Disclosure of environmental information and investments of firms

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27. March 2014

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* I am grateful for the financial support by Grant-in-Aid for Scientific Research.

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Abstract

In recent years, voluntary approaches are expected to function as new environmental protection tools. This article analyzes whether environmental information of firms should be mandatorily disclosed or disclosed voluntarily, where consumers consider the environmental burdens of firms when buying their goods. If a mandatory policy is implemented, every firm in the market will be required to disclose their environmental burdens. On the contrary, only firms that want to disclose their environmental burdens will share their environmental information if a voluntary approach is implemented. This article particularly demonstrates the effects of the disclosure rule (mandatory or voluntary) on investment to reduce environmental burdens. The model has two types of firms, clean and dirty ones. Firms that investigate their environmental burdens and turn out to be dirty can invest to reduce them and become clean before they disclose their environmental information. The main conclusions in this article are as follows. (1) Mandatory disclosure policies may induce firms to invest more than a voluntary approach. (2) Firms may have lower expected profit under the mandatory rule than the voluntary approach. (3) Under full information disclosure policy, the environmental burden is smaller than that of other policies.

JEL: D82, L15, Q55

Keywords: Environmental information disclosure, Investment, Asymmetric information

1. Introduction

This article analyzes whether environmental information of firms should be mandatorily disclosed or disclosed voluntarily, where consumers are conscious of the environmental burdens of firms. Particularly, the article analyzes the effects of the information disclosure rule on investment by firms for the reduction of environmental burdens. The reason for including the effects of investment is because this article assumes the following situation. If the disclosure of environmental information is obligated by the government, firms must examine their environmental burdens. From the examination, a firm understands that its environmental burden is high and consumers take this into account when buying their goods. In this situation, firms may have incentive to invest in the reduction of their environmental burden before their environmental information is disclosed to consumers, resulting in the possibility of increasing their expected profit. On the other hand, if consumers are conscious of the environmental burden of firms, firms have the incentive to improve their environmental burden voluntarily. In consequence, there may not be a need for the government to impose regulations if firms address their environmental issues voluntarily. Therefore, this article compares the effects of voluntary and mandatory disclosures of environmental information in the situation that investment for the reduction of

environmental burden is possible.

Mandatory environmental information disclosure attracts attention as a policy tool which substitutes the existing policy tools such as emission standards and environmental tax. There are many studies written about the effects of mandatory environmental information disclosure, such as Klenindorfer and Orts (1998), Tietenberg (1998), Tietenberg and Wheeler (2001), and Cohen and Santhkumar (2007). The information disclosure policy is considered to reduce the regulator's costs, and promote flexible and self-regulated environmental management (Khanna et al., 1998). In addition, there are problems of asymmetric information between consumers and firms. In many cases, consumers can not check exactly what kinds of toxic substances are emitted from a firm's production process. A mandatory environmental information disclosure policy is expected to solve this asymmetric information. In fact, mandatory environmental information disclosure is introduced many countries, and a well known mandatory disclosure program is the Toxic Release Inventory (TRI) program in the United States (U.S.). Other countries such as Canada, South Korea, Australia, Japan, Mexico, and the European Union (E.U.) also institute similar programs (Cohen and Santhakumar, 2007).

On the other hand, recently many firms have incentive to disclose environmental

information voluntarily.[1] In fact, publication of environmental reports and sales of goods with eco labels are methods of voluntary environmental information disclosure by firms. If firms voluntarily disclose their environmental information, the government will save financially because it will not need to obligate firms to disclose their environmental burdens. Voluntary environmental disclosure, however, gives firms room for strategic behavior. Under voluntary disclosure, firms might disclose only selective information. Sinclair-Desgagné and Golan (2003) analyze the strategic behavior of environmental information disclosure.

Previous studies about the effects of mandatory and voluntary disclosure policies are Shavell (1994), Segerson (1999), and Polinsky and Shavell (2006). They analyze whether firms' private information should be mandatorily disclosed or disclosed voluntarily when firms need to pay costs to acquire their information. In addition to existing studies, this article includes the effects of the disclosure policy on investment to improve environmental burdens. There are many studies about firms' environmental quality improvement such as Arora and Gangopadhyay (1995), Innes and Bial (2002), and Eriksson (2004). These studies mainly analyze the strategic behavior between firms in the duopoly market, and do not include the asymmetric information between firms and consumers.

Furthermore, this article addresses two types of mandatory rules. In the previous studies by Shavell (1994) and Polinsky and Shavell (2006), the mandatory disclosure rule is the following. Firms that acquire their private information[2] must disclose the information. In their analysis, therefore, firms are not obligated to acquire information, and if a firm does not, the information remains disclosed. In this article, we also investigate the mandatory disclosure rule which means that all firms in the market should acquire and disclose their information.

The remainder of this paper is organized as follows. Section 2 presents the model. Section 3 compares the mandatory and voluntary disclosure policies from the view of social welfare. Section 4 is the conclusion and discusses the direction of future research.

2. The Model

This article investigates the disclosure of environmental information, with the model based on Shavell (1994) and Polinsky and Shavell (2006). In addition to those existing studies, we analyze the situation in which firms can invest to improve their environmental burden before they disclose their environmental burden information.

We assume a monopoly market. In the production process, a monopoly firm generates a per unit environmental burden e, and the unit cost of producing the good is

$c, c \geq 0$. There are 2 types of environmental burden, $\{e_g, e_b\}$ and $e_b > e_g > 0$. We call the firm that generates a low environmental burden e_g as "green", and one that generates a high environmental burden e_b as "brown."

Consumers are interested in the environmental burden of a firm and are assumed to buy at most one unit of goods in this market. The utility of consumers is described as $u = v - \theta e - p$. p denotes the price of the good. $v, (v > 0)$ is the value of this good for consumers and is identical for all consumers. However, v does not include the environmental attribute. θ is the marginal disutility of environmental burden of each consumer and is assumed to be distributed continuously with support $[0, \overline{\theta}]$. Let $h(\theta)$ be the probability density over θ and $H(\theta)$ be the cumulative distribution of θ. This utility setting means that consumers can increase their utility by consuming a lower environmental burden good. On the other hand, consumers do not consider the environmental burdens of the entire society.[3] Consumers who obtain positive utility, $v - \theta e - p \geq 0$, would buy the goods. Therefore, demand is given by $H(\frac{v-p}{e})$ and $1 - H(\frac{v-p}{e})$ is consumers who do not buy the good in this market. In this article, a green firm can obtain a higher profit than a brown one that is $\pi(e_g) > \pi(e_b)$ since the more the environmental burden is reduced, the larger the demand gets.

We assume that the monopoly firm does not initially know its type of

environmental burden. The firm can acquire the its environmental burden information with cost $k, (0 \le k \le \bar{k})$. Let $f(k)$ be the probability density over $k, (f(k) > 0)$. We assume that the monopoly firm knows its acquisition cost k, although consumers do not know k of the firm and only knows the distribution f over k. Therefore, there exists an asymmetry of information between firms and consumers for the acquisition cost.

We assume that a firm is green with the probability α and brown with the probability $1-\alpha, (0 < \alpha < 1)$, and this probability is common knowledge between firms and consumers. In the case that information disclosure is not carried out at all, consumers infer the environmental burden of the firm as $e_\mu = \alpha e_g + (1-\alpha) e_b$ and firm obtains the profit $e \in \{e_g, e_b\}$ *and* $0 < e_g < e_b$.

A firm that acquires its environmental burden information can only disclose the environmental information to consumers.[4] As discussed above, the more a firm reduces its environmental burden, the more a firm increases its expected profit $\pi(e)$.

Following the above setting, we compare the three policies, voluntary disclosure and two types of mandatory disclosure of environmental information. The sequence of actions is as follows.

[Stage 1] First, each firm decides whether to acquire its environmental burden

information with cost $k(>0)$. Consumers do not know whether or not a monopoly firm acquires its environmental information.

[Stage 2] A firm that acquires its environmental information can only disclose its environmental burden to consumers.[5] If a firm acquires its environmental information, it could choose one among the following actions, {(i) disclose the environmental burden information, (ii) do not disclose the information (keep silent), and (iii) invest to improve the environmental burden and after that disclose its environmental information}.

To improve its environmental burden, a firm has to incur the cost of investment $t,(0<t)$. We postulate that the size of t is common knowledge. A firm could reduce the environmental burden from e_b to e_g by investment t. As a consequence, the profit of the firm is determined. If a firm does not acquire its environmental information, it can not disclose the information. The firm only keeps silent and obtains profit accordingly.

Figures 1 ,2 and 3 depict the decision tree of each case.

[Figure 1 here]

[Figure 2 here]

[Figure 3 here]

Case 1: Voluntary Disclosure

If the government does not obligate environmental disclosure, the decision making of a monopoly firm is the following. First, we consider the decision making at point S in Figure 1. The expected profit of the firm when it acquires its environmental information is

$$E\pi^{v} = \alpha\pi(e_g) + (1-\alpha)\max\{\pi(e_g) - t, \pi(e_\lambda)\}. \quad (1)$$

Because of the asymmetry of information, consumers can not distinguish the difference between a firm acquiring its environmental information and keeping silent, and a firm that did not acquire its environmental information from the beginning. In this case, consumers predict the silent firms' environmental burden as e_λ and the following inequality holds $e_\mu < e_\lambda < e_b$ (see Appendix 1).

The condition that the firm invests to improve its environmental burden is

$$\pi(e_g) - t \geq \pi(e_\lambda) \quad (2)$$

and the expected profit in disclosing its environmental information, $E\pi^{vI}$, is given by

$$E\pi^{vI} = \pi(e_g) - t(1-\alpha). \quad (3)$$

The condition that the firm does not invest is

$$\pi(e_g) - t < \pi(e_\lambda). \quad (4)$$

The expected profit $E\pi^{vN}$ is, therefore,

$$E\pi^{vN} = \alpha\pi(e_g) + (1-\alpha)\pi(e_\lambda). \quad (5)$$

On the other hand, if the firm does not acquire its environmental information, it could earn the profit $\pi(e_\lambda)$.

Next, considering the decision making of stage1, the condition of environmental information acquired is

$$E\pi^{v} - k \geq \pi(e_\lambda). \quad (6)$$

Then, if (2) is satisfied, the condition of environmental information acquired is $\pi(e_g) - t(1-\alpha) - \pi(e_\lambda) \geq k$. If (4) is satisfied, the condition of environmental information acquired is $\alpha\{\pi(e_g) - \pi(e_\lambda)\} \geq k$.

Proposition 1. Suppose that information disclosure is voluntary. Then

(i) If (6) is not satisfied, a monopoly firm does not acquire its environmental information and obtain profit $\pi(e_\lambda)$.

(ii) If (2) and (6) are satisfied, a monopoly firm acquires its environmental information and invests t. It then obtains $E\pi^{vI}$. In this case, environmental information is disclosed with the probability $\int_0^{E\pi^{vI}-\pi(e_\lambda)} f(k)dk$ and the disclosed environmental burden is always e_g. In addition, because of the asymmetry of information, the expected profit of a brown firm is not $\pi(e_b)$ but $\pi(e_\lambda)$ in choosing

non-disclosure.

(iii) If (4) and (6) are satisfied, a monopoly firm acquires its environmental information and does not invest. It then obtains $E\pi^{vN}$. In this case, environmental information is disclosed with the probability $\alpha\int_0^{E\pi^{vN}-\pi(e_\lambda)} f(k)dk$ and the disclosed environmental burden is always e_g, and a non-disclosed firm obtains the expected profit $\pi(e_\lambda)$ due to the asymmetric information.

Case 2: Mandatory Disclosure Policy; Partial Mandatory Disclosure

Consider the case that the government obligates the disclosure of environmental information to a firm that has acquired its information. The decision making of a monopoly firm is the following. First, we consider the decision making at point S in Figure 2. The expected profit of the firm when it acquires its environmental information is

$$E\pi^{m} = \alpha\pi(e_g) + (1-\alpha)\max\{\pi(e_g) - t, \pi(e_b)\} \tag{7}$$

In this case, if a firm acquires its environmental information, it must disclose the information. Therefore, if a firm does not make an investment, the environmental burden is disclosed as e_g.

The condition that the firm invests to improve its environmental burden is

$$\pi(e_g) - t \geq \pi(e_b), \tag{8}$$

and the expected profit of disclosing its environmental information, $E\pi^{mI}$, is given by

$$E\pi^{mI} = \pi(e_g) - t(1-\alpha). \tag{9}$$

This value is equal to $E\pi^{vI}$. The condition that the firm does not invest is

$$\pi(e_g) - t < \pi(e_b) \tag{10}$$

Then the expected profit $E\pi^{mN}$ is, therefore,

$$E\pi^{mN} = \alpha\pi(e_g) + (1-\alpha)\pi(e_b). \tag{11}$$

$E\pi^{mN}$ equals to $\pi(e_\mu)$. On the other hand, if the firm does not acquire its environmental information, it can obtain the profit $\pi(e_\mu)$.

Considering the decision making of stage 1, the condition of environmental information acquired is

$$E\pi^{m} - k \geq \pi(e_\mu). \tag{12}$$

Then, if (8) is satisfied, the condition of environmental information acquired is $\pi(e_g) - t(1-\alpha) - \pi(e_\mu) \geq k$. By assumption $\pi(e_\mu) > \pi(e_\lambda)$, the left hand side is smaller than the case of voluntary disclosure. Because asymmetric information does not exist in this case, a firm has lower incentive to acquire its environmental information than in the case of voluntary disclosure. If (10) is satisfied, the expected profit of acquiring environmental information is $E\pi^{mN}$ and it equals to $\pi(e_\mu)$. Therefore, for all positive

acquisition costs k, the firm does not acquire environmental information and obtains the profit $\pi(e_\mu)$.

Proposition 2. Suppose that information disclosure is mandatory for firms that acquire their environmental information. Then

(i) If (12) is not satisfied, a monopoly firm does not acquire its environmental information and obtains the profit $\pi(e_\mu)$, and the environmental information is not disclosed.

(ii) If (8) and (12) are satisfied, a monopoly firm acquires its environmental information and invests t. Then it obtains $E\pi^{ml}$. In this case, the probability that the environmental information is disclosed is $\int_0^{E\pi^{ml}-\pi(e_\mu)} f(k)dk$ and the disclosed environmental information is only e_g.

(iii) If (10) and (12) are satisfied, a monopoly firm does not acquire the environmental information and obtains $\pi(e_\mu)$.

Case 3: Mandatory Disclosure; Full Mandatory Disclosure

Considering the situation that the government obligates every firm to inevitably disclose its environmental information, the monopoly firm must then acquire its

environmental information and disclose it. Under this policy, a monopoly firm will always acquire their environmental information and there is no need to consider the decision making at stage1. The expected profit of the monopoly firm is given by

$$E\pi^{M} = \alpha\pi(e_g) + (1-\alpha)\max\{\pi(e_g) - t, \pi(e_b)\} - k\,. \tag{13}$$

The condition that the firm invests to improve its environmental burden is given by (8). Then, the expected profit $E\pi^{MI}$ is given by

$$E\pi^{MI} = \pi(e_g) - t(1-\alpha) - k\,. \tag{14}$$

On the other hand, the condition that the firm does not invest is given by (10). Then, the expected profit $E\pi^{MN}$ is given by

$$E\pi^{MN} = \alpha\pi(e_g) + (1-\alpha)\pi(e_b) - k\,, \tag{15}$$

and $E\pi^{MN}$ equals to $\pi(e_\mu) - k$.

Proposition 3. Suppose that information disclosure is mandatory for all firms. A firm in the market inevitably discloses its environmental burden. Then

(i) If (8) is satisfied, a firm invests for the reduction of its environmental burden. Then the expected profit is $E\pi^{MI}$.

(ii) If (10) is satisfied, a firm does not invest for the reduction of its environmental burden. Then the expected profit is $E\pi^{MN}$ and $E\pi^{MN}$ is smaller than the initial

situation for every positive k.

As a result, the problems of asymmetric information still exist under voluntary disclosure. Consumers can not distinguish a firm that acquires its environmental burden information and remains silent, from a firm that does not acquire it. Therefore, a brown firm obtains a larger profit by choosing non-disclosure over mandatory disclosure. Under the voluntary approach, a monopoly firm would obtain a higher profit than the mandatory disclosure case. On the other hand, mandatory disclosure resolves the problem of asymmetric information. As there are no benefits resulting from asymmetric information, a monopoly firm would invest more than the voluntary disclosure case.

3. Comparison of Disclosure Policies

In this section, we compare the effects of each disclosure policy on social welfare. First, we analyze the effects of these policies on the reduction of a firm's environmental burden. In the initial situation, the environmental burden is e_μ. Under voluntary disclosure, investment that reduces environmental burden is carried out if (2) is satisfied. Then the environmental burden is

$$e^{vI} = e_g \int_0^{E\pi^{vI} - \pi(e_\lambda)} f(k)dk + e_\mu \int_{E\pi^{vI} - \pi(e_\lambda)}^{\bar{k}} f(k)dk . \qquad (16)$$

$\int_0^{E\pi^{vI}-\pi(e_\lambda)} f(k)dk$ is the probability that a monopoly firm acquires its environmental information. Therefore, the environmental burden e^{vI} is smaller than the initial one. If (4) is satisfied, investment is not carried out and the environmental burden remains in the initial situation e_μ.

Under the partial mandatory disclosure policy, if (8) is satisfied, a firm that acquires its environmental information carries out the investment. Then the environmental burden e^{mI} is

$$e^{mI} = e_g \int_0^{E\pi^{mI}-\pi(e_\mu)} f(k)dk + e_\mu \int_{E\pi^{mI}-\pi(e_\mu)}^{\bar{k}} f(k)dk. \tag{17}$$

The environmental burden e^{mI} is smaller than the initial one. In addition, $E\pi^{vI} - \pi(e_\lambda) > E\pi^{mI} - \pi(e_\mu)$ holds since $E\pi^{vI} = E\pi^{mI}$ and $\pi(e_\lambda) < \pi(e_\mu)$. Therefore, $e^{mI} > e^{vI}$ holds. If (10) is satisfied, the environmental burden remains in e_μ.

Under the full mandatory disclosure policy, if (8) is satisfied, a firm inevitably carries out the investment. Then the environmental burden e^{MI} is

$$e^{MI} = e_g \tag{18}$$

If (10) is satisfied, the environmental burden is e_μ. As a consequence, $e^{MI} < e^{vI} < e^{mI}$ holds where (2) is satisfied. The effects of investment on environmental burden are depicted in Figure 4.

[Figure 4 here]

Under voluntary disclosure, the area where environmental burden is reduced from the initial situation is ①＋② in Figure 4 and the expected investment cost is $(1-\alpha)\int_0^{E\pi^{vl}-\pi(e_\lambda)} f(k)dk\frac{\pi(e_g)-\pi(e_\lambda)}{2}$, where $\frac{\pi(e_g)-\pi(e_\lambda)}{2}$ is the average cost of investment. Under the partial mandatory disclosure policy, the area is ①＋④ in Figure 4 and the expected investment cost is $(1-\alpha)\int_0^{E\pi^{ml}-\pi(e_\mu)} f(k)dk\frac{\pi(e_g)-\pi(e_b)}{2}$. Under the full mandatory disclosure policy , the area is ①＋②＋③＋④＋⑤+⑥ in Figure 4 and the expected investment cost is $(1-\alpha)\frac{\pi(e_g)-\pi(e_b)}{2}$. Therefore, under the full mandatory disclosure policy, the environmental burden is lower than that of other policies. In addition, if the investment cost t is low, that is $t < E\pi^{vl}-\pi(e_\lambda)$, the environmental burden of voluntary disclosure is lower than that of partial mandatory disclosure policy. This is because voluntary disclosure gives the firm a larger incentive to acquire its environmental information than partial mandatory disclosure because the effects of asymmetric information exist. Moreover, the upper limit of investment cost in voluntary disclosure is $\pi(e_g)-\pi(e_\lambda)$, which is lower than that of mandatory disclosures. On the other hand, under the full mandatory disclosure, the expected cost of investment reducing environmental burden $(1-\alpha)\frac{\pi(e_g)-\pi(e_b)}{2}$ is higher than that of other policies.[6] This is because full mandatory disclosure does not allow the firm to choose non-disclosure.

Next, we consider the welfare of consumers and monopoly firms. Under voluntary disclosure, the environmental burden of a silent firm is inferred as e_λ by consumers. Then if (2) is satisfied, the firm chooses to invest and the welfare W^{vI} is,

$$\begin{aligned} W^{vI} &= \int_0^{E\pi^{vI}-\pi(e_\lambda)} f(k)dk \int_0^{\frac{v-p}{e_g}} (v-\theta e_g - c)h(\theta)d\theta \\ &+ \int_{E\pi^{vI}-\pi(e_\lambda)}^{\bar{k}} f(k)dk \int_0^{\frac{v-p}{e_\lambda}} (v-\theta e_\lambda - c)h(\theta)d\theta \\ &- (1-\alpha)\int_0^{E\pi^{vI}-\pi(e_\lambda)} f(k)dk \frac{\pi(e_g)-\pi(e_\lambda)}{2} - \int_0^{E\pi^{vI}-\pi(e_\lambda)} kf(k)dk. \end{aligned} \tag{19}$$

In this case, consumers obtain higher utility than in the initial situation by the following two effects; the effect of improvement of environmental burden by investment and the effect of environmental information disclosure. Furthermore, consumers infer that the environmental burden of a silent firm is e_λ, which is smaller than the initial environmental burden e_μ.

If (4) is satisfied under voluntary disclosure, the welfare W^{vN} is

$$\begin{aligned} W^{vN} &= \alpha \int_0^{E\pi^{vN}-\pi(e_\lambda)} f(k)dk \int_0^{\frac{v-p}{e_g}} (v-\theta e_g - c)h(\theta)d\theta \\ &+ \{(1-\alpha)\int_0^{E\pi^{vN}-\pi(e_\lambda)} f(k)dk + \int_{E\pi^{vN}-\pi(e_\lambda)}^{\bar{k}} f(k)dk\} \int_0^{\frac{v-p}{e_\lambda}} (v-\theta e_\lambda - c)h(\theta)d\theta \\ &- \int_0^{E\pi^{vN}-\pi(e_\lambda)} kf(k)dk. \end{aligned} \tag{20}$$

In the case of (20), the environmental burden is not improved and consumers only obtain the effect of environmental information disclosure.

Under the partial mandatory disclosure policy, the firm that acquires its

environmental information must disclose it. Therefore consumers infer the environmental burden of the silent firm as e_μ. In the case (8) is satisfied, if the firm acquires its environmental information, it carries out investment. Then, the welfare of consumers and the monopoly firm is

$$\begin{aligned} W^{mI} &= \int_0^{E\pi^{mI}-\pi(e_\mu)} f(k)dk \int_0^{\frac{v-p}{e_g}} (v-\theta e_g - c)h(\theta)d\theta \\ &+ \int_{E\pi^{mI}-\pi(e_\mu)}^{\bar{k}} f(k)dk \int_0^{\frac{v-p}{e_\mu}} (v-\theta e_\mu - c)h(\theta)d\theta \\ &- (1-\alpha)\int_0^{E\pi^{mI}-\pi(e_\mu)} f(k)dk \frac{\pi(e_g)-\pi(e_b)}{2} - \int_0^{E\pi^{mI}-\pi(e_\mu)} kf(k)dk. \end{aligned} \tag{21}$$

In this situation, consumers can receive the effect of improvement of environmental burden by investment and the effect of environmental information disclosure. On the other hand, the environmental burden of silent firms is e_μ under the partial mandatory policy. In (19), (20) and (21), the first line of the right hand side is welfare in the case that environmental information is disclosed, and the second line is welfare in the case that information is not disclosed. The third line expresses the expected cost of investment and acquiring environmental information. In the case (10) is satisfied, a monopoly firm does not acquire its environmental information. Then the welfare under the partial mandatory disclosure policy is

$$W^{mN} = \int_0^{\frac{v-p}{e_\mu}} (v-\theta e_\mu - c)h(\theta)d\theta \tag{22}$$

This is same as the initial situation.

Under the full mandatory disclosure policy, the firm must disclose its environmental burden information. In the case (8) is satisfied, the firm chooses to invest. Then, the welfare W^{MI} is

$$W^{MI} = \int_0^{\frac{v-p}{e_g}} (v - \theta e_g - c)h(\theta)d\theta - (1-\alpha)\frac{\pi(e_g) - \pi(e_b)}{2} - \int_0^{\bar{k}} kf(k)dk. \quad (23)$$

In this situation, consumers can obtain the effect of improvement of environmental burden by investment and the effect of environmental information disclosure. In addition, there are no silent firms. In the case (10) is satisfied, the welfare under the full mandatory disclosure policy is

$$W^{MN} = \alpha\int_0^{\frac{v-p}{e_g}} (v - \theta e_g - c)h(\theta)d\theta + (1-\alpha)\int_0^{\frac{v-p}{e_b}} (v - \theta e_b - c)h(\theta)d\theta - \int_0^{\bar{k}} kf(k)dk. \quad (24)$$

In this case, consumers could obtain the effect of environmental information disclosure.

Consequently, the social welfare of each case is shown in Table 1.

[Table 1 here]

By disclosing environmental burdens, the demand for green firms increase and the demand for brown ones decrease. However, under full mandatory disclosure policy, environmental information is fully revealed, requiring the highest cost for information acquisition and investment. In addition, the probability of environmental information disclosure under voluntary disclosure is higher than that of partial mandatory disclosure policy. Furthermore, environmental burdens are improved in the cases of (v1), (m1), and

(M1).

The expected profit of a monopoly firm is expressed in Table 2.

[Table 2 here]

As a result, the expected profit under (M2) policy is smaller than that in the initial situation. Full mandatory disclosure policy does not have the option for a firm to not acquire its environmental information. Under (M2) policy, therefore, even if a firm decreases its expected profit by acquiring information, the firm must acquire its environmental information. In addition, the expected profit under (m2) policy is equal to the initial one. There are three cases that a firm does not invest to improve its environmental burden, which are (v2), (m2), and (M2) policies. In these cases, only (v2) policy has the possibility of increasing the expected profit. This is because that under (v2) policy, the firm could obtain expected profit $\pi(e_\lambda)$ by the existence of asymmetric information if it acquired the environmental information and knew itself as brown. On the other hand, the comparison of the expected profit in three cases, (v1), (m1), and (M1) policies is not clear. In these cases, a firm carries out the investment and all cases have possibility of getting higher expected profit than the initial situation.

Proposition 4.

(i) Among the three policies, full mandatory disclosure policy achieves full information disclosure and the lowest environmental burden. On the other hand, the cost of information acquisition and investment in full mandatory disclosure policy is higher than the others.

(ii) Among the three policies, (v2), (m2), and (M2), the expected profit of a monopoly firm is the lowest under (M2) policy and (v2) policy could make the larger expected profit than the initial one.

4. Concluding Remarks

Increasing environmental awareness of consumers affects the behavior of firms. Many consumers are interested in knowing the environmental burden information of firms. Under such circumstances, environmental information disclosure policies attract attention. On the other hand, if firms voluntarily disclose their environmental information, the problems of asymmetric information might be solved by market mechanisms without the intervention of the government. We have developed a model in which a firm can invest to reduce its environmental burden and disclose its environmental information, and compare the effects of three types of environmental policies.

We have solved the decision making problems of firms under the different policies. In this model, under voluntary disclosure, the probability that a firm acquires its environmental information is higher than that of mandatory disclosure. Moreover, a firm invests more under mandatory disclosure because under mandatory disclosure, the effects of asymmetric information disappear. The disclosure rule has effects on consumer utility, firm profit and environmental burden. The effects of each policy on social welfare are ambiguous. This depends on the size of each effect. Regarding each effect, full mandatory disclosure policy achieves full information disclosure and the lowest environmental burden. However, the cost of information acquisition and investment is higher than that of other policies and the expected profit is the lowest. Although voluntary disclosure might achieve a higher expected profit, it does not solve the problems of asymmetric information.

Appendix 1

In the case of voluntary disclosure, there are two types of silent firms. The first are firms that do not acquire their environmental information. Environmental burdens of this type are speculated e_{μ} by consumers, while the latter are firms that acquire their environmental information and they know their environmental burdens are e_b and did

not invest. In this case, the environmental burden is e_b. Therefore, e_λ is expressed as $e_\lambda = \gamma e_\mu + (1-\gamma)e_b$ and γ is posterior probability $(0 < \gamma < 1)$. Therefore, $e_\mu < e_\lambda < e_b$ holds. If (2) is satisfied, then γ is given by

$$\gamma = \frac{1 - \int_0^{E\pi^{vI} - \pi(e_\lambda)} f(k)dk}{1 - \int_0^{E\pi^{vI} - \pi(e_\lambda)} f(k)dk + (1-\alpha)\int_0^{E\pi^{vI} - \pi(e_\lambda)} f(k)dk}.$$

In addition, in the case of (4) is satisfied, the probability could calculate in the same way.

Notes

[1] Voluntary programs of firms are classified into unilateral commitments, public voluntary schemes and negotiated agreements. Some existing studies about voluntary programs are Arora and Cason (1996), Segerson and Miceli (1998), Lyon and Maxwell (2003), Friesen (2006), and Blanco et al. (2009).

[2] In Polinsky and Shavell (2006), acquired information is about the harms of a firm's goods.

[3] For example, although each consumer cares about global warming and buys environmentally friendly goods, they can not realize the improving effects generated by their consumption.

[4] We postulate that firms can not disclose disinformation. Sinclair-Desgagné and Gozlan (2003) analyze the case that disclosed information is not always accurate.

[5] We postulate that firms can not disclose disinformation.

[6] This relationship is sustained even if we include the acquisition cost of a firm's environmental information.

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Figure 1: Voluntary Disclosure

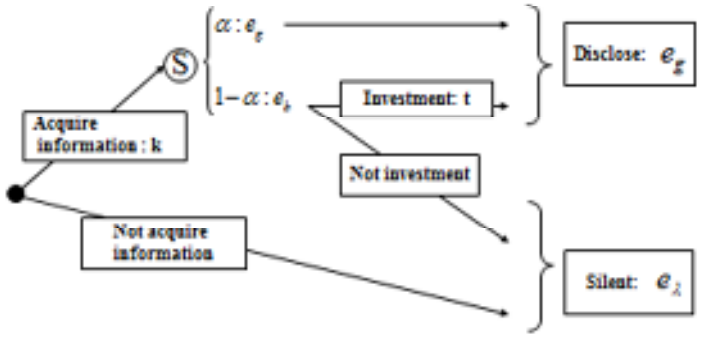

Figure 2: Partial Mandatory Disclosure

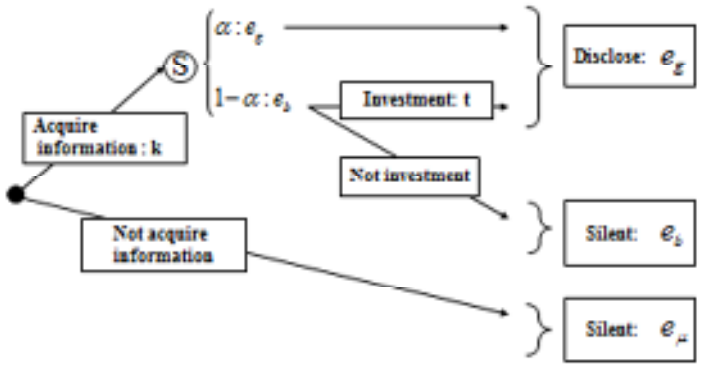

Figure 3: Full Mandatory Disclosure

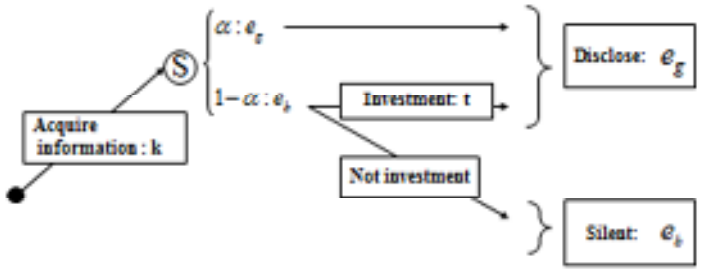

Figure 4 : Investment and Environmental Burden

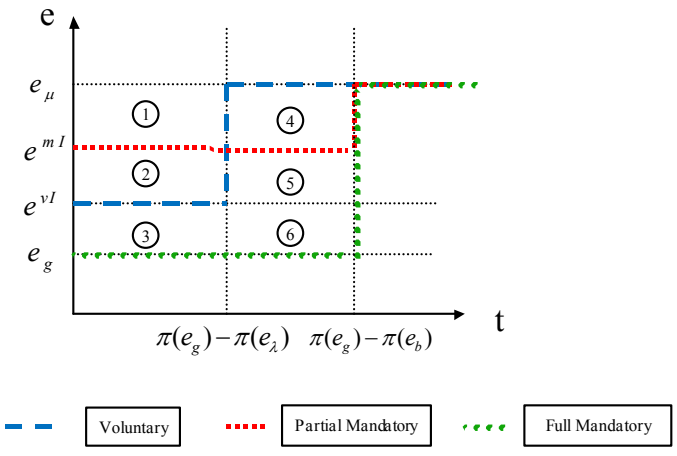

Table 1: Social Welfare

Policy	Condition	Social Welfare
(v1) Voluntary disclosure	(2) is satisfied	(19)−(16)
(v2) Voluntary disclosure	(4) is satisfied	(20)− e_{μ}
(m1) Partial mandatory disclosure	(8) is satisfied	(21)−(17)
(m2) Partial mandatory disclosure	(10) is satisfied	(22)− e_{μ}
(M1) Full mandatory disclosure	(8) is satisfied	(23)− e_{g}
(M2) Full mandatory disclosure	(10) is satisfied	(24)− e_{μ}

Table 2: Expected Profit

Policy	Expected Profit
Initial situation	$\alpha\pi(e_g)+(1-\alpha)\pi(e_b)$
(v1) ((2) is satisfied)	$\int_0^{E\pi^{vI}-\pi(e_\lambda)} f(k)dk\{\pi(e_g)-t(1-\alpha)-\int_0^{E\pi^{vI}-\pi(e_\lambda)} kf(k)dk\} + \int_{E\pi^{vI}-\pi(e_\lambda)}^{\bar{k}} f(k)dk\pi(e_\lambda)$
(v2) ((4) is satisfied)	$\int_0^{E\pi^{vN}-\pi(e_\lambda)} f(k)dk\{\alpha\pi(e_g)+(1-\alpha)\pi(e_\lambda)-\int_0^{E\pi^{vN}-\pi(e_\lambda)} kf(k)dk\} + \int_{E\pi^{vN}-\pi(e_\lambda)}^{\bar{k}} f(k)dk\pi(e_\lambda)$
(m1) ((8) is satisfied)	$\int_0^{E\pi^{mI}-\pi(e_\mu)} f(k)dk\{\pi(e_g)-t(1-\alpha)-\int_0^{E\pi^{mI}-\pi(e_\mu)} kf(k)dk\} + \int_{E\pi^{mI}-\pi(e_\mu)}^{\bar{k}} f(k)dk\pi(e_\mu)$
(m2) ((10) is satisfied)	$\alpha\pi(e_g)+(1-\alpha)\pi(e_b)$
(M1) ((8) is satisfied)	$\pi(e_g)-t(1-\alpha)-\int_0^{\bar{k}} kf(k)dk$
(M2) ((10) is satisfied)	$\alpha\pi(e_g)+(1-\alpha)\pi(e_b)-\int_0^{\bar{k}} kf(k)dk$