Uncertain Certification Standards*

Rick Harbaugh, John W. Maxwell, and Beatrice Roussillon†

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Abstract

When consumers are unsure of the exact standard that a quality certificate or label represents, they must infer the difficulty of the standard in part from observing which firms adopt the label. Key results from the certification and disclosure literatures are thereby altered. First, consumers are more suspicious of a label if a firm with a bad reputation adopts it, so a "Groucho effect" makes certification less appealing to bad firms than average firms or good firms. Second, as the number of available labels increases, the informativeness of certification decreases rather than increases. Third, adoption of a label by one firm need not increase pressure on other firms to also adopt it. Instead, a label can be either "legitimitized" or "spoiled" for use by other products depending on whether a product with a favorable or unfavorable reputation is certified first. These problems are mitigated if certification is mandatory or if some standards are "focal", even if standards remain uncertain. The model is applied to eco-labels and is also revelant for nutrition labels, academic journals, club memberships, diplomas, and other common certification environments.

JEL Classification Categories: L15, L21, D82, Q00

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†Affiliations: Kelley School of Business, Indiana University; Ivey School of Business, University of Western Ontario; Department of Economics, University of Lyon.

I won't belong to any organization that would have me as a member.

– Groucho Marx

1 Introduction

Labels and other certificates of quality prove that the bearer meets some standard, but the exact standard is often uncertain. Consumers must then guess whether a label on a product is more indicative of high quality, or of an undemanding standard for the label. This problem of dual estimation of quality and standards arises in many contexts, such as the ability of a job applicant and the value of his degree, the quality of a hotel and the toughness of the local rating system, the soundness of a company's finances and the standards of its auditor, or the quality of an article and the editorial standards of the journal it appears in. To gain insight into such situations, we investigate how uncertainty over a standard affects the strategic decision of whether or not to be certified. In particular we follow the certification literature in considering certificates that are voluntary and verifiable so that a firm can choose whether to certify its product, but cannot falsely claim that an uncertified product is certified.[1]

The issue of eco-labels for environmental quality illustrates the problem of uncertain certification standards. Research indicates that consumers care about the environmental quality of products but that insufficient information about environmental quality limits their ability to act on these concerns.[2] Industry groups, governments, and NGOs have responded by creating eco-labels for products that are certified to meet certain environmental standards. But academic studies and surveys find that consumers are often unsure of their meaning,[3] especially since there are numerous different labels and each label can signify attainment of different standards for a wide variety of heterogeneous products.[4] Since consumers do not

[1] We assume that certification is costly and that the cost is exogenous (e.g., Viscusi, 1978; Jovanovic, 1982; Verrecchia, 1983) rather than set by the certifier to maximize profits (Lizzeri, 1999). The assumption of non-zero costs distinguishes the certification literature from disclosure games in the accounting literature (e.g., Verrecchia, 2001), persuasion games in the strategic communication literature (e.g., Milgrom, 1981; Okuno-Fujiwara, Postlewaite, and Suzumura, 1990; Lipman and Seppi, 1995; Shin, 2003; Glazer and Rubinstein, 2003), and games with hard evidence in the law and economics literature (e.g., Bull and Watson, 2007). Note that the signaling (Spence, 1973) and cheap talk (Crawford and Sobel, 1982) literatures do not assume verifiability, and that the minimum quality standards literature following Leland (1979) assumes that products not meeting the standard are excluded from the market.

[2] See, for instance, Blend and van Ravenswaay (1999) and Teisl, Roe, and Hicks (2002).

[3] For instance, Van Dam and Reuvekamp (1995) found that the fraction of Dutch consumers with an "adequate or better" understanding of different labels varied from 9 to 91 percent. A 2005 survey of US consumers by the Consumers Union revealed that most respondents incorrectly believed that the label "organic" on food implied that it was free of artificial ingredients and chemical contaminants. The Consumers Union recently called on the USDA to clarify its different standards for "100% organic", "organic" and "made with organic".

[4] For instance, Germany's Blue Angel label has been awarded to over 3,500 different products and services.

know the exact standard for an eco-label, they must jointly update their estimate of the product's quality and of the labeling standard's difficulty based on whether or not the product has the label. Since adoption of an eco-label is usually voluntary, we examine how this updating affects the voluntary decision to disclose one's attainment of the labeling standard.[5]

We find that any uncertainty over the standard has an unambiguously negative effect on a firm's incentive to adopt a label. When the standard is uncertain and the label is affixed to a firm's product, consumers must consider the possibility that the standard for the label was met because the standard is low. Therefore, in what we refer to as the "Groucho effect," consumers lower their estimate of the standard, and the firm benefits less from disclosure than it might otherwise.[6] Similarly, in observing that the firm does not have a label, consumers must consider the possibility that the standard is unexpectedly high. In a "reverse Groucho effect", they raise their estimate of the standard so that failing to meet the standard is not so damaging to the firm. Because of these two effects, we find that any uncertainty over the standard shrinks the set of quality distributions and certification costs supporting a disclosure equilibrium, and similarly expands the set supporting a nondisclosure equilibrium.[7] Moreover, when a disclosure equilibrium does exist, any uncertainty over the standard always reduces the informativeness of the disclosure equilibrium.

In addition to this general reduction in the incentive for label adoption and in the informativeness to consumers of label adoption, uncertainty alters or reverses some key results for certain standards. First, when standards are certain, firms with a poor reputation always have the most incentive to adopt a label to counteract consumer expectations. But with uncertain standards, if a firm is expected to be low quality then the Groucho effect is relatively strong because consumers infer that the standard is probably weak if such a firm can meet it. Therefore, uncertainty over the label makes it difficult for firms with a poor reputation to disprove consumer expectations, so the incentive to adopt the label is reduced. When consumers expect a firm to be high quality, the incentive to adopt the label is also reduced because the reverse Groucho effect is relatively strong and consumers infer that the standard is probably tough if a good firm cannot meet it. Therefore, the loss from not adopting the label is reduced, and good firms might not bother to adopt it even for very low certification costs. Overall we find that uncertainty undermines incentives for disclosure the most for firms that are either thought to be very good or thought to be very bad, so that firms of

[5] Following Leland (1979), the case where firms must meet 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).

[6] The "no-trade theorem" (e.g., Milgrom and Stokey, 1982) in which traders do not want to trade with someone who wants to trade with them is often referred to as the "Groucho Marx theorem". As will be seen, the Groucho effect we identify is distinct from this theorem and from related adverse selection and winner-curse effects.

[7] For simplicity we consider certification costs to include any disclosure costs such as design costs or opportunity costs associated with altering the packaging to highlight the label rather than other product attributes.

intermediate quality often have the most incentive to disclose.

Second, the uncertainty over the label changes the implications of label proliferation in our market. In the certainty case, the more standards that appear the more opportunity there is for firms of different quality levels to certify themselves. But when standards are uncertain, the probability of having a weak standard increases with the number of standards. Since consumers do not know which of multiple standards is more difficult, disclosure proves that a firm has met the easiest standard but nothing more, even if the firm has met a higher standard. As a consequence, the benefit to a firm from disclosure of meeting any standard goes to zero as the number of standards increases, and a nondisclosure equilibrium always exists for a sufficiently high number of standards. Moreover, even when a disclosure equilibrium does exist, its informativeness goes to zero as the number of standards increases.

Third, when standards are certain, the adoption of a label by one firm puts pressure on other firms to also adopt the label. When we consider interactions between firms, we find that uncertainty over the standard generates information externalities between firms that, depending on whether a good firm or bad firm adopts a label, can either "legitimize" or "spoil" the label for use by other firms depending on whether a firm with a favorable or unfavorable reputation is certified first. If a good firm adopts a particular label then bad firms have an incentive to adopt the same label, while good firms instead have an incentive to avoid labels adopted by bad firms. Considering the strategic adoption of labels by a good firm and a bad firm, we find that an equilibrium in which the best label is adopted by each firm exists if and only if the good firm chooses its label first. This result might explain the widespread industry practice of launching new labels by promoting adoption among firms of recognized high quality.

We find that, with or without such externalities between firms, there are often multiple equilibria over a range of certification costs. For instance, if consumers expect a firm to disclose then failure to disclose is particularly damaging to the firm's expected quality so it is likely to disclose unless certification costs are prohibitively high. If disclosure is not expected, however, then the firm loses little from not bothering to disclose, and can save any certification costs. Given that there are multiple equilibria, an industry group, government, or NGO that is promoting a label can encourage disclosure by subsidizing label acquisition costs and by raising consumer expectations that firms will disclose when possible. For example, consumers could be encouraged to "look for the label" when they purchase products. Moreover, when there are multiple labels, we find that some of the disincentive to adopt a label and the loss information from uncertainty can be reduced if consumers are encourage to look for a "focal" label or standard, even when it too is uncertain.

We discuss our results in the context of eco-labeling, but they apply to any certification or labeling scheme about which uncertainty over standards exists. In a broader context, the insights we develop apply to any situation in which observers must jointly update their

beliefs about an agent's quality and an uncertain quality standard. For example, in the original context of Groucho Marx's comment, our model explains why an individual might be reluctant to join a club whose standards are sufficiently weak to admit him. The model also explains why highly regarded individuals or firms may be reluctant to join organizations with unknown standards. There is little reputational benefit from joining but there is a risk of being associated with less reputable types if they too are admitted.[8]

The paper proceeds as follows. In Section 2 we develop the basic model with one certificate, define the conditions for the existence of both disclosure and non-disclosure equilibria, show the existence of the Groucho effect and analyze its impact on informativeness. In Section 3 we analyze the multi-certificate case, showing that the qualitative results of Section 2 continue to hold, and that the Groucho effects are worsened. In Section 4 we present our conclusions.

2 The Basic Model

We consider a firm's decision to voluntarily disclose or not the fact that its product meets a quality standard. To capture the idea that consumers have some information about the likely quality, let quality Q be distributed according to the distribution F with full support on $[0,1]$ and with corresponding density function f. For simplicity we assume that the firm has only one product so we will typically refer to Q as the firm's quality. In this section we assume that there is only one possible standard. In Section 3 we show that these results extend directly to the case of multiple standards, and develop further results for that case.

To capture consumer knowledge about the labeling standard, let the standard S be distributed according to G on $[0,1]$. We will compare the "uncertain" case where G has full support on $[0,1]$ and corresponding density g, with the "certain" case where the realized value of $S = s$ is known. For simplicity we assume Q and S are independent and that the payoff to the firm is its expected quality as estimated by consumers.[9] The firm always knows the realized values of Q and S.[10]

If $Q < S$ the firm does not meet the standard so it has no choice but non-disclosure, i.e., the firm cannot lie because it is illegal to fraudulently affix the eco-label to its product. If $Q \geq S$ the firm has a choice of either non-disclosure or disclosure, i.e., a firm that meets the standard need not disclose this fact. We assume that disclosure has some cost $c \geq 0$. For

[8] Sobel (2001) considers the dynamics of club standards as members are admitted, with an emphasis on when standards will decline. Here we are analyzing a fixed standard that is uncertain, and considering how the estimate of the standard falls.

[9] The assumption that the firm's payoff is its expected quality allows us to abstract from modeling the demand side of the market. As long as firms of higher perceived quality are more profitable, the qualitative results of the paper are unaffected.

[10] Therefore our model has two-dimensional asymmetric information, and one binary verifiable message indicating whether the variable on one dimension is larger than the other.

instance, a firm must formally document its quality control processes and pay an agency to certify them. In our base model, we focus on the firm's disclosure decision for a given quality level so c should not be interpreted as the cost of attaining quality necessary to meet the labeling standard.

If consumers believe that a product has met the standard, the expected quality of the product is the expected quality conditional on it being larger than S, where the value of S is distributed according to G,

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

Similarly if consumers believe that a product has not met the standard, the expected quality of the product is

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

These expectations include the special case where consumers know the realized value of S so that G is degenerate, i.e., the standard is certain. In this case, which is closer to most models in the literature, for a known value $S = s$ the expectations simplify to

$$E[Q|Q \geq s] = \frac{\int_s^1 q dF(q)}{\int_s^1 dF(q)} \tag{3}$$

if the firm is known to have met the labeling standard and to

$$E[Q|Q < s] = \frac{\int_0^s q dF(q)}{\int_0^s dF(q)} \tag{4}$$

if it is known to have not met the standard.

Our equilibrium concept is perfect Bayesian equilibrium with the extra condition that at least one type has a strict incentive to follow the equilibrium strategy. A disclosure equilibrium arises when a firm whose product meets or exceeds the labeling standard always discloses this fact and consumers expect it to do so. Consumers update their estimate of firm quality based on these strategies, so the equilibrium condition is simply that the benefit from disclosing is higher than the cost,

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

The other possible pure strategy equilibrium is a nondisclosure equilibrium in which consumers do not expect a firm to disclose. In this case non-disclosure does not represent bad news so non-disclosure results in a payoff of $E[Q]$ rather than $E[Q|Q < S]$. In the non-disclosure equilibrium unexpected disclosure is an out of equilibrium action. We assume that such an

action is treated as good news that generates a payoff from disclosure of $E[Q|Q \geq S]$.[11] Again, disclosure arises by affixing a label to one's product and we rule out the possibility of fraud. Consequently, the equilibrium condition for the nondisclosure equilibrium is

$$E[Q|Q \geq S] - E[Q] \leq c. \tag{6}$$

Comparing these two conditions, we see that since $E[Q|Q < S] < E[Q]$ the left hand side of (5) is greater than the left hand side of (6) so one or the other of these two conditions must be satisfied for any given c. Thus, at least one of these two pure strategy equilibria always exists. Both conditions are satisfied simultaneously, indicating the existence of multiple equilibria, when

$$E[Q|Q \geq S] - E[Q] \leq c \leq E[Q|Q \geq S] - E[Q|Q < S] \tag{7}$$

which is possible again by the fact that $E[Q|Q < S] < E[Q]$. Regarding when one of the equilibria is unique, the disclosure condition (5) cannot be satisfied for c sufficiently large and the nondisclosure condition (6) cannot be satisfied for c sufficiently small. We state these results as the following proposition.

Proposition 1 *For any F and G with either certain or uncertain standards, there exists $\underline{c}, \overline{c} \in (0,1)$ with $\underline{c} < \overline{c}$ such that a non-disclosure equilibrium exists if $c > \underline{c}$, a disclosure equilibrium exists if $c < \overline{c}$, and both equilibria exist if $c \in [\underline{c}, \overline{c}]$.*

To see the differential effects of certainty and uncertainty, first consider Figure 1(a) where F is uniform and the standard is known to be some realized value s. If it is known that $Q \geq s$ or $Q < s$, then the updated values of Q are given respectively by the upper and lower lines in the figure. If the standard is very high then it is very impressive to beat the standard and not so damning to fall short, while if the standard is very easy it is not very impressive to beat the standard but very damning to fall short. With uniform F, the net gain from meeting the standard is always $E[Q|Q \geq s] - E[Q|Q < s] = (1+s)/2 - s/2 = 1/2$. Now consider Figure 1(b) where again F is uniform and the distribution G of the unknown standard is also uniform. If we were to just average out the gains for different values of s, we would find that the updated expected quality from beating the standard is $E[E[Q|Q \geq s]] = 3/4$ and from falling short is $E[E[Q|Q < s] = 1/4$. But in fact the consumer must jointly estimate both S and Q, so the updated expectations for quality are $E[Q|Q \geq S] = 2/3$ and $E[Q|Q < S] = 1/3$,

[11] That is, we assume that the prior beliefs about Q are concentrated on $[s,1]$ where s is distributed according to G. There is no variation in the incentives of different types to disclose so, as discussed by Banks and Sobel (1987), standard refinements such as the intuitive criterion and divinity do not apply. Harbaugh and To (2005) show that allowing for private receiver information in disclosure games leads the receiver to have skeptical beliefs about unexpected disclosure. Assuming skeptical beliefs leaves most of the predictions of this model unchanged, with the exception that non-disclosure can often be an equilibrium even for zero disclosure costs.

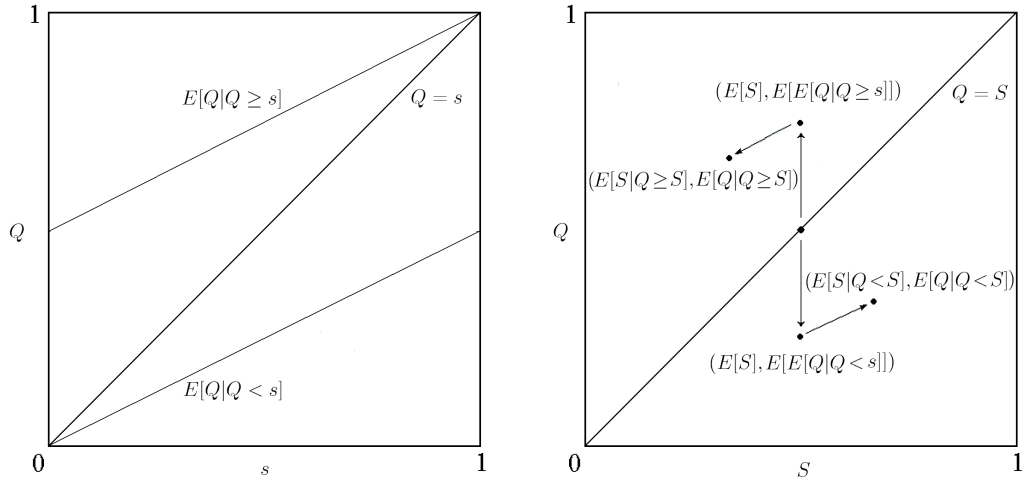

Figure 1: Updated Quality and Standard Estimates

implying that the net gain from meeting the standard is only 1/3. Overall, because of this joint updating, the example illustrates the general pattern,

$$E[E[Q|Q < s]] < E[Q|Q < S] < E[Q] < E[Q|Q \geq S] < E[E[Q|Q \geq s]], \tag{8}$$

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 with the same distribution.

The pattern in (8) arises because, when the standard is unknown, consumers must estimate S at the same time they estimate Q. On the one hand, if the firm discloses that it has met the standard ($Q \geq S$) this is good news about the firm's quality, Q, but it is also bad news about the standard S. We term the downward reduction in the consumer estimate of S due to disclosure the "Groucho effect" – the achievement of the goal diminishes the goal itself. The Groucho effect, in turn, causes the consumer estimate of Q to rise by less than it otherwise would. On the other hand, if the firm fails to disclose that it has met the standard in the disclosure equilibrium ($Q < S$) then this is bad news about Q, but also good news about the toughness of the standard S. We term the impact on S in this case the "reverse Groucho effect" – failing to meet the goal enhances the goal itself.[12] Due to the reverse Groucho effect, failing to meet the standard will result in a less severe reduction in the estimate of Q compared

[12] To paraphrase Groucho Marx, "I would like to join a club that would not have me as a member."

to the reduction that would have resulted without the effect. Therefore uncertainty over the labeling standard plays a moderating role that makes meeting the standard less impressive and not meeting it less damaging.

Now considering the impact of the Groucho and reverse Groucho effects on equilibrium behavior, the relationship in (8) implies that condition (5) for a disclosure equilibrium is more strict with uncertain standards than it is on average for a certain standard, and that condition (6) for a nondisclosure equilibrium is less strict with uncertain standards than it is on average for a certain standard. Thus, the Groucho effect makes the condition for the disclosure equilibrium harder to meet, and the reverse Groucho effect makes the condition for the nondisclosure equilibrium easier to meet. The following proposition shows that this pattern holds generally if we continue to compare the case of uncertain S with the case where S is certain and average out the result over the whole distribution of S.[13]

Proposition 2 *For any F and G, the expected range of disclosure costs supporting a disclosure (nondisclosure) equilibrium is larger (smaller) if the standard is certain rather than uncertain.*

Proof. See the Appendix. ■

The results we have derived so far apply regardless of consumer expectations of the firm's quality. We now consider how the Groucho effect varies with consumer expectations of the quality of the firm and analyze the impact on firm incentives to engage in disclosure or nondisclosure. It is helpful to first consider the parameterized density function

$$f(q;\theta) = \begin{cases} (1+\theta)\, q^{\theta} & \text{for } \theta \geq 0 \\ (1-\theta)\,(1-q)^{-\theta} & \text{for } \theta \leq 0 \end{cases} \tag{9}$$

which encompasses the uniform distribution ($\theta = 0$) and the triangle distribution ($\theta = 1$ and $\theta = -1$).[14] Since $f(q;\theta)$ monotone likelihood ratio dominates $f(q;\theta')$ for $\theta > \theta'$ we will say that, from the ex ante perspective of consumers, firm quality is higher the higher is θ. That is, without any labeling information, consumers have a more favorable ex ante impression of a firm's likely quality the higher is θ.

If standards are certain, disclosure is most attractive for a firm that consumers expect to be bad (low θ) but that in fact meets the standard. However, if standards are uncertain, the Groucho effect is strong because consumers are suspicious of any standard that a bad firm can meet. Therefore it becomes difficult for a firm with a bad reputation to successfully disprove

[13] For the certain case we consider the expected cutoffs $E[\underline{c}]$ and $E[\overline{c}]$ since the exact cutoffs will vary depending on the realization of s.

[14] For integer values of θ, this distribution is equivalent to that of the highest order statistic of a uniform distribution $f_{N:N}$ for $\theta \geq 0$, and that of the lowest order statistic of a uniform distribution $f_{1:N}$ for $\theta < 0$ where $N = |\theta| + 1$.

that it is bad. Conversely, for a firm that is expected to be good (high θ), disclosure offers only slight benefits but the firm can still feel pressured to disclose if consumers think that lack of disclosure implies the firm did not meet the standard. If standards are uncertain, the reverse Groucho effect is strong because consumers infer that failure of a good firm to meet the standard implies the standard was very high. Therefore the pressure on firm with a good reputation to disclose is weakened.

These differential effects on disclosure incentives can be seen in Figures 2(a) and 2(d) for the functional form of F in (9) for uniform G. The boundary of the non-disclosure region (N) from the equilibrium condition (5) is given by the lower line $\underline{c}$, and the boundary for the disclosure region (D) from the equilibrium condition (6) is given by the upper line $\overline{c}$. Both disclosure and nondisclosure equilibria exist in the region between the two lines, so the figure illustrates the multiple equilibrium result for intermediate certification costs of Proposition 1. Compared with Figure 2(a) where the corresponding regions are given based on the expected values of $\underline{c}$ and $\overline{c}$ based on averaging out the exact values for different realizations of s, Figure 2(d) illustrates the result from Proposition 2 that uncertainty over the standard makes disclosure less likely in that, relative to the case of certain standards, the equilibrium range for the disclosure equilibrium is always smaller and the equilibrium range for the non-disclosure equilibrium is always larger.

Considering the effect of firm quality on the disclosure equilibrium, note from Figure 2(a) that for a certain standard the range of c supporting the disclosure equilibrium varies only slightly with firm quality. This pattern holds since the incentive to disclose $E[Q|Q \geq s] - E[Q|Q < s]$ for a known s is relatively insensitive to consumer expectations of whether the firm is good or bad. However, when the standard is uncertain the Groucho and reverse Groucho effects make the equilibrium range more sensitive to θ, and in particular the equilibrium range is largest for the uniform distribution case of $\theta = 0$ where uncertainty over the firm's quality is highest. Moving away from this case, consumers have stronger priors about the likely quality of the firm and the incentive to disclose is weakened. For very negative θ, consumers are so pessimistic about the firm and the Groucho effect is so strong that the good news of disclosure hardly helps at all, i.e., $E[Q|Q \geq S]$ is close to zero so the incentive to disclose $E[Q|Q \geq S] - E[Q|Q < S]$ is also close to zero. A similar story holds for very large θ. Consumers are so optimistic about the firm that the reverse Groucho effect eliminates the bad news from not meeting the standard, with the result that $E[Q|Q < S]$ is close to one so the incentive to disclose $E[Q|Q \geq S] - E[Q|Q < S]$ is again close to zero.

Turning to the cost ranges that support the non-disclosure equilibrium, note that the incentive to break out of the non-disclosure equilibrium differs in an asymmetric fashion as θ moves away from zero. For a certain standard, this asymmetry reflects the fact that the gap $E[Q|Q \geq 1/2] - E[Q]$ is larger for a bad firm than a good firm since $E[Q|Q \geq 1/2]$ is always at least $1/2$. For very bad firms this gap goes to $1/2$ since $E[Q|Q \geq 1/2]$ goes to $1/2$ and $E[Q]$

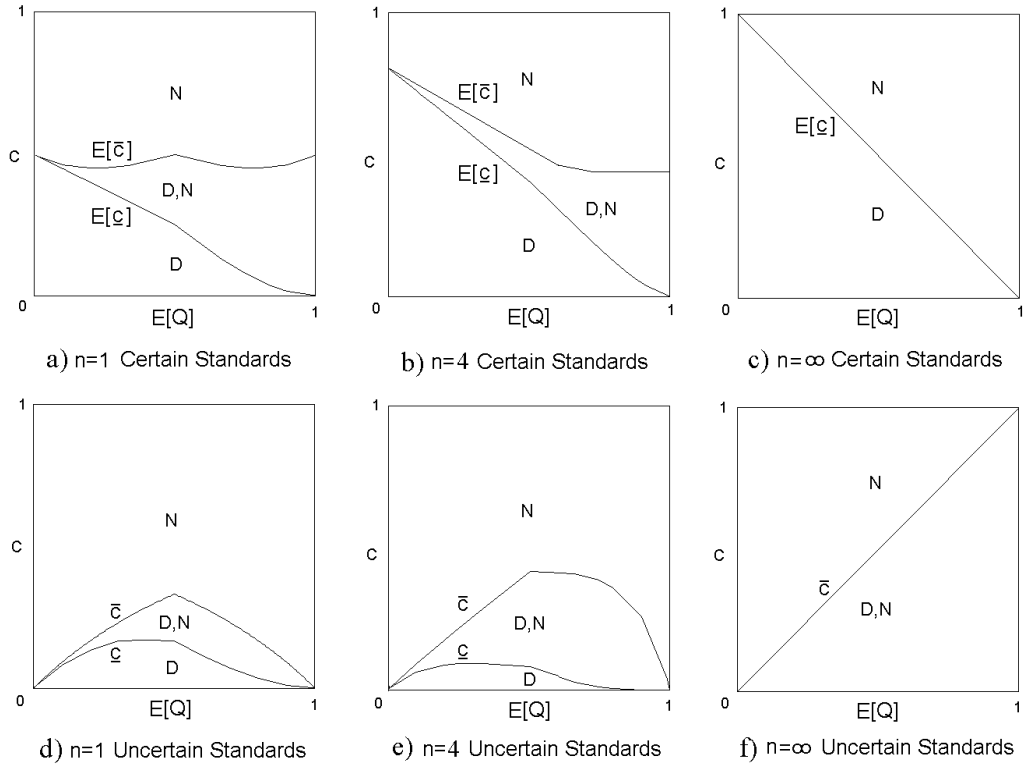

Figure 2: Disclosure (D) and Nondisclosure (N) equilibrium regions

goes to 0, while for very good firms the gap goes to 0 since both $E[Q|Q \geq 1/2]$ and $E[Q]$ go to 1. Therefore the equilibrium region for a non-disclosure equilibrium is larger for good firms than bad firms. When the standard is uncertain this difference is substantially reduced by the Groucho effect. Since the Groucho effect is strongest for bad firms, the incentive for bad firms to break out of the non-disclosure equilibrium is weakened, with the result that the range of costs supporting the non-disclosure equilibrium is again highest for firms of intermediate quality.

Taken together, the results for both the disclosure and non-disclosure equilibria support the idea that, with uncertain standards, firms about which consumers are most uncertain have the greatest attraction to labeling programs.[15] The good news is that labeling provides important information to consumers for these firms. The bad news is that firms that are

[15] Xiao (2006) finds that consumers put the most emphasis on the accreditation status of new firms since their quality is more uncertain. Relatedly, from a sociological perspective Phillips and Zuckerman (2001) find that middle status types have the most incentive to conform given the uncertainty of their status.

thought to be bad but in fact are reasonably good will have difficulty in using a label to prove this to consumers, and that firms that are good and meet the standard will often forgo the label. The lower disclosure incentives for good firms, who in expectation are most likely to earn the label, may be one explanation for the perceived lack of success of many voluntary eco-labeling programs.

We now consider the impact of uncertainty over the standard on the amount of information communicated in the disclosure equilibrium. Recall from our example that the Groucho (reverse Groucho) effect on the estimated standard drives down (up) the consumer estimate of Q, in each case making it closer to its ex ante mean. Put differently, because consumers learn about both Q and S from the firm's disclosure decision, the information about Q alone is less informative than when Q is known. This phenomenon is illustrated in Figure 1 by the fact that the conditional expectations of Q are closer to the unconditional expectation $E[Q] = 1/2$ when there is uncertainty over the labeling standard than when S is known to be $1/2$. To measure the difference in information, the mean-squared-error (MSE) of consumer estimates of Q for the case where S is uncertain is

$$\int_0^1 \left(\int_0^s (q - E[Q|Q < S])^2 dq + \int_s^1 (q - E[Q|Q \geq S])^2 dq \right) ds = 1/18 \tag{10}$$

and the expected MSE (i.e., the MSE averaged over different realized values of S) of consumer estimates of Q for the case where the realized standard is known is

$$\int_0^1 \left(\int_0^s (q - E[Q|Q < s])^2 dq + \int_s^1 (q - E[Q|Q \geq s])^2 dq \right) ds = 1/24 \tag{11}$$

where we have used $E[Q|Q < S] = 1/3$, $E[Q|Q \geq S] = 2/3$, $E[Q|Q < s] = s/2$, and $E[Q|Q \geq s] = (1 + s)/2$. In both cases the error is reduced relative to the non-disclosure equilibrium where the MSE is $Var[Q] = \int_0^1 (q - E[Q])^2 dq = 1/12$. However, due to the Groucho and reverse Groucho effects, the expected reduction in MSE, i.e., the expected increase in estimate precision or "informativeness", is smaller when the standard is uncertain. Although for particular realized values of S the informativeness of disclosure might be higher or lower than the uncertain case, on average uncertainty always reduces informativeness as the following proposition shows generally.

Proposition 3 *For any F and G, the expected informativeness of a disclosure equilibrium is higher if the standard is certain than if it is uncertain.*

Proof. See the Appendix. ■

From a policy perspective, more information about firm quality allows consumers to more accurately allocate their resources and therefore increases social welfare. For instance, as

shown by Jin and Leslie (2003) in the context of hygiene labels for restaurants, more accurate information leads consumers to avoid bad firms.[16] Consequently, governments and NGOs have an incentive to publicize labeling standards so as to reduce the information losses from uncertain standards in the disclosure equilibrium. This is in addition to the incentive identified in Proposition 2 to make standards more certain so as to increase the likelihood of a disclosure equilibrium relatively to the completely uninformative nondisclosure equilibrium. Thus, investments in reducing the uncertainty over a labeling standard result in a double-dividend, enhancing both the likelihood and value of disclosure.

3 Multiple Standards

We now consider the possibility of there being multiple possible standards that a firm could meet, e.g., there are multiple different eco-labels, or multiple different nutrition labels. We assume that the $n \geq 1$ standards are drawn independently from the same distribution G, and following standard notation for order statistics we denote the random variable representing the ith 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 of the best standard.[17]

For simplicity we will assume that if a firm meets multiple different standards it can only disclose one of them. In some cases this captures a real constraint, e.g., an article can be published in at most one journal. In other cases it might be possible to display multiple certificates, e.g., a product can display multiple eco-labels. Since attaining extra certificates is costly this possibility will not affect our main qualitative results, though in some cases it can make a difference as we discuss later. We also restrict attention initially to "symmetric" equilibrium strategies that are not conditioned on arbitrary properties of the ex ante identical standards. That is for now we do not consider "focal" equilibrium strategies where it is assumed that a particular standard or standards will be disclosed if that standard is met.

Since consumers do not know which of multiple standards is more difficult, disclosure under a symmetric disclosure strategy proves that a firm has met the easiest standard but nothing more, even if the firm has in fact met the best standard. From the perspective of consumers, the only information is that the firm has at least met at least one of the n possible standards. That is, regardless of whether the firm's strategy is to reveal the best standard that it meets or the worst standard that it meets, the only information of relevance to the consumer is that the firm has met at least the easiest standard. Given that disclosure only proves that the firm has met the easiest of the n standards, the incentives to disclose or not

[16] In addition, they find that more accurate information leads firms to improve their quality. We take quality as exogenous in our model.

[17] Our model therefore differs from the "Forum Shopping" model of Lerner and Tirole (2004) in which different standards are determined endogenously by standard-setting organizations.

disclose are exactly the same as in the previous section, with the only exception that we replace S with $S_{1:n}$.

Therefore, for uncertain standards, and following the same logic as for conditions (5) and (6), a disclosure equilibrium exists if and only if

$$E[Q|Q \geq S_{1:n}] - E[Q|Q < S_{1:n}] \geq c \tag{12}$$

and a nondisclosure equilibrium exists if and only if

$$E[Q|Q \geq S_{1:n}] - E[Q] \leq c. \tag{13}$$

For certain standards, the introduction of multiple standards introduces the added complexity that consumers can infer which of the n standards has been met. First suppose that F is concave so that f is a decreasing function. Looking back at Figure 1(a), such concavity implies that the difference, $E[Q|Q \geq s] - E[Q|Q < s]$ is increasing in s. Therefore, if we consider multiple standards the greatest incentive to disclose will always be for the highest standard. So for this case a disclosure equlibrium in which at least one type discloses exists if and only if $E[Q|Q \geq s_{n:n}] - E[Q|Q < s_{n:n}] \geq c$. More generally, if F is not concave it could be that for some i the gap from disclosing for a lower standard is higher in that $E[Q|s_{i:n} \leq Q \leq s_{i+1:n}] - E[Q|Q < s_{i:n}] > E[Q|Q \geq s_{n:n}] - E[Q|Q < s_{n:n}]$, in which case it is an equilibrium for firms meeting that lower standard to disclose.[18] Therefore, a disclosure equilibrium exists if and only if

$$\max_{i=1,..,n} \{E[Q|s_{i:n} \leq Q \leq s_{i+1:n}] - E[Q|Q < s_{i:n}]\} \geq c, \tag{14}$$

where, following convention, we define $s_{n+1:n} = 1$. The condition for a nondisclosure equilibrium is simpler because nondisclosure always gives a payoff of $E[Q]$, implying that the incentive to unexpectedly disclose is always highest for those meeting the highest standard. In particular a nondisclosure equilibrium exists if and only if

$$E[Q|Q \geq s_{n:n}] - E[Q] \leq c. \tag{15}$$

As the number of possible standards n increases, the distribution $G_{1:n}$ becomes increasingly weighted toward lower values of S, so that the expected value of Q conditional on disclosing becomes less favorable. Therefore, the value of breaking away from a non-disclosure equilibrium is decreasing in n. This result on nondisclosure contrasts with the case of a known standard. In this case as n becomes large the probability of a high standard increases. Since

[18] Given that they disclose, firms meeting an even higher standard will also want to disclose, but their incentive to disclose is conditional on disclosure by those meeting the lower standard i. Therefore the necessary and sufficient condition for disclosure is determined by the incentives for disclosure by firms meeting standard i.

such a standard is recognized by consumers, the ability of a firm to show off its quality is strengthened and nondisclosure (i.e., the strategy of not disclosing any standard even when it is met) is only an equilibrium when disclosure costs are very high. Regarding disclosure equilibria, the situation is different because failure to disclose is interpreted as inability to meet any standard at all. Therefore, even as the value from disclosing decreases with n, the loss from not disclosing also increases with n, so the net effect on disclosure incentives can be ambiguous. This contrasts with the case of a known standard where increases in n always allow for more possibilities of showing off one's abilities, and therefore always increase the expected range of costs supporting a disclosure equilibrium.

These patterns are seen in Figure 2 where the middle panels (b) and (e) show the disclosure and non-disclosure equilibrium regions for $n = 4$ when standards are certain and uncertain respectively. Compared with the $n = 1$ case in the left two panels, note that the pure disclosure region D expands when standards are certain and shrinks when standards are uncertain. Now considering the right two panels (c) and (f), as n becomes large these patterns become stronger. For certain standards, the ability to show off increases as n becomes large. Since there is no Groucho effect that hurts firms with a low quality reputation, a disclosure equilibrium exists for all costs $c < 1$ if the firm's reputation is sufficiently unfavorable.[19] For uncertain standards, as n increases $G_{1:n}$ becomes increasingly concentrated close to 0. Therefore failing to disclose when disclosure is expected is increasingly damning, so disclosure is attractive when there is a lot to lose, i.e., when the prior $E[Q]$ is high. In particular, as n becomes large the expected quality from disclosing converges to the prior $E[Q]$ and the expected quality from not disclosing converges to 0, so disclosure is an equilibrium for $E[Q] > c$. However, if disclosure is not expected, since the mass of the distribution $G_{1:n}$ becomes increasingly concentrated close to 0, there is essentially no favorable information about Q from having unexpectedly disclosed so the expected value from disclosing converges to the prior $E[Q]$, which is also attainable by nondisclosure. Hence nondisclosure becomes an equilibrium for any cost $c > 0$ of disclosure.

The first part of the following proposition generalizes these insights to show the effect of multiple standards when standards are uncertain. The first part shows that an increase in standards always expands the nondisclosure equilibrium region, as seen in panels (d), (e), and (f) of Figure 2. The second part considers the informativeness of disclosure when a disclosure equilibrium does exist. Recall that Proposition 3 showed that disclosure is always less informative when standards are uncertain, and that this result extends to any n. For large n this result is even stronger in that, even though disclosure can still be an equilibrium for large n, the informativeness of disclosure when standards are uncertain goes to zero in that

[19] By a disclosure equilibrium we mean an equilibrium in which at least some types disclose if they are able to.

estimates of Q are no better than the prior estimates without disclosure.[20] That is, disclosure is completely wasteful in that in equilibrium the firm needs to disclose to prove that it is not of the lowest quality, but the firm does not actually benefit relative to prior expectations. This contrasts with the result for certain standards where as n increases disclosure becomes highly informative for firms who disclose and the only residual uncertainty arises from firms who do not disclose because of the disclosure costs.

Proposition 4 *For any F and G, as the number of uncertain standards increases, (i) the support of a nondisclosure equilibrium increases, and (ii) the informativeness of a symmetric disclosure equilibrium converges to zero.*

Note that the second part of Proposition 4 is closely related to the finding by Lizzeri (1999) that a certification intermediary who is interested in maximizing certification revenues 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,[21] and since the certificate is so easy, almost all of them are able to pay for the certificate and receive it. Therefore the certification intermediary often benefits the most from a low standard. Our model differs in the assumption that there are multiple exogenous certification standards rather than an endogenous standard (or standards) chosen by the certification intermediary, but we find the same result that consumers do not actually benefit from certification even as firms feel forced to expend substantial resources on it.

We now turn to the issue of "focal strategies" based on arbitrary properties of the standards that are unrelated to their difficulty. For instance, if there are two standards A and B, consumers might expect that a firm will always disclose standard A if it has met standard A, regardless of whether the extra standard B is tougher. To understand such strategies the key question is what consumers believe if standard B is disclosed. For certain standards, consumers must believe that the firm has quality that is at least as high as demanded by the standard, so a firm will clearly disclose whichever standard is toughest and any equilibrium based on focal strategies will break down. For uncertain standards, consumers must also believe that the firm has met the standard for B, but consumers do not know whether this standard is better or worse than A. Suppose they believe it is better than A. Then the firm should disclose B when it attains B, so the focal strategy is not an equilibrium. Therefore the relevant case is where consumers believe that a firm will disclose A if it attains A, and will

[20] This is related to Lizzeri's (1999) result than a certification intermediary will choose a very easy standard that almost all firms can meet, with result that almost all firms will pay to avoid looking like they cannot meet the standard, and almost no information is released. Here we are assuming that the difficulty of standards for different certificates, and the number of certificates avaliable, is exogenous.

[21] If F is convex then it can be shown that the gap $E[Q|Q \geq s] - E[Q|Q < s]$ is decreasing in s so firms will pay the highest amount for certification for s approaching 0.

only disclose B if it attains B and not A. Note that in such an equilibrium more information is revealed than in the equilibria we have considered so far. The following proposition shows that this holds more generally.

Proposition 5 *For any F and G, for a sufficiently large number of uncertain standards, if a symmetric disclosure equilibrium exists then there always exists a focal disclosure equilibrium which is more informative.*

As discussed in the introduction, this result provides a large role for 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. Similarly, this result also provides an argument for mandatory disclosure of a particular label, even if consumers do not know the exact standard for the label.

Note that focality of a standard eliminates the problems caused by multiple standards. The result is 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 the presence of additional standards makes it is more likely that there will be some disclosure, implying there is more information for consumers.

Regarding the assumption that only one certificate can be disclosed, this assumption does not affect the conditions for existence of disclosure and nondisclosure equilibria if there are constant or diminishing returns to disclosing attainment of multiple standards. In the examples we consider with uniform F and G, this in indeed the case. But if returns are increasing over some range, then it might be worthwhile to disclose multiple certificates even if it would not be worthwhile to disclose a single certificate, e.g., a restaurant might display multiple certificates in its window. Since the marginal value of any standard goes to 0 as n goes to infinity, the limiting results are unaffected by the possibility of multiple disclosures.

4 Multiple Firms

The above analysis considered the product of a single firm in isolation. Such an assumption is appropriate when each standard is used for multiple different products and its meaning is idiosyncratic to the particular product, or when standards are so confusing or similar-appearing that consumers cannot remember whether the label observed on one product is the same as that observed on another product. But in many cases there are multiple products each facing the same set of distinct standards, so if standards are uncertain then consumers will learn about the standards by observing which firms attain them. Such learning implies

that there is an information externality or spillover that effects the incentives for each firm to disclose.

In this section we consider how such information spillovers affect the adoption of standards by multiple firms.[22] Recall from the $n = 1$ case that consumers will tend to downgrade their estimate of a standard when a firm adopts it. For $n > 1$ this Groucho effect can be counteracted by a "selection effect" if we consider equilibria where a firm chooses to adopt the most demanding standard that it is able to meet. For instance if a firm that is exceptionally good adopts the best of many standards that it meets, then it is highly likely that the adopted standard is much better than average, and consumers will favorably update their impression of the standard. In contrast, if a firm with a reputation for low quality adopts a standard, it is likely to be bad even if it is the best standard that it meets.

To see this consider the parameterized distribution given by (9). As θ becomes very large, implying the firm is expected to be quite good, straightforward calculations show that the expected value of the adopted standard s converges to that of the best standard, $E[S_{n:n}]$. And as θ becomes very negative, implying the firm is expected to be quite bad, similar calculations show that the expected value of the adopted standard S converges to that of the worst standard, $E[S_{1:n}]$. So in the first case the selection effect dominates the Groucho effect, while in the second case the Groucho effect dominates the selection effect.

In the context of multiple firms, the result is that a good firm can "legitimize" a standard and make it more attractive to other firms, while a bad firm can "spoil" a standard and make it less attractive to other firms.[23] To see the impact on disclosure incentives of these differing effects, consider two firms A and B with independent distributions parameterized by $\theta = 1$ and $\theta = -1$ respectively. Suppose that both firms face the same two standards and that they disclose the toughest standard they meet. If both firms disclose the same certificate or label then

$$E[Q_A | S_{1:2} \leq Q_A, Q_B < S_{2:2} \cup S_{1:2} < S_{2:2} \leq Q_A, Q_B] = 0.648 \tag{16}$$

and

$$E[Q_b | S_{1:2} \leq Q_A, Q_B < S_{2:2} \cup S_{1:2} < S_{2:2} \leq Q_A, Q_B] = 0.494. \tag{17}$$

[22] If there are a large number of firms, and if they are distributed i.i.d., consumers might be able to obtain a relatively precise estimate of the standards for different certificates based on how many firms adopt different certificates. However, consumers are only able to learn about the difficulty of a certificate if firms are in fact expected to adopt the certificate. If not, then we are back to our original situation where a single firm can choose to deviate from a nondisclosure equilibrium, but might not find it worthwhile since the standard is unknown. Moroever, since there are often multiple equilibria, the ability of consumers to learn detailed information about standards from how many firms are certified is further limited by strategic uncertainty over which firms are playing which equilibrium.

[23] This legitimization effect is distinct from the impression effect in Chakraborty et al. (2006) where the sequencing decision is based on private rather than public information about product quality and the goal is to generate the most favorable impression of both products.

In this case it is likely that the standard for the label was the weaker of the two standards, so the good firm is actually worse off than its unconditional quality of $E[Q_a] = 2/3$. However, since meeting any standard is still good news for the bad firm, and there is a chance that the standard was the tougher of the two, the bad firm is substantially better off than its unconditional quality of $E[Q_b] = 1/3$.

Now suppose that the two firms adopt different labels. Then,

$$E[Q_A | S_{1:2} \leq Q_A < S_{2:2} < Q_B \cup S_{1:2} \leq Q_B < S_{2:2} \leq Q_A] = 0.767 \tag{18}$$

and

$$E[Q_B | S_{1:2} \leq Q_A < S_{2:2} < Q_B \cup S_{1:2} \leq Q_B < S_{2:2} \leq Q_A] = 0.392. \tag{19}$$

In this case it is very likely that the good firm met the tougher standard while the bad firm only met the weaker standard, so the good firm benefits substantially while the bad firm benefits only slightly.

Comparing the two cases, note that (18)>(16) while (17)>(19) so the good firm prefers that the firms disclose different standards while the bad firm prefers that the firms disclose the same standards.[24] Therefore if the good firm goes first clearly it will want to choose the tougher standard since there is some hope that the bad firm will only meet the weaker standard, in which case the good firm benefits. If the good firm does this then the bad firm will want to adopt the same standard whenever it is able. In contrast, if the bad firm goes first then the good firm has an incentive to always choose the opposite standard as the bad firm, even if it is not the toughest. So it is never an equilibrium for both firms to adopt the toughest standard. The following proposition summarizes this result.

Proposition 6 *Suppose two firms A and B with independent distributions given by (9) with* $\theta = 1$ *and* $\theta = -1$ *respectively face two i.i.d. uncertain uniform standards. Then it is never an equilibrium for both firms to adopt the toughest standard that they meet.*

As discussed in the introduction, a common strategy when introducing a new standard is to try to get the most reputable companies to adopt the standard 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 proposition shows that information spillovers may be one reason for this strategy. Note that we assumed that firms do not care directly how other firms are regarded by consumers, but only care if the standard 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

[24] Therefore there is a second-mover advantage which creates a war of attrition that is clearly an obstacle to the adoption of standards. If the firms must move simultaneously there will be a mixed strategy equilibrium if the good firm thinks it is sufficiently likely that the bad firm can meet both standards.

to other firms by undermining their competitors' perceived quality.[25] The above analysis shows that, even without such incentives, firms need to worry about how the strategic effects of disclosure decisions.

5 Conclusion

Much of the literature on labeling and standards in economics assumes that the labeling standard is known. In reality, considerable uncertainty over labels exists. We have shown that this uncertainty leads to a previously unmodeled phenomenon in which consumers use a firm's labeling decision to simultaneously update their beliefs about the firm's quality and the uncertain labeling standard. This dual updating requirement leads to a "Groucho effect" in which attainment of the standard weakens consumers' expectations of the standard, and a "reverse Groucho effect" in which non-attainment strengthens consumers' expectations of the standard. These effects, in turn, weaken the firm's incentive to adopt the label and strengthen its incentive not to adopt it. Thus, we have shown that uncertainty over labeling standards biases firm incentives towards non-adoption.

We found that the Groucho and reverse Groucho effects reduce the informativeness of firm adoption of a label when adoption does occur. We also found that the Groucho effect is stronger for "bad" firms than for "average" or "good" firms, suggesting that uncertainty has a greater discouraging effect on disclosure by bad firms than by good firms when each firm is considered in isolation. We then showed that in a two-firm setting an external Groucho effect arises where label adoption by a bad firm can "spoil" a label, while label adoption by a good firm can "legitimize" a label.

Clearly there is a role for industry governments, industry groups, and NGOs in addressing these issues. Of course, the simplest policy prescription for governments is to require mandatory adoption of labels, i.e., as is done with many nutrition labels. For industry groups and NGOs, one alternative is to invest in information campaigns aimed at decreasing the level of uncertainty surrounding the meaning of eco-labels. The existence of regions of multiple equilibria in which both disclosure and non-disclosure exist, along with a role for "focal" standards when there are multiple uncertain standards, suggests that "look for the label" promotional campaigns can increase the likelihood that a disclosure equilibrium may arise. Finally, our results suggest that in choosing the balance between setting relatively weak and relatively tough standards, standard-setting organizations should recognize that weak standards can allow bad firms to devalue the perceived quality of a label, thereby discouraging good firms

[25] In contrast with this assumption that higher competitor quality is always bad, in models of vertical quality differentiation firms might prefer to have different qualities to reduce competition (Gabszewicz and Thisse, 1979; Shaked and Sutton, 1982). The resulting effect on disclosure incentives with a fixed standard and exogenous quality is analyzed by Hotz and Hsiao (2004), Levin, Peck and Li (2005), and Board (2006).

from adopting it.

6 Appendix

Proof of Proposition 2: From (1) and (3), for the disclosure equilibrium we need to show that

$$\begin{aligned} & \frac{\int_0^1 \int_s^1 q dF(q) dG(s)}{\int_0^1 \int_s^1 dF(q) dG(s)} - \frac{\int_0^1 \int_0^s q dF(q) dG(s)}{\int_0^1 \int_0^s dF(q) dG(s)} \\ \leq & \int_0^1 \frac{\int_s^1 q dF(q)}{\int_s^1 dF(q)} dG(s) - \int_0^1 \frac{\int_0^s q dF(q)}{\int_0^s dF(q)} dG(s) \end{aligned} \tag{20}$$

and, from (2) and (4), for the nondisclosure equilibrium we need to show that

$$\frac{\int_0^1 \int_s^1 q dF(q) dG(s)}{\int_0^1 \int_s^1 dF(q) dG(s)} \leq \int_0^1 \frac{\int_s^1 q dF(q)}{\int_s^1 dF(q)} dG(s). \tag{21}$$

Considering the nondisclosure equilibrium first, (21) is equivalent to

$$\begin{aligned} & \int_0^1 \left(\frac{\int_s^1 q dF(q)}{\int_0^1 \left(\int_t^1 dF(q) \right) dG(t)} - \frac{\int_s^1 q dF(q)}{\int_s^1 dF(q)} \right) dG(s) \leq 0 \\ \iff & \int_0^1 \left(\int_s^1 q dF(q) \right) \left(\frac{\int_0^1 F(t) dG(t) - F(s)}{\left(1 - \int_0^1 F(t) dG(t) \right) (1 - F(s))} \right) dG(s) \leq 0 \\ \iff & \int_0^1 E[Q|Q \geq s] \left(\int_0^1 F(t) dG(t) - F(s) \right) dG(s) \leq 0 \\ \iff & \int_0^1 E[Q|Q \geq s] \left(1 - \frac{F(s)}{\int_0^1 F(t) dG(t)} \right) dG(s) \leq 0. \end{aligned} \tag{22}$$

Letting $P(s) = \int_0^s F(t) dG(t) / \left(\int_0^1 F(t) dG(t) \right)$, then (22) 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.[26] This is

[26] Note that, having defined the new distribution P, the rest of this proof is just showing that P First Order Stochastically Dominates G.

equivalent to, for all s,

$$\begin{aligned}
& \int_0^s \left(1 - \frac{F(x)}{\int_0^1 F(t)dG(t)}\right) dG(x) \geq 0 \\
\iff \quad & \int_0^s \left(\int_0^1 F(t)dG(t) - F(x)\right) dG(x) \geq 0 \\
\iff \quad & G(s)\int_0^1 F(t)dG(t) - \int_0^s F(t)dG(t) \geq 0 \\
\iff \quad & \int_0^1 F(t)dG(t) - \int_0^s \frac{F(t)}{G(s)}dG(t) \geq 0 \\
\iff \quad & \left([F(t)G(t)]_{t=0}^{t=1} - \int_0^1 f(t)G(t)dt\right) - \left(\left[\frac{F(t)}{G(s)}G(t)\right]_{t=0}^{t=s} - \int_0^s \frac{f(t)}{G(s)}G(t)dt\right) \geq 0 \\
\iff \quad & \left(1 - \int_0^1 f(t)G(t)dt\right) - \left(F(s) - \int_0^s \frac{f(t)}{G(s)}G(t)dt\right) \geq 0 \\
\iff \quad & \int_0^s \frac{f(t)}{G(s)}G(t)dt - \int_0^1 f(t)G(t)dt + 1 - F(s) \geq 0 \\
\iff \quad & \int_0^s \left(\frac{f(t)}{G(s)} - f(t)\right) G(t)dt + 1 - F(s) - \int_s^1 f(t)G(t)dt \geq 0 \\
\iff \quad & \int_0^s \left(\frac{f(t)}{G(s)} - f(t)\right) G(t)dt + \int_s^1 f(t)\left(1 - G(t)\right)dt \geq 0 \qquad (23)
\end{aligned}$$

where we have used integration by parts in the fifth step. The final inequality holds for all s since G is bounded by 1.

Now considering the disclosure equilibrium, given that (21) holds, (20) holds if

$$\frac{\int_0^1 \int_0^s qdF(q)dG(s)}{\int_0^1 \int_0^s dF(q)dG(s)} \geq \int_0^1 \frac{\int_0^s qdF(q)}{\int_0^s dF(q)}dG(s) \qquad (24)$$

which, by the same arguments as above, always holds. ■

Proof of Proposition 3: 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 MSE for the uncertain case is

$$\begin{aligned}
& \int_0^1 \left(\int_0^s (q - \underline{q})^2 dF(q) + \int_s^1 (q - \overline{q})^2 dF(q)\right) dG(s) \\
= \quad & \int_0^1 \left(\int_0^s (q^2 - 2q\underline{q} + \underline{q}^2)dF(q) + \int_s^1 (q^2 - 2q\overline{q} + \overline{q}^2)dF(q)\right) dG(s) \\
= \quad & E[Q^2] + \int_0^1 \left(F(s)\left(\underline{q}^2 - 2\underline{q}\underline{q}(s)\right) + (1 - F(s))\left(\overline{q}^2 - 2\overline{q}\overline{q}(s)\right)\right) dG(s) \qquad (25)
\end{aligned}$$

and the expected MSE for the certain case is

$$\begin{aligned}
&\int_0^1 \left(\int_0^s (q - \underline{q}(s))^2 dF(q) + \int_s^1 (q - \overline{q}(s))^2 dF(q) \right) dG(s) \\
= \;& E[Q^2] + \int_0^1 \left(F(s) \left(\underline{q}(s)^2 - 2\underline{q}(s)^2 \right) + (1 - F(s)) \left(\overline{q}(s)^2 - 2\overline{q}(s)^2 \right) \right) dG(s) \\
= \;& E[Q^2] - \int_0^1 \left(F(s)\underline{q}(s)^2 + (1 - F(s))\overline{q}(s)^2 \right) dG(s). \qquad (26)
\end{aligned}$$

Comparing, (25)–(26) equals

$$\begin{aligned}
&\int_0^1 F(s) \left(\underline{q}^2 - 2\underline{q}\underline{q}(s) \right) + (1 - F(s)) \left(\overline{q}^2 - 2\overline{q}\overline{q}(s) \right) dG(s) \\
&+ \int_0^1 \left(F(s)\underline{q}(s)^2 + (1 - F(s))\overline{q}(s)^2 \right) dG(s) \\
= \;& \int_0^1 F(s) \left(\left(\underline{q}^2 - 2\underline{q}\underline{q}(s) + \underline{q}(s)^2 \right) + (1 - F(s)) \left(\overline{q}^2 - 2\overline{q}\overline{q}(s) + \overline{q}(s)^2 \right) \right) dG(s) \\
= \;& \int_0^1 F(s) \left(\left(\underline{q} - \underline{q}(s) \right)^2 + (1 - F(s)) \left(\overline{q} - \overline{q}(s) \right)^2 \right) dG(s) > 0 \qquad (27)
\end{aligned}$$

so the MSE is larger for the uncertain case. ■

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

$$g_{k:n}(x) = \frac{n!}{(k-1)!(n-k)!} G(x)^{k-1} (1 - G(x))^{n-k} g(x), \qquad (28)$$

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

$$\begin{aligned}
& \frac{g_{1:n}(x)}{g_{1:n+1}(x)} \leq \frac{g_{1:n}(y)}{g_{1:n+1}(y)} \\
\iff \quad & \frac{(n)(1 - G(x))^{n-1} g(x)}{(n+1)(1 - G(x))^n g(x)} \leq \frac{(n)(1 - G(y))^{n-1} g(y)}{(n+1)(1 - G(y))^n g(y)} \\
\iff \quad & \frac{1}{(1 - G(x))} \leq \frac{1}{(1 - G(y))} \\
\iff \quad & G(x) \leq G(y) \qquad (29)
\end{aligned}$$

which holds for all $x < y$. Now we want to show that if $G \succ_{MLR} H$ then it is better good news when the firm bears a standard with distribution G than H, so we need to prove that

$$\frac{\int_0^1 \int_s^1 q dF(q) dG(s)}{\int_0^1 \int_s^1 dF(q) dG(s)} \geq \frac{\int_0^1 \int_s^1 q dF(q) dH(s)}{\int_0^1 \int_s^1 dF(q) dH(s)}. \qquad (30)$$

which can be rewritten as

$$\frac{\int_0^1 E[q|q \geq s](1-F(s))g(s)ds}{\int_0^1 (1-F(s))g(s)ds} \geq \frac{\int_0^1 E[q|q \geq s](1-F(s))h(s)ds}{\int_0^1 (1-F(s))h(s)ds}. \tag{31}$$

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

$$\begin{aligned}
& \frac{g(x)}{g(y)} \leq \frac{h(x)}{h(y)} \\
\iff \quad & \frac{(1-F(x))g(x)}{(1-F(y))g(y)} \leq \frac{(1-F(x))h(x)}{(1-F(y))h(y)} \\
\implies \quad & \frac{\int_0^y (1-F(x))g(x)dx}{(1-F(y))g(y)} \leq \frac{\int_0^y (1-F(x))h(x)dx}{(1-F(y))h(y)} \\
\iff \quad & \frac{\int_0^y (1-F(x))g(x)dx}{p(y)\int_0^1 (1-F(x))g(x)dx} \leq \frac{\int_0^y (1-F(x))h(x)dx}{p(y)\int_0^1 (1-F(x))h(x)dx} \\
\iff \quad & \frac{\int_0^y p(x)dx}{p(y)} \leq \frac{\int_0^y q(x)dx}{q(y)} \\
\iff \quad & \frac{P(y)}{p(y)} \leq \frac{Q(y)}{q(y)}
\end{aligned} \tag{32}$$

so P reverse hazard rate dominates Q which implies $P(s) \succ_{FOSD} Q(s)$ and hence $G \succ_{MLR} H$. 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 (13), the support of a nondisclosure equilibrium is increasing in n.

(ii) In the limit as n increases, a firm always meets the worst of the n standards and expected quality condition on meeting the standard, $E[Q|Q > S_{1:n}]$, converges to the prior $E[Q]$, so no information is conveyed in the disclosure equilibrium. ■

Proof of Proposition 5: (i) In the candidate focal disclosure equilibrium, if a firm does not meet the focal standard it discloses another standard. The estimation of the focal standard is not affected by the number of standards present on the market, so such a focal disclosure equilibrium exists for a wider range of disclosure costs than a symmetric disclosure equilibrium if

$$E[Q|Q \geq S] - E[Q|Q < S_{1:n}] \geq E[Q|Q \geq S_{1:n}] - E[Q|Q < S_{1:n}] \tag{33}$$

or

$$E[Q|Q \geq S] \geq E[Q|Q \geq S_{1:n}] \tag{34}$$

which always holds since $G \succ_{MLR} G_{1:n}$ as shown in the proof of Proposition 4 and since it is always more impressive to meet a standard that MLR dominates another standard as shown in that same proof.

(ii) As n increases recall that the informativeness of a symmetric disclosure equilibrium goes to zero. In contrast the informativeness of a focal disclosure equilibrium goes to that for a single standard, which is always higher. ■

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