Uncertain Standards*

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Abstract

Consumers are rarely sure of the exact standard that a quality certificate or label represents. We show how the resulting need to jointly estimate product quality and standard difficulty undermines the ability of voluntary certification to reduce information asymmetries. First, since consumers are most suspicious of a label when a product with a bad reputation has it, a "Groucho effect" makes certification less rewarding to firms precisely when the information asymmetry is greatest. Second, as the number of available labels increases, the effects of even small amounts of uncertainty are multiplied, and the informativeness of certification decreases rather than increases. Third, uncertainty makes certification and non-certification 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. Fourth, since a label can be either "legitimitized" or "spoiled" for use by other products when a product with a good or bad reputation displays it, firms have an incentive to choose labels strategically. These effects can be eliminated 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 other product labels, academic journals, club memberships, diplomas, and other common certification environments.

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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 difficulty of the standard is often uncertain. Consumers must then estimate whether a label on a product is more indicative of a high quality product, or of an undemanding standard for the label. For instance, when a car buyer sees that a vehicle has a Low Emissions label, she will update both her estimate of the car's environmental quality and of the meaning of the Low Emissions label. If the car in question is a large SUV then the updating on both dimensions is likely to be very different than if the car is a small hybrid. This problem of joint 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 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. We investigate how such joint estimation affects the power of voluntary certification to reduce information asymmetries about product quality, and focus in particular on "eco-labels" for certifying environmental quality.

Consumer uncertainty over the meaning of eco-labels is a widely recognized problem in the policy literature on environmental quality certification. Policy research indicates that consumers are unsure of the meaning of different labels,[1] especially since there are numerous different labels and each label can signify attainment of different standards for a wide variety of heterogeneous products.[2] This uncertainty appears to be a significant reason behind the difficulty of getting labels to be accepted by firms, e.g., the slow adoption of the E.U. Flower eco-label,[3] and the incomplete adoption of eco-labels for forest products.[4] The negative impact of uncertainty on label adoption has motivated attempts to clarify voluntary standards, e.g., different standards for "organic" in the U.S.,[5] or even to replace voluntary standards with

[1] 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. CITEXXX

[2] Something about proliferation of standards. Dutch paper?

[3] For some product categories no products at all have been certified (xx). Surveys indicate that understanding of the label is far lower than of other regional and national eco-labels (Sto and Strandbakken, 2002).

[4] Internationally there are 21 different certification standards with low adoption rates. Consumers appear to have little information about the standards (Fischer et al., 2005).

[5] For instance, in response to confusion over multiple standards for "organic," the US enacted legislation in 2002 setting a unified standard that must be met to use the term in product claims.

mandatory standards, e.g., the historic adoption of mandatory labels for some food products in the U.S.

We show that concern over the effects of standard uncertainty on voluntary certification is well founded. In addition to the direct information loss due to the uncertainty, the optimal responses of consumers and firms lead to furthers losses that can greatly undermine or eliminate the value of voluntary certification. First, certification is most valuable when consumers think that a product is likely to be bad but in fact it is certifiably quite 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 certification standard is probably weak if such a product can meet it. Just as Groucho Marx saw little value in joining a club that would accept him, a firm with a bad reputation that should benefit the most from certification instead gains the least. Therefore the incentive for certification is undermined when the problem of information asymmetry, and therefore the potential gain from certification, is greatest.

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, certification only proves that a firm has met the easiest of the different standards, even if the firm has met a higher standard.[6] We find that the gains to a firm from voluntary certification shrink rather than rise as the number of standards increases, and a non-certification equilibrium always exists for a sufficiently high number of standards. Moreover, even when a certification equilibrium does exist, its informativeness goes to zero as the number of standards increases.

Third, uncertain standards aggravate the problem of strategic uncertainty due to the coexistence of certification and non-certification equilibria. Multiple equilibria arise with voluntary certification because if consumers expect a firm to be certified then lack of certification is particularly damaging to the firm's expected quality, but if certification is not expected then the firm loses less from not being certified and can save on certification costs. With certain standards, 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 standards and that certification and non-certification equilibria always coexist for a sufficiently large number of standards unless certification costs are so high that only non-certification is an equilibrium.

Finally, we find that uncertainty over standards generates information externalities between firms that can lead to strategic behavior that reduces the informativeness of labels.

[6] As a policy report 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). For instance, the Ecolabelling.org website lists 110 different labels for organic foods in use.

Certification of a firm can "legitimize" or "spoil" the label for use by other firms depending on whether a "good" firm with a favorable reputation or a "bad" firm with an unfavorable reputation is certified. Consequently 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. Such strategizing makes it difficult for consumers to rely on the existing reputations of firms as a simple way to learn about different standards. The problem is mitigated if the good firm chooses its label first, which might explain the widespread industry practice of launching new labels by promoting early adoption among firms of recognized high quality.

These results show that uncertainty over standards can greatly undermine the ability of voluntary certification to solve information asymmetries. Mandatory certification also suffers from the direct information losses due to such uncertainty, but it does not face the additional indirect information losses identified above. For instance, currently firms can apply for "Energy Star" labels indicating energy efficiency, but an alternative approach is to require firms to display a label indicating whether or not the product meets the standard.[7] Such a requirement eliminates the multiplicity of equilibria and the strategic incentive to choose standards, and also facilitates learning about the standard by consumers.[8] Therefore these results provide one argument in favor of mandatory versus voluntary certification, even when mandatory standards face the same problem that consumers are not sure of their exact meaning.

Short of mandatory certification, these results imply that there can be a role for governments or NGOs in making a particular standard "focal" in the sense of publicizing it and making consumers expects that firms will adopt the standard if they meet it. This can reduce or eliminate the information losses caused by standard proliferation and by strategic uncertainty over which equilibria are being played by which 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. Attempts to "harmonize" different voluntary standards, e.g., recent efforts in the EU to harmonize eco-labels,[9] can also be seen in this light.

A key source of consumer uncertainty over certification standards is that consumers are often unsure of the source of a label or certificate. Industry groups and for-profit certifiers can have an incentive to appear as pro-consumer or pro-environment NGOs, while NGOs often have an incentive to appear as official government agencies. This problem of confusion over

[7] Under mandatory certification firms not meeting the standard can still offer the product. Leland (1979) analyzes the case of minimum quality standards in which firms can be excluded from the market for not meeting the standard. 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).

[8] Certification increases information to consumers and reduces ex ante expected firm profits by the certification cost, so mandatory certification is desirable if this cost is not too high.

[9] See "Proposal for a Regulation of the European Parliament and of the Council on a Community Ecolabel Scheme," SEC(2008) 2118 and SEC(2008) 2119.

label sources is widely recognized in the policy literature... In some cases the organization's name recognition is sufficient to reduce uncertainty over the source, e.g., the "Heart-Check" label for food products prominently notes that it is awarded by the American Heart Association. But in other cases consumers are likely to remain unsure of the true source, e.g., the similar-appearing "FSC" and "PEFC" 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.

Even when the certification source is clear, the incentives of the source to set a particular standard are not always so clear. If the source is a profit-maximizing certification intermediary, it has an incentive to set the standard at a low level to maximize the number of firms which pay for the certificate (Lizzeri, 1999), but otherwise there is a wide range of possibilities. If the source is an industry group, it has an incentive to set the standard so that all members of the standard-setting coalition and no members of lower quality are certified (xx), but consumers are unlikely to know the details of how a particular coalition size was determined. If the source is an NGO, it might try to maximize information flows to consumers (xx) or punish low quality firms (xx), or instead it might be captured by industry groups favoring easy standards (xx) or by employees wanting to extract revenues or other non-pecuniary benefits from firms (xx). And if the source is a government agency, it might act to maximize consumer welfare (xx) or total welfare (xx), it might be induced by domestic industry to set standards so as to undermine foreign competitors (xx), or it might even act to maximize its own revenues under "user-fee" arrangements.

To capture these uncertainties, we model consumers as having a prior distribution of the certification standard(s) that can be arbitrarily precise or diffuse, and arbitrarily skewed toward higher or lower 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 above analyses in which the standards are either assumed to be common knowledge, or can be inferred from the incentives of certification intermediaries. 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.

The question of mandatory versus voluntary certification or "disclosure" plays a large role in the related literature on verifiable message "persuasion" games (e.g., Milgrom, 1981; Okuno-Fujiwara, Postlewaite, and Suzumura, 1990). The classic "unravelling" result finds that voluntary disclosure through costless, verifiable messages can fully reveal information since even those with bad information have an incentive to prove they do not have worse information. This result indicates that mandatory disclosure is often unnecessary, e.g., consumer product labels should be adopted by firms voluntarily, even when the information is relatively unfavorable. As recognized early on, a number of factors can interfere with the incentive for voluntary disclosure.[10] In particular, the idea that disclosure is often costly, which plays a large role in our analysis, appears early on in this literature as a factor that can disrupt the unravelling result (e.g., Viscusi, 1978; Jovanovic, 1982; Verrecchia, 1983).

Our analysis contributes to these literatures by showing that the combination of costly certification/disclosure and uncertainty is particularly disruptive to voluntary certification, and that the effects are exacerbated when there are multiple standards. The idea that the imperfect nature of certification can have an important effect on certification strategies appears in several papers that differ from ours in other key respects. Fishman and Hagerty (1990) consider costless disclosure of one of multiple noisy signals of "high" or "low" quality and concentrate on whether the sender should be restricted in which signals can be sent. Their results are closely related to our findings on "focal" equilibria as discussed later. Sinclair-Desgagne and Gozlan (2003) also consider binary tests of 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. The key difference from these papers is that we assume that consumers do not know which standards are more difficult.

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, a disreputable individual might find it of little benefit to join a club because the very fact of his membership downgrades the perceived standards of the club. Similarly, reputable individuals or firms have an incentive to join organizations strategically so as to avoid the value of their memberships being degraded by disreputable members. These effects are distinct from other related information effects. For instance, a potential club member might take the willingness of the club to offer membership as an indication that there is little interest by other potential members, which could be analyzed as either adverse selection in the supply of club openings or the winner's curse in the demand for club openings.[11] Our analysis differs because we assume a fixed standard for joining the

[10] The sender might with some probability be uninformed (e.g., Dye, 1985; Shin, 2003), have a strategic incentive to hide information (e.g., Dye, 1986; Okuno-Fujiwara, Postlewaite, and Suzumura, 1990; Board, 2005; Levin, Peck and Ye, 2005), or a reputational incentive to be understated (Grubb, 2008). Or the receiver might be naïve (Dye, 1988), uninformed (Fishman and Hagerty, 2003), boundedly attentive (Hirshleifer, Lim, and Teoh, 2002), or have her own private information (Harbaugh and To, 2006).

[11] Similarly, the no-trade theorem of Milgrom and Stokey (1982) is often referred to as the "Groucho Marx Theorem."

"club" that is uncertain to outsiders who judge both the standard of the club and the quality of its members by the endogenous composition of the club.[12]

The paper proceeds as follows. In Section 2 we develop the basic model with one standard, define the conditions for the existence of both certification and non-certification 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 The Basic Model

We consider a firm's decision of whether to have its product certified that it meets a quality standard. To capture the idea that consumers have some information about the product, let the product's fixed 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 Sections 3 and 4 we extend the model to allow for multiple standards and multiple firms.

To capture consumer knowledge about the quality 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 has 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. The firm always knows the realized values of Q and S. If $Q \geq S$ the firm has a choice of either certification or non-certification, i.e., a firm that meets the standard need not choose to be certified. If $Q < S$ the firm does not meet the standard so it has no choice.

The payoff to the firm is its expected quality as estimated by consumers less a certification cost if it chooses to certify. The expected quality assumption is standard in most certification games and sender-receiver games more generally.[13] It captures situations where, for instance, there are multiple buyers bidding competitively for the product. The certification cost $c \geq 0$ captures any fees to the certifier and any other costs, e.g., the expense of documenting quality control processes, auditing costs by the certifier, and the opportunity cost of providing space on the product packaging for the certification label.[14]

[12] Becker (1990) directly assumes that demand for a club is higher if others want to join the club, and suggests a connection to Groucho Marx's quote. Sobel (2001) considers the dynamics of club standards as members are admitted, with an emphasis on when standards will decline.

[13] As long as firms of higher perceived quality are more profitable, the qualitative results of the paper are unaffected.

[14] When a firm is certified we assume it displays a label informing customers of this fact. For an analysis of

If consumers believe that a product has met the standard, the expected quality of the product is its expected quality conditional on quality Q exceeding the standard 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 believed 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 believed to have not met the standard.

Our equilibrium concept is perfect Bayesian equilibrium subject to a belief-refinement introduced below. In a *certification equilibrium* a firm whose product meets or exceeds the certification standard always certifies this fact, so the lack of a label implies failure to meet the standard.[15] Consumer beliefs used to update firm quality are consistent this firm strategy in equilibrium, so the equilibrium condition is simply that the benefit from certification is higher than the cost,[16]

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

In a *non-certification equilibrium* a firm does not certify its quality even if it can, so lack of certification does not represent bad news that $E[Q|Q < S]$ but represents no news at all,

when withholding a label might be desirable see Harbaugh and To (2006).

[15] When a firm is certified we assume it displays a label informing customers of this fact. For an analysis of when withholding a label might be desirable see Harbaugh and To (2006). Note that since firms know their own quality they only apply for certification when they are certain to receive it. In a model where firms do not know their own quality, Farhi, Lerner, and Tirole (2008) consider the question of whether certification intermediaries disclose which firms fail to meet the certification standard.

[16] If a certification equilibrium exists there is also a partial certification equilibrium where only types in some subset $X \subset [S, 1]$ disclose with the knife-edge result that $E[Q|Q \in X] - E[Q|Q \notin X] = c$. We do not analyze this equilibrium in which all types are indifferent between certification and non-certification.

implying the prior $E[Q]$ is unchanged. Certification in the non-certification 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 unexpected certification is good news that generates the posterior distribution $E[Q|Q \geq S]$.[17] Therefore the equilibrium condition for the non-certification 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 certification condition (5) cannot be satisfied for c sufficiently large and the non-certification condition (6) cannot be satisfied for c sufficiently small. We state these results as the following proposition.

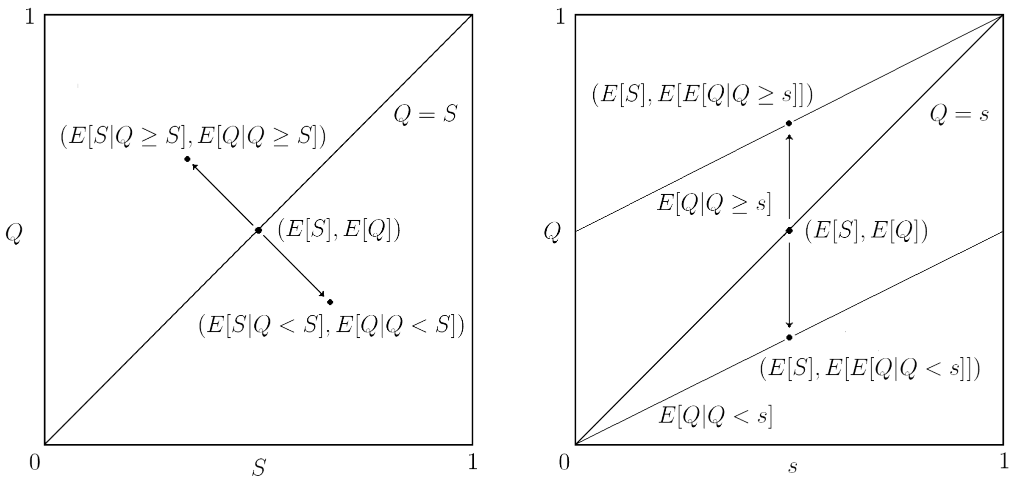
Proposition 1 *With either certain or uncertain standards, there exists* $\underline{c}, \overline{c} \in (0,1)$ *with* $\underline{c} < \overline{c}$ *such that a non-certification equilibrium exists iff* $c \geq \underline{c}$*, a certification equilibrium exists iff* $c \leq \overline{c}$*, and therefore 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 $E[S|Q < S] = 2/3$.[18] 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 certification 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 certification the "reverse Groucho effect" – failing to meet the goal enhances the goal itself.[19] These adjustments lead to a moderating effect on the estimates of Q where consumers

[17] That is, the prior distribution of Q is concentrated on $[s, 1]$ where s is distributed according to G. 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. Allowing for more "skeptical" beliefs about who deviates (e.g., Harbaugh and To, 2005) changes the results slightly, but the overall qualitative effects of uncertainty are unchanged.

[18] Given $Q \geq S$ the updated density of Q is $f(q) = q/(1/2) = 2q$ and the updated density of S is $g(s) = (1-s)/(1/2) = 2 - 2s$. The densities are reversed for $Q < S$.

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



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

Figure 1: Updated Quality and Standard Estimates

are both less favorably impressed by certification and less unfavorably impressed by lack of certification.

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 according to G we get the 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

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

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.

The relationship in (8) implies that condition (5) for a certification equilibrium is more strict with uncertain standards than it is on average for a certain standard, and that condition (6) for a non-certification 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 certification equilibrium harder to meet, and the reverse Groucho effect makes the condition for the non-certification equilibrium easier to meet. The following proposition shows that this result generated by the pattern in (8) holds generally when we compare the cost cutoffs $\underline{c} = E[Q|Q \geq S] - E[Q]$ and $\overline{c} = E[Q|Q \geq S] - E[Q|Q < S]$ for the case of an uncertain standard S with the expected or average cutoffs $E[\underline{c}] = E[E[Q|Q \geq s]] - E[Q]$. and $E[\overline{c}] = E[E[Q|Q \geq s]] - E[E[Q|Q < s]]$ for different realized values of a certain standard $S = s$.

Proposition 2 *The expected range of certification costs supporting a certification (non-certification) equilibrium is smaller (larger) if the standard is uncertain rather than certain.*

Proof. This proof and all subsequent proofs are in the Appendix. ■

To gain further insight into these differences, consider Figure 2 where G is uniform and F follows the Beta distribution $B(q; a, b)$ which has mean $E[Q] = a/(a+b)$. The Beta distribution is always log-concave, is convex if $a \geq 1$ and $b = 1$, and is concave if $a = 1$ and $b \geq 1$.[20] We assume that one or the other of these parameter restriction holds so the distribution is either convex (a "good firm") or concave (a "bad firm") and so that the distribution is uniquely determined by $E[Q]$ as pictured in the Figure.

Figure 2(a) shows the cost cutoff $\underline{c}$ for the boundary of the non-certification region (N) from the equilibrium condition (5), and the cost cutoff $\overline{c}$ for the boundary of the certification region (C) from the equilibrium condition (6). Both certification and non-certification equilibria exist in the region between the two lines, so the figure illustrates the multiple equilibrium result of Proposition 1. Figure 2(d) shows the certain standard case where the corresponding regions are determined by the expected values $E[\underline{c}]$ and $E[\overline{c}]$ based on averaging out the exact values for different realizations of $S = s$. Comparison of the figures illustrates the result from Proposition 2 that uncertainty over the standard makes certification less likely in that, relative to the case of certain standards, the equilibrium range for the certification equilibrium is always smaller and the equilibrium range for the non-certification equilibrium is always larger.

Considering the effect of prior expectations about firm quality, when standards are uncertain the Groucho effect is strongest for "bad firms" which consumers view most unfavorably because consumers are suspicious of any standard that such a firm can meet. Therefore it becomes difficult for a firm with a bad reputation to successfully disprove that it is bad. This is seen in Figure 2(a) where the certification region is at a minimum and the non-certification region is at a maximum for $E[Q]$ approaching 0.[21] In contrast, when standards are certain there is no Groucho effect so bad firms have the strongest incentive to certify. This

[20] For instance, the Beta distribution reduces to the uniform distribution for $a = b = 1$, a rising triangle distribution for $a = 2$ and $b = 1$, and a falling triangle distribution for $a = 1$ and $b = 2$.

[21] For very high $E[Q]$ the reverse Groucho effect also reduces the certification incentive. Certification in-

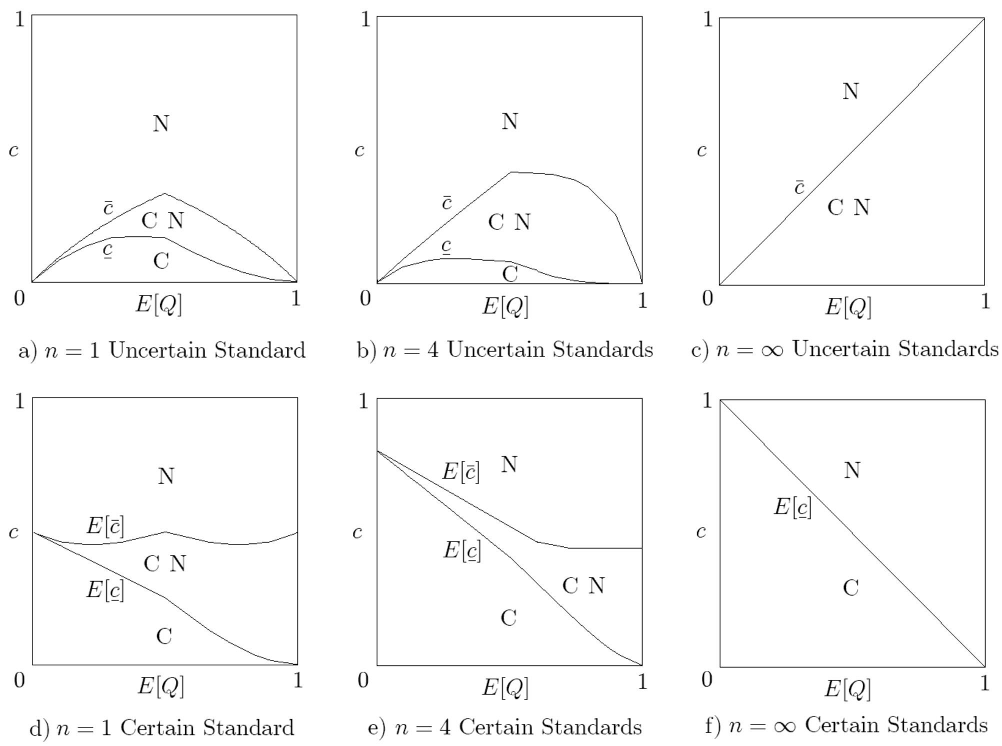


Figure 2: Certification (C) and Non-certification (N) Equilibrium Regions

is seen in Figure 2(a) where the certification equilibrium region is at a maximum and the non-certification region at its minimum for low $E[Q]$. As will be seen in the following section, and as illustrated in the remaining panels of Figure 2, the divergence between the certain and uncertain cases becomes increasingly stark as the number of standards increases.

Proposition 2 shows that a certification equilibrium is less likely when standards are uncertain in the sense that such an equilibrium is supported by a narrower range of costs. Now consider the impact of uncertainty on the amount of information communicated when the certification equilibrium does exist. Recall from (8) 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 certification decision, the information about Q alone is less informative than when

centives are strongest when priors about the firm firm are weakest. This is consistent with result from Xiao (2006) 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 meet social norms given the uncertainty of their status.

S is known. In particular, for the case of uniform F and G in Figure 1 the mean-squared-error (MSE) of consumer estimates of Q when S is uncertain is

$$\int_0^1 \left(\int_0^s (q - E[Q|Q < S])^2 dq + \int_s^1 (q - E[Q|Q \geq S])^2 dq \right) ds = 1/18 \tag{9}$$

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

$$\int_0^1 \left(\int_0^s (q - E[Q|Q < s])^2 dq + \int_s^1 (q - E[Q|Q \geq s])^2 dq \right) ds = 1/24. \tag{10}$$

In both cases the error is reduced relative to the non-certification equilibrium where the MSE is $Var[Q] = 1/12$, but 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 certification might be higher or lower than in the uncertain case, uncertainty reduces informativeness on average as the following proposition shows for general F and G.

Proposition 3 *The expected informativeness of a certification equilibrium is lower if the standard is uncertain than if it is certain.*

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.[22] Consequently, governments and NGOs, to the extent that they care about social welfare, have an incentive to publicize labeling standards so as to reduce the information losses from uncertain standards in the certification 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 certification equilibrium relatively to the completely uninformative non-certification equilibrium. Thus, investments in clarifying label standards can result in a double-dividend, enhancing both the likelihood and value of certification.

In the following section we show how the negative effects of uncertainty on voluntary certification are compounded as the number of standards increases.

3 Multiple Standards

Often there are multiple different standards that a firm could meet, e.g., there are multiple different eco-labels, or multiple different safety labels. As discussed in the introduction, the

[22] In addition, they find that more accurate information leads firms to improve their quality. We take quality as exogenous in our model. Lerner and Tirole (2006) allow for firms to adjust their quality in response to different standards.

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 10 different labels for carbon, over 40 different labels for textiles, and over 100 different labels for food products. It might seem that more options should give firms more ability to show off their quality, so that certification increases. But the proliferation of standards is often blamed for creating confusion among consumers that weakens the credibility of all labels and reduces certification rates (Fischer et al., 2005). This suggests that an increase in standards can aggravate the underlying problem of standard uncertainty.

To gain insight into how the proliferation of standards interacts with standard uncertainty, we now assume that there are $n \geq 1$ standards which are drawn independently from the same distribution G and each have the same cost c. 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. 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 multiple different standards it can only certify one of them. In some cases this captures a physical or contractual constraint, e.g., a lawyer can only join one partnership or 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 and displaying 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.[23] We also restrict attention initially to a "symmetric" certification strategy where the firm adopts the toughest standard that it meets independent of any arbitrary properties of the ex ante identical standards.[24] That is, for now we do not consider "focal" equilibrium strategies where it is assumed that a particular standard will be certified if that standard is met.

[23] The restriction to one standard does not affect the conditions for existence of certification and non-certification equilibria if there are constant or diminishing returns to certifying attainment of multiple standards. 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 standards even if it would not be worthwhile to certify having met a single standard, e.g., a restaurant might display multiple certificates in its window. Since the marginal value of any standard goes to 0 as the number of standards increases, the limiting results of this section are unaffected by the possibility of multiple certifications.

[24] It is straightforward that any equilibrium symmetric strategy provides equivalent information about firm quality to consumers. For instance, if a firm has a strategy of always adopting the second toughest standard that it meets and not adopting a standard if it only meets one standard, then if in fact it only meets one standard it has an incentive to deviate and adopt the one standard. If this strategy is adjusted so that the firm is expected to disclose the one standard in this case, then consumers learn the same information as if the firm always disclosed the toughest standard.

Since consumers do not know which of the standards is more difficult, certification under a symmetric certification strategy only 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 of use in computing the firm's expected quality is that the firm has met at least one of the n possible standards. Hence the incentives to certify or not certify 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 (5) and (6), for uncertain standards a *symmetric certification equilibrium* exists if and only if

$$E[Q|Q \geq S_{1:n}] - E[Q|Q < S_{1:n}] \geq c \tag{11}$$

and a non-certification equilibrium exists if and only if

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

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 certification equilibrium for certain standards as an equilibrium in which any of the different standards is certified. For instance, a firm might find it worth the costs to certify a high standard if it meets it but not worth the costs to only certify a lower standard.[25] Following (xx), a certification 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,[26] i.e., if and only if

$$\max_{i=1,..,n} \{E[Q|s_{i:n} \leq Q \leq s_{i+1:n}] - E[Q|Q < s_{i:n}]\} \geq c, \tag{13}$$

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

$$E[Q|Q \geq s_{n:n}] - E[Q] \leq c. \tag{14}$$

As shown in Figure 2, these conditions imply that behavior with uncertain standards diverges dramatically from that with certain standards as the number of standards n increases.

[25] That is, due to certification costs, there need not be full "unravelling" in which all firms above the lowest quality certify (e.g., Viscusi, 1978).

[26] Given that firms meeting standard i certify, firms meeting an even higher standard will also want to certify, so the binding constraint is for standard i.

Comparing panel (a) with panels (b) and (c), as n increases the incentive for "bad" firms to certify disappears, while the incentive for "good" firms to certify becomes completely dependent on consumer expectations about whether certification is expected or not, i.e., both certification and non-certification are always equilibria for such firms. In contrast, comparing panel (d) with panels (e) and (f), for certain standards as n increases the incentive for "bad" firms to certify becomes increasingly strong, while the incentive for "good" firms to certify disappears.

These differences arise because an increase in the number of certain standards gives firms more opportunities to disprove low expectations, but an increase in the number of uncertain standards means that the persuasive value of certification falls. In particular, for uncertain standards in the limit as n increases $G_{1:n}$ puts all weight on $S = 0$, so certification is meaningless while failure to certify is quite damning. Therefore (11) and (12) simplify to $E[Q] - 0 \geq c$ and $E[Q] - E[Q] \leq c$, so we get the pattern in panel (c) where a certification equilibrium exists for any c if and only if the prior estimate $E[Q]$ is sufficiently good, and a non-certification equilibrium always exists. Hence we find that "bad" firms find it impossible to disprove expectations, while "good" firms face strategic uncertainty over whether they should certify or not. If certification is not expected then they gain nothing from unexpectedly certifying, but if certification is expected and they don't certify then consumers infer they are of the lowest possible type.

For certain standards in the limit as n increases there is essentially a different standard for each possible quality, so the problem reduces to the well-understood case where the firm can prove its exact quality and conditions (13) and (14) simplify to $\max_s \{s - E[Q|Q < s]\} \geq c$ and $1 - E[Q] \leq c$ respectively. If F is log-concave as in the Beta distribution used in Figure 2, then $s - E[Q|Q < s]$ is increasing in s (Bagnoli and Bergstrom, 2005, Lemma 1), so following Lizzeri (1999, Theorem 1),[27] if $1 - E[Q] \geq c$ there is a unique certification equilibrium in which types q such that $q - E[Q|Q < q] = c$ and higher all certify and lower types do not certify. Therefore we get the pattern in panel (f) where for any given $c > 0$ certification is the unique equilibrium for a bad enough prior estimate $E[Q]$ and non-certification is the unique equilibrium for a good enough prior estimate $E[Q]$.

The following proposition shows that these patterns in Figure 2 are not limited to the distributional assumptions of the example. They hold generally for uncertain standards and hold for certain standards as long as the distribution of F is log-concave. The results for certain standards follow almost directly from Lizzeri (1999, Theorem 1).

Proposition 4 *Suppose there are n i.i.d. standards. If standards are uncertain, (i) the support of a non-certification equilibrium is increasing in n, and, in the limit as n increases: (ii)*

[27] Lizzeri (1999) analyzes this case where certification costs are given and each quality level can be certified as a step toward understanding the case where costs and standards are chosen by the certification intermediary to maximize profits.

non-certification is an equilibrium for all $c > 0$*; (iii) symmetric certification is an equilibrium if and only if* $E[Q] \geq c$*; and (iv) the symmetric certification equilibrium is uninformative. If standards are certain and* F *is log-concave, in the limit as* n *increases: (v) non-certification is almost surely an equilibrium if and only if* $E[Q] \geq 1 - c$*; and (vi) certification is almost surely an equilibrium if and only if* $E[Q] \leq 1 - c$*.*

Recall that Proposition 3 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 certification can still be an equilibrium for large n, the informativeness of certification when standards are uncertain goes to zero in that estimates of Q are no better than the prior estimates without certification. Certification is therefore completely wasteful in that 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 certification becomes highly informative for firms who certify and the only residual uncertainty arises from firms who do not certify because of the certification costs.

This finding that certification provides no new information as n increases is 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, 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 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, and that there is a fixed cost to certification rather than a price adjusted by the 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.

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 (xx). 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. Similarly, in academic environments it is often the case that a particular journal is focal for a discipline so that failure to publish in that journal is a bad sign even if another journal is known by specialists in the field to be more selective.

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 decreases information flows, we now consider "focal certification strategies" based on arbitrary properties of the standards that are unrelated to their difficulty. In such a strategy there is one standard, say standard X, that a firm is expected to adopt if it can. If the firm adopts another standard, say standard Y, then it is assumed that it could not meet standard X and that standard Y was the best of the other standards it did meet. For certain standards, a firm will clearly certify whichever standard is toughest so any equilibrium based on focal strategies will break down. But for uncertain standards, consumers do not know which standard is tougher so such a focal certification equilibrium is possible. Such an equilibrium is more informative than a symmetric certification equilibrium as the following proposition shows.[28]

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

The focality of a standard eliminates the problems caused by multiplicity of voluntary 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 certification, implying there is more information for consumers. 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.

This 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

[28] The following proposition looks at the case where costs are sufficiently low that a firm will adopt another standard if it cannot meet the focal standard, even though adopting the other standard is less impressive. It can also be an equilibrium for a firm to adopt the focal standard if it can and to not adopt any standard if it cannot meet the focal standard. For sufficiently many standards such an equilibrium is more informative than the symmetric disclosure equilibrium.

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.[29]

Whether in practice information campaigns can successfully make standards "focal" is an empirical question. An alternative solution is to simply make it mandatory for a firm to disclose whether it meets a particular standard. In this case bad news on this mandatory 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.

4 Multiple Firms

The results so far highlight the negative impact on certification incentives from uncertain standards. If there are multiple firms adopting or not adopting different standards, and labels are sufficiently distinct to be easily differentiated and remembered, it might seem that eventually consumers should be able to learn relatively detailed estimates of the difficulty of different standards from these adoption patterns. In this section we show that, when certification is voluntary, the problem of learning is complicated both by multiple equilibria and by the incentives of firms to choose standards strategically in a way that interferes with learning.

First consider the simplest case where there are m firms with i.i.d. qualities $Q_1, ..., Q_m$ facing a single 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. If all firms which can meet the standard certify, then the fraction of firms which certify is clearly quite informative about the difficulty of the standard. Indeed by a standard Law of Large Numbers result, as the number of firms increases, the estimate of the standard becomes asymptotically precise. As stated in the first part of the following Proposition, this implies that the situation for each firm is equivalent to that of a single firm facing a certain standard as examined in Section 2.

However, because there are often multiple equilibria, there is still no assurance that consumers will learn about the standard from observing the certification pattern of firms. Suppose that each firm does not expect the gains from certification to be worth the certification costs. Then each firm receives the prior estimate $E[Q_i]$ and if a firm deviates consumers learn no

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

more than they did in Section 2, so the gain from deviating is just $E[Q_i|Q_i \geq S]$. Hence, as stated in the second part of the following Proposition, the condition for a nondisclosure equilibrium remains exactly the same as that of a single firm facing an uncertain standard as examined in Section 2.

Proposition 6 *Suppose m i.i.d. firms face a single standard. If the standard is uncertain: (i) the expected support of a certification equilibrium converges to that of a single firm with a certain standard as m increases; and (ii) the expected support of a non-certification equilibrium is the same as for $m = 1$. (iii) If the standard is certain the expected support of any equilibrium is the same as for $m = 1$.*

Looking back at Figure 2, this Proposition implies that the region where the certification and non-certification equilibria coexist expands from the "C,N" regions in the separate panels of (a) and (d) to encompass the area underneath $E[\overline{c}]$ in panel (a) and above $\underline{c}$ 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 multiple equilibria. NEW This uncertainty can leave consumers even less sure of the standard than if there were no opportunity to observe the certification behavior of multiple firms.[30]

Now considering the case where there are both multiple firms and multiple standards, we find that learning about standards is made more difficult because adoption of one standard by a firm creates an information externality or spillover that can affect the incentives for other firms to certify. With multiple standards if a firm always adopts the toughest standard that it meets then adoption of a standard might be good news about the standard which counteracts the Groucho effect. With multiple firms this "selection effect" implies that a good firm can "legitimize" a standard and make it more attractive to other firms, and a bad firm can "spoil" a standard and make it less attractive to other firms. As a result firms 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 i.i.d. standards and two i.i.d. firms. If one firm has the strategy of adopting the toughest standard it meets and the prior F is very favorable, then the standard which it adopts is likely to be the better one. This gives the other firm an incentive to adopt the same standard, regardless of whether the standard is really the toughest. Conversely, if the prior F is very unfavorable, then the standard which is adopted is still likely to be the worse one. This gives the other firm has an incentive to adopt

[30] 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 any major laundry detergent products either as reflecting a non-certification equilibrium or as strong evidence that the certification standard for detergents is very strict. In this case the former interpretation appears to be correct (Rubik and Frankl, 2005).

the opposite standard, regardless of whether it is really the toughest. Therefore in both cases firms have an incentive to deviate from a simple strategy of adopting the toughest standard.

This is seen in Figure 3(a) for two firms with i.i.d. quality given by the Beta distribution as before. Define $E[Q_i|\text{Same}]$ as the expected quality of firm i when the toughest standard that each firm meets is the same, and $E[Q_i|\text{Different}]$ as the expected quality of firm i when this is not true. For the case of two i.i.d. standards and two i.i.d. standards, the former equals

$$E[Q_i|S_{1:2} \leq Q_1, Q_2 < S_{2:2} \cup S_{1:2} < S_{2:2} \leq Q_1, Q_2] \tag{15}$$

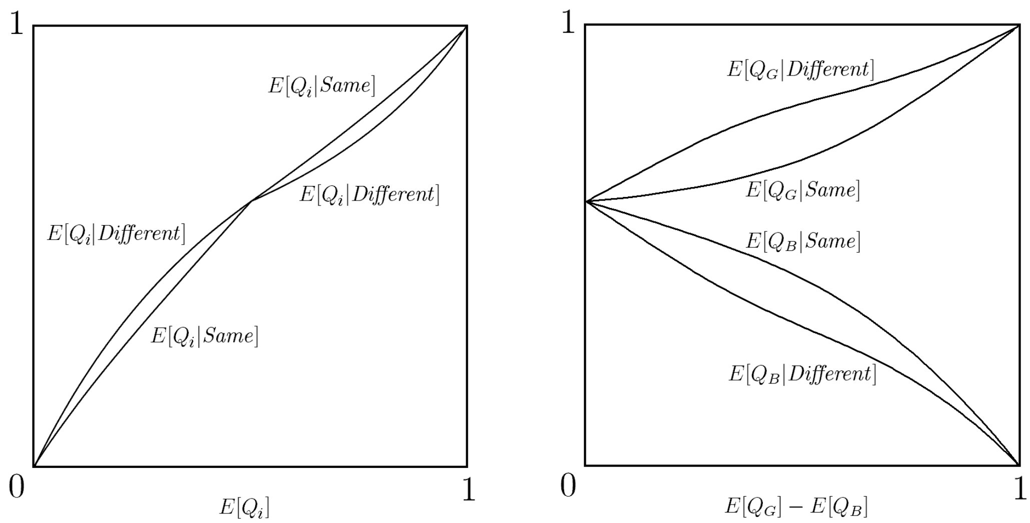
and the latter equals

$$E[Q_i|S_{1:2} \leq Q_1 < S_{2:2} < Q_2 \cup S_{1:2} \leq Q_2 < S_{2:2} \leq Q_1]. \tag{16}$$

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 (15)>(16) both firms will prefer to adopt the same standard even if one meets a higher standard, and if (15)<(16) both firms will prefer to adopt a different standard even if they both meet the higher standard. Only in the knife-edge case where (15)=(16) and the firms are just indifferent, is it an equilibrium for firms to follow the symmetric always adopt the toughest standard they meet. 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. The following proposition states this result more generally for m firms and n standards where again the realized difficulties and qualities are known by the firms but only F, G, c, m, and n are known to consumers. The proof follows from the above argument.

Proposition 7 *Suppose m i.i.d. firms face n i.i.d. standards. i) If the standards are uncertain then for $m > 1$ there exists a symmetric certification equilibrium only if $E[Q_i|Same] = E[Q_i|Different]$. ii) If the standards are certain then the support of any equilibrium is the same as for $m = 1$.*

The incentive to choose standards strategically can be aggravated if consumers have different priors about the different firms. Figure 3(b) shows the case where a "good" firm G has convex Beta distribution parameterized by $(\theta, 1)$ and a "bad" firm B has the symmetric concave independent Beta distribution parameterized by $(1, \theta)$ so $E[Q_G] - E[Q_B] = (\theta - 1)/(\theta + 1)$. When $\theta = 1$ so both firms have uniformly distributed quality, $E[Q_G] = E[Q_B] = 1/2$, there is no incentive to be strategic, but as soon as a gap emerges the good firm always wants to choose a different standard than the bad firm, and the bad firm always wants to choose the same standard as the good firm. If both firms adopt the same standard, it is likely that only the weaker of the two standards was met, which is bad news for the good firm but still good news for the bad firm. And if both firms adopt different standards, it is likely that the good firm met the tougher standard and the bad firm met the weaker standard, so the good firm



a) Two I.I.D. Firms

b) Good Firm and Bad Firm

Figure 3: Strategic Choice of Standards

gains and the bad firm loses. So there cannot be an equilibrium in which each firm always adopts the toughest standard it meets. Instead, if both firms meet both standards, there must be a mixed strategy equilibrium where the bad firm tries to choose the same standard as the good firm and the good firm tries to avoid such an outcome.

These problems with multiple equilibria and strategic choice of standards are eliminated if certification is mandatory. If all firms are required to display a quality certificate, then consumers can learn about the meaning of the standards from their experiences with different products. And if there are multiple different standards, making one standard the mandatory standard removes the incentive or ability to adopt standards selectively. Similarly, government or NGO efforts to make one standard focal can also reduce the multiple equilibrium problem as shown in Section 3, and can help avoid the strategizing in the symmetric equilibrium analyzed above. For instance, if it is believed that a firm always adopts standard X unless it can only meet standard Y and not standard X, then clearly each firm has an incentive to adopt standard X regardless of what the other firms do.

As discussed 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.[31] Similar strategies occur in many other contexts, e.g., new

[31] Since there is a second-mover advantage that can create a war of attrition, a good firm needs some incentive to move first.

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 firm moves first then the bad firm can always choose the same standard if it is capable of doing so. Therefore the good firm has no incentive to deliberately choose a weaker standard and, if it faces any uncertainty at all over whether the bad firm will meet the tougher standard, it has a strict incentive to choose the tougher standard.

Finally, we have 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 to other firms by undermining their competitors' perceived quality.[32] The above analysis shows that, even without such product market externalities, firms need to worry about the strategic effects of certification decisions.

5 Conclusion

The policy literature on eco-labels and other quality certification schemes has long recognized that consumer uncertainty over the standards needed for certification is a major hurdle to their adoption and effective use. We show that concern over the effects of such uncertainty is well-founded. Since consumers must jointly update the quality of the product and the difficulty of the standard, there are direct information losses and also substantial indirect losses as firms decide whether it is worthwhile to be certified and, if so, which of multiple labels or certificates to adopt. We find that uncertainty discourages certification when it is most beneficial to consumers and firms, that the effects of uncertainty are aggravated by the proliferation of different standards, that strategic uncertainty due to multiple equilibria becomes particularly problematic as the number of standards increases, and that information spillovers give firms an incentive to strategically choose among different standards so as to make learning about standards more difficult for consumers.

Mandatory standards can also suffer from direct information losses due to uncertainty but preclude the additional indirect losses due to firm certification decisions, and can also facilitate consumer learning about standards. Therefore these results provide an additional consideration in the debate over voluntary versus mandatory certification of product quality. Short of mandatory standards, we find that 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,

[32] However, 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), Board (2005), and Levin, Peck and Li (2005).

can increase certification incentives, reduce the problem of strategic uncertainty due to multiple equilibria, and eliminate the incentive to choose among standards strategically due to information spillovers from other firms.

6 Appendix

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

$$\frac{\int_0^1\int_s^1 qdF(q)dG(s)}{\int_0^1\int_s^1 dF(q)dG(s)} - \frac{\int_0^1\int_0^s qdF(q)dG(s)}{\int_0^1\int_0^s dF(q)dG(s)}$$
$$\leq \int_0^1 \frac{\int_s^1 qdF(q)}{\int_s^1 dF(q)}dG(s) - \int_0^1 \frac{\int_0^s qdF(q)}{\int_0^s dF(q)}dG(s) \tag{17}$$

and, from (2) and (4), for the non-certification equilibrium we need to show that

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

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

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

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.[33] This is

[33] 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,

$$
\begin{aligned}
& \int_0^s \left(1 - \frac{F(x)}{\int_0^1 F(t)dG(t)}\right) dG(x) \geq 0 \\
\iff & \int_0^s \left(\int_0^1 F(t)dG(t) - F(x)\right) dG(x) \geq 0 \\
\iff & G(s)\int_0^1 F(t)dG(t) - \int_0^s F(t)dG(t) \geq 0 \\
\iff & \int_0^1 F(t)dG(t) - \int_0^s \frac{F(t)}{G(s)}dG(t) \geq 0 \\
\iff & \left([F(t)G(t)]_{t=0}^{t=1} - \int_0^1 f(t)G(t)dt\right) - \left(\left[\frac{F(t)}{G(s)}G(t)\right]_{t=0}^{t=s} - \int_0^s \frac{f(t)}{G(s)}G(t)dt\right) \geq 0 \\
\iff & \left(1 - \int_0^1 f(t)G(t)dt\right) - \left(F(s) - \int_0^s \frac{f(t)}{G(s)}G(t)dt\right) \geq 0 \\
\iff & \int_0^s \frac{f(t)}{G(s)}G(t)dt - \int_0^1 f(t)G(t)dt + 1 - F(s) \geq 0 \\
\iff & \int_0^s \left(\frac{f(t)}{G(s)} - f(t)\right) G(t)dt + 1 - F(s) - \int_s^1 f(t)G(t)dt \geq 0 \\
\iff & \int_0^s \left(\frac{f(t)}{G(s)} - f(t)\right) G(t)dt + \int_s^1 f(t)\left(1 - G(t)\right) dt \geq 0 \qquad (20)
\end{aligned}
$$

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 certification equilibrium, given that (18) holds, (17) holds if

$$\frac{\int_0^1 \int_0^s q dF(q)dG(s)}{\int_0^1 \int_0^s dF(q)dG(s)} \geq \int_0^1 \frac{\int_0^s q dF(q)}{\int_0^s dF(q)} dG(s) \qquad (21)$$

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

$$
\begin{aligned}
& \int_0^1 \left(\int_0^s (q - \underline{q})^2 dF(q) + \int_s^1 (q - \overline{q})^2 dF(q)\right) dG(s) \\
= & \int_0^1 \left(\int_0^s (q^2 - 2q\underline{q} + \underline{q}^2) dF(q) + \int_s^1 (q^2 - 2q\overline{q} + \overline{q}^2) dF(q)\right) dG(s) \\
= & E[Q^2] + \int_0^1 \left(F(s)\left(\underline{q}^2 - 2\underline{q}\underline{q}(s)\right) + (1 - F(s))\left(\overline{q}^2 - 2\overline{q}\overline{q}(s)\right)\right) dG(s) \qquad (22)
\end{aligned}
$$

and the expected MSE for the certain case is

$$\begin{aligned}
& \int_0^1 \left(\int_0^s (q - \underline{q}(s))^2 dF(q) + \int_s^1 (q - \overline{q}(s))^2 dF(q) \right) dG(s) \\
= \quad & E[Q^2] + \int_0^1 \left(F(s) \left(\underline{q}(s)^2 - 2\underline{q}(s)^2 \right) + (1 - F(s)) \left(\overline{q}(s)^2 - 2\overline{q}(s)^2 \right) \right) dG(s) \\
= \quad & E[Q^2] - \int_0^1 \left(F(s)\underline{q}(s)^2 + (1 - F(s))\overline{q}(s)^2 \right) dG(s). \qquad (23)
\end{aligned}$$

Comparing, (22)–(23) equals

$$\begin{aligned}
& \int_0^1 F(s) \left(\underline{q}^2 - 2\underline{q}\underline{q}(s) \right) + (1 - F(s)) \left(\overline{q}^2 - 2\overline{q}\overline{q}(s) \right) dG(s) \\
& + \int_0^1 \left(F(s)\underline{q}(s)^2 + (1 - F(s))\overline{q}(s)^2 \right) dG(s) \\
= \quad & \int_0^1 F(s) \left(\left(\underline{q}^2 - 2\underline{q}\underline{q}(s) + \underline{q}(s)^2 \right) + (1 - F(s)) \left(\overline{q}^2 - 2\overline{q}\overline{q}(s) + \overline{q}(s)^2 \right) \right) dG(s) \\
= \quad & \int_0^1 F(s) \left(\left(\underline{q} - \underline{q}(s) \right)^2 + (1 - F(s)) \left(\overline{q} - \overline{q}(s) \right)^2 \right) dG(s) > 0 \qquad (24)
\end{aligned}$$

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

$$g_{k:n}(x) = \frac{n!}{(k-1)!(n-k)!} G(x)^{k-1} (1 - G(x))^{n-k} g(x), \qquad (25)$$

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

$$\begin{aligned}
& \frac{g_{1:n}(x)}{g_{1:n+1}(x)} \leq \frac{g_{1:n}(y)}{g_{1:n+1}(y)} \\
\iff \quad & \frac{(n)(1 - G(x))^{n-1} g(x)}{(n+1)(1 - G(x))^n g(x)} \leq \frac{(n)(1 - G(y))^{n-1} g(y)}{(n+1)(1 - G(y))^n g(y)} \\
\iff \quad & \frac{1}{(1 - G(x))} \leq \frac{1}{(1 - G(y))} \\
\iff \quad & G(x) \leq G(y) \qquad (26)
\end{aligned}$$

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

$$\frac{\int_0^1 \int_s^1 q dF(q) dG(s)}{\int_0^1 \int_s^1 dF(q) dG(s)} \geq \frac{\int_0^1 \int_s^1 q dF(q) dH(s)}{\int_0^1 \int_s^1 dF(q) dH(s)}. \qquad (27)$$

which can be rewritten as

$$\frac{\int_0^1 E[q|q \geq s](1-F(s))g(s)ds}{\int_0^1 (1-F(s))g(s)ds} \geq \frac{\int_0^1 E[q|q \geq s](1-F(s))h(s)ds}{\int_0^1 (1-F(s))h(s)ds}. \tag{28}$$

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 $x < y$,

$$\begin{aligned}
& \frac{g(x)}{g(y)} \leq \frac{h(x)}{h(y)} \\
\iff & \frac{(1-F(x))g(x)}{(1-F(y))g(y)} \leq \frac{(1-F(x))h(x)}{(1-F(y))h(y)} \\
\implies & \frac{\int_0^y (1-F(x))g(x)dx}{(1-F(y))g(y)} \leq \frac{\int_0^y (1-F(x))h(x)dx}{(1-F(y))h(y)} \\
\iff & \frac{\int_0^y (1-F(x))g(x)dx}{p(y)\int_0^1 (1-F(x))g(x)dx} \leq \frac{\int_0^y (1-F(x))h(x)dx}{p(y)\int_0^1 (1-F(x))h(x)dx} \\
\iff & \frac{\int_0^y p(x)dx}{p(y)} \leq \frac{\int_0^y q(x)dx}{q(y)} \\
\iff & \frac{P(y)}{p(y)} \leq \frac{Q(y)}{q(y)}
\end{aligned} \tag{29}$$

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 (12), the support of a non-certification equilibrium is increasing in n.

(ii) Formalizing the argument in the text, 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 ε in the limit. Hence the expected quality from unexpected certification converges to 0 in the limit, and the necessary and sufficient condition (12) for non-certification reduces to $E[Q] - E[Q] \leq c$ or $c \geq 0$.

(iii) By the same argument as in (iv), the expected quality from non-certification when types who can certify any standard converges to 0 in the limit, and expected quality from such certification converges to $E[Q]$ in the limit, so the necessary and sufficient condition (11) for a symmetric certification equilibrium reduces to $E[Q] - 0 \geq c$.

(iv) By the same argument as in (iv) 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 certification 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-certification equilibrium if the firm certifies then it has expected quality $E[Q|\underline{s} \le q < \overline{s}]$ and if it does not certify then it still has expected quality $E[Q]$, so non-certification is an equilibrium if and only if $E[Q|\underline{s} \le q < \overline{s}] \le c$. 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 m. Therefore, since $E[Q|\underline{s} \le q < \overline{s}] \in [\underline{s}, \overline{s}]$, for any firm of type q, in the limit $E[Q|\underline{s} \le q < \overline{s}] = q$ almost surely. So the condition for a non-certification equilibrium is $q - E[Q] \le c$ for all q, or $1 - E[Q] \le c$.

(vi) Following the same argument as in (v), the condition for a symmetric certification equilibrium is $E[Q|\underline{s} \le q < \overline{s}] - E[Q|q \le \underline{s}] \le c$, which converges to $q - E[Q|Q \le q] \le c$ almost surely. Following Lizzeri (1999, Theorem 1), the LHS is increasing in q if F is quasiconcave (Bagnoli and Bergstrom, 2005), so there is a unique q^* such that the condition holds with equality. In any equilibrium all types $q < q^*$ do not certify and all types $q \ge q^*$ do certify. ■

Proof of Proposition 5: (i) Consider a focal certification 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 certification equilibrium exists if types meeting the focal standard adopt it,

$$E[Q|Q \ge S] - E[Q|Q < S_{1:n}] \ge c, \tag{30}$$

and types meeting another standard adopt it,

$$E[Q|S_{1:n} \le Q \le S] - E[Q|Q < S_{1:n}] \ge c. \tag{31}$$

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, $S_{1:n} \le Q < S$, or that the firm met the focal standard, $Q \ge S$. In a symmetric certification equilibrium they learn only that the firm met or did not meet the lowest standard, $Q < S_{1:n}$ or $Q \ge S_{1:n}$. 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 certification equilibrium strategy of certifying when it meets the standard. Then the conditional density of S given that k of m firms certify is

$$g(s|Q_{m-k:m} < S \le Q_{m-k+1:m}) = \frac{(1 - F(s))^k F(s)^{m-k}}{\int_0^1 (1 - F(s))^k F(s)^{m-k} dG(s)}. \tag{32}$$

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,

$$\lim_{m\to\infty} g(s|Q_{m-k:m} < S \leq Q_{m-k+1:m}) = \lim_{m\to\infty} \frac{(1-F(s))^{m(1-F(s'))}F(s)^{mF(s')}}{\int_0^1 (1-F(s))^{m(1-F(s'))}F(s)^{mF(s')}dG(s)}. \quad (33)$$

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

$$\lim_{m\to\infty} \frac{g(s|Q_{m-k:m} < S \leq Q_{m-k+1:m})}{g(s'|Q_{m-k:m} < S \leq Q_{m-k+1:m})} = 0 \quad (34)$$

for any $s \neq s'$. From (33) this ratio is just

$$\lim_{m\to\infty} \left(\left(\frac{(1-F(s))}{(1-F(s'))} \right)^{1-F(s')} \left(\frac{F(s)}{F(s')} \right)^{F(s')} \right)^m . \quad (35)$$

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

$$E[\bar{c}] = E[E[Q_i|Q_i > s]] - E[E[Q_i|Q_i < s]], \quad (36)$$

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

(ii) Suppose each firm follows a strategy of non-certification. The expected payoff from nondisclosure for a single firm is just $E[Q_i]$. If a single firm deviates, then as discussed our belief refinement is that the certification 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-certification is

$$E[Q_i|Q_i > S]] - E[Q_i] < c \quad (37)$$

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

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

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