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Information Disclosure Policies: When Do They Bring Environmental Improvements?

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Abstract There has been a growing interest among policy makers on the use of information disclosure policies for pollution control. This paper theoretically assesses the consequences of information disclosure policies and identifies the conditions under which such policies are likely to bring environmental improvements. Based on a dynamic game framework, the paper shows that both eco-labeling and more general full information disclosure policies may not always result in pollution reduction. Full information disclosure policies are likely to be effective if the product is not heavily polluting and if the minimum quality standard is set quite low. The paper also identifies the conditions under which all consumers are strictly better off with information disclosure policies.

Keywords information disclosure · voluntary approaches · eco-label · pollution · asymmetric information

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Introduction

Increasing numbers of national and regional surveys show that consumers are willing to pay a premium for environmentally friendly products (Cairncross, 1992; Cason & Gangadharan, 2002; Kirchhoff, 2000; Wasik, 1996). In the presence of environmentally aware consumers, firms have incentives to produce environmentally friendly products in order to differentiate their products from otherwise similar products and command a price premium (Arora & Gangopadhyay, 1995). However, the environmental attribute of the product is known to only producers and consumers cannot typically evaluate the environmental claims even in repeated use. Because of

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this information asymmetry, firms have found it very difficult to credibly communicate their environmental performances. Thus, for green consumerism to be effective, government has an important role in providing consumers with credible information on the pollution profile of the products they potentially purchase (Pearce, Markandya, & Barbier, 1989).

In response to increasing green consumerism, a number of government-sponsored policies have been implemented which alleviate asymmetric information through disclosure of credible information about environmental quality of the product or pollution profile of firms. Among such policies, a famous example would be eco-labeling; a label is awarded if the products satisfy certification thresholds. Other policies include hazard information disclosures which inform consumers of the environmental hazards that could be caused by particular products (e.g., US EPA's Automobile Pollution Rankings), green electricity pricing in which customers pay a premium for electricity produced from renewable sources (Lamarre, 1997), and various government-sponsored voluntary programs in which participants (or products) are publicly recognized. These policies are not limited to OECD countries. For example, Indonesia's Program for Pollution Control, Evaluation and Rating (PROPER) publicly discloses environmental performance of domestic factories in a five-rating scheme.

Because of widespread popularity, information disclosure policies are called "the third wave of environmental policies" after direct regulations and market-based instruments (Tietenberg & Wheeler, 2001). Governments envision that information disclosure works as a cost-effective policy tool to complement or substitute existing regulatory tools. With information disclosure policies, firms can credibly communicate the environmental quality of their products and may have incentives to voluntarily employ environmentally preferred production methods beyond legal requirement in order to attract environmentally conscious consumers.

There are concerns, however, about their effectiveness in mitigating environmental externalities. Critics argue that information disclosure policies in general may not ensure adequate environmental protection since polluters will not be forced to make abatement efforts beyond minimum legal requirements with information disclosure itself (Gibson, 1999). Mattoo and Singh (1994) and Swallow and Sedjo (2000) raised concerns about eco-labeling. Using graphical analyses, they showed eco-labeling cannot only be ineffective but also cause an adverse effect on the environment. However, there is a paucity of formal empirical and theoretical analyses on the effectiveness of information disclosure policies in achieving the stated objectives.

This paper theoretically assesses the effects of information disclosure policies on the environment. The model employs a dynamic game framework in order to allow firms and consumers to behave strategically in response to the introduction of information disclosure policies. Using this model, I first analyze the effect of information disclosure policies, such as eco-labeling, that reveal binary information of whether the quality of the product is above a certain threshold or not. I then analyze more general disclosure policies that reveal full information about the quality of the product. In addition, I compare information disclosure policies with traditional regulatory tools. The paper then identifies the conditions under which information disclosure policies are likely to bring improvements in environmental quality and social welfare, and make policy recommendations based on the findings.

The author recognizes that these results may depend on the specific model and the assumptions used in the analyses, and this paper does not intend to "prove" these claims. Rather, it is intended to caution optimistic views that information disclosure policies will always improve environmental quality and to illustrate the rationale for caution. The main purpose of the paper is to make policy recommendations by identifying when and under what conditions information disclosure policies are likely to bring desirable outcomes.

The Model

The basic features of the model are modified from the quality differentiation literature (see, for example, Arora & Gangopadhyay, 1995; Bansal & Gangopadhyay, 2003; Ronnen, 1991 and Shaked & Sutton, 1982). Suppose there are only two firms in the industry, H and L. Firms produce a differentiated product in terms of the impact on the environment. Production generates a per unit pollutant D. There is an end-of-pipe cleaning technology that can reduce per unit pollutant to $D - e_i$, where e_i measures the degree of cleaning, i=H, L. In what follows, I call e_i an environmental quality of a firm's product. Each firm is assumed to offer only one quality of the product. Without loss of generality, I denote the firm that produces a higher quality product as firm H and the firm with a lower quality product as firm L.[1] Let $\underline{e} > 0$ be the minimum environmental quality that firms' products are required to satisfy by the minimum quality standard. As is standard in the quality differentiation literature, firms are assumed to incur fixed costs that are dependent on environmental quality of the product and constant variable costs that are assumed to be zero for simplicity. Let firm H's and L's fixed cost functions be $C_i = C(e_i)$, i=H, L. The cost functions are assumed to be globally convex.

The formulation of the utility function follows that developed by Arora and Gangopadhyay (1995) and Bansal and Gangopadhyay (2003), both of which analyzed environmental policies in the presence of environmentally aware consumers. There is a continuum of consumers, indexed by θ. Each consumer demands at most one unit of the product and derives utility

$$U = \theta e_i - p_i - Z,$$

where p_i is the price of the product of firm i, and Z is the aggregate level of pollution. Consumers are willing to pay a higher price for products that have higher environmental quality. Marginal willingness to pay for environmental quality is reflected in θ, which is assumed to be uniformly distributed on $\left[0, \overline{\theta}\right]$. Therefore, although all consumers prefer products with higher quality, consumers differ in their intensities for environmental quality. An alternative interpretation is that the reciprocal of θ represents a marginal utility of income and therefore consumers have different intensities due to income differences. Specifically, a higher θ corresponds to a lower marginal utility of income and therefore a higher income (Tirole, 1988).

[1] As is standard in the quality differentiation literature, I do not address how the roles of high and low quality producing firms are determined.

Total pollution Z depends on environmental quality of the products (clean-up levels) and the quantity produced q_i. Therefore, $Z = (D - e_H)q_H + (D - e_L)q_L$. Consumers prefer a product with higher environmental quality, but consumers treat aggregate pollution Z as public bad. Therefore, as in Bansal and Gangopadhyay (2003), this model assumes that although Z does not affect individual actions, consumers perceive some utility from buying environmentally friendly products. This formulation can be rationalized by the existence of altruism or warm glow (Andreoni, 1989). In addition, numerous surveys have shown that consumers are willing to pay a premium for environmentally friendly products (Cairncross, 1992; Cason & Gangadharan, 2002; Kirchhoff, 2000; Wasik, 1996), and a laboratory experiment and an empirical study confirm that consumers' willingness to pay translates into actual purchasing behaviors even when consumers are not directly affected by the pollution (Bjorner, Hansen, & Russell, 2004; Cason & Gangadharan, 2002; Lamarre, 1997; Moscovitz, 1993).

I assume that an environmental quality of the product is a credence attribute, so that the quality above the minimum required level is only communicable with information disclosure policies such as eco-labeling.[2] Consumers know that producing higher quality products is costly. Thus, consumers' belief of the quality of the product is the minimum required level under the absence of any information disclosure policies. Firms play a two-stage game. In the first stage, firms choose environmental quality of the product e_i.[3] The choice of quality levels becomes observable before the second stage under information disclosure policies. In the second stage, firms simultaneously choose quantity (output level) and compete in a Cournot fashion. The solution concept I will employ is subgame perfect equilibrium. As usual, the solution can be found by backward induction.

The consumer indifferent between buying the high quality product and the low quality product has a taste parameter $\theta_{HL} = \frac{p_H - p_L}{e_H - e_L}$. The consumer indifferent between buying the low quality product and not buying at all has a taste parameter $\theta_L = \frac{p_L}{e_L}$. Note that all consumers with $\theta_{HL} \leq \theta \leq \overline{\theta}$ will buy the high quality product and all those with $\theta_L < \theta \leq \theta_{HL}$ will buy the low quality product. Consumers with $0 < \theta \leq \theta_L$ will not buy either product. The assumption of uncovered market is necessary because the inverse demand functions cannot be derived for each firm if the market is covered. See Motta (1993) for this assumption.

Consequences of Eco-labeling

Using the model described in the previous section, this section analyzes the effect on the environment of information disclosure policies that reveal binary information of the environmental quality of the product. To make the story more explicit, I consider

[2] Individual consumers are assumed not to have an incentive to acquire the information by themselves because their individual gains are so small in comparison to the costs of acquiring such information.

[3] In the case of eco-labeling analyzed in the next section, firms simultaneously decide whether or not to apply for the eco-label and environmental quality in the first stage. For simplicity, I assume that the application fee is sufficiently small and exclude it from the analysis.

only binary-type eco-labeling, but with small modifications the same analysis applies to other information disclosure policies that reveal binary information, such as whether firms participate in a voluntary program or not.

A binary-type eco-label is a proof of certification that the environmental quality of the product is at or above a certain threshold $\widetilde{e}$. Consumers know that producing higher quality products is costly and thus consumers' belief of the quality of the product is either the minimum required level if the product does not have a label or the threshold level if the product has a label. Therefore, if firms apply for the label and the product satisfies the threshold, firms can credibly communicate that the quality of the product is at the threshold $\widetilde{e}$ (but cannot communicate above this threshold).[4]

Equilibrium with Eco-labeling

The second-stage quantity choice game is solved as follows. Quantity demanded to the firms H's and L's products are given, respectively by

$$q_{\mathrm{H}} = \overline{\theta} - \theta_{\mathrm{HL}} = \overline{\theta} - \frac{p_{\mathrm{H}} - p_{\mathrm{L}}}{e_{\mathrm{H}} - e_{\mathrm{L}}} \tag{1}$$

$$q_{\mathrm{L}} = \theta_{\mathrm{HL}} - \theta_{\mathrm{L}} = \frac{p_{\mathrm{H}} - p_{\mathrm{L}}}{e_{\mathrm{H}} - e_{\mathrm{L}}} - \frac{p_{\mathrm{L}}}{e_{\mathrm{L}}}. \tag{1$'$}$$

In the second stage, firms maximize profits by choosing quantity, given the first stage quality choices of the products. In order to express profits as functions of only quantity and quality, prices are expressed from Eqs. 1 and 1′ as

$$p_{\mathrm{H}} = \overline{\theta} e_{\mathrm{H}} - q_{\mathrm{L}} e_{\mathrm{L}} - q_{\mathrm{H}} e_{\mathrm{H}}$$
$$p_{\mathrm{L}} = \left(\overline{\theta} - q_{\mathrm{H}} - q_{\mathrm{L}}\right) e_{\mathrm{L}}.$$

Substituting these, profits are expressed as

$$\pi_{\mathrm{H}} = p_{\mathrm{H}} q_{\mathrm{H}} - c(e_{\mathrm{H}}) = \left(\overline{\theta} e_{\mathrm{H}} - q_{\mathrm{L}} e_{\mathrm{L}}\right) q_{\mathrm{H}} - q_{\mathrm{H}}^2 e_{\mathrm{H}} - c(e_{\mathrm{H}}) \tag{2}$$

$$\pi_{\mathrm{L}} = p_{\mathrm{L}} q_{\mathrm{L}} - c(e_{\mathrm{H}}) = \left(\overline{\theta} e_{\mathrm{L}} - q_{\mathrm{H}} e_{\mathrm{L}}\right) q_{\mathrm{L}} - q_{\mathrm{L}}^2 e_{\mathrm{L}} - c(e_{\mathrm{L}}) \tag{2$'$}$$

Firms choose quantity in the second stage. The first-order conditions become

$$\frac{\partial \pi_{\mathrm{H}}}{\partial q_{\mathrm{H}}} = \overline{\theta} e_{\mathrm{H}} - q_{\mathrm{L}} e_{\mathrm{L}} - 2 q_{\mathrm{H}} e_{\mathrm{H}} = 0 \tag{3}$$

$$\frac{\partial \pi_{\mathrm{L}}}{\partial q_{\mathrm{L}}} = \left(\overline{\theta} - q_{\mathrm{H}} - 2 q_{\mathrm{L}}\right) e_{\mathrm{L}} = 0. \tag{3$'$}$$

It is easy to see that the second order sufficient conditions are satisfied.

[4] This paper does not analyze the case where the quality of the product certified by the label is not perfectly credible. See Kirchhoff (2000) for such analyses.

The first-stage quality choice game is solved as follows. Solving the first-order conditions (3) and (3′) for quantities yields

$$q_{\mathrm{H}} = \frac{(2e_{\mathrm{H}} - e_{\mathrm{L}})\overline{\theta}}{4e_{\mathrm{H}} - e_{\mathrm{L}}} \tag{4}$$

$$q_{\mathrm{L}} = \frac{e_{\mathrm{H}}\overline{\theta}}{4e_{\mathrm{H}} - e_{\mathrm{L}}}. \tag{4'}$$

By substituting these into Eqs. 2 and 2′, profit functions are represented as functions of only the first-stage choice of qualities as follows;

$$\pi_{\mathrm{H}} = \left[\frac{\overline{\theta}(2e_{\mathrm{H}} - e_{\mathrm{L}})}{4e_{\mathrm{H}} - e_{\mathrm{L}}}\right]^2 e_{\mathrm{H}} - c(e_{\mathrm{H}}) \tag{5}$$

$$\pi_{\mathrm{L}} = \left(\frac{\overline{\theta}e_{\mathrm{H}}}{4e_{\mathrm{H}} - e_{\mathrm{L}}}\right)^2 e_{\mathrm{L}} - c(e_{\mathrm{L}}). \tag{5'}$$

The choice of quality levels depends on whether firms choose to apply for the eco-label. Firms choose $e_i = \widetilde{e}$ if they apply for the label and $e_{\mathrm{i}} = \underline{e}$ if they do not apply. The following lemma states that the decision to apply for the label depends on the level of the threshold for certification.

Lemma 1 *Consider raising a threshold $\widetilde{e}$ incrementally from $\underline{e}$. Suppose firm H has an incentive to apply for the label if the threshold for certification is set sufficiently low and the per-unit pollution D is large enough so that the threshold can be raised until the case* (2) *below can happen. Then,* (1) *there is a quality level such that both firms apply for the label if the threshold is set below that quality level and only firm H applies if the threshold is set above that quality level, and* (2) *neither firm applies for the label if the threshold is set sufficiently high.*

Proof See Appendix.

Lemma 1 states that the number of firms with an eco-label changes as the threshold is raised. The following analysis will focus on the case where only firm H applies for the label. In actual programs, there are typically both certified and non-certified products. Thus, other two cases do not possess much practical relevance and will not be addressed in this paper.

If only firm H applies, firm H chooses $e_{\mathrm{H}} = \widetilde{e}$ and firm L chooses $e_{\mathrm{L}} = \underline{e}$. Substituting these into Eqs. 4 and 4′ yields the following equilibrium outcomes;

$$q_{\mathrm{H}} = \frac{(2\widetilde{e} - \underline{e})\overline{\theta}}{4\widetilde{e} - \underline{e}} \tag{6}$$

$$q_{\mathrm{L}} = \frac{\widetilde{e}\overline{\theta}}{4\widetilde{e} - \underline{e}} \tag{6'}$$

$$p_{\mathrm{H}} = \frac{(2\widetilde{e} - \underline{e})\widetilde{e}\overline{\theta}}{4\widetilde{e} - \underline{e}} \tag{7}$$

$$p_{\mathrm{L}} = \frac{\widetilde{e}\underline{e}\overline{\theta}}{4\widetilde{e} - \underline{e}} \tag{7'}$$

$$\theta_{\mathrm{HL}} = \frac{2\widetilde{e}\overline{\theta}}{4\widetilde{e} - \underline{e}} \tag{8}$$

$$\theta_{\mathrm{L}} = \frac{\widetilde{e}\overline{\theta}}{4\widetilde{e} - \underline{e}} \tag{8'}$$

$$\pi_{\mathrm{H}} = \left(\frac{(2\widetilde{e} - \underline{e})\overline{\theta}}{4\widetilde{e} - \underline{e}}\right)^2 \widetilde{e} - c(\widetilde{e}) \tag{9}$$

$$\pi_{\mathrm{L}} = \left(\frac{\widetilde{e}\overline{\theta}}{4\widetilde{e} - \underline{e}}\right)^2 \underline{e} - c(\underline{e}) \tag{9'}$$

$$Z = \frac{(D(3\widetilde{e} - \underline{e}) - 2\widetilde{e}^2)\overline{\theta}}{4\widetilde{e} - \underline{e}}. \tag{10}$$

Equilibrium without Eco-labeling

In order to analyze the effect of eco-labeling, the equilibrium without eco-labeling needs to be derived. Since firms cannot communicate quality levels above the minimum quality required by the minimum quality standard, both firms choose $e_{\mathrm{H}}= e_{\mathrm{L}}=\underline{e}$. Substituting these into Eqs. 4 and 4′ yields

$$q_{\mathrm{H}} = q_{\mathrm{L}} = \frac{\overline{\theta}}{3} \tag{11}$$

$$p_{\mathrm{H}} = p_{\mathrm{L}} = \frac{\underline{e}}{3}\overline{\theta} \tag{12}$$

$$\theta_{\mathrm{HL}} = \theta_{\mathrm{L}} = \frac{\overline{\theta}}{3} \tag{13}$$

$$\pi_{\mathrm{H}} = \pi_{\mathrm{L}} = \frac{\overline{\theta}^2}{9}\underline{e} - c(\underline{e}) \tag{14}$$

$$Z = \frac{2}{3}\overline{\theta}(D - \underline{e}). \tag{15}$$

Effect of Eco-labeling on the Environment

Using the results derived above, I now investigate the effect of eco-labeling on aggregate pollution level.

Proposition 1 *Aggregate pollution may increase with eco-labeling compared to the absence of eco-labeling. In particular, aggregate pollution will increase with eco-labeling if* $D - 6\widetilde{e} + 2\underline{e} > 0$.

Proof From Eqs. 10 and 15, a pollution change after introduction of eco-labeling is given by

$$\begin{aligned} &Z(\text{with eco-labeling}) - Z(\text{without eco-labeling}) \\ &= \frac{\overline{\theta}\left(\widetilde{e}-\underline{e}\right)}{3\left(4\widetilde{e}-\underline{e}\right)}\left[D - 6\widetilde{e} + 2\underline{e}\right] \end{aligned} \tag{16}$$

The overall sign of Eq. 16 depends on the magnitude of the terms in the bracket. Since D does not affect firm behaviors, for large values of D, the inequality $D - 6\widetilde{e} + 2\underline{e} > 0$ must hold (for example, $D = 6\widetilde{e}$). Thus, for D, $\underline{e}$, and $\widetilde{e}$ such that $D - 6\widetilde{e} + 2\underline{e} > 0$, aggregate pollution is larger with eco-labeling compared to the absence of eco-labeling. The converse is true if $D - 6\widetilde{e} + 2\underline{e} < 0$ (for example, $D = 4\widetilde{e}$ satisfies the inequality.) ■

The above proposition states that although the environmental quality of each product improves with eco-labeling, aggregate pollution may increase compared to the absence of eco-labeling. This possibility arises because total demand for the products increases due to differentiation. Note first that more consumers participate in the market (more consumers buy products) with eco-labeling compared to equilibrium without eco-labeling. This statement can be confirmed by noting from Eqs. 8′ and 13 that the consumer who is indifferent between buying and not buying the product has a smaller preference parameter θ under eco-labeling compared to under the absence of eco-labeling. An increase in demand is induced by the fact that eco-labeling provides firms with a means to differentiate their products. Because of differentiation, firm H can command a large price premium from highly environmentally-conscious consumers by producing a high quality product. In response, firm L optimally chooses a lower price (by choosing a quantity) in order to attract consumers with relatively weaker preferences for the environment. Note that the price of the product with the quality $\underline{e}$ is cheaper with eco-labeling than without eco-labeling. This can be easily confirmed by comparing the prices in Eqs. 7′ and 12. Because of this lower price, consumers with $\frac{\widetilde{e}\,\overline{\theta}}{4\widetilde{e}-\underline{e}} < \theta < \frac{\overline{\theta}}{3}$ now participate in the market and buy the product with quality $\underline{e}$ under eco-labeling, although these consumers do not buy the product without eco-labeling. Because of these new participants, the total demand for the products increases and this may increase aggregate pollution despite improvement in environmental quality at the individual product level.

Therefore, eco-labeling has two opposing impacts on the environment: (1) Aggregate pollution decreases because environmental quality at the product level improves. In particular, consumers with $\theta > \frac{2\widetilde{e}\,\overline{\theta}}{4\widetilde{e}-\underline{e}}$ (Eq. 8) buy products that have smaller negative impact on the environment; and (2) aggregate pollution increases because demand increases as consumers with $\frac{\widetilde{e}\,\overline{\theta}}{4\widetilde{e}-\underline{e}} < \theta < \frac{\overline{\theta}}{3}$ enter the market. In general, it is ambiguous which of these two forces has larger impact on the environment.

A natural question is, "When is aggregate pollution likely to decrease?" A necessary and sufficient condition for aggregate pollution to decrease after introduction of eco-labeling is given by

$$D + 2\underline{e} < 6\widetilde{e}.$$

This condition is more likely to hold when (1) zero-abatement per unit pollution D is small relative to $\widetilde{e}$ and $\underline{e}$, (2) the minimum quality standard $\underline{e}$ is set quite low, and (3) the eco-labeling threshold $\widetilde{e}$ is set sufficiently high. As a special case, eco-labeling always reduces aggregate pollution if the threshold is high such that $\widetilde{e} \geq \frac{D}{4}$. These conditions have an important implication for the choice of an appropriate level of threshold for certification, which has been a subject of recent debate. National eco-labeling programs often set thresholds high enough so that only a small fraction of the products in the market is awarded eco-label. On the other hand, some producers and industry associations set up their own label that does not require much more than the minimum standard in order to create an impression of being environmentally friendly. The above results indicate that the general guidelines used in national programs are appropriate but eco-labeling programs created by some producers may have an adverse effect on the environment particularly when the threshold is not high enough.

Consequences of Full Information Disclosure Policies

The previous section analyzed the consequences of binary-type eco-labeling and showed that the introduction of eco-labeling may have an adverse effect on the environment. Information disclosure policies that reveal binary information about the environmental quality of the product result in a partial resolution of asymmetric information. This section extends the previous analysis to policies that reveal full information about the environmental quality. For example, Pollutant Release and Transfer Registers (known as the Toxics Release Inventory in the United States) reveal firms' emissions of potentially harmful chemicals. Since emissions figures are continuous rather than binary, this type of policy results in full resolution of asymmetric information.[5] Labels or programs that award few categories for the quality of the product (e.g., 1–5 ratings) can reasonably be approximated as having continuous measures of the environmental quality. The following analysis shows that the result of the previous section is not specific to binary-type eco-labeling.

[5] In this example, consumers may take emissions as the quality of a firm's product. Again, this paper does not analyze the case where the disclosed information is not perfectly credible.

Effect of Full Information Disclosure Policies on the Environment

The second-stage quantity choice game is exactly the same as that under eco-labeling. For the first-stage quality choice, the first-order conditions are given by differentiating Eqs. 5 and 5′,

$$\frac{\overline{\theta}^2}{(4e_{\mathrm{H}} - e_{\mathrm{L}})^3}\left(16e_{\mathrm{H}}^3 - 12e_{\mathrm{H}}^2 e_{\mathrm{L}} + 4e_{\mathrm{H}} e^{2_{\mathrm{L}} - e_{\mathrm{L}}^3}\right) - c'(\mathrm{e}_{\mathrm{H}}) = 0 \tag{17}$$

$$\frac{\overline{\theta}^2}{(4e_{\mathrm{H}} - e_{\mathrm{L}})^3}\left(4e_{\mathrm{H}}^3 + e_{\mathrm{H}}^2 e_{\mathrm{L}}\right) - c'(e_{\mathrm{L}}) = 0. \tag{17′}$$

The equilibrium quality choice pair $(e_{\mathrm{H}}^*, e_{\mathrm{L}}^*)$ can be derived from these two equations.[6] Substituting the solution $(e_{\mathrm{H}}^*, e_{\mathrm{L}}^*)$ into Eqs. 4 and 4′ yields the following equilibrium outcomes;

$$q_{\mathrm{H}} = \frac{\left(2e_{\mathrm{H}}^* - e_{\mathrm{L}}^*\right)\overline{\theta}}{4e_{\mathrm{H}}^* - e_{\mathrm{L}}^*} \tag{18}$$

$$q_{\mathrm{L}} = \frac{e_{\mathrm{H}}^*\overline{\theta}}{4e_{\mathrm{H}}^* - e_{\mathrm{L}}^*} \tag{18′}$$

$$p_{\mathrm{H}} = \frac{\left(2e_{\mathrm{H}}^* - e_{\mathrm{L}}^*\right)e_{\mathrm{H}}^*\overline{\theta}}{4e_{\mathrm{H}}^* - e_{\mathrm{L}}^*} \tag{19}$$

$$p_{\mathrm{L}} = \frac{e_{\mathrm{H}}^* e_{\mathrm{L}}^*\overline{\theta}}{4e_{\mathrm{H}}^* - e_{\mathrm{L}}^*} \tag{19′}$$

$$\theta_{\mathrm{HL}} = \frac{2e_{\mathrm{H}}^*\overline{\theta}}{4e_{\mathrm{H}}^* - e_{\mathrm{L}}^*} \tag{20}$$

$$\theta_{\mathrm{L}} = \frac{e_{\mathrm{H}}^*\overline{\theta}}{4e_{\mathrm{H}}^* - e_{\mathrm{L}}^*} \tag{20′}$$

[6] In the case of corner solution, $e_{\mathrm{L}}^* = \underline{e}$. Otherwise, $e_{\mathrm{L}}^* > \underline{e}$.

$$\pi_{\mathrm{H}} = \left(\frac{\left(2e_{\mathrm{H}}^{*} - e_{\mathrm{L}}^{*}\right)\overline{\theta}}{4e_{\mathrm{H}}^{*} - e_{\mathrm{L}}^{*}} \right)^{2} e_{\mathrm{H}}^{*} - c\left(e_{\mathrm{H}}^{*}\right) \tag{21}$$

$$\pi_{\mathrm{L}} = \left(\frac{e_{\mathrm{H}}^{*}\overline{\theta}}{4e_{\mathrm{H}}^{*} - e_{\mathrm{L}}^{*}} \right)^{2} e_{\mathrm{L}}^{*} - c\left(e_{\mathrm{L}}^{*}\right) \tag{21'}$$

$$Z = \frac{D\left(3e_{\mathrm{H}}^{*} - e_{\mathrm{L}}^{*}\right) - 2\left(e_{\mathrm{H}}^{*}\right)^{2}}{4e_{\mathrm{H}}^{*} - e_{\mathrm{L}}^{*}}\overline{\theta} \tag{22}$$

The following proposition compares aggregate pollution with and without full information disclosure policies.

Proposition 2 *Aggregate pollution may increase with full information disclosure policies compared to without such policies. In particular, aggregate pollution will increase with full information disclosure policies if* $D + 2\underline{e} > 6e_{\mathrm{H}}^{*} + \frac{6e_{\mathrm{H}}^{*}\left(e_{\mathrm{L}}^{*} - \underline{e}\right)}{e_{\mathrm{H}}^{*} - e_{\mathrm{L}}^{*}}$.

Proof If the minimum quality standard is very high, both firms choose $e_{\mathrm{i}}^{*} = \underline{e}$. Under this case, the aggregate pollution under full information disclosure policies is the same as that under the absence of disclosure policies. For other cases, a change in the pollution level with information disclosure policies is given by

$$Z(\text{with full information disclosure policies}) - Z(\text{without information disclosure policies})$$

$$= \frac{\overline{\theta}\left(e_{\mathrm{H}}^{*} - e_{\mathrm{L}}^{*}\right)}{3\left(4e_{\mathrm{H}}^{*} - e_{\mathrm{L}}^{*}\right)}\left[D - 6e_{\mathrm{H}}^{*} + 2\underline{e} - \frac{6e_{\mathrm{H}}^{*}\left(e_{\mathrm{L}}^{*} - \underline{e}\right)}{e_{\mathrm{H}}^{*} - e_{\mathrm{L}}^{*}}\right] \tag{23}$$

The overall sign of Eq. 23 depends on the magnitude of the terms in the bracket. Since D does not affect firm behaviors, for sufficiently large values of D, the inequality $D - 6e_{\mathrm{H}}^{*} + 2\underline{e} - \frac{6e_{\mathrm{H}}^{*}\left(e_{\mathrm{L}}^{*} - \underline{e}\right)}{e_{\mathrm{H}}^{*} - e_{\mathrm{L}}^{*}} > 0$ must hold. Thus, for D, $\underline{e}$, and $\widetilde{e}$ such that $D + 2\underline{e} > 6e_{\mathrm{H}}^{*} + \frac{6e_{\mathrm{H}}^{*}\left(e_{\mathrm{L}}^{*} - \underline{e}\right)}{e_{\mathrm{H}}^{*} - e_{\mathrm{L}}^{*}}$, aggregate pollution is larger under full information disclosure policies compared to the absence of such policies. The converse is true if $D + 2\underline{e} < 6e_{\mathrm{H}}^{*} + \frac{6e_{\mathrm{H}}^{*}\left(e_{\mathrm{L}}^{*} - \underline{e}\right)}{e_{\mathrm{H}}^{*} - e_{\mathrm{L}}^{*}}$. (For example, $D = e_{\mathrm{H}}^{*}$ satisfies the inequality.) ■

As in the case of eco-labeling, aggregate pollution is potentially larger under full information disclosure policies compared to the absence of such policies. The mechanism through which this possibility arises is the same: Although the environmental quality of each product is higher under disclosure policies, aggregate pollution may become larger due to an increase in total demand. Under full information disclosure policies, firms can differentiate their products in terms of the impact on the environment. Because of differentiation, it is optimal for firm H to produce a high quality product and command a large price premium from highly environmentally-conscious consumers. At the same time, it is optimal for firm L to produce a lower quality product and choose a lower price (by choosing an output level) in order to attract consumers with relatively weaker preferences for the environment. Because of this firm L's strategy, more consumers participate in the market as can be confirmed by comparing Eqs. 13 and 20′ (the consumer who is indifferent between buying and not buying the product has a smaller preference parameter θ under full information disclosure policies). Specifically, consumers with $\frac{e_H^*\bar{\theta}}{4e_H^* - e_L^*} < \theta < \frac{\bar{\theta}}{3}$ now participate in the market and buy the product with quality e_L^*. Because of these new participants, the total demand for the products increases and this may increase aggregate pollution as well. Similar to eco-labeling, there are two opposing effects of information provision: (1) Aggregate pollution decreases because consumers with $\theta > \frac{2e_H^*\bar{\theta}}{4e_H^* - e_L^*}$ (Eq. 20) buy firm H's products and those with $\theta > \frac{e_H^*\bar{\theta}}{4e_H^* - e_L^*}$ (Eq. 20′) buy firm L's products, both of which have smaller negative impact on the environment; and (2) aggregate pollution increases because demand increases as consumers with $\frac{e_H^*\bar{\theta}}{4e_H^* - e_L^*} < \theta < \frac{\bar{\theta}}{3}$ enter the market. In general, it is ambiguous which of these two forces has larger impact on the environment.

A necessary and sufficient condition for aggregate pollution to decrease with full information disclosure policies is given by

$$D + 2\underline{e} < 6e_H^* + \frac{6e_H^*\left(e_L^* - \underline{e}\right)}{e_H^* - e_L^*}.$$

This condition is more likely to hold when (1) zero-abatement per unit pollution D is small relative to e_H^* and $\underline{e}$, (2) the minimum quality standard is set quite low, and (3) firm H voluntarily chooses sufficiently high quality. As a special case, aggregate pollution always decreases with full information disclosure policies if firm H's quality choice is sufficiently high such that $e_H^* \geq \frac{D}{4}$. The conditions (1) and (2) indicate that information disclosure policies are likely to be effective if the product is not heavily polluting and the existing regulation (the minimum quality standard) is not stringent. Then encouraging firms to voluntarily reduce pollution through information disclosure is likely to bring environmental improvements.

Effect of Full Information Disclosure Policies on Social Welfare

The analyses thus far have been confined to the effect of disclosure policies on the environment, but policy makers may also be interested in the effect on social welfare. This subsection illustrates that social welfare is significantly affected by aggregate pollution level and therefore there is a rationale to focus on the effect on the environment. Social welfare (SW) can be defined as the sum of profits and consumer welfare;[7]

$$SW = \pi_H + \pi_L + \int_0^{\bar{\theta}} (\theta e_i - p_i - Z)d\theta$$

[7] Producer's surplus in this model is equivalent to profits.

In general, it is ambiguous whether or not social welfare is higher under information disclosure policies compared to the absence of such policies. This ambiguity can be explained by the theory of the second best, which states that correcting a market imperfection may not improve social welfare in the presence of other distortions (Lipsey & Lancaster, 1956). In this case, correcting asymmetric information may not always improve social welfare in the presence of environmental externalities.

Even though the impact on social welfare is ambiguous, social welfare is largely affected by the environmental quality through consumer welfare because consumers are directly affected by aggregate pollution as Z enters each consumer's utility. The following proposition states that information disclosure policies may benefit all consumers unambiguously if aggregate pollution decreases. Therefore, there is a higher possibility that social welfare increases if aggregate pollution decreases.

Proposition 3 *Suppose aggregate pollution under full information disclosure policies is smaller than that without such policies. If the minimum quality standard is sufficiently high such that* $e_L^* = \underline{e}$*, all consumers are strictly better off under full information disclosure policies compared to the absence of such policies.*

Proof Consumers are divided into four segments; (1) those who do not buy the product both under full information disclosure policies and under the absence of disclosure policies; (2) those who buy the product only under disclosure policies; (3) those who buy firm L's product under disclosure policies; and (4) those who buy firm H's product under disclosure policies.

(1) Those who do not buy the product are affected only through changes in aggregate pollution level. Thus, these consumers are strictly better off under disclosure policies as long as aggregate pollution is smaller than that without disclosure policies.
(2) Consumers with $\frac{e_H^*\bar{\theta}}{4e_H^* - e_L^*} < \theta < \frac{\bar{\theta}}{3}$ do not buy the product under the absence of disclosure policies. These consumers buy firm L's product under disclosure policies although they could have chosen not to buy the product as under the absence of disclosure policies. Thus, these consumers are strictly better off under disclosure policies as long as aggregate pollution is smaller compared to the absence of disclosure policies.
(3) If $e_L^* = \underline{e}$, the price of the product with quality $\underline{e}$ becomes lower under full information disclosure policies compared to under the absence of disclosure policies (Eqs. 12 and 19′). These consumers buy the product with quality $\underline{e}$ both under disclosure policies and under the absence of disclosure policies, but the price is lower under disclosure policies. Thus, they are strictly better off under disclosure policies as long as aggregate pollution is smaller.
(4) Those who buy firm H's product under disclosure policies could have chosen the product with quality $\underline{e}$ that has now lower price but did not. Thus, these consumers are strictly better off under disclosure policies as long as aggregate pollution is smaller compared to the absence of disclosure policies. ■

Note that the claim of this proposition is likely to hold even when $e_L^* > \underline{e}$ as long as e_L^* is close to $\underline{e}$. Under full information disclosure policies, there are two sources of benefit to consumers. First, since firms can differentiate their products in terms of the impact on the environment, higher-quality products will be produced. Thus, highly environmentally-conscious consumers are better off from availability of high quality products. Second, other consumers are better off from a decrease in the price of the product with lower quality. Because of competition, the price of the product with a quality $\underline{e}$, which was the only available quality under the absence of disclosure policies, becomes lower under disclosure policies. Therefore, consumers who do not have strong preferences for environmental quality are better off from being able to buy the lower quality product at a lower price. Since consumers are also affected by aggregate pollution, it is generally ambiguous whether or not consumers are better off under disclosure policies. However, as long as aggregate pollution does not increase, all consumers are strictly better off under disclosure policies. Therefore, there is a higher possibility that credible information provision about environmental quality increases social welfare through the impact on consumer welfare if aggregate pollution decreases.[8]

A Note on Government Intervention

Although the presence of environmentally aware consumers encourages firms to voluntarily choose quality levels above the minimum quality standard, the choice of quality levels characterized by Eqs. 17 and 17′ may not be socially optimal. In this case, a uniform or discriminatory ad valorem subsidy induces both firms to choose higher qualities (see Bansal & Gangopadhyay, 2003, for details). Let t_i be an ad valorem subsidy on firm i. A uniform subsidy is characterized by a special case when $t_H = t_L$. The first-stage profits are modified to

$$\pi_H = (1 + t_H)\left[\frac{\bar{\theta}(2e_H - e_L)}{4e_H - e_L}\right]^2 e_H - c(e_H)$$

$$\pi_L = (1 + t_L)\left(\frac{\bar{\theta}e_H}{4e_H - e_L}\right)^2 e_L - c(e_L).$$

With government intervention, a new equilibrium (e_H^{**}, e_L^{**}) will be reached. However, all the previous qualitative results hold even if (e_H^{*}, e_L^{*}) is replaced by (e_H^{**}, e_L^{**}). This happens because improving the quality of individual product by subsidy may not necessarily reduce aggregate pollution by the same reasoning – total demand may increase. Thus, even when quality choice levels are appropriately controlled by government interventions, there is a possibility that aggregate pollution becomes larger under full information disclosure policies compared to the absence of such policies.

[8] The effect of information disclosure on producer's surplus is ambiguous because it is likely that firm H is better off but firm L is worse off. For example, if $e_L^{*} = \underline{e}$, it is easy to show that firm H's profit is larger but firm L's profit is smaller under full information disclosure policies compared to under the absence of disclosure policies.

Comparison with Minimum Quality Standards

Thus far, the analyses have focused on aggregate pollution with and without information disclosure policies. As stated in introduction, governments envision that disclosure policies can complement or substitute traditional regulatory tools. Thus, it is important to compare the effectiveness of information disclosure policies with that of traditional regulatory tools in reducing aggregate pollution. This subsection briefly investigates this issue.

Proposition 4 *Aggregate pollution unambiguously decreases as the minimum quality standard is raised under the absence of information disclosure policies.*

Proof From Eq. 15,

$$\frac{\partial Z}{\partial \underline{e}} = -\frac{2}{3}\overline{\theta} < 0. \qquad \blacksquare$$

While information disclosure policies have an ambiguous effect on the environment as shown above, raising a minimum quality standard unambiguously reduces aggregate pollution. This result arises because demand does not increase while quality of each product improves. Since firms can credibly communicate only the minimum quality, quality competition is limited and thus the price of the product with the minimum quality does not become lower as the minimum quality standard is raised. Therefore, participants in the market do not increase. Policy implications of this result will be discussed in the next section.

Policy Implications and Conclusion

This paper investigated the consequences of information disclosure policies. I showed that aggregate pollution may become larger under information disclosure policies (both under binary-type eco-labeling and under full information disclosure policies) compared to under the absence of any information disclosure policies. This possibility arises because the total demand for the product increases although environmental quality of each product improves. However, if a firm voluntarily chooses sufficiently high quality or if the minimum quality standard is set quite low, aggregate pollution is likely to decrease with full information disclosure policies.

The author would like to stress that this paper is not intended to provide unsupportive evidence of information disclosure policies. The author is aware that the above results may depend on the specific model and the assumptions used in the analyses. Rather, this paper is intended to caution optimistic views that information disclosure policies will always improve environmental quality and to illustrate the rationale for caution. To conclude, there are two policy implications based on the results.

First, with increasing popularity of information disclosure policies, governments may envision using these policies to substitute or complement existing regulations. However, policy makers need to be aware that disclosure policies may not result in pollution reduction. The comparison with minimum quality standards shows that minimum quality standards are more effective in reducing aggregate pollution in a sense that they reduce aggregate pollution unambiguously. Therefore, if reducing a particular type of pollution is an urgent issue (e.g., the pollutant is highly toxic), minimum quality standards seem a desirable choice. On the other hand, information disclosure policies are likely to be effective if the product is not heavily polluting and if for some political or economic reasons the minimum quality standard is set quite low and it is difficult to raise the standard.[9] Then encouraging firms to voluntarily reduce pollution through information disclosure is likely to bring environmental improvements.

Second, disclosure policies should be justified on ethical grounds such as community right to know, not on their effectiveness in reducing pollution. Those who are exposed to environmental risks are regarded as having the right to know about the risks, as established by such law as Emergency Planning and Community Right-to-Know Act of 1986 in the United States (Tietenberg & Wheeler, 2001). Thus, although information disclosure policies may not always result in pollution reduction, this possibility should not be used against promoting information disclosure policies.

Information disclosure policies are likely to improve environmental quality at the individual product level, but empirical studies on the effect on aggregate pollution are scant. Clearly, more empirical research is needed to identify whether the regulatory conditions favor the use of information disclosure policies or traditional command and control policies such as minimum quality standards.

Appendix

Proof of Lemma 1

Consider how firm L's profit changes when the threshold $\widetilde{e}$ is incrementally increased from $\underline{e}$. By assumption, firm H applies for the eco-label when $\widetilde{e}$ is set sufficiently low and therefore $e_{\mathrm{H}} = \widetilde{e}$. I compare firm L's profit when it chooses to apply for the label and when it chooses not to apply.

If L chooses to apply, the profit is given by (substituting $e_{\mathrm{L}} = \widetilde{e}$ into Eq. 5′),

$$\pi_{\mathrm{L}} = \frac{\overline{\theta}^2}{9}\widetilde{e} - c(\widetilde{e})$$

If the threshold is increased, the change in the profit is characterized by

$$\frac{\partial \pi_{\mathrm{L}}}{\partial \widetilde{e}} = \frac{\overline{\theta}^2}{9} - c'(\widetilde{e})$$

$$\frac{\partial^2 \pi_{\mathrm{L}}}{\partial \widetilde{e}^2} = -c''(\widetilde{e}) < 0.$$

The first derivative of the profit function is positive as long as the slope of the cost function is not too steep. As a special case, firm L may never choose to apply

[9] For example, if there are hundreds of potentially harmful (but not highly toxic) chemicals, the monitoring and enforcement costs may be prohibitively costly with minimum quality standards.

for the label if the minimum quality standard is set high so that the slope of the cost function at the minimum standard is sufficiently steep. Otherwise, firm L has an incentive to apply for the label and the profit increases initially as the threshold is increased from the minimum required level $\underline{e}$. However, with a convex cost function, the profit ultimately decreases at an increasing rate as the second derivative shows.

If L chooses not to apply for the label, from Eq. 5′,

$$\frac{\partial \pi_{\mathrm{L}}}{\partial \tilde{e}} = \frac{-2\tilde{e}\underline{e}^2\overline{\theta}^2}{(4\tilde{e}-\underline{e})^3} < 0$$

$$\frac{\partial^2 \pi_{\mathrm{L}}}{\partial \tilde{e}^2} = \frac{(16\tilde{e}+2\underline{e})\underline{e}^2\overline{\theta}^2}{(4\tilde{e}-\underline{e})^4} > 0$$

Thus, the profit decreases but at a decreasing rate. Therefore, if $\tilde{e}$ is sufficiently high, L's profit without applying for the eco-label becomes larger than that with the label. Therefore, there is a quality level such that firm L applies for the label if the threshold is set below that quality level and does not apply if the threshold is set above that quality level.

If firm L switches from applying for the label to not applying for the label, firm H's profit increases and therefore firm H continues to apply for the label even if firm L chooses not to apply. This can be seen as follows. Suppose when the threshold is set at $\underline{e}$, firm L is indifferent between applying and not applying for the label. Firm H's profit when firm L applies for the label is given by

$$\pi_{\mathrm{H}} = \frac{\overline{\theta}^2}{9}\tilde{e} - c(\tilde{e}).$$

and the profit when firm L does not apply is given by Eq. 9. The difference between Eq. 9 and this equation is given by

$$\left[\frac{\tilde{e}+(\tilde{e}-\underline{e})}{3\tilde{e}+(\tilde{e}-\underline{e})}\right]^2\overline{\theta}^2\tilde{e} - \frac{\overline{\theta}^2}{9}\tilde{e},$$

and this is positive since $\left[\frac{\tilde{e}+(\tilde{e}-\underline{e})}{3\tilde{e}+(\tilde{e}-\underline{e})}\right]^2 > \frac{1}{9}$. Thus, firm H continues to apply for the eco-label even if firm L switches from applying to not applying for the label. Therefore, there is a quality level such that both firms apply for the label if the threshold is set below that quality level and only firm H applies if the threshold is set above that quality level.

To see that firm H does not apply for the label if the threshold is set sufficiently high, note that firm H's profit given by Eq. 9 is also expressed as

$$\pi_{\mathrm{H}} = \frac{\overline{\theta}^2}{4}\tilde{e} - \frac{\tilde{e}\underline{e}\left(2\tilde{e}-\frac{3}{4}\underline{e}\right)\overline{\theta}^2}{(4\tilde{e}-\underline{e})^2} - c(\tilde{e}).$$

The first term is positive but the second and the third terms are negative. Since cost function is convex, the third term dominates the first term as $\widetilde{e}$ increases. Thus, if $\widetilde{e}$ is sufficiently high, the profit becomes lower than that without applying for the label and therefore firm H chooses not to apply for the label. ■

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