The Groucho Effect of Uncertain Standards

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Abstract

Consumers are rarely sure of the exact standard that product labels and other certificates of quality represent. We show that any such uncertainty creates a "Groucho effect" in which seeing that a product has a label leads consumers to infer that the standard for the label itself is not very demanding. Label adoption is therefore always less likely to be an equilibrium than without uncertainty over the standard, and if it is an equilibrium it is always less informative than without such uncertainty. The Groucho effect leads to an information externality so better firms are reluctant to adopt labels if worse firms adopt them. Applying the model to eco-labels, we find that industry groups, governments, and NGOs can increase label adoption by publicizing labeling criteria, by encouraging consumers to expect label adoption when there are multiple equilibria, and by setting high standards that are less likely to be devalued by low quality firms. *JEL* Classification Categories: L15, L21, D82, Q00
Key Words: Eco-labels, disclosure, certification, persuasion, standards

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. Therefore consumers must determine 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 an article and the editorial standards of the journal it appears in, the quality of a hotel and the toughness of the local rating system, or the soundness of a company's finances and the standards of its auditor. However, the literature on certification and product labeling assumes that standards are fully known, so the dual estimation problem is not considered.[1]

We analyze the general problem of uncertainty over both quality and standards in the context of product labels, with particular attention to eco-labels for environmental quality. 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 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] Consumers might have an idea of the likely standard for an eco-label, but they are unlikely to know the exact standard, so they will update their estimate of both the product's quality and the standard's difficulty based on whether or not the product has an eco-label. Since adoption of an eco-label is usually

[1] The certification literature on costly disclosure (Viscusi, 1978; Jovanovic, 1982; Verrecchia, 1983; Lizzeri, 1999) assumes that the standard is known, as does the closely related literature on persuasion games with costless disclosure (Milgrom, 1981; Grossman, 1981; Okuno-Fujiwara, Postlewaite, and Suzumura, 1990; Lipman and Seppi, 1995; Shin, 2003).

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

[3] 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. And 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.

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 quite generally that any uncertainty over the standard reduces the range of certification costs supporting a disclosure equilibrium, and increases the range of certification costs 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.

The Groucho and reverse Groucho effects undermine disclosure incentives most when consumers have strong prior beliefs about the quality of the firm. Consistent with Groucho Marx's insight, we find that 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 opposite situation arises. If the firm does not meet the standard, the reverse Groucho effect is relatively strong because 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.

When we consider interactions between firms, we find that uncertainty over the standard generates information externalities between firms that, over a wide range of para-

[5] Since the label is voluntary, its only role is informational. Following Leland (1979) there is a large literature on minimum quality standards where a product must attain a certain standard to be sold. Arora and Gangopadhyay (1995) and Lutz, Lyon, and Maxwell (2000) study the application to environmental quality and Amacher, Koskela, and Ollikainen (2004) and Mattoo and Singh (1994) study the application to eco-labeling.

[6] The effect we identify in this paper should not be confused with the Groucho effect previously identified in the computer science literature. The computer science Groucho effect refers to the automated addition of glasses and a large nose to the digital image of a face and is unrelated to our analysis.

[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.

meters, can lead to an equilibrium in which a firm that consumers expect is good fails to adopt the label even if it meets the standard, while a firm that consumers expect is bad does adopt the label when it meets the standard. The information externality arises because consumers update their estimate of the standard based on their prior estimates of each firm and on whether or not each firm has a label. The Groucho effect is stronger when a bad firm discloses than when a good firm discloses, so if a bad firm adopts a label this spills over to consumer estimates of the good firm via the estimated standard. As a result, adoption of a label by a bad firm can sufficiently undermine the label that it is no longer worthwhile for a good firm to also adopt it.

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.

These results also appear to capture recent experiences with the new European Union Eco-Labeling Award Scheme (the EU Flower) in which the EU is having trouble convincing large multi-national firms to affix the Flower label to their products. For instance, no large multinational corporation has adopted the Flower label for laundry detergent products, while the market penetration of such products carrying the Nordic Swan eco-label in Scandinavian countries ranges from 10 to 70 percent, and includes large multi-nationals such as Proctor and Gamble, Unilever, Colgate-Palmolive and Rickett Benckiser (Rubik and Frankl, 2005). One factor in the reluctance of multi-national firms to adopt the EU Flower label might be consumer uncertainty over the standards behind it. Consumer surveys indicate that understanding of the label is substantially lower than that of regional and national eco-labels such as the Nordic Swan label and Germany's Blue Angel label (Sto and Strandbakken, 2002).

In a self-regulatory context our results suggest that uncertainty makes labeling programs difficult to establish by industry groups. Members must incur the costs of establishing such programs, and consumer uncertainty over the standard means that fewer firms will find adoption attractive for any given certification cost. Consequently, the fixed cost of establishing the scheme will be spread across fewer members, further reducing incentives to join the scheme. This suggests that governments and NGOs can play a useful role in subsidizing at least part of the fixed costs of establishing industry-based labeling pro-

grams. Many industry-targeted voluntary labeling programs, such as Natural Gas Star, feature implicit government subsidies in the form of program promotion and the provision of direct technical assistance to program members.[8]

We discuss our results in the context of eco-labeling, but they apply to any certification or labeling scheme about which uncertainty over standards exits. 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.[9] 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.[10]

The paper proceeds as follows. In Section 2 we develop the basic model, define the conditions for the existence of both disclosure and non-disclosure equilibria, show the existence of the Groucho effect and discuss the role of standard-setting groups in promoting voluntary disclosure. In Section 3 we consider three extensions of the model, including the case of two firms where there is an information externality that arises from the Groucho effect. In Section 4 we present our conclusions.

2 The 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 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. To capture consumer knowledge about the labeling standard, let the standard s be distributed according to G on $[0, 1]$.[11] We will compare the "uncertain" case where G has full support on $[0, 1]$ and

[8] See Lyon and Maxwell (2004) Ch. 9 for a discussion of implicit subsidies provided by several government voluntary programs.

[9] Becker (1990) assumes that demand for a club is higher if others want to join the club, and suggests a connection to Groucho Marx's quote, but does not analyze the information effects that could justify such an assumption, such as adverse selection in the supply of club openings or the winner's curse in the demand for club openings. The Groucho effect we identify is distinct from these other well-known information effects because we assume an uncertain but fixed standard for joining the club.

[10] 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.

[11] We assume as single fixed standard set by an outside authority. Therefore we do not consider issues such as "forum shopping" in which firms choose among different standards (Lerner and Tirole, 2004).

corresponding density g, with the "certain" case where the realized value of 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.[12] The firm always knows the realized values of q and s.[13]

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 $c > 0$. For 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.[14] We examine the case of endogenous quality in an extension in Section 3.3 below.

If consumers observe 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 observe 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. In this case of a certain standard, which is closer to most models in the literature, for a known value $s = s'$ the expectations simplify to

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

[12] 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 all the disclosure incentives we examine in the paper hold.

[13] 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.

[14] Amacher, Koskela, and Ollikainen (2004) note that initial eco-labeling standards are often designed to admit a fraction of industry participants based on their current quality levels. The standard may be adjusted at a later date to encourage innovation.

if the firm discloses that it has 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 does not disclose.

We limit attention to pure strategy Perfect Bayesian Equilibria so that consumers update firm quality using Bayes Rule based on equilibrium strategies when possible. 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. 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 will result in a payoff of $E[q]$ rather than $E[q|q < s]$, since non-disclosure is not conditional on failure to meet the standard. 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 $E[q|q \geq s]$.[15] 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.

[15] 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.

Proposition 1 *(i) A pure strategy equilibrium always exists, (ii) for an intermediate range of costs c multiple pure strategy equilibria exist, and (iii) for cost c sufficiently high (low) the nondisclosure (disclosure) equilibrium is the unique pure strategy equilibrium.*

Recalling that G may be degenerate we see that these existence results hold regardless of whether the standard is known or is uncertain. However, uncertainty can affect the likelihood of disclosure. To see the role of uncertainty, suppose that F is uniform on $[0,1]$ and that the standard is known to be $s' = 1/2$. In this case if the firm meets the standard then $E[q|q \geq s'] = (1+s')/2 = 3/4$ and $E[q|q < s'] = s'/2 = 1/4$. Now suppose that the standard is not known but G is also uniform on $[0,1]$ and so has an expected value of $1/2$. Then straightforward calculations show that $E[q|q \geq s] = 2/3$ and $E[q|q < s] = 1/3$. This example shows the following pattern

$$E[q|q < \overline{s}] < E[q|q < s] < \overline{q} < E[q|q \geq s] < E[q|q \geq \overline{s}]. \tag{8}$$

where $\overline{s} = E[s]$ and $\overline{q} = E[q]$. Thus, disclosure of having met the standard is good news, but it is better news if the labeling standard is known for sure than if it is uncertain with the same mean. Likewise, not meeting the labeling standard is bad news, but it is worse news if the standard is known for sure than if it is uncertain with the same mean. Therefore uncertainty over the labeling standard plays a moderating role that makes meeting the standard less impressive and not meeting it less damaging.

This pattern 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.[16] Due to the reverse Groucho effect, failing to meet the standard will result in a less severe reduction in the estimate of q compared to the reduction that would have resulted without the effect.

Figure 1 shows the Groucho and reverse Groucho effects where F and G are both uniform so the expected values of q and s are both $1/2$. If the labeling standard is known for sure to be $s = 1/2$, then clearly consumers learn nothing about s and the only information is about q. In this case the updated estimate of q given the good news that $q \geq s$ is $q = 3/4$, and the updated estimate of q given the bad news that $q < s$ is

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

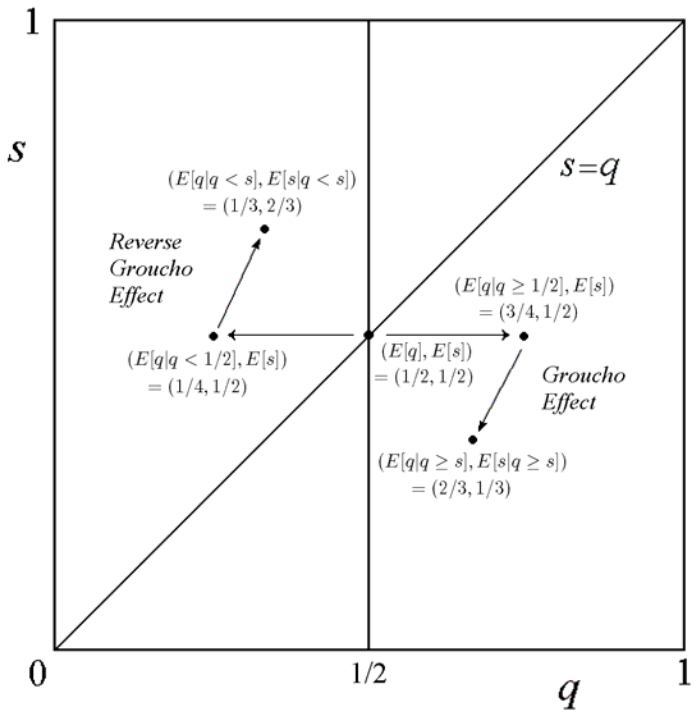

Figure 1: Groucho and Reverse Groucho Effects

$q = 1/4$. These updated estimates are seen in the shifts to the left and right from the prior of $q = 1/2$. If instead s is uncertain these estimates change because any relative information about q also implies information about s. If $q \geq s$ then the support of the two distributions is in the lower triangle of Figure 1, which implies good news about q and bad news about s, and also that the good news about q is not as good as if s were known. Similarly, if $q < s$ then the support of the two distributions is in the upper triangle, which implies bad news about q and good news about s, and also that the bad news about q is not as bad as if s were known. The result is the moderating pattern shown in equation (8).

2.1 The Effect on Disclosure Incentives

We have seen that the Groucho effect makes disclosure of a label less impressive, while the reverse Groucho effect makes non-disclosure less damaging to the firm. Now consider the impact on equilibrium behavior. Again, to fix ideas, first consider the example introduced

above were F is uniform and $s = 1/2$. In this case the disclosure equilibrium condition (5) reduces to $(1+s)/2 - s/2 \geq c$ or, $c \leq 1/2$, and the nondisclosure equilibrium condition (6) reduces to $(1+s)/2 - 1/2 \leq c$ or $c \geq 1/4$. For the uncertain standard s with uniform G, the corresponding conditions are $2/3 - 1/3 \geq c$ or $c \leq 1/3$ for the disclosure equilibrium, and $2/3 - 1/2 \leq c$ or $c \geq 1/6$ for the nondisclosure equilibrium. 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 compare the case of uncertain s with the case where s is certain and average out the result over the whole distribution of s.[17]

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

Proof. See the Appendix. ■

Taken together, Propositions 1 and 2 indicate a number of different strategies industry groups, governments, and NGOs might undertake to promote disclosure in an eco-labeling context. First, since there will often be multiple equilibria, they can encourage disclosure by raising consumer expectations that firms that can disclose do in fact disclose. Such expectations can preclude the nondisclosure equilibrium in favor of the disclosure equilibrium when both exist. Second, they can work to lower the costs of disclosure, in which case disclosure becomes the unique equilibrium. Finally, they can work to diminish uncertainty over the meaning of the labels which, as mentioned in the introduction, is often considerable. Uncertainty reduces the gains from meeting the standard and also reduces the losses from not meeting the standard. Thus, disclosure is unambiguously encouraged when standards are made clear, even if the underlying standard is not altered.

2.2 The Effect on Informativeness of Disclosure

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 s is known. This phenomenon is illustrated in Figure 1 by the fact that the conditional expectations of q are closer to the unconditional expectation

[17] For the certain case we consider the expected range of costs since the result will vary depending on the realization of s. In Figure 1 we simplify the presentation by concentrating on the particular realization where s equals its mean. For uniform F and G, the range of costs for this case is the same as the expected range of costs for different realizations of s, but for more general distributions this need not be true.

$E[q] = 1/2$ 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

$$\int_0^1 \left(\int_0^s (q - \frac{1}{3})^2 dq + \int_s^1 (q - \frac{2}{3})^2 dq \right) ds = 1/18 \tag{9}$$

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

$$\int_0^1 \left(\int_0^s (q - \frac{s}{2})^2 dq + \int_s^1 (q - \frac{1+s}{2})^2 dq \right) ds = 1/24. \tag{10}$$

In both cases the error is reduced relative to the non-disclosure equilibrium where the MSE is $\int_0^1 (q - \frac{1}{2})^2 dq = 1/12$. However, due to the Groucho and reverse Groucho effects, the reduction in MSE, i.e., the increase in estimate accuracy, is smaller when the standard is not known. This result holds generally as the following proposition shows.

Proposition 3 *In the disclosure equilibrium the expected mean-squared-error of consumer estimates of q is higher 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.[18] 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.

2.3 The Role of Firm Quality

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

[18] In addition, they find that more accurate information leads firms to improve their quality. We take quality as exogenous in our base model and consider the issue of endogenous quality in Section 3.3.

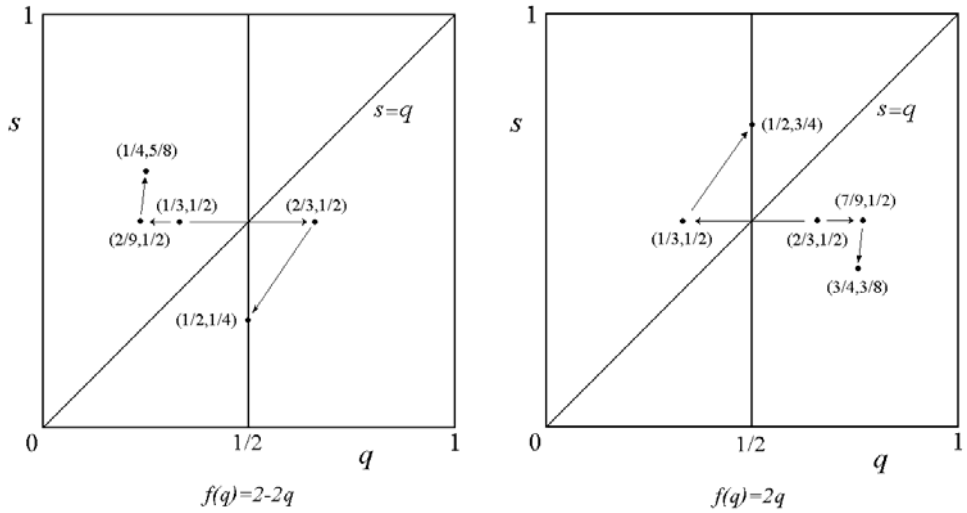

Figure 2: Groucho and reverse Groucho effects for bad (left) and good (right) firms

the quality of the firm and analyze the impact on firm incentives to engage in disclosure or non-disclosure. It is helpful to first consider the parameterized density function

$$f(x;\theta) = \begin{cases} (1+\theta)\, x^{\theta} & \text{for } \theta \geq 0 \\ (1-\theta)\,(1-x)^{-\theta} & \text{for } \theta \leq 0 \end{cases} \tag{11}$$

which encompasses several common distributions, including the uniform distribution ($\theta = 0$), the triangle distribution ($\theta = 1$), and the reverse triangle distribution ($\theta = -1$). Since $f(x;\theta)$ monotone likelihood ratio dominates $f(x;\theta')$ 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.

Figure 2 shows the Groucho effect for a "bad firm" with $\theta = -1$ and a "good firm" with $\theta = 1$. Considering the bad firm first, its ex ante expected quality is $E[q] = 1/3$ and this rises sharply to $E[q|q \geq 1/2] = 2/3$ if the firm meets the standard and the standard is known to be $s = 1/2$. But if the standard is unknown the Groucho effect is stronger than in the uniform case ($\theta = 0$ as shown in Figure 1) because consumers are suspicious of any standard that a bad firm can meet, $E[s|q \geq s] = 1/4$. As a result the expected quality with an unknown standard rises only half as much to $E[q|q \geq s] = 1/2$. If the firm does not meet the standard these patterns are reversed. The bad news is not particularly damaging even for the known standard $s = 1/2$ since the firm was expected to be bad

anyway. The reverse Groucho effect from Figure 1 is still present but it is weakened since there is no reason to think the standard is particularly tough based on failure of a bad firm to attain it. As a result the reverse Groucho effect only slightly moderates the already weak negative inference about firm type from failure to meet the standard.

Now considering the good firm, its ex ante expected quality is much higher at $E[q] = 2/3$, and this rises slightly to $E[q|q \geq 1/2] = 3/4$ if the firm meets the known standard $s = 1/2$. Uncertainty over the standard further moderates this rise, but the Groucho effect is weak since the fact that a good firm meets the standard does little to undermine consumer estimates of the standard. If the firm does not meet the known standard $s = 1/2$ then expected quality falls sharply to $E[q|q < 1/2] = 1/3$, but the reverse Groucho effect is quite strong since consumers will anticipate that if a good firm did not meet the standard the standard is likely to be tough. Therefore the negative inference from not meeting the standard is moderated considerably by uncertainty over the standard, and $E[q|q < s] = 1/2$.

This result on the relative strength of the Groucho effect, $E[s] - E[s|q \geq s]$, and the reverse Groucho effect, $E[s|q < s] - E[s]$, for good and bad firms holds more generally as the following proposition shows. For the proposition we define a firm as "good" if the density f is continuous and increasing (e.g., $\theta > 0$) and "bad" if the density f is continuous and decreasing (e.g., $\theta < 0$).

Proposition 4 *The size of the (reverse) Groucho effect is smaller (larger) for a good firm than a bad firm.*

Proof. See the Appendix. ■

The impact of these differences on equilibrium behavior can be seen in Figure 3 where the light lines represent the disclosure and non-disclosure equilibrium conditions (5) and (6) for firms of type θ when the labeling standard s is known to be $1/2$, while the dark lines illustrate the same conditions when the labeling standard is uncertain and is distributed uniformly on $[0, 1]$. In each case the upper line traces out the set of costs c for which the disclosure equilibrium condition is satisfied with equality, while the lower line illustrates the same for the non-disclosure equilibrium condition. Disclosure equilibria exist in the regions below the upper lines, while non-disclosure equilibria exist in the regions above the lower lines, so the figure illustrates the multiple equilibrium result for intermediate certification costs of Proposition 1. The figure also shows that uncertainty over the standard makes disclosure less likely in that, relative to the case of known $s = 1/2$, the equilibrium range for the disclosure equilibrium is always smaller and the equilibrium range for the non-disclosure equilibrium is larger for most parameter values.[19]

[19] Proposition 2 shows that the expected range of costs supporting the non-disclosure equilibrium is always larger for an uncertain standard than for a certain standard where the expectation is over all

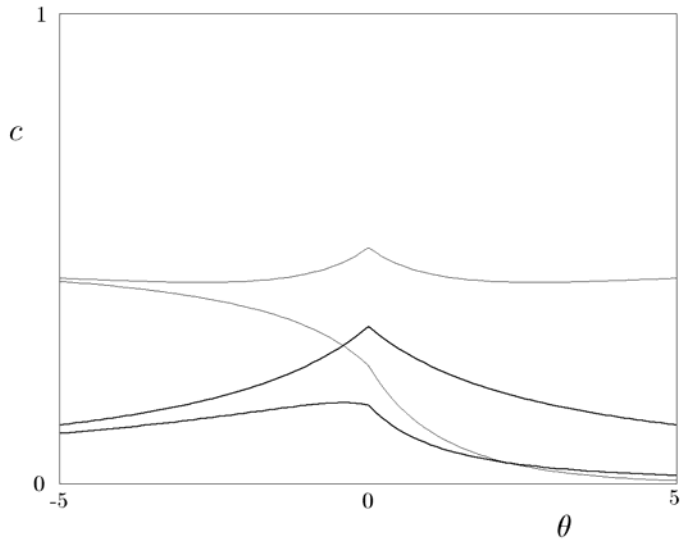

Figure 3: Disclosure and non-disclosure equilibrium regions

Considering the effect of firm quality on the disclosure equilibrium, note from Figure 3 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 $E[q|q \geq 1/2] - E[q|q < 1/2]$ is relatively insensitive to consumer expectations of whether the firm is good or bad.[20] 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.

possible realizations of s. Here we are showing the equilibrium range for the particular realized value of $s = 1/2$.

[20] For our example of uniform G, the incentive is $E[q|q \geq 1/2] - E[q|q < 1/2] = 3/4 - 1/4 = 1/2$ for $\theta = 0$. As θ goes to positive infinity the incentive goes to $E[q|q \geq 1/2] - E[q|q < 1/2] = 1 - 1/2 = 1/2$ and as θ goes to negative infinity the incentive goes to $1/2 - 0 = 1/2$.

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 $E[q]$ 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.[21] The good news is that labeling provides important information to consumers for these firms. The bad news is that firms that are 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.

3 Extensions

We now briefly consider three extensions of the base model.

3.1 External Groucho Effect

In the base model we considered "good" and "bad" firms but analyzed each in isolation. To gain some insight into the multi-firm case, we now consider the same model but with two different firms A and B facing the same standard. Since both firms face the same standard, disclosure or non-disclosure by either firm provides consumers with information about the standard that is also relevant for evaluating the other firm, so there is an information externality that effects the incentives for each firm to disclose. This "external Groucho effect" is in addition to any competitive effects that might arise. For instance, as we discuss next in Section 3.2, the two firms might be in the same market and each firm

[21] Xiao (2006) finds that consumers put the most emphasis on the accreditation status of new firms since their quality is more uncertain.

might have an incentive to make the other firm look bad so as to earn more market share.

We concentrate on the most interesting case where each firm can disclose if it wants to, i.e., $q \geq s$, and this is common knowledge between the firms, though not among consumers. The four possible pure strategy equilibria are a both-disclose equilibrium, a neither-disclose equilibrium, a good firm disclose equilibrium and a bad firm disclose equilibrium. Following the same notation for expectations introduced in the previous section, the both-disclose equilibrium exists if, for $i, j = A, B$, $i \neq j$,

$$E[q_i | q_i \geq s, q_j > s] - E[q_i | q_j < s, q_j > s] \geq c. \tag{12}$$

For example, consider the parameterized distribution introduced in (11) where the quality distributions of firms A and B are given by $f(q; a)$ and $f(q; b)$ respectively and G is uniform. Then, for $a = 1$ and $b = -1$, calculations show that the binding condition is for the bad firm, $c \leq .306$, which differs only moderately from the condition $c \leq 1/4$ found in Section 2.3 for the case without any information externality.

The neither-disclose equilibrium exists if, for $i = A, B$,

$$E[q_i | q_i \geq s] - E[q_i] < c. \tag{13}$$

Note that there is no information spillover in this case since if one firm deviates and disclose the other firm is still not expected to disclose so the updated standard does not affect their expected quality. Therefore the constraints are the same as when we considered the good and bad firms in isolation.

Finally, and most interestingly, a one-firm disclosure equilibrium with disclosure by firm A exists if

$$E[q_A | q_A \geq s] - E[q_A | q_A < s] \geq c \tag{14}$$

and

$$E[q_B | q_A \geq s, q_B \geq s] - E[q_B] < c. \tag{15}$$

For $a = 1$ and $b = -1$, the conditions reduce to $3/4 - 1/2 \geq c$ and $13/27 - 1/3 < c$, so an equilibrium with disclosure by only the good firm exists for $c \in [.148, .25]$. For $a = -1$ and $b = 1$, the conditions are $1/2 - 1/4 \geq c$ and $34/49 - 2/3 < c$, so an equilibrium with disclosure by only the bad firm exists for $c \in [.027, .25]$. If we compare these conditions with those from Section 2.3, the region in which it is an equilibrium for the good firm only to disclose shrinks, and the region in which it is an equilibrium for the bad firm only to disclose expands. That is, the information spillover reduces the incentive of the good firm to disclose relative to that of the bad firm. The spillover eliminates the Groucho effect advantage that the good firm enjoys without disclosure by the bad firm, and thereby

leaves the bad firm with an unambiguously stronger incentive to disclose so as to counteract consumers' low initial expectations.[22]

To understand these differences, note from (6) and (15) that the fact that the other firm disclosed weakens the incentive to deviate from non-disclosure, i.e., $E[q_B|q_B \geq s] > E[q_B|q_A \geq s, q_B \geq s]$. This is due to the external Groucho effect that the estimate of s is reduced by the other firm also meeting the standard, $E[s|q_B \geq s] > E[s|q_A \geq s, q_B \geq s]$. Recall that Proposition 4 shows that the Groucho effect is stronger for a bad firm than a good firm, $E[s|q_B \geq s] > E[s|q_A \geq s]$ if A is a bad firm, so the gap $E[s|q_B \geq s] - E[s|q_A \geq s, q_B \geq s]$ must be larger if A is a bad firm, i.e., the external Groucho effect is larger if a bad firm discloses. This in turn explains why the incentive for the good firm to deviate is weakened more when the bad firm discloses, i.e., why $E[q_B|q_B \geq s] - E[q_B|q_A \geq s, q_B \geq s]$ is larger if A is the bad firm as found in the parameterized example above.

3.2 Undermining the Competition

In the above analysis of the external Groucho effect we assume 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. However, 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.

To capture competitive effects, suppose that the payoff for each firm is their estimated quality minus any certification costs minus γ times the expected quality of the other firm for some $\gamma > 0$.[23] Of particular interest is how competitive effects influence the equilibrium where only one firm discloses. Conditions (14) and (15) for firm A to disclose and firm B to not disclose become

$$(E[q_A|q_A \geq s] - \gamma E[q_B|q_A \geq s]) - (E[q_A|q_A < s] - \gamma E[q_B|q_A < s]) \geq c \tag{16}$$

and

$$(E[q_B|q_A \geq s, q_B \geq s] - \gamma E[q_A|q_A \geq s, q_B \geq s]) - (E[q_B] - \gamma E[q_A|q_A \geq s]) < c. \tag{17}$$

Note that since firm B is not expected to disclose there is no effect of disclosure by A on $E[q_B]$, i.e., $E[q_B|q_A \geq s] = E[q_B|q_A < s]$, so (16) reduces to (14). However, since

[22] Note that even if a bad firm is more likely to pursue a disclosure strategy, it is less likely to meet the standard so in practice it need not be true that bad firms are observed to disclose more frequently. Here we are considering the case where both firms meet the standard.

[23] In contrast with this assumption that higher competitor quailty 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).

$E[q_A|q_A \geq s, q_B \geq s] < E[q_A|q_A \geq s]$ due to the external Groucho effect, the LHS of (17) is larger than that of (15) so firm B now has a greater incentive to break out of the nondisclosure equilibrium. Therefore the region in which it is an equilibrium for firm A to disclose and firm B to not disclose is reduced by the desire to undermine the competition via the external Groucho effect. Since the external Groucho effect is stronger when a bad firm discloses than when a good firm discloses, this reduction is larger if firm A is the good firm, i.e., competition disproportionately reduces the likelihood of an equilibrium where good firms disclose and bad firms do not.

3.3 Endogenous Quality

So far we have assumed that the quality of the firm is exogenous and that obtaining the label has a fixed certification cost c. Now consider the case where the firm chooses quality $q \in [0, 1]$ to maximize its profits where the certification cost c is an increasing function of the chosen quality. Clearly the firm will choose $q = s$ if it decides to get a label, and choose $q = 0$ otherwise. If there is no uncertainty over s then the problem is very simple – a firm will get a label if the gain in perceived quality is worth the cost, or $s - 0 \geq c(s)$.

Now suppose that consumers do not know the exact standard. If a firm chooses to get a label for some standard s, i.e., to set $q = s$, it will also do so for a lower standard since the cost is lower and consumers cannot tell the difference. Consumers will expect this behavior, so a partial disclosure equilibrium will have the form that for some $s^* \in (0, 1)$ a firm chooses to attain a given standard $s \leq s^*$ where s^* is such that

$$E[s|s \leq s^*] = c(s^*). \tag{18}$$

Note that since both $E[s|s \leq s^*]$ and $c(s^*)$ are increasing there is no assurance that such an equilibrium exists or is unique without further restrictions on G and c.

To see the role of uncertainty over the standard, consider the case where G is uniform. The equilibrium condition is then

$$\frac{\int_0^{s^*} s ds}{\int_0^{s^*} ds} = c(s^*) \tag{19}$$

or $s^*/2 = c(s^*)$. In contrast, for the certain standard case the equilibrium condition is just $s \geq c(s)$ for any given s so there is always more incentive to adopt the standard when it is certain. For instance, if $c = a + bq^2$ then the fixed cost a is like the certification cost in our base model and the parameter b captures the cost of improving quality. In this case for $a = 0$ and $b = 1$, for an uncertain standard the unique (partial) disclosure equilibrium is $s^* = 1/2$, while for any certain standard $s \in [0, 1]$ disclosure is always an equilibrium.

Regarding information externalities across firms, if firms have the same costs then the issue does not arise with endogenous quality since there is no extra information about the

standard from the fact that an additional firm discloses. But if there is heterogeneity in firm costs, e.g., different values of b in the cost function, then disclosure by a "bad firm" with high costs reduces the estimate of the standard more than disclosure by a "good firm" with low costs. Similar issues as in the two-firm models of Sections 3.1 and 3.2 therefore arise.

4 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 it, and a "reverse Groucho effect" in which non-attainment strengthens consumers' expectations of it. 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 "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 one firm reduces the estimated standard and thereby reduces the adoption incentive of the other firm. This effect is stronger for label adoption by a bad firm, so this effect can raise the likelihood of an asymmetric equilibrium in which a bad firm adopts the label and a good firm does not. Finally, examining the case in which firms need to invest in quality enhancements to display the label, we found that the same problem arises that investment and adoption by a bad firm can discourage investment and adoption by a good firm.

Clearly there is a role for industry groups, governments, and NGOs in addressing these issues. The simplest policy prescription, of course, is to invest in information campaigns aimed at decreasing the level of uncertainty surrounding the meaning of eco-labels. However, the existence of regions of multiple equilibria in which both disclosure and non-disclosure exist, 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 from adopting it.

5 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 $\int_0^1 E[q|q \geq s] dP(s) \geq \int_0^1 E[q|q \geq s] dG(s)$. Therefore, since $E[q|q \geq s]$ is increasing in s, the inequality holds if $P \succ_{FOSD} G$, i.e., $G(s) \geq P(s)$ for all s. This is equivalent to, for all

s,

$$\begin{aligned}
& \int_0^s \left(1 - \frac{F(x)}{\int_0^1 F(t)dG(t)}\right) dG(x) \geq 0 \\
\iff \quad & \int_0^s \left(\int_0^1 F(t)dG(t) - F(x)\right) dG(x) \geq 0 \\
\iff \quad & G(s)\int_0^1 F(t)dG(t) - \int_0^s F(t)dG(t) \geq 0 \\
\iff \quad & \int_0^1 F(t)dG(t) - \int_0^s \frac{F(t)}{G(s)}dG(t) \geq 0 \\
\iff \quad & E[F(t)] - E[F(t)|t < s] \geq 0 \qquad (23)
\end{aligned}$$

which holds for all s since F is increasing and the expectation is truncated from above.

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: When s is uncertain let $\underline{q} = E[q|q < s]$ and $\overline{q} = E[q|q \geq s]$, and when s is the realized value 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

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

Comparing, (25)–(26) equals

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

so the MSE is larger for the uncertain case. ■

Proof of Proposition 4: Let the distribution F with density f represent the case of a good firm ($f' > 0$) and let the distribution H with density h represent the case of a bad firm ($h' < 0$). For the Groucho effect, we want to show that the gap $E[s] - E[s|q \geq s]$ is larger for H than F, or

$$\int_0^1 s dG(s) - \frac{\int_0^1 \int_s^1 s dH(q) dG(s)}{\int_0^1 \int_s^1 dH(q) dG(s)} \geq \int_0^1 s dG(s) - \frac{\int_0^1 \int_s^1 s dF(q) dG(s)}{\int_0^1 \int_s^1 dF(q) dG(s)}, \qquad (28)$$

which holds if

$$\frac{\int_0^1 s(1-F(s)) dG(s)}{\int_0^1 (1-F(s)) dG(s)} \geq \frac{\int_0^1 s(1-H(s)) dG(s)}{\int_0^1 (1-H(s)) dG(s)}. \qquad (29)$$

Letting

$$P(s) = \frac{\int_0^s (1-F(t)) dG(t)}{\int_0^1 (1-F(t)) dG(t)} \qquad (30)$$

and

$$Q(s) = \frac{\int_0^s (1-H(t)) dG(t)}{\int_0^1 (1-H(t)) dG(t)} \qquad (31)$$

condition (29) holds if $P \succ_{FOSD} Q$, i.e., $Q(s) \geq P(s)$ for all s. Let $d(s) = Q(s) - P(s)$ and note that $d(0) = 0$ and $d(1) = 0$. Therefore $d(s) \geq 0$ for all s if (i) $d(s)$ approaches 0 from above as s falls to 0, (ii) $d(s)$ approaches 0 from above as s rises to 1 and, (iii) d is twice-differentiable and $d'(s) = 0$ at most twice, thereby precluding the possibility that $d(s)$ dips below zero after $s = 0$ and rises again before $s = 1$. Checking (i),

$$\begin{aligned}
d'(s) &= \frac{(1-H(s)g(s)}{\int_0^1 (1-H(t)) dG(t)} - \frac{(1-F(s))g(s)}{\int_0^1 (1-F(t)) dG(t)} \\
&= \frac{(1-H(s)) \int_0^1 f(t)G(t)dt - (1-F(s)) \int_0^1 h(t)G(t)dt}{\int_0^1 f(t)G(t)dt \int_0^1 h(t)G(t)dt} \\
&= \frac{\int_0^1 \left(f(t)\left(1-H(s)\right) - h(t)\left(1-F(s)\right)\right) G(t)dt}{\int_0^1 f(t)G(t)dt \int_0^1 h(t)G(t)dt} \qquad (32)
\end{aligned}$$

where in the next to last step we have used integration by parts to substitute $\int_0^1 f(t)G(t)dt$ for $\int_0^1 (1-F(t))dG(t)$ and $\int_0^1 h(t)G(t)dt$ for $\int_0^1 (1-H(t))dG(t)$. Therefore $d'(0)$ is positive if $\int_0^1 (f(t)-h(t))\,G(t)dt > 0$ which holds since $F \succ_{FOSD} H$ and G is increasing. Note from (32) that $d'(1) = 0$, so for (ii) we need to check if $d''(1) > 0$, or, from (32),

$$\int_0^1 (-f(t)h(1) + h(t)f(1))\,G(t)dt > 0. \tag{33}$$

Noting that $-f(t)h(1) + h(t)f(1)$ is decreasing in t by the assumptions $f' > 0$ and $h' < 0$, and that $-f(1)h(1) + h(1)f(1) = 0$, it must be that $-f(t)h(1) + h(t)f(1) \geq 0$ for all t so (33) holds. Now checking (iii), if $d'(s)$ is globally concave or convex then $d'(s) = 0$ at most twice. From (32),

$$d'''(s) = \frac{\int_0^1 (-f(t)h'(s) + h(t)f'(s))\,G(t)dt}{\int_0^1 f(t)G(t)dt \int_0^1 h(t)G(t)dt} > 0 \tag{34}$$

where the inequality follows by the assumptions $f' > 0$ and $h' < 0$. Therefore (28) holds.

Regarding the reverse Groucho effect, it is stronger for F than H if

$$\frac{\int_0^1 \int_0^s sdF(q)dG(s)}{\int_0^1 \int_0^s dF(q)dG(s)} - \int_0^1 sdG(s) \geq \frac{\int_0^1 \int_0^s sdH(q)dG(s)}{\int_0^1 \int_0^s dH(q)dG(s)} - \int_0^1 sdG(s) \tag{35}$$

which holds for $f' > 0$ and $h' < 0$ by the same logic as above. ■

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