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Abstract

This study theoretically examines green portfolio standards with monetary penalties in an oligopoly market. We find that green portfolio standards are inefficient policy tools if the purpose of the government is to promote green products, whereas they attain first-best optimality if the purpose is to restrict non-green products. Green portfolio standards may work well under the mixed aims of promoting green and restricting non-green products. Moreover, by applying the principle of our results, we highlight the inefficiency of an employment promotion program for handicapped workers in Japan.

Keywords: green industrial policy, negative externality of gray products, positive externality of green products, renewable portfolio standards, zero emission vehicle program, employment promotion program

JEL Classification: Q58, Q48, L51

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1 Introduction

Global warming is a hot issue in both politics and academics. A standard policy for environmental problems is the introduction of carbon pricing, such as emission taxes and tradable emission permits. Several theoretical studies in environmental economics encourage the use of these instruments from the perspective of cost-effectiveness, and in fact, many countries have adopted carbon pricing policies. Nevertheless, both in the presence and absence of carbon pricing policies, many other (additional) environmental policies have been widely adopted (Bőhringer et al., 2017; Cohen and Keiser, 2017; and Demirel et al., 2018). Portfolio standard policies that impose targets for the ratio of green products among all products are one such environmental policy and are widely adopted across countries and industries.

There are two possible rationales for introducing green portfolio standards. One is to control negative externalities of gray products, which are not internalized by carbon pricing. For example, an increase in non-zero emission vehicles or coal-fired power plants may be harmful for the local environment as well as the global environment. The second rationale is to promote positive externalities of green products. For example, an increase in zero emission vehicles or renewable plants may improve social awareness of green activities and create additional gain as public service announcement. Zero emission vehicles, such as electric vehicles and fuel cell vehicles, and renewable plants, such as wind power generators, require many inputs, and an increase in these products may create new industries. Thus, the government may use green portfolio standards as industry policies.[1]

In this study, we show that green portfolio standards work well to internalize the negative externality of gray products. However, the standards are not efficient if the purpose of the policies is only to internalize positive externalities of green products. Green portfolio standards may work well under the mixed purposes of promoting green and restricting non-green products, if the negative externality related to the latter purpose is sufficiently large.

Bento et al. (2018) established an important contribution in this field. They formulated

[1]Lyon and Yin (2010), Schmalensee (2012), and Jenner et al. (2012) noted that adoption of renewable portfolio standard policies has been at least partially driven by promoting renewable energy rather than reducing emissions.

a general equilibrium model that examines the two effects of promoting green products and restricting emissions. The authors showed that renewable portfolio standards can yield either large renewable resource booms or large emissions savings but not both. There are two differences between our study and theirs. First, we investigate an imperfectly competitive market, whereas they discussed a perfectively competitive market. Second, we discuss the first-best optimality of green portfolio standard policies, whereas they did not discuss the optimality of green portfolio standard policies.

The rest of the paper is organized as follows. The next section formulates our model in which firms are subject to the portfolio standard for green outputs in an oligopoly market. Section 3 provides our main results. In Section 4, we apply the portfolio standard to labor inputs and discuss the inefficiency of an employment promotion program of handicapped workers in Japan. Section 5 concludes.

2 The Model

We consider an n-firm symmetric oligopoly market wherein firms choose their outputs (Cournot competition). There are two differentiated products, green and gray products. In the context of renewable portfolio standards, the green product is electricity produced by renewable power plants. In the context of zero-emission vehicle programs, the green product is a zero-emission vehicle, such as an electric vehicle or a fuel cell vehicle. Each firm i ($i = 1, 2, ..., n$) chooses the output of gray product $x_i \geq 0$ and that of green product $y_i \geq 0$. Let $X \equiv \sum_{i=1}^{n} x_i$ and $Y \equiv \sum_{i=1}^{n} y_i$ be the total output of the gray and green products, respectively, and let p_X and p_Y be the price of the gray and green products, respectively. Let $c(x_i, y_i)$ be the firm i's production cost function. It is twice continuously differentiable, convex, and satisfies $\partial c/\partial x_i > 0$ and $\partial c/\partial y_i > 0$. Let $b(x_i, y_i)$ be the private (internalized without green portfolio standards) benefit function from the green output. It is twice continuously differentiable, convex, $\partial b/\partial x_i \leq 0$, and $\partial b/\partial y_i \geq 0$. For instance, an increase in y_i may improve the firm's reputation and the firm may be able to raise funds with lower capital costs.

The government regulates the ratio of green output as $y_i/(x_i + y_i) \geq r$, where $r \in [0, 1]$.[2] Firms that fall short of the green output targets pay the penalty (or procure permits) according to the level of shortage (i.e., $y_i - r(x_i + y_i) = rx_i - (1 - r)y_i$), and firms that overachieve the targets receive the subsidy (or sell permits). Let $t \geq 0$ be the level of the unit penalty (subsidy).[3] The government first chooses t and r, and then firms compete in the product markets.

The green (gray) product may yield positive (negative) externalities that the government is concerned with. Let $B(X, Y)$ denote the social benefit due to the externalities. We assume that it is twice continuously differentiable, convex, and satisfies $\partial B/\partial X \leq 0$ and $\partial B/\partial Y \geq 0$. If $\partial B/\partial X = 0$ and $\partial B/\partial Y > 0$, the government should internalize the positive externalities of green products, that is, the policy purpose is to promote green products. If $\partial B/\partial X < 0$ and $\partial B/\partial Y = 0$, the government should internalize the negative externalities of gray products, that is, the policy purpose is to restrict gray products. If $\partial B/\partial X < 0$ and $\partial B/\partial Y > 0$, the government has a mixed purpose.

The demand system of these two products is obtained by the following representative (aggregate) consumer problem, which maximizes quasi-linear utility:

$$\max_{X,Y,M} U(X, Y) + M \quad \text{s.t. } p_X X + p_Y Y + M \leq I,$$

where $M \geq 0$ is the consumption of an outside good (numeraire) that is competitively provided (with a unitary price) and I is income that consists of profits of firms in the industry and fixed income from outside the industry. We assume that the sub-utility U is twice continuously differentiable, strictly concave, and increasing. Each consumer is a price taker. From the first-order conditions for utility maximization, we obtain

$$p_k = \frac{\partial U}{\partial k}(X, Y) \qquad k = X, Y, \tag{1}$$

[2]This regulation is equivalent to $x_i/(x_i + y_i) \leq 1 - r$. If we regard x_i as emissions generated from the gray output and $(1 - r)$ as the upper limit of emissions per unit of output, the green portfolio standard policy is similar to the emission intensity regulation. For the relationship between the two policies, see Ino and Matsumura (2019b). For a discussion of the welfare effects of emission intensity regulation, see Helfand, (1991), Farzin (2003), Lahiri and Ono (2007), Holland et al. (2009), Ino and Matsumura (2019a), and Hirose and Matsumura (2020).

[3]If tradable permits of green products rather than direct pricing by the government is introduced, t is the equilibrium price of the permit, and the government can control the price by issuing additional permits or by purchasing permits from firms that overachieved the targets.

that is, we obtain the inverse demand system, $p_X(X,Y)$ and $p_Y(X,Y)$. Note that the strict concavity of U implies downward slopes for this demand (i.e., $\partial p_X/\partial X = \partial U^2/\partial^2 X < 0$ and $\partial p_Y/\partial Y = \partial U^2/\partial^2 Y < 0$). We assume that the two products are substitutes (i.e., $\partial p_X/\partial Y = \partial p_Y/\partial X = \partial U^2/\partial X \partial Y \leq 0$). Moreover, we assume that an increase of X reduces p_X more significantly than p_Y (i.e., $\partial p_X/\partial X \leq \partial p_X/\partial Y$ and $\partial p_Y/\partial Y \leq \partial p_Y/\partial X$). These are standard assumptions in the literature on oligopoly markets (Vives, 1999).

Firm i's profit is

$$\pi_i \equiv p_X(X,Y)x_i + p_Y(X,Y)y_i - c(x_i,y_i) + b(x_i,y_i) - t[rx_i - (1-r)y_i].$$

Social welfare is

$$W \equiv U(X,Y) - \sum_{i=1}^{n}(c(x_i,y_i) - b(x_i,y_i)) + B(X,Y).$$

3 Results

The first-order conditions of profit-maximization for firm i are

$$\begin{aligned} \frac{\partial p_X}{\partial X}x_i + \frac{\partial p_Y}{\partial X}y_i + p_X - \frac{\partial c}{\partial x_i} + \frac{\partial b}{\partial x_i} - tr &= 0, \quad (2)\\ \frac{\partial p_X}{\partial Y}x_i + \frac{\partial p_Y}{\partial Y}y_i + p_Y - \frac{\partial c}{\partial y_i} + \frac{\partial b}{\partial y_i} + t(1-r) &= 0. \quad (3) \end{aligned}$$

Assuming a unique interior solution, these conditions lead to the market equilibrium outcomes.

The first-order conditions of welfare-maximization are

$$\begin{aligned} p_X - \frac{\partial c}{\partial x_i} + \frac{\partial b}{\partial x_i} + \frac{\partial B}{\partial X} &= 0, \quad (4)\\ p_Y - \frac{\partial c}{\partial y_i} + \frac{\partial b}{\partial y_i} + \frac{\partial B}{\partial Y} &= 0, \quad (5) \end{aligned}$$

where we use (1). Assuming a unique interior solution, these conditions lead to the socially optimal outcomes. Let the superscript * denote the socially optimal outcomes.

Define

$$MD_X \equiv -\frac{\partial B(X^*,Y^*)}{\partial X}, \qquad MB_Y \equiv \frac{\partial B(X^*,Y^*)}{\partial Y}.$$

MD_X (MB_Y) is the marginal damage (benefit) of negative (positive) externality caused by an increase in the gray (green) product at the socially optimal point.

We now present our results.

Proposition 1 *(i) If*

$$MD_X < -\frac{\partial p_X}{\partial X} x_i^* - \frac{\partial p_Y}{\partial X} y_i^*, \tag{6}$$

the socially optimal outcome is not achieved by the green portfolio standard policy.

(ii) If (6) is not satisfied, the socially optimal outcome is achieved by

$$\begin{aligned} t^* &= MD_X + MB_Y + \left(\frac{\partial p_X}{\partial X} - \frac{\partial p_X}{\partial Y}\right) x_i^* + \left(\frac{\partial p_Y}{\partial X} - \frac{\partial p_Y}{\partial Y}\right) y_i^*, \\ r^* &= \frac{1}{t^*}\left(MD_X + \frac{\partial p_X}{\partial X} x_i^* + \frac{\partial p_Y}{\partial X} y_i^*\right). \end{aligned}$$

Proof See the Appendix.

Proposition 1(i) implies that if no negative externality of gray products exists (i.e., $MD_X = 0$), the portfolio standard policy is never optimal. In other words, if the policy purpose is only to promote green products rather than to restrict gray products, a portfolio standard policy is inefficient.

If (6) is satisfied, welfare loss of suboptimal production caused by firms' market power (right-hand side) dominates welfare loss caused by negative externality of gray products (left-hand side). Therefore, the production of gray products should be stimulated rather than restricted. A green portfolio standard policy restricts production of gray products and thus, it accelerates the loss of underproduction, which is not optimal.

Proposition 1(ii) suggests that the green portfolio standards work well unless the negative externality effect of gray products is too small. Proposition 1(ii) states that the optimal unit penalty on firms that do not meet the targets increases with the sum of the marginal social benefit of green products and the marginal social damage of gray products. Proposition 1(ii) also suggests that the greater the marginal benefit of green products is, the lower (higher) the target level of green products ratio (the penalty price) should be. An increase in t directly increases the incentive of green product production, whereas an increase in r may reduce it because it raises production costs in the industry. Therefore, when the positive externality of green products is significant, a higher penalty is more efficient than a larger ratio of green product requirement.

4 Analysis of the portfolio standard in labor markets

Our principle can generally apply to other policies that promote or restrict activities yielding positive or negative externalities. For example, hiring physically handicapped workers is considered to be socially desirable. In this case, the government can regulate the ratio of handicapped employees among all employees in a firm, and if a firm does not meet (overachieve) the regulation, the firm pays a penalty (obtains a subsidy). The Japanese government formulated such a regulation by the Act for Promotion of Employment of Persons with Disabilities (Ministry of Health, Labour and Welfare, 2019). In this section, we extend our model to investigate this regulation.

There are two inputs, labor inputs of non-handicapped and handicapped employees. We consider an n-firm symmetric oligopoly market wherein each firm i chooses $l_i \geq 0$ (number of non-handicapped employees) and $h_i \geq 0$ (number of handicapped employees). Let $q_i = f(l_i, h_i)$ be the production function, where $q_i \geq 0$ is firm i's output. Let $Q \equiv \sum_{i=1}^{n} q_i$ be the total output. We assume that f is twice continuously differentiable, strictly concave, and increasing. The inverse demand function is $p(Q)$ and $p' < 0$ as long as $p > 0$.

The government regulates the ratio of handicapped employees as $h_i/(l_i + h_i) \geq r$, where $r \in [0, 1]$. Firms that fall short of targets pay the penalty (or procure permits) according to the level of shortage, and firms that overachieve the targets receive the subsidy (or sell permits). Let $t \geq 0$ be the level of unit penalty (subsidy). The government chooses t and r.

Firm i's profit is

$$\pi_i \equiv p(Q)q_i - w_L l_i - w_H h_i + b(l_i, h_i) - t[rl_i - (1-r)h_i],$$

where w_L and w_H are the wages of non-handicapped and handicapped employees, respectively, and $b(l_i, h_i)$ is the private (internalized without this regulation) benefit function. $b(l_i, h_i)$ is twice continuously differentiable, convex, and $\partial b/\partial h_i \geq 0$. We assume that labor markets are perfectly competitive and firms are price takers in the labor markets (i.e., w_L and w_H are given exogenously).

The employment of workers, especially handicapped workers, may yield positive externalities that the government is concerned with. Let $B(L, H)$ denote the benefit of the externalities where $L \equiv \sum_{i=1}^{n} l_i$ and $H \equiv \sum_{i=1}^{n} h_i$. We assume that it is twice continuously differentiable, convex, and satisfies $\partial B/\partial L \geq 0$ and $\partial B/\partial H \geq 0$. In other words, the employment of both handicapped and non-handicapped workers do not yield negative externalities, although we allow the degree of positive externality to differ between them. Then, social welfare is given by

$$W \equiv \int_0^Q p(z)dz - \sum_{i=1}^{n}(w_L l_i + w_H h_i - b(l_i, h_i)) + B(L, H).$$

The first-order conditions of profit maximization for firm i are

$$p + p' q_i - w_L + \frac{\partial b}{\partial l_i} - tr = 0, \tag{7}$$

$$p + p' q_i - w_H + \frac{\partial b}{\partial h_i} + t(1 - r) = 0. \tag{8}$$

Assuming a unique interior solution, these conditions lead to the market equilibrium outcomes.

The first-order conditions for the welfare maximization problem are

$$p - w_L + \frac{\partial b}{\partial l_i} + \frac{\partial B}{\partial L} = 0, \tag{9}$$

$$p - w_H + \frac{\partial b}{\partial h_i} + \frac{\partial B}{\partial H} = 0. \tag{10}$$

Assuming a unique interior solution, these conditions lead to the socially optimal outcomes.

Proposition 2 *The socially optimal outcome is never achieved by the regulation.*

Proof See the Appendix.

As mentioned above, it is natural to assume that hiring non-handicapped workers does not yield negative externality. Because the regulation provides a disincentive for hiring non-handicapped workers, the employment level of non-handicapped workers becomes suboptimal. Therefore, in contrast to the green portfolio standard, this policy always causes welfare loss.

5 Concluding remarks

This study investigates green portfolio standards with monetary penalty for firms that fall short of targets. We show that this policy is efficient only if the negative externality of non-green product exceeds the threshold value. This result implies that green portfolio standards are not efficient if the purpose of the policy is only to promote green products, whereas they are efficient for restricting non-green products.

In this study, we do not explicitly consider other environmental policy tools, such as carbon pricing, which may affect the costs of firms and/or demand for green and non-green products. Investigating the relationship between optimal green portfolio standards and carbon pricing remains for future research.

Appendix

Proof of Proposition 1

(i) Comparing (4) and (2), we find that the socially optimal outcome is achieved only if

$$MD_X + \frac{\partial p_X}{\partial X} x_i^* + \frac{\partial p_Y}{\partial X} y_i^* = tr. \tag{11}$$

Because $t \geq 0$ and $r \in [0, 1]$, this equality never holds if (6) is satisfied.

(ii) As shown in the proof of (i), the socially optimal outcome is achieved only if (6) is not satisfied. Substituting (11) into (3) and comparing it with (5), we obtain t^*. Substituting t^* into (11), we obtain r^*. Note that $t^* \geq 0$ and $r^* \in [0, 1]$ because $-\partial p_X/\partial Y \geq 0$, $-\partial p_Y/\partial Y \geq 0$ and (6) is not satisfied. ■

Proof of Proposition 2

Comparing (9) and (7), we find that the socially optimal outcome is achieved only if $p'q_i - tr = \partial B/\partial L$. Because $p'q_i - tr < 0$ and $\partial B/\partial L \geq 0$, this equality never holds. ■

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