1 (1-F(x))h(x)dx} \\
\iff \quad & \frac{\int_0^y p(x)dx}{p(y)} \leq \frac{\int_0^y q(x)dx}{q(y)} \\
\iff \quad & \frac{P(y)}{p(y)} \leq \frac{Q(y)}{q(y)}
\end{aligned} \tag{25}$$

so $P$ reverse hazard rate dominates $Q$ which implies $P \succ_{FOSD} Q$ and hence (23) holds. Letting $G = G_{1:N}$ and $H = G_{1:n+1}$ this establishes that $E[Q|Q > S_{1:n}] \geq E[Q|Q > S_{1:n+1}]$. Therefore, from (8), the support of a non-labeling equilibrium is increasing in $n$.

(ii) By the Glivenko-Cantelli Theorem, the empirical distribution $G_n(s)$ of $n$ standards converges uniformly to the theoretical distribution $G$ as $n$ goes to infinity, implying that for any $\varepsilon > 0$ the minimum of these standards is almost surely less than $\varepsilon$ in the limit. Hence the expected quality from unexpected labeling converges to $E[Q]$ in the limit, and the necessary and sufficient condition (8) for a non-labeling equilibrium reduces to $E[Q] - E[Q] \leq c$ or $c \geq 0$.

(iii) By the same argument as in (ii), the expected quality from non-labeling converges to 0 and from labeling converges to $E[Q]$ in the limit as $n$ increases, so the necessary and sufficient condition (7) for a symmetric labeling equilibrium reduces to $E[Q] - 0 \geq c$.

(iv) By the same argument as in (ii), in the limit as $n$ increases a firm meets the worst of the $n$ standards almost surely and expected quality conditional on meeting the standard equals $E[Q]$, so the expected MSE in the labeling equilibrium just equals the variance of $F$.

(v) For any firm of type $q$, consider the largest realized standard $\underline{s}$ such that $q \geq \underline{s}$ and the smallest realized standard $\overline{s}$ such that $\overline{s} \geq q$. Given $\underline{s}$ and $\overline{s}$, in a non-labeling equilibrium if the firm certifies then it has expected quality $E[Q|\underline{s} \leq Q < \overline{s}]$ and if it does not certify then it still has expected quality $E[Q]$, so non-labeling is an equilibrium if and only if $E[Q|\underline{s} \leq Q < \overline{s}] - E[Q] \leq c$. By the Glivenko-Cantelli Theorem, the empirical distribution $G_n(s)$ of $n$ standards converges uniformly to the theoretical distribution $G$ as $n$ goes to infinity, so for any $\varepsilon > 0$, for any $q$, $\max\{q - \underline{s}, \overline{s} - q\} < \varepsilon$ for sufficiently large $n$. Therefore, since $E[Q|\underline{s} \leq Q < \overline{s}] \in [\underline{s}, \overline{s}]$, for any firm of type $q$, in the limit $E[Q|\underline{s} \leq Q < \overline{s}] = q$ almost surely. So the condition for a non-labeling equilibrium is $q - E[Q] \leq c$ for all $q$, or $1 - E[Q] \leq c$.

(vi) Following the same argument as in (v), the condition for a symmetric labeling equilibrium is $E[Q|\underline{s} \leq Q < \overline{s}] - E[Q|q \leq \underline{s}] \geq c$ for some $q$, which converges to $q - E[Q|Q \leq q] \geq c$ almost surely. Following Lizzeri (1999, Theorem 1), the LHS is increasing in $q$ if $F$ is logconcave (Bagnoli and Bergstrom, 2005), so this condition is met for some $q$ if and only if it holds for $q = 1$, or $1 - E[Q] \geq c$. ■

**Proof of Proposition 5:** (i) Consider a focal labeling equilibrium in which a firm that does not meet the focal standard instead adopts the highest other standard it meets. The estimation of the focal standard is not affected by the number of standards present on the market, so such a focal labeling equilibrium exists if

$$E[Q|Q \geq S] - E[Q|Q < S_{1:n}] \geq c, \tag{26}$$

and

$$E[Q|S_{1:n} \leq Q \leq S] - E[Q|Q < S_{1:n}] \geq c. \tag{27}$$

The latter condition is clearly binding and holds for sufficiently low $c$. In such an equilibrium consumers learn that the firm did not meet even the lowest standard, $Q < S_{1:n}$, or that the firm met the lowest standard but not the focal standard, $S_{1:n} \leq Q < S$, or that the firm met the focal standard, $Q \geq S$. In a symmetric labeling equilibrium they learn only that the firm met or did not meet the lowest standard, $Q < S_{1:n}$ or $Q \geq S_{1:n}$. The former partition is finer so it reveals more information.

(ii) Suppose the firm is following a focal certification strategy of always adopting a standard $X$ even if standard $Y$ is tougher. Since consumers know which standard is tougher, this is only possible if consumer beliefs "punish" the firm for choosing $Y$ out of equilibrium. But under our belief refinement, we assume that any type is equally likely to have deviated, so the expected quality of adopting $Y$ is higher and the proposed strategy is not an equilibrium. ■

**Proof of Proposition 6:** (i) Suppose each firm follows the labeling equilibrium strategy of certifying when it meets the standard. Then the conditional density of $S$ given that $k$ of $m$ firms certify is

$$g(s|Q_{m-k:m} < S \leq Q_{m-k+1:m}) = \frac{(1-F(s))^k F(s)^{m-k}}{\int_0^1 (1-F(s))^k F(s)^{m-k} dG(s)}. \tag{28}$$

From the Glivenko-Cantelli theorem, the empirical distribution $F_m(q)$ of $m$ firm qualities converges uniformly to the theoretical distribution $F$ as $m$ goes to infinity. Therefore for any realization of $s = s'$, $\lim_{m\to\infty} k/m = 1 - F(s')$ almost surely. Hence,

$$\lim_{m\to\infty} g(s|Q_{m-k:m} < S \leq Q_{m-k+1:m}) = \lim_{m\to\infty} \frac{(1-F(s))^{m(1-F(s'))} F(s)^{mF(s')}}{\int_0^1 (1-F(s))^{m(1-F(s'))} F(s)^{mF(s')} dG(s)}. \tag{29}$$

For any $m$, it is straightforward to show that the MLE estimate of $s$ is $s'$. We want to show that this estimate is asymptotically precise in that

$$\lim_{m\to\infty} \frac{g(s|Q_{m-k:m} < S \leq Q_{m-k+1:m})}{g(s'|Q_{m-k:m} < S \leq Q_{m-k+1:m})} = 0 \tag{30}$$

for any $s \neq s'$. From (29) this ratio is just

$$\lim_{m\to\infty} \left( \left( \frac{(1-F(s))}{(1-F(s'))} \right)^{1-F(s')} \left( \frac{F(s)}{F(s')} \right)^{F(s')} \right)^m . \tag{31}$$

Taking the log of the base and differentiating with respect to $s$, the base reaches a unique maximum of 1 at $s = s'$. Therefore for any $s \neq s'$, the base is less than 1, implying the whole term goes to 0 as $m \to \infty$. This confirms that, in the limit for large $m$, for each realization of $s$ from the distribution $G$ consumers infer $s$ exactly. The condition for each firm to follow the proposed strategy is then $E[Q_i|Q_i > s] - E[Q_i|Q_i < s] \geq c$, implying that the expected support for the equilibrium over the distribution of possible standards is $c < E[\bar{c}]$ where

$$E[\bar{c}] = E[E[Q_i|Q_i > s]] - E[E[Q_i|Q_i < s]], \tag{32}$$

which is the same as that for a single firm facing a certain standard.

(ii) Suppose each firm follows a strategy of not labeling. The expected payoff for a single firm is just $E[Q_i]$. If a single firm deviates, then as discussed our belief refinement is that the label is treated as good news that concentrates the posterior distribution of $Q_i$ on $[s, 1]$ where $s$ is distributed according to $G$. Therefore the payoff to a single firm from deviating is $E[Q_i|Q_i > S] - c$, so the equilibrium condition for non-labeling is

$$E[Q_i|Q_i > S] - E[Q_i] < c \tag{33}$$

which is the same as that for a single firm facing an uncertain standard.

(iii) If the standard is certain then consumers by definition learn nothing about the distribution of standards from which firms adopt which labels. Hence the equilibrium conditions are the same as if there is only one firm. ■

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