Environ Econ Policy Stud (2019) 21:25–36
https://doi.org/10.1007/s10018-018-0220-2

RESEARCH ARTICLE

Discriminatory tax and subsidy on environmental behaviors

Yoshinori Wada[1]

Received: 9 June 2017 / Accepted: 25 May 2018 / Published online: 5 June 2018

Abstract This paper investigates the consumption tax and subsidy as an environmental policy instrument for environmentally aware consumers by applying the model of price discrimination. We discover that a higher rate of subsidy should be set for less eco-friendly consumers for the purpose of achieving socially optimal environmental qualities under positive externalities and this retrogressive subsidization differs from the current progressive subsidization in the Japanese automobile industry, and could alleviate crowding out effects on prosocial behavior. Moreover, it is revealed that the optimal policy instrument for eco-friendlier consumers shifts from a subsidy to a tax, as the level of negative externalities increases.

Keywords Externalities · Environmental awareness · Incentives · Price discrimination · Pigouvian tax/subsidy

JEL Classification D03 · D86 · H23 · L12 · Q58

1 Introduction

This paper examines the consumption tax and subsidy on green and dirty products in the market. In our model, consumers behave differently in terms of environmental awareness, and a firm can supply a variety of products that affect differently environmental change, and the tax or subsidy is set. This setup of our model has often been employed in previous studies on environmental tax and subsidy. Cremer and Thisse (1999) suggest that an ad valorem tax may improve welfare, even though the

✉ Yoshinori Wada
ywada@mail.doshisha.ac.jp

[1] Faculty of Economics, Doshisha University, Kyoto 602-8580, Japan

quality creates a positive externality. Morage-Gonzalez and Padron-Fumero (2002) investigate uniform and non-uniform product charges, and technology subsidization in the duopolistic market. Bansal and Gangopadhyay (2003) show that while a discriminatory subsidy policy reduces total pollution and enhances aggregate welfare, a discriminatory tax policy may increase total pollution and reduce welfare. Lombardini-Riiponen (2005) reveals that a uniform ad valorem tax with an emission tax or a subsidy to consumers choosing the green goods can lead to the social optimum. Bansal (2008) indicates that as the level of negative externalities increases, the optimal policy shifts from a tax to a subsidy policy. Matsukawa (2012) discovers that an emission tax always dominates a subsidy, by applying a discrete–continuous model of consumer choice. These preceding studies found types of desirable environmental policies, but did not examine precisely the relationships between private companies and public bodies, who set policy instruments in the market, and did not contemplate difficulties in dealing with consumers' environmental awareness. We will analyze theoretically the relationship between a private firm and a regulator, and consumers' environmental awareness as hidden characteristic.

To investigate optimal taxation or subsidization for environmentally aware consumers, we develop the model in Mussa and Rosen (1978) that investigates the monopoly's pricing behavior with product differentiation, by incorporating externalities and policy instruments into their analysis. Our model illustrates current manufacturing industries in which products are highly differentiated and environmental technology is highly developed by dominant firms. Furthermore, our analysis deals with an environmental regulatory practice in which private companies are obliged to report environmental qualities within their products and consumers are taxed or subsidized. Baron and Myerson (1982) analyze a regulatory policy by applying an incentive scheme, in which a regulator as principal and a regulated monopoly as agent are designed. Baron (1985) analyzes a nonlocalized pollution externality, in which a public utilities' commission and an environmental protection regulator are principals and they provide different types of regulation to a monopolist as agent. He assumes that the environmental protection regulator acts as a von Stackelberg leader and hence can choose its pollution control policy as if it knew the agent's hidden information, because the public utilities' commission as a follower designs an incentive contract subject to the agent's hidden information. This approach of sharing hidden information in Baron (1985) is applied to our analysis of implementing policy instruments. Thomas (1995) and Aggarwal and Lichtenberg (2005) also investigate desirable environmental policies in the incentive scheme and suggest the importance of policy combination. Their analysis considers properly hidden information, however, their regulatory setting does not reflect current tax or subsidy policies on consumption in the market.

We reveal that a higher rate of a subsidy should be chosen not for eco-friendlier consumers, but for less eco-friendly consumers and a combination of a tax and subsidy is optimal when a low level of negative externalities exists. Such retrogressive subsidization for eco-friendly behaviors differs from the current progressive tax benefit policy in the Japanese automobile industry, in which automobile taxes are discounted more for eco-friendlier cars. On the other hand, studies that analyze environmental policies and prosocial behaviors might support our theoretical result. For example, Kallbekken et al. (2011) reveal that the behavior of Pigouvian tax aversion is generally observed and inequality of revenue recycling may inspire support for Pigouvian tax. Ariely et al. (2009) suggest that the tax benefit for hybrid cars damages the signaling value vested in hybrid cars and therefore is not a desirable policy to facilitate the adoption of a new environmentally friendly technology. Banerjee and Schogren (2012) contemplate the crowding out effect of monetary rewards on prosocial behavior and show that good reputation makes the landowner contribute more than the optimal level of private land for species protection.

The rest of this paper is organized as follows. Section 2 provides the basic framework of the model for price discrimination with externalities and discriminatory policy instruments. Section 3 derives the optimal incentive scheme and Sect. 4 characterizes the discriminatory policy instrument and derives welfare loss caused by an optimal uniform policy instrument. Section 5 summarizes our findings and points out the ways of developing our analysis.

2 The model

This section explains the model of the incentive contract between consumers as agents and a private monopolistic firm as a principal, considering externalities and tax and subsidy policies on consumption. The basic framework of our model follows the model of the monopoly's pricing with quality differentiation in Mussa and Rosen (1978) and Tirole (1988). Our model assumes that a private monopoly or a firm can supply different levels of environmental qualities, and consumers are environmentally aware and choose the set of environmental qualities and prices.[1] Moreover, it is assumed that their consumption causes environmental externalities. Into the basic incentive contract, we add discriminatory policy instruments set by the regulator who aims to achieve socially optimal environmental qualities. Two types of consumers exist and are characterized by the parameter $\theta \in \{\bar{\theta}, \underline{\theta}\}(\bar{\theta} > \underline{\theta} > 0)$. Type $\bar{\theta}$ has a relatively higher demand for environmental qualities. Type $\underline{\theta}$ has a relatively lower demand. θ is unknown to the firm and the regulator. The number of consumers is normalized to one. The population of type $\bar{\theta}$ is λ, and that of type $\underline{\theta}$ is $1 - \lambda$. The firm submits the two sets of environmental qualities and prices such as $(\bar{q}, \bar{P}(q))$, and $(\underline{q}, \underline{P}(q))$ from $q \in \{\bar{q}, \underline{q}\}$ and $P(q) \in \{\bar{P}(q), \underline{P}(q)\}$ to the consumers who can choose only one set of environmental qualities and prices. The regulator sets discriminatory policy instruments based on information of the environmental qualities submitted by the firm, as if he/she knew the hidden characteristic of the agents.[2] This behavior will reflect the current environmental regulatory practice in the market. For example, private firms are obliged to report environmental qualities

[1] Tirole (1988) uses the term 'tariff' for the price submitted by the monopoly under price discrimination.

[2] This behavior of the regulator is examined in Baron (1985).

in their products to the regulator, while they have abilities to gather information of consumers and to design incentive schemes.[3]

The regulator determines the rates of the tax or subsidy on environmental qualities for the purpose of achieving the socially optimal level of environmental qualities. The discriminatory policy instruments are given by $\bar{s}\bar{q}$ for type $\bar{\theta}$ and $\underline{s}\underline{q}$ for type $\underline{\theta}$. $\bar{s}$ and $\underline{s}$ denote the rates of the policy instruments. If the rate is positive, the policy instrument means a subsidy. If the rate is negative, the policy instrument implies a tax. The menu submitted to the two types of consumers is denoted by $\{(\bar{q}, \bar{P}, \bar{s}), (\underline{q}, \underline{P}, \underline{s})\}$.

The utility function $\bar{V}$ for type $\bar{\theta}$, and $\underline{V}$ for type $\underline{\theta}$ are as follows:

$$\bar{V}(\bar{q}, \bar{P}, \bar{s}) \equiv \bar{\theta}\bar{q} - \bar{P} + E + \bar{s}\bar{q}, \tag{1}$$

$$\underline{V}(\underline{q}, \underline{P}, \underline{s}) \equiv \underline{\theta}\underline{q} - \underline{P} + \underline{E} + \underline{s}\underline{q}, \tag{2}$$

where $E \equiv \gamma \cdot [\lambda\bar{q} + (1 - \lambda)\underline{q}]$ is economy-wide externalities.

Equation (1) expresses the utility function of higher-demand consumers and Eq. (2) expresses the utility function of lower-demand consumers. If the marginal effect of externalities γ is positive, E illustrates positive externalities. In this situation, the environmental qualities are connected to green products and leads to environmental improvement. Then, type $\bar{\theta}$ or a higher-demand consumer corresponds to an eco-friendlier consumer, and type $\underline{\theta}$ or a lower-demand consumer corresponds to a less eco-friendly consumer. On the other hand, if γ is negative, E illustrates negative externalities. In this situation, the environmental qualities are related to dirty products and results in environmental damage. Here, type $\bar{\theta}$ or a higher-demand consumer is less eco-friendly and type $\underline{\theta}$ or a lower-demand consumer is eco-friendlier. If $\gamma = 0$, there is no externality among the consumers, and the environmental qualities have no effect on environmental change. From the above discussion, θ should be interpreted as marginal preferences not only for consuming the environmental qualities, but also for contributing to environmental change.

We turn to characterize the private monopoly or the firm as principal in the incentive contract. The firm cannot identify the demand type of the consumers. Then, the expected profit function of the firm is given by:

$$\pi = \lambda[\bar{P} - C(\bar{q})] + (1 - \lambda) \cdot [\underline{P} - C(\underline{q})], \tag{3}$$

$$\text{where } C'(\bar{q}),\ C'(\underline{q}) \geq 0 \quad \text{and} \quad C''(\bar{q}), C''(\underline{q}) \geq 0\,.$$

$C(\bar{q})$ and $C(\underline{q})$ denote the strictly convex cost functions of the environmental qualities and are assumed to be differentiable with respect to the qualities.

Our model can reflect current manufacturing industries in which products are highly differentiated. Let us explain the behaviors of Japanese dominant automobile manufacturers with highly developed environmental technology and differentiated models. The manufacturers will not produce only perfect eco-friendly cars, which

[3] This obligational practice to report environmental qualities such as the emission level of NO_X or SO_X per product has been introduced generally in many industries.

drastically contribute to environmental improvement, even though they have already developed technology sufficient to produce perfect eco-friendly cars. Instead, the manufacturers will determine different levels of exhaust gas per car by considering consumers' environmental awareness. At the same time, they are obliged to report the emission levels per car. As a result, in the manufacturers' product lines, we find several types of eco-friendly cars such as electric, hybrid, and fuel-efficient compact cars. Through such an industrial practice, consumers' eco-friendliness could decide indirectly the level of environmental improvement.

3 Incentive contract with externalities

In this section, we analyze the firm's maximization problem, given the policy instruments. To avoid the agents' arbitrary actions, the firm should consider incentive compatibility (IC) and individual rationality (IR) constraints and submit the different combinations of the environmental qualities and prices for the different types of the consumers. We assume that nobody can change the submitted menu and the consumers cannot take any cooperative action. The IR constraints are:

$$\bar{V}(\bar{q}, \bar{P}, \bar{s}) \geq \bar{U}_0 + E, \quad \text{and} \quad \underline{V}(\underline{q}, \underline{P}, \underline{s}) \geq \underline{U}_0 + E,$$

where $\bar{U}_0$ and $\underline{U}_0$ are the consumers' reservation utilities set to zero and E is the economy-wide externalities which are given to each consumer since the consumers are negligible in the sense that they are measured as zero. The IC constraints are:

$$\bar{V}(\bar{q}, \bar{P}, \bar{s}) \geq \underline{V}(\underline{q}, \underline{P}, \underline{s}) \quad \text{and} \quad \underline{V}(\underline{q}, \underline{P}, \underline{s}) \geq \bar{V}(\bar{q}, \bar{P}, \bar{s}).$$

From the usual procedure, the IR constraint for the lower type and the IC constraint for the higher type are shown to be binding. From the IR constraint for the lower type, we obtain:

$$\begin{aligned} \underline{V} = \underline{\theta}\underline{q} - \underline{P} + E + \underline{s}\underline{q} \geq 0 + E \\ \Leftrightarrow \underline{P} \leq \underline{\theta}\underline{q} + \underline{s}\underline{q}. \end{aligned} \tag{4}$$

From the IC constraint for the higher type, we obtain:

$$\bar{\theta}\bar{q} - \bar{P} + E + \bar{s}\bar{q} \geq \bar{\theta}\underline{q} - \underline{P} + E + \underline{s}\underline{q}. \tag{5}$$

These two conditions satisfy all the IR and IC constraints.[4] From (4) and (5), we obtain:

$$\underline{P} = (\underline{\theta} + \underline{s}) \cdot \underline{q}, \tag{6}$$

[4] We prove that Eqs. (6) and (7) satisfy the IR constraint for the higher type and the IC constraint for the lower type in Appendix 1.

$$\bar{P} = (\bar{\theta} + \bar{s}) \cdot \bar{q} - (\bar{\theta} - \underline{\theta}) \cdot \underline{q}. \tag{7}$$

The term $(\bar{\theta} - \underline{\theta}) \cdot \underline{q}$ in (7) corresponds to information rent. Note that the prices submitted by the firm have no term including the economy-wide externalities, because the firm compensates the externalities and does not carry them onto the prices.

By substituting Eqs. (6) and (7) into Eq. (3), we obtain the conditions that the optimal qualities $(\bar{q}^M, \underline{q}^M)$ satisfy:

$$C'(\bar{q}^M) = \bar{\theta} + \bar{s}, \tag{8}$$

$$C'(\underline{q}^M) = \underline{\theta} + \underline{s} - \frac{\lambda}{1-\lambda}(\bar{\theta} - \underline{\theta}). \tag{9}$$

This result reflects a standard adverse selection or nonlinear pricing model in Tirole (1988). When no policy instrument is deployed;$\bar{s} = \underline{s} = 0$, the firm supplies the environmental quality optimally for the higher-demand consumer; however, it is less for the lower-demand consumer due to information rent to limit the rent that accrues to the higher type. Based on this result, we investigate necessary policy instruments in the next section.

4 The choice of policy instruments

In this section, policy instruments set by the regulator are examined. The regulator sets the policy instruments on the environmental qualities submitted by the private monopoly for the purpose of achieving socially optimal environmental qualities. As is already discussed, the regulator can set the policy instruments based on information offered by the firm. Firstly, we derive the conditions for the socially optimal levels of the environmental qualities and characterize the discriminatory policy instruments. Secondly, we derive a uniform policy instrument and reveal that social welfare loss is caused by the uniform policy instrument.

The social welfare function W^0 is defined as a sum of the consumers' utilities and the firm's profit with no policy instrument or $\bar{s} = \underline{s} = 0$. The maximization problem of the social welfare with respect to the environmental qualities is described by:

$$\begin{aligned} \underset{\bar{q},\underline{q}}{\text{Max}}\ W^0 &= \lambda\bar{V} + (1-\lambda) \cdot \underline{V} + \pi - \lambda\bar{s}\bar{q} - (1-\lambda)\underline{s}\underline{q} \\ &= \lambda \cdot [\gamma\bar{q} + \bar{\theta}\bar{q} - C(\bar{q})] + (1-\lambda) \cdot [\gamma\underline{q} + \bar{\theta}\underline{q} - C(\underline{q})\,]. \end{aligned} \tag{10}$$

Then the first-best solution $(\bar{q}^*,\ \underline{q}^*)$ satisfies[5]:

[5] These first-order conditions satisfy the second-order conditions because of the convexity of the cost functions.

$$\frac{\partial W^0}{\partial \bar{q}} = \lambda[\gamma + \bar{\theta} - C'(\bar{q}^*)] = 0, \tag{11}$$

$$\frac{\partial W^0}{\partial \underline{q}} = (1-\lambda)[\gamma + \underline{\theta} - C'(\underline{q}^*)] = 0. \tag{12}$$

Therefore, we obtain:

$$C'(\bar{q}^*) = \gamma + \bar{\theta}, \tag{13}$$

$$C'(\underline{q}^*) = \gamma + \underline{\theta}. \tag{14}$$

Equations (13) and (14) are the conditions for the socially optimal environmental qualities. By equating the social optimal conditions in (13) and (14) with the firm's profit maximal conditions in (8) and (9), we obtain the values of the discriminatory policy instruments to achieve the socially optimal qualities for each type of consumers as:

$$\bar{s}^* = \gamma, \tag{15}$$

$$\underline{s}^* = \gamma + \frac{\lambda}{1-\lambda}(\bar{\theta} - \underline{\theta}). \tag{16}$$

Equation (15) illustrates that the rate of the optimal discriminatory policy instrument for the higher type coincides with the traditional Pigouvian result. The intuition of this result is as follows: The higher type is supplied optimally under the incentive scheme, while the lower type is supplied less than the socially optimal level due to information rent. Thus, the regulator needs to compensate more for the lower type. We summarize the characteristics of the discriminatory policy instruments in Propositions 1 and 2, comparing the values in Eqs. (15) and (16) and contemplating the sign of γ.

Proposition 1 If positive externalities (i.e., $\gamma > 0$) exist, subsidies should be set for both demand types of the consumers for the purpose of achieving the socially optimal levels of the environmental qualities. However, the rate of the subsidy for lower-demand (less eco-friendly) consumers is higher than that for higher-demand (eco-friendlier) consumers by $\frac{\lambda}{1-\lambda}(\bar{\theta} - \underline{\theta})$.

Proof See Appendix 2

Proposition 1 illustrates the characteristic of the discriminatory policy instruments for positive externalities caused by green products. Our analysis suggests that a higher rate of the subsidy should be set for less eco-friendly consumers.

Table 1 Externalities, products, and discriminatory policy instruments

Externalities (products)/ types of consumers	Positive ($\gamma > 0$) (green products)	Negative ($\gamma < 0$) (dirty products)	No externalities ($\gamma = 0$) (neutral products)
Higher-demand consumers	Lower rate of subsidy	Higher rate of tax	No policy
Lower-demand consumers	Higher rate of subsidy	Lower rate of tax or subsidy	Subsidy

This policy arrangement contradicts the current tax benefit policy in the Japanese automobile industry, in which the higher rates of the tax benefits for eco-friendlier products are introduced. On the other hand, this retrogressive subsidization, which offers less monetary payoffs for eco-friendlier consumers, might reflect a desirable policy instrument that alleviates crowding out effects on eco-friendly behaviors.[6] Ackert et al. (2007) show that individuals being willing to pay more tax or accept less subsidy when efficiency is improved by tax or subsidy policies. This study could infer that retrogressive subsidization can be desirable for eco-friendly motivation because it improves simultaneously social efficiency and environmental situations. Shogren (2012) suggests, however, that a further research is required to know whose behavior is likely to be crowded out by a given environmental policy instrument. Hence, comprehensive effects of retrogressive subsidization for eco-friendly behaviors should be further examined by scrutinizing prosocial behaviors as eco-friendly behaviors.

Proposition 2 If negative externalities (i.e., $\gamma < 0$) exist, a tax for less eco-friendly (higher-demand) consumers is necessary for achieving the socially optimal environmental quality. On the other hand, for eco-friendlier (lower-demand) consumers, a subsidy should be introduced when $-\frac{\lambda}{1-\lambda}(\bar{\theta} - \underline{\theta}) < \gamma < 0$ is satisfied.

Proof See Appendix 2

Proposition 2 characterizes the necessary policy arrangement for achieving the socially optimal environmental qualities, when negative externalities such as pollution or greenhouse effect by dirty products exist. Our analysis shows that there is a situation in which subsidization should be set for eco-friendlier consumers regardless of the existence of negative externalities. Moreover, it can be inferred that the optimal policy for eco-friendlier consumers should shift from a subsidy to a tax, as the level of negative externalities increases. This result contrasts with Bansal (2008) showing an optimal policy shifting from a tax to a subsidy, as the level of negative externalities increases. Table 1 summarizes the characteristics of the discriminatory policy instruments.

[6] See Banerjee and Schogren (2012) and Shogren(2012) for details.

We turn to deriving an optimal uniform policy instrument and the welfare loss caused by the uniform policy instrument. Uniform policy instruments are desirable in terms of fairness, but welfare losses caused by policy instruments could discourage fairness-seeking behaviors, as shown in experimental studies.[7] To derive an optimal uniform policy instrument, we follow the procedure to derive the optimal uniform Pigouvian tax in Barnett (1980). We set an uniform policy instrument $s = \bar{s} = \underline{s}$. Then we can obtain the social welfare function $W^U(\bar{q}^M(s), \underline{q}^M(s))$ which satisfies the optimal conditions for the environmental qualities in (8) and (9) as:

$$W^U = \lambda \cdot [\gamma \bar{q}^M(s) + \bar{\theta}\bar{q}^M(s) - C(\bar{q}^M(s))] + (1-\lambda) \cdot [\gamma \underline{q}^M(s) + \bar{\theta}\underline{q}^M(s) - C(\underline{q}^M(s))]. \tag{17}$$

The first-order condition to maximize W^U with respect to s is:

$$\begin{aligned} \frac{\mathrm{d}W^U}{\mathrm{d}s} &= \frac{\partial W^U}{\partial \bar{q}^M} \cdot \frac{\mathrm{d}\bar{q}^M}{\mathrm{d}s} + \frac{\partial W^U}{\partial \underline{q}^M} \cdot \frac{\mathrm{d}\underline{q}^M}{\mathrm{d}s} \\ &= \lambda[\gamma + \bar{\theta} - C'(\bar{q}^M(s))]\frac{\mathrm{d}\bar{q}^M}{\mathrm{d}s} + (1-\lambda)[\gamma + \underline{\theta} - C'(\underline{q}^M(s))]\frac{\mathrm{d}\underline{q}^M}{\mathrm{d}s} = 0. \end{aligned} \tag{18}$$

Substituting $s = \bar{s} = \underline{s}$ into Eqs. (8) and (9), we obtain:

$$C'(\bar{q}^M) = \underline{\theta} + s, \tag{19}$$

$$C'(\underline{q}^M) = \underline{\theta} + s - \frac{\lambda}{1-\lambda}(\bar{\theta} - \underline{\theta}). \tag{20}$$

Substituting (19) and (20) into (18), we get:

$$\frac{\mathrm{d}W^U}{\mathrm{d}s} = -\left[\lambda\frac{\mathrm{d}\bar{q}^M}{\mathrm{d}s} + (1-\lambda)\frac{\mathrm{d}\underline{q}^M}{\mathrm{d}s}\right] \cdot s + \gamma\left[\lambda\frac{\mathrm{d}\bar{q}^M}{\mathrm{d}s} + (1-\lambda)\right]\frac{\mathrm{d}\underline{q}^M}{\mathrm{d}s} + \lambda(\bar{\theta} - \underline{\theta})\frac{\mathrm{d}\underline{q}^M}{\mathrm{d}s} = 0, \tag{21}$$

where $\frac{\mathrm{d}\bar{q}^M}{\mathrm{d}s} = \frac{1}{c''(\bar{q}^M)} > 0$ and $\frac{\mathrm{d}\underline{q}^M}{\mathrm{d}s} = \frac{1}{c''(\underline{q}^M)} > 0$.

By calculating (21), we derive the optimal uniform policy instrument s^U as:

$$s^U = \gamma + \frac{\lambda(\bar{\theta} - \underline{\theta})\frac{\mathrm{d}\underline{q}^M}{\mathrm{d}s}}{\lambda\frac{\mathrm{d}\bar{q}^M}{\mathrm{d}s} + (1-\lambda)\frac{\mathrm{d}\underline{q}^M}{\mathrm{d}s}}. \tag{22}$$

7 See Kallbekken et al. (2011), Ackert et al. (2007) and Durante et al. (2014) for details.

Note that the optimal policy instrument as a rate of consumption tax/subsidy is equal to the marginal rate of externalities (i.e., $s^U = \gamma$), if there is no information rent (i.e., $\lambda(\bar{\theta} - \underline{\theta}) = 0$) in the right-hand side in (22). This result illustrates the traditional Pigouvian tax/subsidy formulation. To facilitate the calculation, we assume $C(q) = \frac{1}{2}cq^2 (c > 0)$. Then, we can rewrite s^U as:

$$s^U = \gamma + \lambda(\bar{\theta} - \underline{\theta}) = \lambda\bar{s}^* + (1 - \lambda)\underline{s}^*. \tag{23}$$

Equation (23) implies that the optimal uniform policy instrument is equal to the weighted average of the optimal discriminatory policy instruments. If positive externalities exist (i.e., $\gamma > 0$), the optimal uniform policy is always subsidization. On the other hand, if negative externalities exist (i.e., $\gamma < 0$) and information rent denoted by $\lambda(\bar{\theta} - \underline{\theta})$ is sufficiently small (large), taxation (subsidization) should be chosen.

Now, we derive the welfare loss brought by the uniform policy instrument. The difference between the social welfare under the optimal discriminatory policy, W^{D*}, and the social welfare under the optimal uniform policy W^{U*} is calculated as:

$$W^{D*} - W^{U*} = \frac{\lambda^3(\bar{\theta} - \underline{\theta})^2}{2c(1 - \lambda)} > 0. \tag{24}$$

The welfare loss increases as λ and $(\bar{\theta} - \underline{\theta})$ increase. It can be concluded that the discriminatory policy instrument is more desirable in terms of efficiency, while this instrument might discourage fairness-seeking motivation.[8]

5 Concluding remarks

We examined discriminatory policy instruments on consumption, when a private monopoly can differentiate environmental qualities and environmentally aware consumers behave differently under existing both positive and negative externalities. We discovered that a higher rate of subsidy should be set for less eco-friendly consumers for the purpose of achieving socially optimal environmental qualities when positive externalities exist. Moreover, we found that subsidization on dirty products is necessary for achieving a socially optimal level of qualities, when negative externalities are small enough.

When our model analyzed the incentive contract with a private firm, who submits environmental qualities and prices, and consumers, who are environmentally aware and cause externalities, it simplified the supplier's market structure and the relationship among consumers. More realistic models can be developed. Moreover, it will be necessary to discuss further actual effects of retrogressive subsidization on environmental behaviors in terms of fairness and incentives. These assignments remain to be investigated.

[8] This result differs from Kolstad (1987) suggesting that uniform regulation is more desirable than discriminatory regulation in terms of efficiency.

Appendix 1

We prove that Eqs. (6) and (7) are the necessary and sufficient conditions for satisfying the IR and IC constraints of the two types of consumers. Firstly, we prove that the IR constraint for a higher type $\bar{\theta}$ is satisfied at the optimum. The IR constraint for type $\underline{\theta}$ is:

$$\bar{V} = \bar{\theta}\bar{q}^* - \bar{P} + E + \bar{s}\bar{q}^* \geq 0 + E. \tag{25}$$

By substituting Eq. (7) into (25), (25) can be rewritten as:

$$\bar{V} = \bar{\theta}\bar{q}^* - (\bar{\theta} + \bar{s}) \cdot \bar{q}^* + (\bar{\theta} - \underline{\theta}) \cdot \underline{q}^* + \bar{s}\bar{q}^* \geq 0. \tag{26}$$

By calculating the right side of (26), we obtain:

$$(\bar{\theta} - \underline{\theta}) \cdot \underline{q}^*. \tag{27}$$

By assumption, (27) is always nonnegative. Thus, (25) is always satisfied. Next, we prove that the IC constraint for type $\underline{\theta}$ is satisfied with the optimal solution. We can write the IC constraint for type $\underline{\theta}$ as:

$$\underline{\theta}\underline{q}^* - \underline{P} + E + \underline{s}\underline{q}^* \geq \underline{\theta}\bar{q}^* - \bar{P} + E + \bar{s}\bar{q}^*. \tag{28}$$

By substituting (6) and (7), (28) can be rewritten as:

$$0 \geq (\underline{\theta} - \bar{\theta}) \cdot (\bar{q}^* - \underline{q}^*). \tag{29}$$

Equation (29) is always satisfied at the optimum. Therefore, Eq. (28) is always satisfied at the optimum. As a result, Eqs. (6) and (7) satisfy the IR and IC constraints for the two types of consumers.

□.

Appendix 2

We prove Proposition 1. By the assumptions of $\lambda \geq 0$, and $\bar{\theta} > \underline{\theta}$, $\frac{\lambda}{1-\lambda}(\bar{\theta} - \underline{\theta})$ in Eq. (16) is a positive value. This means that $\bar{s}^*$ and $\underline{s}^*$ are both positive values at the optimum. Since a positive value of s corresponds to a subsidy in our setting, the subsidy is a necessary instrument for both types for the purpose of achieving socially optimal qualities. We can get directly $\underline{s}^* - \bar{s}^* = \frac{\lambda}{1-\lambda}(\bar{\theta} - \underline{\theta}) > 0$. Hence, the value of $\underline{s}^*$ for a lower-demand consumer is higher than $\bar{s}^*$ for a higher-demand consumer.

□.

Next, we prove Proposition 2. From the condition of $\gamma < 0$, $\bar{s}^*$ in (15) is always negative. Hence, taxation is always chosen for the higher-demand consumer. The value of $\underline{s}^*$ in (16) is positive, which implies that the necessary policy instrument is a subsidy, if $-\frac{\lambda}{1-\lambda}(\bar{\theta} - \underline{\theta}) < \gamma < 0$. On the other hand, the value of $\underline{s}^*$ in (16) is negative, which implies that the necessary policy instrument is a tax, if $\gamma < -\frac{\lambda}{1-\lambda}(\bar{\theta} - \underline{\theta})$.

□.

References

Ackert FL, Martinez-Vazquez J, Rider M (2007) Social preferences and tax policy design: some experimental evidence. Econ Inq 45(3):487–501
Aggarwal RM, Lichtenberg E (2005) Pigouvian taxation under double moral hazard. J Environ Econ Manag 49:301–310
Ariely D, Bracha A, Meier S (2009) Doing good or doing well? Image motivation and monetary incentives in behaving prosocially. Am Econ Rev 99(1):544–555
Banerjee P, Schogren FJ (2012) Material interests, moral reputation and crowding out species protection on private land. J Environ Econ Manag 63:137–149
Bansal S (2008) Choice and design of regulatory instruments in the presence of green consumers. Resour Energy Econ 30:345–368
Bansal S, Gangopadhyay S (2003) Tax/subsidy policy in the presence of environmentally aware consumers. J Environ Econ Manag 45(3):33–55
Barnett AH (1980) Pigouvian tax rule under monopoly. Am Econ Rev 70(5):1037–1041
Baron DP (1985) Noncooperative regulation of a nonlocalized externality. Rand J Econ 16(4):553–568
Baron DP, Myerson RB (1982) Regulating a monopolist with unknown costs. Econometrica 50:911–930
Cremer H, Thisse J-F (1999) On the taxation of polluting products in a differentiated industry. Eur Econ Rev 43:575–594
Durante R, Putterman L, van der Weele J (2014) Preferences for redistribution and perception of fairness: an experimental study. J Eur Econ Assoc 12(4):1059–1086
Kallbekken S, Kroll S, Cherry LT (2011) Do you not like Pigou or do you not understand him? Tax aversion and revenue recycling in the lab. J Environ Econ Manag 62:53–64
Kolstad CD (1987) Uniformity versus differentiation in regulating externalities. J Environ Econ Manag 14:386–399
Lombardini-Riiponen C (2005) Optimal tax policy under environmental quality competition. Environ Resour Econ 32:317–336
Matsukawa I (2012) The welfare effects of environmental taxation of a green market where consumers emit a pollutant. Environ Resour Econ 52:87–107
Morage-Gonzalez JL, Padron-Fumero N (2002) Environmental policy in a green market. Environ Resour Econ 22:419–447
Mussa M, Rosen S (1978) Monopoly and product quality. J Econ Theory 18:301–317
Shogren J (2012) Behavioural economics and environmental incentives, OECD environmental working papers no. 49
Thomas A (1995) Regulating pollution under asymmetric information: the case of industrial wastewater treatment. J Environ Econ Manag 28:357–373
Tirole J (1988) The theory of industrial organization. MIT Press, Cambridge