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Green Certification, Heterogeneous Producers, and Green Consumers: A Welfare Analysis of Environmental Regulations

by

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Abstract: We develop a vertical differentiation model to analyze welfare implications of environmental policies in a competitive market with production and consumption heterogeneity. Consumers with heterogeneous preferences choose between non-green and certified green products, while producers with heterogeneous production costs decide whether to engage in green production. In order for green products to be recognized by consumers, producers must join a green club. Key findings are summarized as follows. (i) The number of green producers, environmental standard, and overall welfare under the market solution are all socially sub-optimal. (ii) The introduction of a subsidy policy for greener production and standards is shown to increase social welfare, but is not Pareto optimal. (iii) A dual policy, which combines abatement subsidizes for a greener production standard and a tax charge for green certification, is shown to be the Pareto-optimal outcome.

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JEL codes: Q58, D41, D71, H23

1. Introduction

Environmental awareness has grown drastically over the last several decades. As concerns have developed, consumer taste and preference in the products they purchase have shifted. Preferences for greener products have become ubiquitous; as such the demand for green products continues to expand. This demand is what has driven the market for green products (Michels 2008). Hamilton and Zilbermann (2006), in reference to a marketing intelligence service, [1] indicate that "green products account for approximately 9% of new-products introductions in the United States." Furthermore, consumer spending on LOHAS (lifestyles of Health and Sustainability) related products has already eclipsed $250 billion according to LOHAS journal (Dosey 2010).

However, consumer preference for green products is far from uniform. The typical approach incorporates consumer heterogeneity either by location (e.g., Kurtyka and Mahenc 2011; Conrad 2005) or by the level of green preference (e.g., Amacher et al. 2004). Much of the contemporary literature analyzing green preferences assumes that consumers can directly observe a producer's emissions and the benefits from clean production, thus making government intervention straightforward.

The introduction of new "green" products adds additional utility for consumers with green preferences, but claims made by the producers of green products often come into question. Similar to credence products discussed by Baron (2011), consumers do not have access to the necessary information about green products to verify the claims of producers. These asymmetries in the market for green products have led to the development of third party verification or certification, by so called "green clubs." In the market where product quality information is asymmetric, green clubs represent an important tool for both green consumers and producers. Producers that voluntarily join green clubs are subjected to verification and additional standards. This differs from voluntary agreements and standards discussed by Segerson and Miceli (1998), which are proposed as an alternative to regulation or legislation.

But what benefits do producers receive from certification? As noted by Potoski and Prakash (2005), club participation is effective because "its broad positive standing with external

[1] In their paper, Hamilton and Zilbermann (2006) refer to ProductScan Online, Marketing Intelligence Service Ltd. 1999.

audiences provides a reputational benefit…”[2] Basically, “…producers can differentiate their product from those of producers whose products do not meet the standard” (Baron 2011). As a result, socially responsible producers and their verified green products are capable of gaining a positive reputation and a premium in an expanding market. As green products have become more prevalent, so to have third party monitors. The EPA lists dozens of programs or “clubs” to verify and promote use of clean methods of production (EPA 2014).

New studies have begun evaluating green products when consumers are unable to directly identify a producer’s environmental attributes. To inform consumers, producers require certification either by using eco-labeling or joining green clubs. These certifications have been evaluated under various market structures, such as product types (Hamilton and Zilberman 2006), available technologies (Mason 2006), and in the context of environmental innovation (Dosi and Moretto 2001). While it has been shown that emission standards may not necessarily increase social welfare (Moraga-Gonzalez and Pardon-Fumero 2002), others such as Grolleau et al. (2007) have analyzed the strategic aspect of imperfect certification. Mason (2011) assumes certification is a noisy test with potentially incorrect outcomes, while van’t Veld and Kotchen (2011) evaluate several certification types and discuss how imperfect monitoring can affect market outcomes and product standards using implicit functions.

Examining producers with different costs for abatement or environmental friendliness is also commonly studied in the environmental literature. Doni and Ricchiuti (2013); Moraga-Gonzalez and Pardon-Fumero (2002); and Amacher et al. (2004) analyze how heterogeneous costs affect market outcomes in the presence of heterogeneously concerned consumers. They focus on two producers (high and low cost), and allow consumers a range of preferences for the producers products. Additional work by Lombardini-Riipinen (2005) shows that socially optimal outcome can be achieved using an emission tax. While David and Sinclair-Desgagne (2005) examine a variety of regulatory of instruments, including voluntary agreements.[3] Our study complements these previous contributions, by expanding the analyzing to competitive markets with heterogeneous producers and evaluating the influence of green clubs. While this may apply to several industries, it is particularly relevant for agricultural producers, which are

[2] This is in reference to ISO 14001, a green club with over 1,500 members in the United States. See Potoski and Prakash (2005).

[3] Since participation in a green club is purely voluntary, club admittance by a firm is essentially subjection to a “voluntary agreement.”

heterogeneous in nature.

Our goal is to examine the heterogeneity of producers within competitive markets with green clubs, so we can expand the policy implications. Similar to Ben Youssef and Lahmandi-Ayed (2008); Baksi and Bose (2006), we focus our analysis on issues related to the use of eco-certification in the presence of heterogeneous consumers. Our contribution is important for several reasons. First, environmental friendliness is not limited to duopoly or even the oligopoly case. Second, a producer's abatement costs and profits are certainly not uniform, especially when a market is served by heterogeneous producers with differential costs of production. Third, we can evaluate how eco-certification and environmental regulation affect the endogeneity of market structure in terms of the number of green and non-green producers. Specifically, our analysis allows for the exit of producers from a market.

Our approach shows that the number of green producers, the level of environmental standard, and the level of overall welfare under the competitive market solution are all socially sub-optimal. This leads us to examine what are possible measures by government to correct the Pareto sub-optimality. We find that the introduction of a subsidy policy for greener production or a tax charge for green certification by a club (which we refer to as an "eco-certification tax") generates a positive effect on social welfare. Nevertheless, this welfare-improving policy is not Pareto optimal(i.e., the second-best outcome). This prompts us to analyze the efficacy of dual policy instruments that combine subsidizes for a greener production standard and an eco-certification tax. We show that this dual-tool policy helps achieve the first-best or Pareto-optimal outcome in environmental standards and overall welfare.

The remainder of this paper is structured as follows. In Section 2, we lay out the analytical framework for heterogeneous consumers, heterogeneous producers, and green clubs. We then derive the equilibrium outcome under perfect competition. In Section 3, we examine the socially optimal outcome, which serves as the benchmark to show the Pareto sub-optimality of the market equilibrium. In Sections 4 and 5 we focus our analyses on welfare implications of two environmental policies: one involves a single-tool policy on greener production or certification, and the other involves a double-tool policy of both greener production subsidies and a green certification tax. Section 6 relaxes some assumptions and discusses additional extensions of our analysis. Section 7 concludes.

2. The Analytical Framework

We beginning our analysis by considering green production as a two-stage game in the absence of government intervention.[4] This allows us to examine the equilibrium outcome of the game under the market solution. In the first stage, a green club determines the certification standard that a producer's product should meet in order for the producer to be qualified as a member. Once the green product standard is set, the second stage occurs, and producers determine if they should join the green club and produce certified green products.

To characterize market interaction between producers and consumers, we first discuss the preferences of consumers.

2.1 *Heterogeneous Consumers*

Using a vertical product differentiation framework, we assume that consumers with heterogeneous preferences are uniformly distributed between zero and one on a market line. We determine the consumer's location on the line by using the strength of their green preference. For analytical simplicity, we assume that each consumer purchases one unit of a product, whether it is green or non-green.[5] The preference function of a consumer located at x, where $x \in [0,1]$, is specified as follows:

$$U(x) = \begin{cases} v + (1-x)\tau\theta + \beta\psi - (P + P_e) & \text{if purchasing green product;} \\ v + \beta\psi - P & \text{if purchasing non-green product;} \\ \beta\psi & \text{if no product is purchased.} \end{cases} \quad (1)$$

where v represents the utility from the non-green product, P represents market price of the non-green product, P_e represents the mark-up for the green product, θ is the abatement or "environmental friendliness" of the green product, and τ scales the "warm glow" or utility from consuming the green product.[6] Therefore, the degree of a consumer's environmental

[4]Another stage of policy implementation is added when we evaluate regulatory implications.

[5]We assume a full covered market where each consumer purchases either a green or non-green product, which is considered as a "necessity" to all consumers, but our results are unaffected by the coverage of the market. For studies of a full covered market using a vertical product differentiation setting see, for example, Cremer and Thisse (1994), Crampes and Hollander (1995), Wauthy (1996), Ecchia and Lambertini (1997), Maxwell (1998), and Andaluz (2000).

[6]Here we assume that θ and τ are not correlated. However, Teisl et al.(2002) suggest that one aim of green labels is to "educate consumers about the environmental impacts of the product's manufacture, use, and disposal, thereby leading to a change in purchasing behavior…" Thus, it's possible that higher standards could actually shift user utility of green products. However, we leave this for a future study. The notion of warm glow is borrowed from

conscientiousness in purchasing the green product is represented by $(1-x)\tau\theta$. This means that consumers close to zero (one) place a high (low) value on green product. As in van't Veld and Kotchen (2011), we use β to capture the benefit to the public of having one unit of the green product. The overall benefit (i.e., positive externality) to the public of the green product market is then measured by $\beta\psi$, where $\psi = n\theta$ and n is the total quantity of the green product sold in the market. Note that the value of n remains to be determined in equilibrium.

Setting the utility from green consumption equal to the utility from non-green consumption, we have from (1) that $v+(1-x)\tau\theta+\beta\psi-(P+P_e)=v+\beta\psi-P$, which implies that the marginal green consumer or the quantity of the green product demanded (n_D) is:

$$n_D = \tilde{x} = 1-\frac{P_e}{\theta\tau}. \tag{2}$$

The number of green consumers is represented by the interval $[0,\tilde{x}]$, while the number of non-green consumers is $[\tilde{x},1]$.[7] Since our focus is on green products within a competitive marker we assume that $v = P$.[8] Next, we discuss the production decisions of producers.

2.2 *Heterogeneous Producers and Green Clubs*

Similar to Mason (2011), we examine the scenario where consumers cannot identify a producer's environmental friendliness, thus producers must join a club in order for environmental friendliness to be recognized. The club provides information to consumers by monitoring its members' production methods. As a result, clubs face multiple objectives, as noted by Potoski and Prakash (2005) in their discussions about green clubs and voluntary programs:

"Effective clubs must overcome two collective action problems successfully to provide a broader public benefit. First, they must induce sufficient members to take on the costs of joining the club. They can do so by providing members a nonrival but potentially excludable reputational benefit. Second, to produce public benefits, effective clubs must ensure members continue to adhere to club standards" (p. 246).

To represent the club's operating costs, we borrow from van't Veld and Kotchen (2011) and assume that the cost of managing a green club increases with the number of member

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Andreoni (2006).

[7] As the number of consumers is normalized to one, we have $0 \le 1-(P_e/\theta\tau) \le 1$, which implies that $\theta\tau \ge P_e \ge 0$.

[8] Since $v = P$ consumer surplus is unaffected by the quantity of non-green products purchased.

producers, but we explicitly represent club costs, and assume they are quadratic in the number of members: $Cl(\tilde{y}) = \gamma\tilde{y}^2$, where $\tilde{y}$ is the number of producers that join the club. The club's costs thus represent the expenses of having products inspected and certified. Since costs are shared equally among all member producers, each individual's membership fee is $\gamma\tilde{y}.$ As a result, the membership fees received by the club are equal to the club's operating costs.

To reflect the heterogeneity of producers, we consider a case similar to Fischer and Lyon (2014),where producers are uniformly distributed according to their differing marginal costs of production. Similar to Timmer (1971), we assume that each producer produces one unit of output. Each producer decides whether to use green or non-green methods to produce their output. Following Lombardini-Riipinen (2005) and Garcia-Gallego and Georgantzis (2009), we further consider that abatement associated with the green product is quadratic in cost. The profit function for an arbitrary producer $y \in [0,1]$ is then represented by:

$$\Pi(y) = \begin{cases} P + P_e - (c + y\varepsilon\theta^2 + \gamma\tilde{y}) & \text{if producing a green product in a club;} \\ P - c & \text{if producing non-green product.} \end{cases} \quad (3)$$

where c represents the marginal cost of non-green production, and ε represents marginal cost of increasing a products' cleanliness. We assume that producers that are more efficient (or have higher Ricardian rents) also have lower abatement costs. The market is competitive, but all producers have non-negative profits with the non-green product, so $P = c.$[9] By equating the green product profit with the non-green profit, we can discern the marginal producer indifferent to either production type. We have from equation (3) that $P + P_e - (c + y\varepsilon\theta^2 + \gamma\tilde{y}) = P - c.$ Solving the equation gives the marginal green producer,[10]which also defines the quantity of the green product supplied (n_S):

$$n_S = y = \frac{P_e}{\varepsilon\theta^2 + \gamma}. \quad (4)$$

Thus the number of green producers is represented by the interval [0, $\tilde{y}$], while the number of non-green producers is $[\tilde{y},1]$.[11]

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[9] Since $P = c$ producer surplus is unaffected by the quantity of non-green products sold, and the coverage of the non-green market is no impact on our results.

[10] Note that the marginal green firm, y, has the property: $y = \tilde{y}.$

[11]We have the additional restriction that $0 \le P_e / (\varepsilon\theta^2 + \gamma) \le 1,$ which implies that $0 \le P_e \le \varepsilon\theta^2 + \gamma.$

2.3 *Green Club Objective*

There are also a variety of potential manager entities of the club with a diverse set of objectives: industrial group maximizing member profits, government maximizing social welfare, or environmentalist clubs maximizing environmental protection. As previously discussed, a club is likely to face multiple objectives simultaneously. To gain validity a club must emphasize product differentiation (as discussed by Baron 2011), thus a club must set and enforce higher standards. In addition, an important aspect of a green club is that they change perception, since eco-labels bring awareness to green products (Rahbar and Wahid 2001). As noted by Teisl et al. (2002), "… one aim of eco-labels is to educate consumers about the environmental impacts of the product's manufacture, use, and disposal, thereby leading to a change in purchasing behavior…." For this reason we assume that a club will provide trustworthy or "perfect" environmental information about its member,[12] but this also means that an effective green club will reach as many consumers as possible. At the same time, a profit maximizing producer will not join a club unless there is sufficient demand for a green product. For that reason, we assume that the club maximizes its standard while maintaining an equilibrium in the green product market.

Obviously, if producers cannot sell their green product they have no incentive to pay for club membership; similarly if a shortage of the green product exists, clubs will seek more members or higher standards. Without sufficient supply, the club's exposure is limited, thus undermining the clubs objective of rising awareness as discussed by Lehtonen (1997).Therefore, we believe in a competitive market our club objective more closely represents a green NGO club's objective when compared to a club with only an environmental or profit objective. In the context of a "purely" environmental or profit objective within a competitive market, the result is likely a niche market with extremely high standards or prices, serving few consumers and having very little impact socially. Therefore, our modeling coincides with the incentives clubs and producers will realistically face.[13]Specifically, for the producers it requires both a green price premium ($P_e \geq y\varepsilon\theta^2 + \gamma y$) and sufficient demand for the green product ($n \geq \tilde{y}$).[14]

[12] See Bonroy and Constantatos (2008) for further discussions about perfect and imperfect labeling.
[13]For analysis on different clubs and variety of objectives with homogenous firms see van't Veld and Kotchen (2011). Additional club objectives can be examined in our structure, however, our focus is policy and welfare implication, thus we leave that topic for future study.
[14] In order for a club to operate, i.e., $n > 0$, the value of n should satisfy the following condition:

2.4 ***Market Solution with a Green Club***

Consider the simple case in which the green club sets an optimal cleanliness standard (θ) for the purpose of reaching as many environmentally conscientious consumers as possible such that $n_D = n_S$ in the competitive market. In equilibrium, the quantity of a green product demanded is equal to that of the green product produced.[15] Denoting n in the subsequent analysis as the *equilibrium* quantity of the green product sold, we have from (2) and (4) that $n_D = n_S = n$, that is,

$$\frac{\theta\tau - P_e}{\theta\tau} = \frac{P_e}{\varepsilon\theta^2 + \gamma}. \tag{5}$$

This implies that the equilibrium premium for the green product satisfies the following condition:

$$P_e = \frac{\tau\theta(\varepsilon\theta^2 + \gamma)}{\theta(\varepsilon\theta + \tau) + \gamma}. \tag{6}$$

Equation (6) shows that there is a "demand effect" as discussed by Bonroy and Constantatos (2014), where a higher standard increasing consumer's willingness-to-pay, which benefits producer's with lower abatement costs. Substituting P_e from (6) back into n_D from (2) yields

$$n = \frac{\tau\theta}{\theta(\varepsilon\theta + \tau) + \gamma}. \tag{7}$$

The cleanliness standard that maintains market equilibrium $(n_D = n_S)$ can be identified by taking the first-order condition (FOC) for the club with respect to the level of environmental friendliness θ. Based on n in (7), the problem facing the club is to solve the following problem:

$$\underset{\{\theta\}}{\text{Max}}\ n = \frac{\tau\theta}{\theta(\varepsilon\theta + \tau) + \gamma}.$$

Solving for the optimal standard set by the green club (denoted by the superscript "*GC*") yields

$$\theta^{GC} = \sqrt{\frac{\gamma}{\varepsilon}}. \tag{8}$$

Substituting θ^{GC} from (8) back into n in (7), we have the equilibrium number of green producers in the market as:

$0 \le \theta\tau/(\varepsilon\theta^2 + \tau\theta + \gamma) \le 1$, which implies that $-(\gamma/\gamma) \le \theta^2$ or $\theta > 0$.

[15] The number of green products consumed is $n = \min\{\tilde{x}, \tilde{y}\}$, where $\tilde{y}$ is the number of green products produced, therefore in equilibrium $n = \tilde{x} = \tilde{y}$.

$$n^{GC} = \frac{\tau}{(\tau + 2\sqrt{\gamma\varepsilon})}. \tag{9}$$

It follows immediately from (9) that $0 < n^{GC} < 1$. Similarly, we substitute θ^{GC} from (8) into (6) to identify the green product premium:

$$P_e^{GC} = \frac{2\tau\gamma}{\tau + 2\sqrt{\gamma\varepsilon}}. \tag{10}$$

Using θ^{GC} in (8) we obtain the following comparative-static derivatives:

$$\frac{\partial\theta^{GC}}{\partial\tau} = 0,\ \frac{\partial\theta^{GC}}{\partial\varepsilon} = -\frac{\sqrt{\gamma\varepsilon}}{2\varepsilon^2} < 0, \text{and} \frac{\partial\theta^{GC}}{\partial\gamma} = \frac{1}{2\sqrt{\gamma\varepsilon}} > 0. \tag{11}$$

From (11), there are several interesting observations. First, consumer's cleanliness preference does not influence the club standard. This could be interpreted as consumer's ability to encourage the existence of a standard, but not to influence the level. This may seem odd at first, but if we assume that green consumer would prefer all their products be clean, green clubs should be observed in every industries. However, green products will only be brought to market if producers can remain profitable while providing the products. All this depends producers' costs, so higher environmental cleanliness or club costs determine whether a producer is subject itself to the standard.

Next, from n^{GC} in (9), we obtain:[16]

$$\frac{\partial n^{GC}}{\partial\tau} > 0,\ \frac{\partial n^{GC}}{\partial\varepsilon} < 0,\ \text{and}\ \frac{\partial n^{GC}}{\partial\gamma} < 0. \tag{12}$$

The signs in equations (12) come as no surprise. As preferences for green products increase so does club participation. For producers, as the club membership or abatement costs increase, it disincentives club membership for marginal producers.

Lastly, from P_e^{GC} in (10), we obtain:[17]

$$\frac{\partial P_e^{GC}}{\partial\tau} > 0,\ \frac{\partial P_e^{GC}}{\partial\varepsilon} < 0,\ \text{and}\ \frac{\partial P_e^{GC}}{\partial\gamma} > 0. \tag{13}$$

Equations (13) show some interesting results with regards to the green price. First, as club

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[16] It will be shown that in order for the club to exist and have members the inequality $\tau > 2\sqrt{\varepsilon\gamma}$ must hold. Detailed expressions for the comparative-static derivatives in (12) can be found in Appendix A-1.

[17] Detailed expressions for the comparative-static derivatives in (13) can be found in Appendix A-2.

membership fees rise, the green price premium increases. However, when abatement costs increase, the green price premium decreases. The reason being that increasing abatement costs leads to lower standards being set by the club which reduces the level of product differentiation between green and non-green products. As a consequence, green price premium decreases. This, combined with our previous result, means that greater consumer preferences for a green product do not result in higher cleanliness standards set by the club, but instead affects the price of the green products.

With all the results from the above comparative statics, we establish the first proposition:

PROPOSITION 1. *In an economy in which consumers choose between green and non-green products and heterogeneous producers may join a green club in order for environmental friendliness to be recognized(through green product certification), we have the following results:*

(i) *An increase in τ, the degree of consumers' environmental conscientiousness, increases both the quantity and price of the green product sold in the market. But the optimal level of environmental standard set by the green club is unaffected by τ.*

(ii) *An increase in ε, the cost of abatement, reduces the quantity and price of the green product, while decreasing the green product's standard.*

(iii) *An increase in γ, the club membership cost, raises the green product's standard and price, but lowers the quantity of the green product sold.*

3. Evaluating the Market Solution from the Social Welfare Perspective

In this section, we derive the social welfare measures for the market presented in the above sections. This allows us to calculate the benefits derived from the market solution with a green club and compare it to the social planner's solution.[18] A welfare comparison between the alternative scenarios allows us to identify whether the market solution can maximize social welfare, and help determine the regulatory role of the government (if any).

3.1 *Social Welfare in the Market Solution*

We begin with the calculation of consumer benefits. Note that $\beta\psi$ is the external benefit to the society from the sale of the green product, where $\psi = n\theta$. Integrating over all consumers

[18]In order for the club to be operating we require that $\theta > 0$ and $n > 0$.

buying either green or non-green products, the consumer surplus measure is given by

$$CS = \int_0^x [v + (1-x)\tau\theta + \beta\psi - (P + P_e)]dx + \int_x^1 (v + \beta\psi - P)dx.$$

In equilibrium, the quantity of green product sold (n) is equal to the number of green consumer (x). Using the competitive market property that the non-green product price is equal to its value or $P = v,$ we simplify the above CS expression to be[19]

$$CS = \beta\theta n + \frac{\theta\tau x(2-x)}{2} - P_e x. \qquad (14)$$

The consumer surplus measure in (14) is broken up into three terms: public green benefit, private green benefit, and green premium, respectfully.

Similarly, integrating over all producers producing either green or non-green products, the producer surplus measure is given by

$$PS = \int_0^y (P + P_e - (c + y\varepsilon\theta^2 + \gamma y))dy + \int_y^1 (P - c)dy.$$

As before, incorporating the competitive market property associated with the non-green product that its price is equal to the cost of production for the marginal producer, $P = c,$ we simplify the above PS expression to be[20]

$$PS = P_e y - \frac{(\varepsilon\theta^2 + \gamma)y^2}{2}. \qquad (15)$$

The producer surplus measure in (15) is broken up into two terms: green price premium and green cost.

As in the literature, social welfare is taken as the sum of consumer and producer surplus, which yields:

$$SW = [\beta\theta n + \frac{\theta\tau(2-x)x}{2} - P_e x] + [P_e y - \frac{(\varepsilon\theta^2 + \gamma)y^2}{2}].$$

Evaluating SW at the market equilibrium,[21] where $x = y = n,$ we have

$$SW = \theta\beta n + \frac{n\theta\tau(2-n)}{2} - \frac{(\gamma + \varepsilon\theta^2)n^2}{2}. \qquad (16)$$

The three terms that constitute social welfare can be identified as: public green benefit, private

[19] For a detailed derivation of the consumer surplus measure, see Appendix A-3.
[20] For a detailed derivation of the producer surplus measure, see Appendix A-4.
[21] If we optimize social welfare using the equilibrium condition in equation (7), the optimal club size would be trivial, specifically, $n \to 0$.

green benefit, as well as green cost.

Substituting θ^{GC} and n^{GC} from (8) and (9) into the welfare function in (16), after arranging terms, we have

$$SW^{GC} = \frac{\tau\sqrt{\gamma\varepsilon}(2\beta+\tau)}{2\varepsilon(\tau+2\sqrt{\gamma\varepsilon})}. \tag{17}$$

Based on SW^{GC} in (17), we have several interesting observations. First, as expected social welfare is strictly increasing with β, thus greater public benefits result in greater social welfare. Moreover, the comparative-static derivatives of SW^{GC} in (17) with respect to τ, ε, and γ are:[22]

$$\frac{\partial SW^{GC}}{\partial \tau} > 0,\ \frac{\partial SW^{GC}}{\partial \varepsilon} < 0, \text{and} \frac{\partial SW^{GC}}{\partial \gamma} > 0. \tag{18}$$

The economic implications of the first two derivatives in (18) are as expected. First, higher preferences for green products yield greater social welfare. Secondly, as the cost of abatement increases, social welfare decreases. The last derivative in (18) is less intuitive and more significant. For that reason, we state:

Corollary 1. *In the presence of heterogeneous producers, social welfare increases with higher club membership costs.*

Normally, a higher club cost should decrease social welfare since it discourages producers from joining a club and producing green products. However, in the presence of heterogeneous producers the appeal of joining a club puts a pressure on the club to lower the standard and accept producers with higher abatement costs. As shown in (7) and (13c), this lowers the green price premium and increases demand for the green product. If the club membership fee were higher, only producers with low abatement costs would find it beneficial to join. Furthermore, the lower abatement cost producers are more likely to accept a higher standard, which yields higher price premiums. This result is analogous to Buchanan's (1965) Theory of a Club which he describes as a "theory of optimal exclusion, as well as one of inclusion."Basically, the argument is that the club needs members to operate, but the exclusivity of club is directly related to its effectiveness.

To evaluate the efficacy of the market solution with a green club, we need to identify the conditions (in terms of the number of producers producing the green product and the level of

[22] Detailed expressions for the comparative-static derivatives in (18) can be found in Appendix A-5.

environmental standard) under which social welfare is maximized. This leads us to examine the environmental issues from the perspective of a social planner who seeks to maximize overall welfare.

3.2 *Optimal Welfare in the Social Planner's Solution*

In the framework we consider, the socially optimal outcome is found using the approach by van't Veld and Kotchen (2011). The social planner determines optimal club standard and size, or values of θ and $n,$ that maximize overall welfare as given in (16b)[23]. The first-order Kuhn-Tucker conditions are: [24]

$$\frac{\partial SW}{\partial \theta} = \frac{n(2\beta + 2\tau - n\tau - 2n\varepsilon\theta)}{2} \leq 0 \text{ and } \frac{\partial SW}{\partial n} = \theta\beta - n\gamma + \theta\tau - n\theta\tau - n\varepsilon\theta^2 \leq 0.$$

Assuming temporarily that these conditions are binding, the optimal values of θ and n are:

$$\theta = \frac{2\beta + 2\tau - n\tau}{2n\varepsilon}, \tag{20a}$$

$$n = \frac{\theta(\beta + \tau)}{\theta(\tau + \varepsilon\theta) + \gamma}. \tag{20b}$$

Substituting θ from (20a) into n in (20b) and considering the boundary conditions on the number of consumer's purchasing the green product $(0 \leq n_D \leq 1),$ we obtain candidates for the social planner's (denoted with "*SP*") equilibrium number of green producers:

$$n^{SP} = \left\{0, \frac{2\tau(\beta + \tau)}{\tau^2 - 4\gamma\varepsilon}\right\}. \tag{21}$$

Since $0 \leq n^{SP} \leq 1,$ this implies that $0 \leq 2\tau^2 + 2\beta\tau \leq \tau^2 - 4\gamma\varepsilon$. In order for the club to exist, the condition that $\tau^2 - 4\gamma\varepsilon > 0$ requires that $\tau > 2\sqrt{\varepsilon\gamma}.$ Evaluating the above condition $2\tau^2 + 2\beta\tau \leq \tau^2 - 4\gamma\varepsilon,$ implies that $\tau^2 + 2\tau\beta \leq -4\gamma\varepsilon,$ which obviously cannot happen. We thus have the inequality condition that $2\tau^2 + 2\beta\tau \geq \tau^2 - 4\gamma\varepsilon > 0.$ This indicates that if the market

[23] Instead of using both instruments (club standard and club size), the social planner could use just one. However, by using just one instrument, the social planner will be unable to obtain the same level of social welfare. If the social planner only utilizes the standard, a sub-optimal (or fewer) producers will sign up for the green club. At the same time, if the social planner utilizes the number of producers in the club, a sub-optimal standard will be selected.

[24] Second order condition is: $\frac{\partial^2 SW}{\partial n^2}\frac{\partial^2 SW}{\partial \theta^2} - \frac{\partial^2 SW}{\partial n \partial \theta}\frac{\partial^2 SW}{\partial \theta \partial n} = (\varepsilon\theta^2 + \tau\theta + \gamma)(n^2\varepsilon) - [\beta + \tau(1-n) - 2n\theta\varepsilon]^2$, which is satisfied if: the club's member cost is sufficient large or the marginal benefits and cost of higher environment standards are similar in magnitude, specifically: $[\beta + \tau(1-n) - 2n\theta\varepsilon]^2 < (\varepsilon\theta^2 + \tau\theta + \gamma)(n^2\varepsilon)$. We assume this condition holds.

contains a green club then the socially optimal number of green producers is:

$$n^{SP} = 1. \tag{22a}$$

Substituting $n^{SP} = 1$ from (22a) back into θ in (20a) yields

$$\theta^{SP} = \frac{2\beta + \tau}{2\varepsilon}. \tag{22b}$$

Based on n^{SP}, θ^{SP}, and the social welfare function in (16), we have

$$SW^{SP} = \frac{(2\beta + \tau)^2}{8\varepsilon} - \frac{\gamma}{2}. \tag{22c}$$

From (22c),the comparative-static derivatives of the social planner's social welfare are:

$$\frac{\partial SW^{SP}}{\partial \beta} > 0,\ \frac{\partial SW^{SP}}{\partial \tau} > 0,\ \frac{\partial SW^{SP}}{\partial \varepsilon} < 0, \text{and} \frac{\partial SW^{SP}}{\partial \gamma} < 0.$$

As before, public benefits from having a green product, and consumer preferences for the green product all positively affect social welfare. Additionally, higher abatement costs negatively affect social welfare. One key implication departing from the market solution with a green club is the negative effect of higher club membership costs on social welfare. This seems appropriate, since the social planner decides the club participation and standard, the club costs no longer needs to disincentivize high cost producers from joining a club. To summarize this result:

Corollary 2. *Higher club membership costs decrease the maximum attainable level of social welfare in the social planner's solution. However, higher club costs increase social welfare in the market solution.*

In the previous section, we see that as the club become more exclusive by increasing the standard, members receive a higher green price premium. However, the social planner need not worry about the exclusiveness of the club-determined standard, since it can decide both the level of participation and the standard. Therefore, membership costs become a hurdle for a social planner that negatively affects social welfare.

3.3 *Comparison*

Next, we examine differences between the market solution and the social planner's solution. We begin by evaluating the difference in the number of producers producing the green product. In view of (9) and (22a), we see immediately that the market solution with a green club will never serve the entire market or to state another way: $n^{GC} \geq n^{SP}$.

Next, we compare the environmental standard in each scenario by using θ^{GC} in (8) and θ^{SP}, in (22b). Assuming that the market solution yields a higher standard in order to identify conditions where $\theta^{GC} \geq \theta^{SP}$, we have

$$\sqrt{\frac{\gamma}{\varepsilon}} \geq \frac{2\beta + \tau}{2\varepsilon}.$$

It can easily be verified that this condition violates the constrained condition that $\tau > 2\sqrt{\gamma\varepsilon}$. Therefore, we conclude that the standard set by the green club in the market solution is strictly below that in the social planner's solution. We thus have

$$\theta^{GC} < \theta^{SP}.$$

Finally, we verify differences in overall welfare using SW^{GC} in (17) and SW^{SP} in (22c). Again, we analyze whether the market solution is superior to the social planner's solution, or specifically, $SW^{GC} \geq SW^{SP}$. This yields the following condition:

$$\frac{\tau(\tau\sqrt{\gamma\varepsilon} - 2\gamma\varepsilon)(2\beta + \tau)}{2\varepsilon(\tau^2 - 4\gamma\varepsilon)} \geq \frac{(2\beta + \tau)^2}{8\varepsilon} - \frac{\gamma}{2}.$$

Since $\tau > 2\sqrt{\gamma\varepsilon}$ in the presence of the green club, the social planner's welfare is relatively higher. That is, $SW^{GC} < SW^{SP}$.[25] We thus have

PROPOSITION 2. *The market solution has a lower environmental standard, a lower number of green producers, and a lower level of overall welfare relative to the social planner's solution. That is,* $\theta^{GC} < \theta^{SP}$, $n^{GC} < n^{SP}$, *and* $SW^{GC} < SW^{SP}$.

4. Welfare Implications of a Single-Tool Environmental Policy

We have shown that the market solution with a green club is Pareto sub-optimal, so naturally, some regulatory questions arise: What regulatory measures that can be taken by government to correct the Pareto sub-optimality? Will subsidies for greener production standard be a socially optimal policy? In this section, we examine the efficacy of various policies in the

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[25] Showing that $SW^{GC} < SW^{SP}$ requires proving that $[(2\beta + \tau)^2 - 4\gamma](\tau^2 - 4\gamma\varepsilon) > 4\tau(\tau\sqrt{\gamma\varepsilon} - 2\gamma)(2\beta + \tau)$. If we let $\tau = 2\sqrt{\gamma\varepsilon} + a$, this condition simplifies to: $a^3 + 4a(\beta^2 + a\beta + \gamma\varepsilon - \gamma) + 4\sqrt{\gamma\varepsilon}[(a + 2\beta)^2 + 4\beta\sqrt{\gamma\varepsilon} - 4\gamma] > 0$, which is sufficiently positive whenever $\beta^2 + a\beta + \gamma\varepsilon > \gamma$ and $(a + 2\beta)^2 + 4\beta\sqrt{\gamma\varepsilon} > 4\gamma$. We assume these conditions hold.

presence of a green club. This extends the work by David and Sinclair-Desgagne (2005), by evaluating the use of regulation in the presence of a voluntary agreement (club participation) and of Heyes and Maxwell (2004), who analyze the effects of regulatory policy and non-government labeling when both occur concurrently in a market. Our approach allows the club to act as a monitor of the producers actions, thus allowing the government to set regulation according to member producers' actions.

We begin by constructing green production as a three-stage game. In the first stage, the government determines subsidies and taxes (either for abatement or club membership) to maximize social welfare. In the second stage, the club sets the maximum level of cleanliness standard that maintains equilibrium in the green product market. In the third and last stage, each profit-maximizing producer decides on joining join the club according to the standard and price for the green product.

4.1 *Green Production with Abatement Subsidies*

In this case, we incorporate a tactic used by Segerson and Miceli (1998), where regulators use a "carrot" approach. The government provides a subsidy (denoted as s_A) to the producer for each unit of abatement. We can identify the number of green producers by solving by the following equality $P+P_e-(c+y\varepsilon\theta^2+\gamma y)+s_A\theta=P-c$. This yields the marginal green producer or the quantity of the green product supplied as:

$$n_{S,A}=y=\frac{P_e+s_A\theta}{\gamma+\varepsilon\theta^2}. \tag{23}$$

One observation from (23) is that abatement subsidies increase the number of green producers.[26]

As before, we solve for the quantity of the green product sold in the market by setting n_D from (2) equal to $n_{S,A}$ from (23). This shows that while in equilibrium, green price premium must satisfy:

$$P_e=\frac{(\varepsilon\theta^2-s_A\theta+\gamma)\,\theta\tau}{\gamma+\theta\tau+\varepsilon\theta^2}. \tag{24}$$

Substituting P_e in (24) back into n_D in (2) yields[27]

[26] The number of green firms must satisfy this condition: $0\le y\le 1.$ This implies that $0\le (P_e+s\theta)\big/(\gamma+\theta^2\varepsilon)\le 1$ or to state another way: $0\le P_e\le \theta^2\varepsilon+\gamma-s\theta.$

$$n = \frac{(s_A + \tau)\theta}{(\varepsilon\theta + \tau)\theta + \gamma}. \quad (25)$$

Market solution based on the green club objective as discussed earlier can be found by taking the derivative of n in (25) with respect to θ and setting the resulting expressions to zero. This yields the optimal standard set by the green club in the presence of an abatement subsidy (denoted by "C*A*") scenario. That is,

$$\theta^{CA} = \sqrt{\frac{\gamma}{\varepsilon}}. \quad (26a)$$

Substituting θ^{CA} back into n from (25), we have

$$n^{CA} = \frac{(s_A + \tau)}{\tau + 2\sqrt{\gamma\varepsilon}}. \quad (26b)$$

With (26a), we use P_e in (24) to calculate the equilibrium value of green premium,[28]

$$P_e^{CA} = \frac{\tau[2\gamma\varepsilon(s_A + \tau) - (s_A\tau + 4\gamma\varepsilon)\sqrt{\gamma\varepsilon}]}{\varepsilon(\tau^2 - 4\gamma\varepsilon)}. \quad (26c)$$

Note the absence of the abatement subsidy in the clubs emission standard, while it is present in the green price premium and the equilibrium number of green producers. From (26b), we can see that a higher abatement subsidy leads to more producers joining a club which, in turn, results in a lower green price premium.

Next, we determine if the abatement subsidy can yield the optimal number of green producers and the optimal emission standard. Setting $n^{SP} = n^{CA}$ leads to a subsidy of:

$$s_A^* = 2\sqrt{\gamma\varepsilon}.$$

Therefore, we conclude that obtaining the socially optimal number of green producers is possible with an emissions subsidy.

Using the same approach, we determine the optimal abatement subsidy that generates the social planner's emission standard by solving $\theta^{SP} = \theta^{CA}$, which yields:

$$\frac{2\beta + \tau}{2\varepsilon} = \sqrt{\frac{\gamma}{\varepsilon}},$$

[27]Note the condition that $0 \le [(s+\tau)\theta] / (\varepsilon\theta^2 + \tau\theta + \gamma) \le 1$ which implies that: $\theta^2 \ge (s\theta - \gamma)/\varepsilon$.

[28]The green product premium is positive, $P_e > 0$, if $(s_A\theta - \gamma)/\varepsilon < \theta^2$.

which doesn't hold since $\tau > 2\sqrt{\gamma\varepsilon}$. Therefore, the abatement subsidy can never lead to the same standard. The resulting standard is always below that of the social planner's. We thus have

PROPOSITION 3. *While an emission subsidy can yield the optimal green club participation, there is no emission subsidy that will generate the Pareto-optimal green standard in the market solution. That is,* $\theta^{CA} < \theta^{SP}$, $n^{CA} = n^{SP}$, *and* $SW^{CA} < SW^{SP}$.

4.2 *Green Production with Membership Subsidies/Taxes*

We next examine the effects of a government subsidy (denoted as s_M) for producers when they join a club. Similar to the previous case, we can identify the number of green producers by solving the following equality: $P + P_e - (c + y\varepsilon\theta^2 + \gamma y) + s_M = P - c$. Solving for y yields the supply of green products:

$$n_{S,M} = y = \frac{P_e + s_M}{\gamma + \varepsilon\theta^2}. \tag{27}$$

Setting demand for green product, n_D, from (2) equal to the new supply of the green product $n_{S,M}$ from (27), we find that the green product premium is:

$$P_e = \frac{\tau\theta(\varepsilon\theta^2 - s_M + \gamma)}{\theta(\tau + \varepsilon\theta) + \gamma}. \tag{28}$$

Substituting P_e from (28) back into n_D in (2) yields the number of green producers:

$$n = \frac{s_M + \tau\theta}{\theta(\tau + \varepsilon\theta) + \gamma}. \tag{29}$$

Market solution based on the green club objective can be determined by taking the derivative of n in (29) with respect to θ and setting the resulting expressions to zero. This yields the optimal environmental standard set by the club with membership tax/subsidy (denoted by "C*M*") as

$$\theta^{CM} = \sqrt{\frac{(\gamma - s_M)}{\varepsilon}}. \tag{30a}$$

Substituting θ^{CM} from (30a) into n in (29), we have

$$n^{CM} = \frac{\tau[\tau - 2\sqrt{(\gamma - s_M)\varepsilon}]}{\tau^2 - 4\gamma\varepsilon}. \tag{30b}$$

With (30a), we use P_e in (28) to calculate the green price premium: [29]

$$P_e^{CM} = \frac{2\tau(\gamma - s_M)\sqrt{(\gamma - s)\varepsilon}}{(2\gamma - s_M)\varepsilon + \tau\sqrt{(\gamma - s)\varepsilon}}. \tag{30c}$$

Note the presence of the membership subsidy in the club emission standard, green price premium, and the quantity of green producers, unlike the emission subsidy case.

Using the same approach as before, we determine the optimal membership subsidy/tax that results in the social planner's emission standard by solving $\theta^{CM} = \theta^{SW}$, which yields:[30]

$$s_M^* = \gamma - \frac{(2\beta + \tau)^2}{4\varepsilon}.$$

Careful examination of the expression for s_M^* reveals that the optimal membership subsidy to ensure the social planner's standard is actually a tax.[31] While this may seem counter-intuitive, recall that a club must ensure its members can sell their products. Therefore, if the government taxes club membership, the number of producers with green production is reduced, thus allowing the club to raise its standard. Unlike the emission subsidy scenario, a proper membership tax leads to the socially optimal emission standard. The tax can be considered a certification expense in the same spirit as Hamilton and Zilberman (2006), for that reason we refer to it as an eco-certification tax.

Next, we determine if the proper eco-certification tax can yield the optimal number of producers and emission standards. For $n^{SW} \le n^{CM}$, it requires that $s_M \ge \gamma + \varepsilon\theta^2$. Since $s_M < \gamma$, we can conclude that no eco-certification tax will satisfy the inequality condition. Therefore, we have

PROPOSITION 4. *While a tax charge for green certification can yield the optimal green standard, there is no membership subsidy/tax that will generate the socially optimal level of green club participation. That is,* $\theta^{CM} = \theta^{SP}$, $n^{CM} < n^{SP}$, *and* $SW^{CM} < SW^{SP}$.

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[29] Note that $P_e > 0$ if $(s - \gamma)/\varepsilon < \theta^2$.

[30] The associated welfare calculations for the club membership case are provided in the appendix.

[31] In order for $s_M^* > 0$, $4\gamma\varepsilon < (2\beta + \tau)^2$ must hold. If we let $\tau = 2\sqrt{\gamma\varepsilon} + \alpha$, where $\alpha > 0$, then we can rewrite the previous inequality as: $4\gamma\varepsilon < 4\beta(2\sqrt{\gamma\varepsilon} + \alpha + \beta) + 4\gamma\varepsilon + \alpha(4\sqrt{\gamma\varepsilon} + \alpha)$, which cannot hold, thus implies that $s_M^* < 0$.

5. Welfare Implications of a Double-Tool Environmental Policy

We have shown that even with an emission subsidy or club membership tax, the equilibrium outcome is Pareto sub-optimal. This suggests that there is no single policy tool capable of achieving the socially optimal outcome in the presence of green clubs. In this section, we evaluate the use of dual tool by regulator, and examine if it can lead to the socially optimal outcome.

As in the previous analyses, we construct green production as a three-stage game. However, the first stage differs from our previous set-up. In the first stage, the government determines both the abatement and club membership subsidies/taxes to maximize social welfare. The second and third stages of the game remain unchanged: the club sets the cleanliness standard while maintaining equilibrium in the green product market. In last stage, each producer decides on joining the club according to the demand for the green product.

5.1 *A Double-Tool Approach*

Similar to the previous section, we begin by introducing the subsidy for green production (S) and subsidy for club membership (ω) in the green producer profit function. We can identify the producers making a green product market by solving:

$$P + P_e - (c + y\varepsilon\theta^2 + \gamma y) + S\theta + \omega = P - c.$$

This gives the supply of green products:

$$n_S = \frac{P_e + S\theta + \omega}{\gamma + \varepsilon\theta^2}. \qquad (31)$$

To determine the equilibrium number of green producers, we set the supply of and demand for the green product equal to one another using n_S in (31) and n_D in (2), respectively. Solving for the green product premium yields

$$P_e = \frac{(\varepsilon\theta^2 - S\theta + \gamma - \omega)\theta\tau}{\theta(\tau + \varepsilon\theta) + \gamma}. \qquad (32)$$

Substituting P_e from (32) back into n_D in (2), we have the equilibrium number of green producers:[32]

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[32]Note that $0 \le [(s+\tau)\theta+\omega]/[\varepsilon\theta^2+\tau\theta+\gamma] \le 1$, which implies that: $\theta^2 \ge (\omega+s\theta-\gamma)/\varepsilon$.

$$n = \frac{(S+\tau)\theta + \omega}{\theta(\tau + \varepsilon\theta) + \gamma}. \tag{33}$$

Market solution based on the green club objective can be found by taking the derivative of n in (33) with respect to θ and setting the resulting expression to zero. This gives the optimal environmental standard set by the green club with the dual policy (denoted by "*CD*") as:

$$\theta^{CD} = \frac{\sqrt{\Phi} - \varepsilon\omega}{\varepsilon(S+\tau)}, \tag{34a}$$

where $\Phi \equiv \varepsilon[\gamma(S+\tau)^2 + \omega(\varepsilon\omega - S\tau - \tau^2)]$. Substituting θ^{CD} in (34a) back into n in (33), we have

$$n^{CD} = \frac{\sqrt{\Phi}(S+\tau)^2}{2\Phi + \sqrt{\Phi}\,(S\tau + \tau^2 - 2\varepsilon\omega)}. \tag{34b}$$

Making use of (32) and (34b), we calculate the green price premium:[33]

$$P_e^{CD} = \frac{\tau(\sqrt{\Phi} - \varepsilon\omega)[2\Phi - (\sqrt{\Phi} - \varepsilon\omega)(S\tau + S^2 + 2\varepsilon\omega)]}{\varepsilon(S+\tau)[2\Phi + (\sqrt{\Phi} - \varepsilon\omega)(S\tau + \tau^2 - 2\varepsilon\omega)]}. \tag{34c}$$

5.2 *Social Planner's Solution with Dual Policy*

The eco-certification tax shows up in the club emission standard, green price premium, and the number of green producers, unlike the emission subsidy case. In addition, the abatement subsidy shows up in the green price premium and the number of green producers. This means that potentially, the eco-certification tax could be used to optimize the club standard, while the emission subsidy could be used to optimize club participation. We begin by setting the dual policy club standard equal to social planner's club standard, or $\theta^{CD} = \theta^{SP}$, and solving for the club eco-certification tax ω that yields the socially optimal club standard. From this, we obtain:

$$\omega = \frac{(S+\tau)[4\gamma\varepsilon - (2\beta+\tau)^2]}{8(\beta+\tau)\varepsilon}. \tag{35}$$

Therefore, using (40a) as our club membership policy rule, we ensure the optimal club standard is obtainable. Substituting ω in (35) back into (34b) yields

$$n^{CD} = \frac{S+\tau}{2(\beta+\tau)}. \tag{36}$$

Setting n^{CD} in (36) equal to the socially optimal number of producers, i.e., $n^{CD} = n^{SP} = 1$, and

[33]Note that $P_e > 0$ if $(s\theta + \omega - \gamma)/\varepsilon < \theta^2$.

solving for the optimal emission subsidy, we have

$$S^{*}=2\beta+\tau. \tag{37}$$

Using S^{*} in (37), we simplify the optimal eco-certification tax provided in (35) to:

$$\omega^{*}=\gamma-\frac{(2\beta+\tau)^{2}}{4\varepsilon}. \tag{38}$$

Together, the results in (37) and (38) provide a dual policy rule that ensures the first-best solution. Or to state another way:

PROPOSITION 5: *While a single tool policy cannot yield the socially optimal outcome, a dual tool policy is the first best or Pareto optimum, if the government sets dual policy of* $\omega^{*}=\gamma-(2\beta+\tau)^{2}/4\varepsilon$ *and* $S^{*}=2\beta+\tau$*.That is, given* S^{*} *and* ω^{*}*, we have* $\theta^{CD}=\theta^{SP}$*,* $n^{CD}=n^{SP}$*, and* $SW^{CD}=SW^{SP}$*.*

If government adopts a dual policy which combines subsidizes for a greener production standard and taxes for the club membership of green producers, the policy is able to achieve Pareto optimality in environmental standards, the number of green producers, and overall welfare.

6. Extensions[34]

In this section, we reevaluate our market structure to identify conditions under which our finding continues to hold. Our analysis focuses on the costs of producing of green products and the objective of the certifier.

6.1*Heterogeneous producers or input costs*

Following Bonroy and Lemarie (2012), we evaluate perfect competition with a representative producer facing costs according to demands for input necessary for green production. We denote the green price premium as p_i, which is dependent on the number of producers producing green products. Assuming, as before, that each produces only one unit of output, so "*i*" denotes both the number of green producers and the quantity of output. We assume

[34] This extension section is due completely to an anonymous reviewer's suggestions to analyze alternative objectives that certifier may have. One is when a private certifier is a profit maximizing monopoly and the other is when an industry certifier maximizes green producers' surplus. We are graceful to the reviewer's insightful and constructive suggestions which allow us to have a more complete analysis in terms of comparing alternative equilibrium outcomes.

that green production costs are $c_i(r,\gamma)$, where r represents the marginal cost of green inputs and, borrowing from our previous analysis, γ represents the marginal cost of certification.

Inputs for green production vary from traditional production. As demand for green inputs increase, it is likely that price of inputs for green production would increase, thereby raising the production costs of green products.[35] Regardless, for completeness we assume that input costs for green production can take three forms: 1) increasing with output, 2) constant, or 3) decreasing with output. We begin by examining how various input cost structures affect the market green products.

We evaluate constant cost using a functional form: $c_i(r,\gamma) = ar + \gamma$, where a is a positive scalar. If $p_i > ar + \gamma$, the representative producer will convert green production, therefore it yields a border solution. On the other hand if $p_i < ar + \gamma$, the producer (and all producers) will convert to green production. Similarly, with decreasing costs $(c_i = (ar + \gamma)/i)$, we also find a border solution. If output reaches the point where $ip_i > ar + \gamma$, all producers will convert to green production. If, on the other hand, production never reaches this critical mass, then $ip_i < ar + b\gamma$, and no producers will convert to green production. Therefore, neither of these costs structures will necessarily yield the same results as our initial analysis.

To evaluate costs that are increasing with green output, we use the functional form of $c_i(r,\gamma) = i(ar + \gamma)$. Note that the profit for any green producers is: $\pi = p_i - c_i$ (since they are assumed homogeneous). In a competitive market, producers' convert to green production until $\pi = 0$, which implies: $p_i = c_i$, therefore supply is:

$$p_i = i(ar + \gamma). \tag{39}$$

Next, we examine demand for green products, which depends on the quantity produced. Letting $U = p_i - (1-i)\tau\theta$, where θ denotes the heterogeneity among consumers, we can incorporate green preferences into our analysis. Consumers purchase the green product if $U \geq 0$. We identifying the marginal consumer in order to ascertain the quantity of green products purchased. This allows us to represent demand as:

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[35]Increasing production costs for green producers could also occur if inputs costs are constant, but transportation costs increase as more producer adjust to green production.

$$p_i = (1-i)\tau\theta. \tag{40}$$

Setting the demand and supply to equal, we can obtain equilibrium quantity and price as:

$$i^* = \frac{\tau\theta}{\tau\theta + ar + \gamma}; \tag{41a}$$

$$p_i^* = \frac{\theta\tau(r+\gamma)}{ar + \gamma + \theta\tau}. \tag{41b}$$

If we set $ar = \varepsilon\theta^2$, reevaluate Equation (41a), and compare the results to Equation (6) we find that $p_i^* = P_e$. Similarly, if we reevaluate Equation (41b), and compare the results to Equation (7) we find that $i^* = n$. This shows that the outcome with increasing input costs for green production are quantitatively identical to the findings of the analyses in the previous sections. Therefore, our results require only that green input costs increase with use.

6.2 *Private Certifier*

In the previous analysis, the certifying club is taken to maximize their standard, while ensuring that a market exists for their members. This requires that the club be mindful of the availability of certified products as well as their ability to reach environmentally conscientious consumers. In this section, we evaluate two alternative objectives that the certifier may have, while assuming producers are heterogeneous (as initially evaluated).

The first scenario is where a private certifier is a profit maximizing monopoly. Similar to Bottega and De Freitas (2009), we assume that the private certifier has all the bargaining power; we also assume, for simplicity, that monitoring costs are fixed. The club adjusts the cost of club membership in order to maximize their revenue (and profit). This occurs when the club fee is equal to the price of green products less the costs of production, or equivalently:

$$\gamma = (1-n)\tau\theta - n\varepsilon\theta^2. \tag{42a}$$

The certifier's revenue is therefore γn, which is maximized when:

$$n = \frac{\tau}{2(\tau + \theta\varepsilon)}. \tag{42b}$$

Substituting (42b) back into (42a) gives the certifier's revenue as a function of the club standard:

$$\gamma n = \frac{\theta\tau^2}{4(\tau + \theta\varepsilon)}. \tag{42c}$$

Note that equation (42c) is strictly increasing in θ, illustrating that a private certifier will select the highest standard possible. Let $0 \le \theta \le \theta_h$, where θ_h the highest standard possible. The private certifier will choose $\gamma = \tau\theta_h/2$. From this, we can identify the number of green producers, the green standard, and green premium with a private certifier (denoted by "*PC*") as:

$$n^{PC} = \frac{\tau}{2(\tau + \theta_h \varepsilon)}; \theta^{PC} = \theta_h; P_e^{PC} = \frac{\tau\theta_h(\tau + 2\varepsilon\theta_h)}{2\tau + 2\varepsilon\theta_h}. \quad (43)$$

6.3 ***Industry Certifier (or Club)***

Next, we evaluate an industry club that maximizes green producers' surplus. Similar to our previous analysis, we assume that the marginal cost of club membership is constant. From the industry club's perspective their objective is to maximize:

$$PS_{green} = P_e y - \frac{y\varepsilon\theta^2}{2} - \gamma. \quad (44a)$$

In order to maximize green producers' surplus, the industry club selects output (or number of producers) and standard to maximize PS_{green} in (44a). This yields:

$$n = \frac{1}{4\tau}(2\tau - \theta\varepsilon). \quad (44b)$$

Substituting (44b) back into (44a), we identify the optimal standard that maximizes green producers' surplus. This gives the certifier's revenue as a function of the club standard:

$$PS_{green} = \frac{\theta^3\varepsilon^2 - 4\theta^2\tau\varepsilon + 4\theta\tau^2 - 16\gamma\tau}{16\tau}. \quad (44c)$$

Using (44c), we identify the number of green producers, the green standard, and green premium with an industry club (denoted by "*IN*") as:

$$n^{IN} = \frac{1}{3}; \theta^{IN} = \frac{2\tau}{3\varepsilon}; P_e^{IN} = \frac{4\tau^2}{9\varepsilon}. \quad (45)$$

Based on our results from the green club (Equations 8, 9 and 10), social planner's outcome (Equation 22), Private Certifier (Equations 43) and Industry Club (Equation 45), we can compare the number of green producers, the green standard, and green premium. Assuming that $2\varepsilon\theta_h < \tau < 6\beta$ and noting that $\tau \ge 2\sqrt{\gamma\varepsilon}$, we have the following rankings:

$\theta^{PC} > \theta^{SP} > \theta^{IN} > \theta^{GC}$ and $n^{SP} > n^{GC} > n^{PC} > n^{IN}$.

This shows that regardless of the certifier and their objective, the results are sub-optimal. An industry club will restrict producer access in order to benefit its members. A private certifier will raise the green standard, but only to restrict access and raise the green premium for their own gain. As a result, we see that irrespective of the certifier, additional policy is necessary in order to obtain the socially optimal outcome.

7. Concluding Remarks

In this paper, we have endeavored to analyze welfare implications of environmental regulations for an economy in which heterogeneous consumers choose between green and non-green products, and producers may join a green club in order for environmental friendliness to be recognized. In the analysis, we take into account the heterogeneity of producers in production and abatement costs. This allows us examine competitive markets, and analyze how eco-certifications and environmental regulation affect the endogeneity of green production. New research has incorporated the role of green clubs, but omitted heterogeneity of consumers. Our results are distinctly different from previous studies and have implications for club and regulatory decisions within a competitive market.

We have shown that club operation in a competitive market is welfare-improving and, similar to Ibanez and Grolleau (2008), decreases the level of pollution. However, it results in a lower number of green producers with a lower environmental standard than is socially optimal. The implementation of environmental policies can help improve Pareto efficiency. In addition, the use of an abatement subsidy increases club participation, which is welfare-improving, but is not Pareto optimal. Applying an eco-certification tax is also welfare-improving, but is still sub-optimal. Unlike previous research analyzing duopoly markets in the context of eco-labels, our results show that there is no single policy which will yield the socially optimal outcome.

Finally, we suggest the implementation of a mixed policy, which combines subsidizes for a greener production standard and a certification tax for producers that want to join a green club. This policy mix is shown to be Pareto optimal (that is, the first-best optimum) in environmental standards and overall welfare, and therefore shows the potential gains from regulatory involvement in competitive markets with green clubs.

Some caveats about the analysis with this paper, and hence the potentially interesting extensions of the simple model, should be mentioned. First, in comparing aggregate welfare between market solution and social planner's solution, we examine the case that a green club chooses an optimal cleanness standard for reaching as many environmentally conscientious consumers as possible without considering alternative club objectives (such as profit maximization for members or those in line with environmentalist clubs maximizing environmental protection).[36] It would be interesting to see how these alternative objectives affect market equilibrium and the social efficiency of green product certification. Second, our simple analysis abstracts from the possibility of competition among green clubs (see, e.g., Fishcer and Lyon 2014). Third, we look at efficiency/inefficiency of a market with green and non-green products without taking into account the credibility problems of certification agencies or the product fraud problems in green markets.[37] These are interesting issues for future research.

[36]The segmentation of the market in green and non-green producers due to product differentiation may allow member firms in a club to make greater profits when the objective of the club is to maximize profit of its members.
[37]The contribution by Hamilton and Zilberman (2006) addresses issues on fraud in green markets. In our analysis, we find that even in the absence of credibility or fraud, the free-market equilibrium is socially inefficient in terms of the number of green products available to environmentally conscientious consumers.

Appendix

A-1.Given that the equilibrium number of green producers in the market is: $n^{GC} = \frac{\tau}{(\tau + 2\sqrt{\gamma\varepsilon})}$,

we take the derivative of n^{GC} with respect to τ, ε, and γ to obtain the following:

$$\frac{\partial n^{GC}}{\partial \tau} = \frac{2[\tau^2\sqrt{\gamma\varepsilon} - 4\gamma\varepsilon(\tau + \sqrt{\gamma\varepsilon})]}{(\tau^2 - 4\gamma\varepsilon)^2} > 0,$$

$$\frac{\partial n^{GC}}{\partial \varepsilon} = \frac{-\tau\gamma}{\sqrt{\gamma\varepsilon}(\tau + 2\sqrt{\gamma\varepsilon})^2} < 0,$$

$$\frac{\partial n^{GC}}{\partial \gamma} = \frac{-\tau\varepsilon}{\sqrt{\gamma\varepsilon}(\tau + 2\sqrt{\gamma\varepsilon})^2} < 0.$$

A-2.Given that the equilibrium value of the green product premium is: $P_e^{GC} = \frac{2\tau\gamma}{\tau + 2\sqrt{\gamma\varepsilon}}$, we take the derivative of P_e^{GC} with respect to τ, ε, and γ to obtain the following:

$$\frac{\partial P_e^{GC}}{\partial \tau} = \frac{4\gamma(\tau^2\sqrt{\gamma\varepsilon} - 4\tau\gamma\varepsilon + 4\gamma\varepsilon\sqrt{\gamma\varepsilon})}{(\tau^2 - 4\gamma\varepsilon)^2} > 0,$$

$$\frac{\partial P_e^{GC}}{\partial \varepsilon} = \frac{-2\tau\gamma^2}{\sqrt{\gamma\varepsilon}(\tau + 2\sqrt{\gamma\varepsilon})^2} < 0,$$

$$\frac{\partial P_e^{GC}}{\partial \gamma} = \frac{2\tau(\tau + \sqrt{\gamma\varepsilon})}{(\tau + 2\sqrt{\gamma\varepsilon})^2} > 0.$$

A-3. ***Consumer surplus***

According to the preferences of heterogeneous consumers as specified in (1), we have

$$CS = \int_0^x [v + (1-x)\tau\theta + \beta\psi - (P + P_e)]dx + \int_x^1 (v + \beta\psi - P)dx.$$

Note that $\beta\psi$ is the *external benefit* to the society from the green product's environmental friendliness or abatement, where $\psi = \theta n$ and n is the equilibrium quantity of the green product sold in the market. We then have

$$CS = \int_0^x [v + (1-x)\tau\theta + \beta\theta n - (P + P_e)]dx + \int_x^1 (v + \beta\theta n - P)dx,$$

which is re-written as

$$CS = \int_0^x [(1-x)\tau\theta - P_e]dx + \int_0^x (v + \beta\theta n - P)dx + \int_x^1 (v + \beta\theta n - P)dx$$

$$= \left[\tau\theta x - \frac{\tau\theta x^2}{2} - P_e x\right]_0^x + \left[vx + \beta\theta n x - Px\right]_0^1$$

$$= \left[\frac{\theta\tau x(2-x)}{2} - P_e x\right] + (v + \beta\theta n - P).$$

Competitive market for the non-green product implies that the equilibrium price for the good is equal to its price, that is, $P = v$. In addition, the equilibrium quantity of the green product sold (n) is equal to the number of green consumers (x). It follows that

$$CS = \beta\theta n + \frac{\theta\tau x(2-x)}{2} - P_e x,$$

where $\beta\theta n$ is public benefit from the green product, $[\theta\tau x(2-x)]/2$ is private benefit to green consumers, and $P_e x$ is the amount of premium to green producers.

A-4. ***Producer surplus***

According to the profit functions of green and non-green producers as specified in (3), we have

$$PS = \int_0^y (P + P_e - y\varepsilon\theta^2 - c - \gamma y)dy + \int_y^1 (P-c)dy,$$

which is re-written as

$$PS = \int_0^y (P_e - y\varepsilon\theta^2 - \gamma y)dy + (P-c)$$

$$= \left[P_e - \frac{\varepsilon\theta^2 y^2}{2} - \frac{\gamma y^2}{2} \right]_0^y + (P-c)$$

$$= P_e y - \frac{(\varepsilon\theta^2+\gamma)y^2}{2} + (P-c).$$

Competitive market for the green product implies that the equilibrium price for the good is equal to the cost of production for the marginal producer, that is, $P = c$. We thus have

$$PS = P_e y - \frac{(\varepsilon\theta^2+\gamma)y^2}{2}.$$

where $P_e y$ is green price premium, and $(\varepsilon\theta^2+\gamma)y^2/2$ is green cost.

A-5. Given that the equilibrium level of social welfare is:

$$SW^{GC} = \frac{\tau\sqrt{\gamma\varepsilon}(2\beta+\tau)}{2\varepsilon(\tau+2\sqrt{\gamma\varepsilon})},$$

we take the derivative of SW^{GC} with respect to τ, ε, and γ to obtain the following:

$$\frac{\partial SW^{GC}}{\partial \tau} = \frac{\left(\tau - 2\sqrt{\gamma\varepsilon}\right)^2(\tau^2\sqrt{\gamma\varepsilon} + 4\beta\gamma\varepsilon + 4\tau\gamma\varepsilon)}{2\varepsilon(\tau^2-4\gamma\varepsilon)^2} > 0,$$

$$\frac{\partial SW^{GC}}{\partial \varepsilon} = -\frac{\tau\sqrt{\gamma\varepsilon}(2\beta+\tau)[\tau^3+4\gamma\varepsilon(4\sqrt{\gamma\varepsilon}-3\tau)]}{4\varepsilon^2(\tau^2-4\gamma\varepsilon)^2} < 0,$$

$$\frac{\partial SW^{GC}}{\partial \gamma} = \frac{\tau^2(2\beta+\tau)(\tau^2+4\gamma\varepsilon-4\tau\sqrt{\gamma\varepsilon})\sqrt{\gamma\varepsilon}}{4\gamma\varepsilon(\tau^2-4\gamma\varepsilon)^2} > 0.$$

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