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Environmental policies and political feasibility: Eco-labels versus emission taxes[☆]

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ABSTRACT

This paper examines the economic and political implications of two market-based policies, eco-certifications and emission taxes. We evaluate each policy's effects on the environment, investment in clean technology, and social welfare under imperfect competition. We find that eco-certification reduces total damage to the environment, increases consumer benefits, and is socially desirable. However, polluting firms will never voluntarily accept the socially optimal eco-standard, leading to suboptimal certification programs. Unless the marginal damage to the environment from emissions is sufficiently low and demand is sufficiently large, environmental damage occurring under voluntary eco-certification is higher in comparison to alternative policies. We examine the welfare impacts of each policy to identify social preferences. Using realized market benefits to construct policy preferences, we show conditions under which the socially optimal environmental policy is unlikely to be politically feasible. Our results explain the popularity and suboptimal qualities of eco-certification programs.

1. Introduction

Environmental regulations have shifted significantly over the last fifty years, from command and control approaches to the more market-based approaches. Contemporary policies have adjusted more towards emission permits and taxes to regulate pollution. These policies yield benefits over previous approaches by allowing policymakers to set prices or quantity of emission. More importantly, these policies better align incentives within the market. Both emission taxes and permits (if set optimally) would, in theory, result in identical price and quantity of emissions. However, the feasibility of such policies often depends on the political and public perspective, which can make enactment challenging. These policies increase the cost of production and disproportionately punishes "dirtier" firms, which are often older and more established.

Recently, environmental certifications have gained popularity as an alternative to environmental policy. Certification programs are voluntary agreements utilizing market-based incentives, as discussed by Alberini and Segerson (2002), consumers' preferences encourage "environmentally-friendly goods through the marketplace".[1] Over the last decade, the

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1 Alberini and Segerson (2002) mention that: "With sufficient demand, exploiting the market for green products can increase market share and firm profits, even when the cost for green products are higher. However, the number of final consumer products for which such a niche exists is likely to be small". The use of these programs has increases significantly in the past decade.

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use of environmental certification, eco-labels, or "eco-certification" has increased significantly in use, and according to the USDA (2013), certified products have become the fastest-growing segment in some markets. Eco-certifications allow businesses to display evidence of their environmental practices (which are verified by a third party) to consumers, and thereby allow producers to charge a premium to consumers. The EPA lists categories of goods to help consumers buy "greener" products, and in some instances provides certification for products (EPA, 2016). As stressed by the studies in Loureiro and Lotade (2005) and Schumacher (2010), environmentally conscientious consumers are certainly willing to pay a premium for eco-labeled products.

The premium price green producers charge, for a certified product, incentivizes clean production, thus rewarding green production. This illustrates a stark contrast between emission taxes (or permits) and eco-labeling. Emission taxes represent a "stick" or punishment for dirty producers, while eco-labels offer a "carrot" to clean producers. From an environment policy prospect, the comparison of these regulatory approaches provides an opportunity to evaluate differing incentive schemes and examine their effects on firm behavior.

Several studies have evaluated the use of eco-labels (e.g., Amacher et al., 2004; Baksi and Bose, 2007; Ben Youssef and Lahmandi-Ayed, 2008; Ibanez and Grolleau, 2008). Mason (2006) examines the role technology and output decision have on firm certification decisions. Hamilton and Zilberman (2006) show that eco-certification benefits producers by increasing profits, while Grolleau et al. (2007) indicate that eco-labels can have an ambiguous effect in the context of Stackelberg competition. Mason (2011) evaluates eco-certification as a noisy test and shows that it can be either increase or decrease welfare. Walter and Chang (2017) show that eco-labels in competitive markets are not socially optimal. Cappelen and Ognedal (2017) show that voluntary certification may negatively affect the share of socially responsible production by reducing prices in the market for uncertified products. As a result, the certification program crowds out socially responsible producers who do not certify. Whether voluntary certification results in social welfare improvement is shown to depend on the costs of certification.

Work by van't Veld and Kotchen (2011) illustrates the significance of the certifying entity. By evaluating the standard set by various green clubs (environmental, industry, and government), van't Veld and Kotchen show that in the presence of imperfect monitoring, non-government groups provide better outcomes. At the same time, Dosi and Moretto (2001) evaluate the reliability of eco-labeling as an environmental policy, illustrating how eco-labeling can increase environmental innovation and reduce overall pollution, thereby demonstrating the potential of eco-labels as a policy tool if used aptly. While work by Grolleau et al. (2009) highlights consumer types (altruist vs. egoist), and how their preferences influence the effectiveness of eco-labels. They show that the environmental quality of an eco-labeled product can be driven by consumers with a high level of (public) environmental concern, but eco-labeling can also potentially price out consumers with only private concern (egoist).

Much of the contemporary research has analyzed the impacts of eco-labels within a market, but an evaluation of their practicality as a policy tool is warranted. As discussed by Tews et al. (2003), new environmental policies have implemented a variety of approaches (eco-labels, emission taxes, national policy plans/sustainable development, and information provisions). These new tools have replaced the traditional command and control approaches; however, many of these tools differ in their diffusion and effectiveness. Previous research has evaluated different subsets of these environmental policies. Requate (1998) shows that emission permits and taxes often yield similar, if not identical outcomes. While work by Segerson and Miceli (1998) evaluate a similar "carrot" and "stick" scenario with voluntary agreements, in the context of control threats or cost subsidies. These studies highlight the need to evaluate the effectiveness of different policies. Work by Espínola-Arredondo and Muñoz García (2016) examines firms' incentives for developing a new green product and identifies conditions under which an excessive amount of green goods ends up being socially inefficient. This indicates that the social inefficacy of excess green firms could arise when their products do not have sufficient strong environmental properties. The authors suggest, among other things, the use of traditional environmental policies (such as emission fees and subsidies) to induce socially optimal outcomes. More recently, Walter (2020) examines the merits of various market-based environmental policies in a competitive market but omits the diffusion of abatement technology. However, to our knowledge, previous research has yet to compare political support for environmental policies in the context of social welfare.

In this paper, we compare the relative effectiveness and political feasibility of two policies, eco-certification and emission taxes. We examine both policy tools within an imperfectly competitive market and evaluate their impacts on investment in clean technology, environmental damage, and social welfare. In addition, we comprise the political nature of environmental policy by including firm profit, the severity of environmental damages, and consumers' environmental conscientiousness to obtain a measure of political support. This allows us to represent support for different policies and identify regulatory preferences.

Our analysis contributes to the literature on environmental regulation in multiple ways. First, we identify conditions under which eco-certification is the socially optimal policy and relative to an emission tax policy, clean technology investment is always higher under eco-certification. Second, we examine the policy implications associated with varying levels of environmental damage. For example, when marginal environmental damage from emissions is high, social welfare is higher under an eco-certification program than under an emission tax policy. However, total environmental damage is relatively lower under the eco-certification program. Third, by identifying the "winners" and "losers" with each policy, we can examine the political support for different policies and explain the increasing popularity of eco-certification as a policy tool for environmental regulation. Our analytical results also highlight the importance of consumers' perspectives in the context of environmental policy.[2]

In our discussion about political feasibility, we assume that the marginal cost of environmental damage, caused by production, affects the general support for a policy. In other words, as environmental damages from a specific industry increase, we expect both market and non-market participants to pay more attention to the environmental regulations governing an industry's production. When environmental damages from production increase, we expect that support for direct enforcement (i.e., emission taxes) increases. This relationship follows from the findings of Grolleau et al. (2009), which highlights the discrepancies between consumer types concerned with personal benefits as opposed to public benefits. This relevant, but subtle, assumption ensures that the level of (public) environmental concern correlates to the magnitude of environmental damages occurring. More importantly, we model heterogeneity among consumers' environmental preferences, thereby allowing environmental concern to vary across population and markets. As a result, electorate advocacy increases with consumers' environmental preferences or environmental damages. Using this approach, our analysis connects environmental concerns to both market activity and political engagement. Our results illustrate the quandary that exists between the implementation and effectiveness of different environmental policies.

2. Analytical framework

We begin by modeling a duopoly where polluting firms produce a homogenous good and engage in Cournot competition in the product market. Market demand facing the firms is taken to be linear: $p = a - (q_1 + q_2)$, where p is the market price, a is a positive parameter representing the size of the market, and q_i is the quantity of output produced by firm $i (i = 1, 2)$. For analytical simplicity, we assume zero product costs for the firms. It follows that in the absence of government regulations of any form, the variable profit function of firm i is $\pi_i = pq_i = [a - (q_1 + q_2)]q_i$. The demand equation implies that consumer surplus is equal to $CS = (q_1 + q_2)^2/2$.

Each firm's production unavoidably generates waste or pollution which negatively affects the quality of the environment. Denote d as the (constant) marginal damage to the environment resulting from each unit of output produced. The total environmental damage (D) is $D = d(q_1 + q_2)$. As in the literature, social welfare is defined as the sum of consumer surplus and firm profits minus the total damage to the environment. That is, $SW = CS + \pi_1 + \pi_2 - D$.

Our analysis proceeds as follows: we begin by first solving for the market equilibrium in which there are no environmental regulations of any form. We then examine two alternative government policies, one involves the requirement of eco-certification and the other involves the imposition of an emission tax on the polluting firms. We assume that firm emissions are already monitored by the government, thus instituting a tax or eco-label has little or no additional cost.

2.1. No government regulations

Let superscript "N" denote the equilibrium outcome without any policy or program in place. It is easy to verify that Cournot output competition leads to the following results for price, quantities of the good produced by the firms, and their profits:

$$p^N = \frac{a}{3}; \quad q_1^N = q_2^N = \frac{a}{3}; \quad \pi_1^N = \pi_2^N = \frac{a^2}{9}. \tag{1a}$$

We then calculate the equilibrium levels of consumer surplus, total environmental damage, and social welfare:[3]

$$CS^N = \frac{2a^2}{9}; \quad D^N = \frac{2ad}{3}; \quad SW^N = \frac{2a(2a-3d)}{9}. \tag{1b}$$

2.2. Government regulations: Eco-certifications and tax emissions

In analyzing an environmental policy, we consider a three-stage game. At stage one, the government sets its policy (either eco-standard (s) or the tax rate (τ)). At stage two, the competing firms invest in abatement technology (to meet the eco-standard set or reduce tax payments). At stage three, the firms engage in Cournot competition in the product market.

2 Schumacher's (2010) evaluation of how taxes/subsidies affect consumer preferences in the context of eco-labels shows that consumers with a preference for green products would prefer a tax on dirty production. However, consumers more concerned with the price of a product (as opposed to green production) will not support taxes on dirty production.

3 Note that SW ≥ 0, when $a \geq 3d/2$. We assume this condition holds.

2.2.1. Socially optimal eco-certifications

Similar to Liu et al. (2015), we assume that abatement exhibits decreasing returns to scale and represent abatement costs as a quadratic function. Under eco-certification, the market price and firm profit are calculated by: ;

$$p = (a + s) - (q_1 + q_2); \quad \pi_i = pq_i - r^2 = [(a + s) - (q_i + q_j)]q_i - r^2;$$

where s reflects an increase in consumers' willingness to pay due to product certification standard (Manasakis et al., 2013; Liu et al., 2015), and r represents a firm's fractional reduction in emission due to investment in abatement technology.[4] For many industries, firms purchase abatement technology developed by third parties. As is common in the literature, we represent abatement marginal costs as linear.

The inclusion of s is consistent with the observation that environmentally conscientious consumers are willing to pay a premium for eco-labeled products (Loureiro and Lotade, 2005; Schumacher, 2010). As a result, demand increases (from cleaner production) only occur when consumers observe an eco-certification. However, lax certification standards or false certifications, used as a marketing technique, allow firms to charge a premium for their product while limiting their abatement efforts.[5] We assume government certifications sufficiently test and communicate any eco-labels. Therefore, the certificating entity in our analysis perfectly identifies abatement associated with each product and effectively communicate this to consumers.

Given that investment in abatement technology is costly, we expect that any profit-maximizing firm will minimize their investment by settling r such that it satisfies the standard set by the government. That is, firms will set: $r = s$. When both firms accept the standard requirements and engage in Cournot competition, we have

$$p = \frac{a - s}{3}; \quad q_1 = q_2 = \frac{a + s}{3}; \quad \pi_1 = \pi_2 = \frac{(a - 2s)(a + 4s)}{9};$$

$$CS = \frac{2(a + s)^2}{2}; \quad D = \frac{2d(1 - s)(a + s)}{3};$$

$$SW = \frac{2(a + s)^2 + 2(a - 2s)(a + 4s)}{9} - \frac{2d(1 - s)(a + s)}{3}. \tag{2a}$$

Given that ecolabels are designed to provide information to consumers concerned about the environmental damage created from firms' production, we expect that eco-labeling reflects all three of these components (consumer surplus, environmental damage, and firm profit). Therefore, we assume the objective of the government is to determine an optimal standard of the eco-label that maximizes social welfare as given in (2a). Solving for the optimal eco-standard yields[6]

$$s^{Eco} = \frac{4a - 3d + 3ad}{2(7 - 3d)}. \tag{2b}$$

where the superscript "*Eco*" denotes the case of eco-certification. It is easy to verify that

$$\frac{\partial s^{Eco}}{\partial a} = \frac{3d + 4}{14 - 6d} > 0 \quad \text{and} \quad \frac{\partial s^{Eco}}{\partial d} = \frac{3(11a - 7)}{2(7 - 3d)^2} > 0.$$

Substituting s^{Eco} from (2b) back into (2a), we have the following equilibrium results:[7,8]

$$p^{Eco} = \frac{6a - d - ad}{2(7 - 3d)}; \quad q_1^{Eco} = q_2^{Eco} = \frac{6a - d - ad}{2(7 - 3d)}$$

$$CS^{Eco} = \frac{(6a - d - ad)^2}{2(7 - 3d)^2}; \quad \pi_1^{Eco} = \pi_2^{Eco} = \frac{(a + d - 2ad)(5a - 2d + ad)}{(3d - 7)^2};$$

$$D^{Eco} = \frac{d(6a - d - ad)(14 - 4a - 3d - 3ad)}{2(7 - 3d)^2};$$

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4 If $p = a + s - (q_1 + q_2)$, then we still obtain that $CS = \frac{1}{2}(a + s - p)(q_1 + q_2) = \frac{1}{2}(q_1 + q_2)^2$.

5 As pointed out by a reviewer, the effectiveness of certification affects the correlation between price premium and firm abatement. The objective of the certification can differ by entity (van't Veld and Kotchen, 2011), but eco-labels use can amount to effective marketing (Walter, 2020). Therefore, our analysis is focused on labeling with clear objectives that can be effectively communicated to consumers, examples could include energy rantings (EnergyStar), substitutes for ozone depleting products (EPA's SNAP), or produced without specific chemicals (USDA Organic).

6 The optimal eco-standard is also the level of emission abatement from clean technology). It is easy to verify that a maximum exists: $\frac{\partial SW^{Eco}}{\partial s} = \frac{8a - 6d - 28s + 6ad + 12ds}{9} = 0$ and SOC: $\frac{\partial^2 SW^{Eco}}{\partial s^2} = \frac{12d - 28}{9} < 0$ when $d < \frac{7}{3}$. We assume this condition holds.

7 For $D^{Eco} > 0$, it requires that $0 < d < 1.03$. We assume this condition holds.

8 The use of lax certification standards or false certifications results in greater environmental damage and firm profit, but lower social welfare. As pointed out by a reviewer, if ineffective labeling is prevalent, either due lax standards or ineffective communication with consumers, their impact on environmental damage and social welfare is a valid argument against using eco-labeling as a policy tool.

$$SW^{Eco} = \frac{2ad^2 + a^2d^2 - 12ad + 8a^2 + d^2}{2(7 - 3d)}. \tag{3}$$

Comparing the equilibrium outcome in (3) under eco-certification to that in (1c) without government eco-certification program, we have the following:

$$CS^{Eco} - CS^N = \frac{(32a - 3d - 9ad)(4a - 3d + 3ad)}{18(3d - 7)^2} > 0;$$

$$\pi_i^{Eco} - \pi_i^N = -\frac{(a - 6d + 9ad)(4a - 3d + 3ad)}{9(7 - 3d)^2} < 0;$$

$$D^{Eco} - D^N = \frac{d(14 - 18a - 3d + 3ad)(4a - 3d + 3ad)}{6(7 - 3d)^2} < 0;$$

$$SW^{Eco} - SW^N = \frac{(4a - 3d + 3ad)^2}{18(7 - 3d)} > 0. \tag{4}$$

The results in (4) permit us to establish the first proposition:

Proposition 1. *Compared to the case without any government programs, (socially optimal) eco-certification benefits consumers ($CS^{Eco} > CS^N$) but can never be voluntary to polluting firms since their profits are affected negatively ($\pi_i^{Eco} < \pi_i^N$). However, eco-certification unambiguously reduces total damage to the environment ($D^{Eco} < D^N$) and is socially desirable. ($SW^{Eco} > SW^N$). In the case of compulsory certification, the optimal eco-standard increases with market size (a) and the marginal environmental damage (d) of emissions.*

This analysis highlights both the benefits and limitations of eco-certifications use by the government. As a policy tool, eco-certifications effectively increase social welfare and decrease environmental damage. However, as a market-based solution eco-certification would be ineffective since no firm would voluntarily subject themselves to the standard to lower their profits, unless there is a strategic use, such as imposing these standards on the industry as a method of increasing rival costs (for more on this, see Grolleau et al., 2007). Furthermore, the effects of compulsory eco-certification would mirror the use of product standards.[9]

Stringent eco-certification likely results in two responses by firms. The first is apparent, firms do not undertake any abatement efforts and produce as normal. The second response is more disparaging. In the absence of profit increasing eco-label, firm(s) are likely to create their own label to profit from consumer environmental consciousness. The limited offerings or practicality of current eco-labeling by the regulatory agency has likely exacerbated the diffusion of ecolabels. The proliferation of eco-labeling may further decrease their ability to credibly signal information to consumers (Yokessa and Marette, 2019) and in the absence of monitoring and credible enforcement, eco-labeling can devolve into a marketing tactic.[10]

2.2.2. Emission taxes

Unlike eco-labels, emission taxes are generally aimed at mitigating the damages that specific pollutants create.[11] Therefore, we consider the case that the government enforces *the first-best* emission (or Pigovian) tax on each unit of pollution,[12] where a *first-best* tax rule says that "the emission tax should be set equal to marginal damage cost" (Ulph, 1996).[13] Firms independently engage in emission–reduction investments (denoted as r_i for $i = 1, 2$) to lower emission payments before making their output decisions under Cournot competition. Given that consumers are unaware of clean production methods firms employ, consumer demand is unchanged by the clean-technology investment by firms. As a result, the market price and firm profit are:

$$p = a - (q_1 + q_2); \quad \pi_i = pq_i - \tau q_i + r_i \tau q_i - r_i^2.$$

9 Montero (2002) compares R&D incentives created by standards and permits, and shows the standards can offer greater incentives for imperfectly competitive markets. Ishikawa and Okubo (2011) evaluates the use of product standards within an international trade context.

10 van't Veld and Kotchen (2011) examine certification by different groups (e.g. environmentalists, industry, govt.) and assume a credible monitoring system exists to ensure firms meet the standard.

11 As pointed out by a reviewer, a socially optimal emission tax would correct for inefficiencies created by imperfect competition. This analysis is obviously justified, but we provided a different analysis for two reasons. First, the socially optimal emission tax yields an intractable outcome. Second, eco-labels have often crafted for specific industries, thereby accounting for consumer concerns, environmental damage, and producer surplus, e.g., furniture, cleaning products, coffee, etc. While, emission taxes are often crafted for specific pollutants, e.g., carbon, CFCs. We are unaware of an emission tax aimed ay combating both emissions and imperfect competition.

12 Barnett (1980) discusses the use of a Pigouvian tax in the context of market power.

13 Pigouvian tax corrects for a negative externality by taxing at a rate equal to the damages caused by the externality. Requires. For additional discussion see Baumol (1972).

With emission taxation, tax revenue and social welfare are calculated as:

$$TR = \tau[(q_1 - r_1q_1) + (q_2 - r_2q_2)]; \quad SW = CS + \pi_1 + \pi_2 - D + TR.$$

Imposing the first best emission tax rate means that government taxes emissions at a rate equal to the marginal damages the polluting firms cause. That is, $\tau = d$. We calculate the equilibrium results as follows:

$$p^T = \frac{6d + 3a - 2ad^2}{9 - 2d^2}; \quad r_1^T = r_2^T = \frac{2(a-d)d}{9-2d^2}; \quad q_1^T = q_2^T = \frac{3(a-d)}{9-2d^2};$$

$$CS^T = \frac{18(a-d)^2}{(9-2d^2)^2}; \quad \pi_1^T = \pi_2^T = \frac{(3-2d)(3+2d)(a-d)^2}{(9-2d^2)^2}; \quad D^T = \frac{6d(9-2ad)(a-d)}{(9-2d^2)^2};$$

$$TR^T = \frac{(12ad^3 + 54ad - 12a^2d^2 - 54d^2)}{(9-2d^2)^2}; \quad SW^T = \frac{4(a-d)^2}{9-2d^2}, \tag{5}$$

where the superscript "T" denotes the case of an emission tax policy.

Comparing the equilibrium outcome in (4) under an emission tax to the unregulated market equilibrium in (1), yields:

$$CS^T - CS^N = -\frac{2d(9-2ad)(18a-9d-2ad^2)}{9(9-2d^2)^2} < 0;$$

$$\pi_i^T - \pi_i^N = -\frac{162a - 81d - 72ad^2 + 4a^2d^3 + 36d^3}{9(9-2d^2)^2} < 0;$$

$$D^T - D^N = -\frac{2(4ad^3 - 54ad + 18a^2 + 81)d^2}{3(9-2d^2)^2} < 0;$$

$$SW^T - SW^N = \frac{2d(90a^2d - 8a^2d^3 + 12ad^4 - 144ad^2 - 81a + 18d^3 + 162d)}{9(9-2d^2)^2} > 0. \tag{6}$$

In view of the results in (6), we have

Corollary 1. *Compared to the case without any government regulation, an emission tax policy reduces consumer surplus since total consumption decreases ($CS^T < CS^N$). The tax policy lowers the profits of the polluting firms ($\pi_i^T < \pi_i^N$) and unambiguously reduces total environment damage ($D^T < D^N$). The emission tax policy is, however, socially desirable ($SW^T > SW^N$).*

2.2.3. Voluntary eco-certification

For eco-certification programs to be voluntary, it must incentivize firms to adopt the emission standard created by the certifying agent. This will occur if π_i as shown in (2a) is no less than π_i^N as shown in (1a). The condition that $\pi_i \geq \pi_i^N$ implies that $s \leq a/4$.[14] While the standards necessary for voluntary eco-certifications inherently fail short of the government's ideal standard, as noted by Ishikawa and Okubo (2011), governments are often more permissive with industry standards that impose high compliance costs. In this regard, a voluntary eco-certification represents a less stringent policy that industry will condone.

Let s^V denote the voluntary standard where $s^V = a/4$, and assume an indifferent firm will voluntarily adopt the standard, which means the firm will utilize the eco-certification.[15] Substituting s^V back into (2a), we have the following equilibrium results:

$$p^V = \frac{5a}{12}; \quad q_1^V = q_2^V = \frac{5a}{12}; \quad CS^V = \frac{25a^2}{72}; \quad \pi_1^V = \pi_2^V = \frac{a^2}{9};$$

$$D^V = \frac{5a(4-a)d}{24}; \quad SW^V = \frac{a(41a - 60d + 15ad)}{72}. \tag{7}$$

We observe that both consumer surplus and firm profit are unaffected by environmental damage. For firms, eco-labeling provides a method by which to monetize and profit from investment in clean technology. Therefore, environmental damages are irrelevant to their decisions. Consumers' willingness to pay for eco-labeled products is based on

[14] For a detailed derivation for this result, see A-1 in the Appendix.

[15] This approach more closely represents EPA recommendations of eco-labels for federal purchasing. As noted from EPA (2017), "EPA has noted where standards have followed the practices of the development of "Voluntary Consensus Standards" as defined by Office and Management Budget Circular A-119. Section 12(d) of The National Technology Transfer and Advancement Act (NTTAA, PL 103–114) calls federal agencies to use Voluntary Consensus Standards (VCS) in lieu of government-unique standards in their procurement and regulatory activities, except where inconsistent with law or otherwise impractical".

their concern for environmental damage. However, the premium on eco-labeled products stems from a relative reduction of emissions and consumers are unlikely to know the corresponding damages or reduction in damages from a specific product.

Comparing the equilibrium outcome in (7) with voluntary eco-certification to that in (1c) without any government program, we have:

$$CS^V - CS^N = \frac{a^2}{8} > 0; \quad D^V - D^N = \frac{(4-5a)ad}{24};$$

$$SW^V - SW^N = \frac{a(3a+5ad-4d)}{24} > 0. \tag{8}$$

These results in (8) allow us to state the following:

Corollary 2. *Voluntary eco-certification increases with market size (a), raise the certification standard, and increases the program's effectiveness in reducing environmental damage relative to the case without any government programs. Overall, voluntary eco-certification benefit consumers ($CS^V > CS^N$) and is socially desirable ($SW^V > SW^N$).*

These results show some hope that voluntary eco-certification could be a meaningful environmental program. The use of voluntary eco-certification increases both consumer surplus and social welfare. However, its effectiveness as an environmental program depends on the demand for the product. For the program to effectively reduce environmental damage, product demand must be sufficiently large ($a > 0.8$), which is likely the type of markets where this policy is considered.

3. Analysis and implications for the environment and social welfare

In this section, we compare the effectiveness of each eco-certification to emission taxes. Since our focus is on the usefulness of eco-certification as an environmental tool relative to emission tax, we analyze each eco-certification scenario (compulsory and voluntary) directly to the emission tax scenario.

3.1. Compulsory eco-certification programs vs. emission tax policies

We first analyze and compare the two alternative policies.[16] Looking at the difference between the emission abatement under a compulsory eco-standard (r^{Eco}) and an emission tax (r^T). We find that $r^{Eco} - r^T > 0$, indicating that the mandatory eco-standard is more effective at increasing the use of clean technology. In contrast, an examination of the equilibrium output indicates that $q_i^{Eco} - q_i^T > 0$, or that emission taxes create more significant reductions in production.

For consumers, we have $CS^{Eco} > CS^T$. For producers, we have $\pi_i^{Eco} - \pi_i^T = -Z_4/H$, where $H = (7-3d)^2(9-2d^2)^2 > 0$ and Z_4 as a function of d.[17] There are two important results from our analysis: (i) For a low value of d, we have $Z_4 < 0$, which implies that $\pi_i^{Eco} > \pi_i^T$. (ii) For a high value of d, we have $Z_4 > 0$, which implies that $\pi_i^T > \pi_i^{Eco}$. We, thus, have

Proposition 2. *Consumers unambiguously are better off with a compulsory eco-standard than emission tax; however, producers' preferred policy is dependent on the level of environmental damage.*

From the perspective of consumers, their best option is publicly supporting compulsory eco-standard over tax emission. Eco-standards provide additional intrinsic value to purchased products due to the information communicated. Furthermore, compulsory standards ensure that firms must sufficiently reduce their emissions. From the firms' perspective, emission taxes provide flexibility by allowing firms to pay the tax or sufficient investment in abatement. However, compulsory eco-standards can benefits firms if consumers' intrinsic value from eco-label allows firms to raise prices. Therefore, when environmental damage is low consumers and producers prefer the compulsory eco-standard. As environmental damage increases and abatement costs increase exponentially, firms begin to prefer the flexibility of the emission tax. In this case, no policy will have unanimous support and the benefactors of these policies will vary, which may provide details about their political feasibility.

Next, we compare the overall environmental damage and social welfare of each policy.[18] Comparing total environmental damage reveals that $D^{Eco} - D^T = Z_5/H$, where Z_5 as a function of d can be found in Appendix A.6. There are two possibilities. When the value of d is low, we have $Z_5 > 0$, which implies that $D^T < D^{Eco}$. When the value of d is high, we have $Z_5 < 0$, which implies that $D^{Eco} < D^T$.

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[16] Calculations provided in Appendix for clean technology (Appendix A.2), firm output (Appendix A.3), consumer surplus (Appendix A.4), and firm profit (Appendix A.5).

[17] The Appendix A.4 provided the functional form for Z_4.

[18] Calculations for environmental damage and social welfare are in Appendix A.7 and Appendix A.8, respectively.

Finally, we look at the difference in social welfare:

$$SW^{Eco} - SW^{T} = \frac{Z_6}{2(7-3d)(9-2d^2)},$$

where Z_6 as a function of d can be found in Appendix A.7. There are two possibilities. When the value of d is low, we have $Z_6 < 0$, which implies that $SW^T > SW^{Eco}$. When the value of d is high, we have $Z_6 > 0$, which implies that $SW^{Eco} > SW^T$. Summarizing these results as follows

Corollary 3. *Comparing policies we find that: (i) Investment in abatement technology is highest under compulsory eco-certification; (ii) When the marginal damage to the environment from emissions is sufficiently low, total environmental damage is relatively lower and social welfare is relatively higher under the emission tax policy; (iv) When the marginal damage to the environment from emissions is sufficiently high, total environmental damage is relatively lower and social welfare is relatively higher under the compulsory eco-certification program.*

The comparison of eco-standard and emission taxes has important implications from a policy perspective. As discussed in Proposition 2, compulsory eco-standards require firms to sufficiently reduce their emissions. As a result, firms are forced to further invest in abatement technology relative to other policies. In addition, we previously found that compulsory eco-standards is the preferred approach policy for all market participants (consumers and producers) when production yields low levels of environmental damage. However, this analysis ignored the resulting environmental damage.

Importantly, we find that with low levels of environmental damage, the optimal policy is emission taxes. The ideal eco-standard depends heavily on consumers' desire for responsibly produced products. However, the intrinsic value yielded from purchasing eco-labeled products may not accurately correspond to the benefits of the labeling. Consumers may desire labeled products (even with accurate information) less than the environmental benefits certifying required. As a result, consumers still obtain a greater surplus from an eco-labeled product, but the underlying environmental damage is enough to result in a lower level of social welfare, relative to emission taxes. This shows a misalignment between the affected parties and support for the ideal policy. While a policy will not be favored by all market participants, in this context, neither side (consumers or producers) will advocate for the most effective policy. As environmental damage from production increases, compulsory eco-standard forces firms to invest in abatement beyond what emission tax requires yielded to lower environmental damage and greater social welfare.

3.2. Voluntary eco-certification programs vs. emission tax policies

Next, we compare the equilibrium outcomes between voluntary eco-certification programs and emission tax policies. Based on the results in (5) and (6),[19] we find that the equilibrium level of output produced by each polluting firm is lower under a voluntary eco-certification program than under an emission tax policy. This allows each firm to make a relatively higher profit under the voluntary program. That is, $q_i^V < q_i^T$ and $\pi_i^V > \pi_i^T$.

As for consumer surplus, we find that $CS^V < CS^T$ when market demand is low and marginal damage is high. However, when the market demand is high, we have $CS^V > CS^T$. This suggests that consumers are better off under voluntary eco-certification programs when market demands for products are high. Furthermore, as shown in Section 2, both consumer surplus and firm profit are unaffected by environmental damage in the case of voluntary eco-standards but are negatively impact in the case of emissions policy.

Proposition 3. *Producers are unambiguously are better off with voluntary eco-standard than emission tax; however, consumers' preferred policy is dependent on the level of demand.*

Relative to the compulsory eco-standard, we obtain a similar (but distinctly different) result. In the case of voluntary eco-standards, producers will always support eco-standard over tax emission. In the case of lower levels of demand, we see that, again, both consumers and producers would prefer an eco-standard, and in the context of more serious environmental damage, consumers and producer will not have unanimous support for either policy.

As before, we next compare how each policy impacts overall environmental damage and social welfare. Using the results in Appendix A.4, which compare each policy's impacts. The comparison of total damage to the environment between voluntary programs and emission tax policies reveals that $D^V > D^T$, when market demand is high and hence marginal damage is high. Under the same circumstances, we find that $SW^V > SW^T$. That is, welfare is higher under a voluntary eco-certification program than under an emission tax policy when demand is high. At the same time, when demand is sufficiently low, we have $D^V > D^T$. Examining social welfare under the same conditions we find that $SW^V < SW^T$. We use Table 1 to summarize the outcomes from our comparison.

19 Calculation provided in Appendix A.8

Table 1
Comparison of voluntary eco-labels to emission taxes.

		Total output	Firm profit	Consumer surplus	Total env. damage	Social welfare
High demand	High marginal env. damage	$<$	$>$	$>$	$>$	$>$
	Low marginal env. damage	$<$	$>$	$>$	$<$	$>$
Low demand	High marginal env. damage	$<$	$>$	$<$	$>$	$<$
	Low marginal env. damage	$<$	$>$	$>$	$>$	$<$

From these outcomes, we can state:

Proposition 4. *Comparing policies we find that: (i) Unless the marginal damage to the environment from emissions is sufficiently low and market demand is adequately large, total environmental damage is relatively higher under the voluntary eco-certification; (ii) When demand is large enough, social welfare is relatively lower under emission tax policy, but when demand is critically small social welfare is relatively lower under the voluntary eco-certification program.*

While our results do not identify a "best" policy, we can identify conditions under-which each policy will be more effective. With higher demand, voluntary eco-labels are a better approach. However, it will not necessarily create the greatest incentives for dirty firms to reduce their emissions. In markets with greater marginal environmental damage from production, emission taxes are more effective in reducing overall environmental damage.

4. Policy implications and political feasibility

The comparison of these equilibrium policy outcomes yields several valuable insights about environmental policy. Kotchen et al. (2013) argue that the willingness to pay for different programs such as cap and trade, taxes, or other regulation is similar. If we assume consumers' willingness-to-pay for an environmental policy is identical to the premium associated with an eco-labels, then consumers would be indifferent to paying either: 1) higher prices, due to an effective emission tax (effective in that emissions are reduced) or 2) paying a premium, equal in size, for eco-labeled products with a standard that requires an equivalent reduction in emissions. However, comparing these outcomes is not straightforward. One reason is that the burden from an emission tax falls on both consumers and producers equivalent to marginal environmental damage created from production. In this scenario, the emission tax generates enough funds to cover abetment efforts to potentially undo any damages.[20] Eco-labels, on the other hand, create a direct transfer from consumers to producers through a premium which may exceed a firm's abatement costs. Unlike emissions taxes, the higher prices created by eco-labels represents the value consumers place on information about production.

Eco-labels also have both inconspicuous and conspicuous benefits for a consumer, which may not necessarily occur with the consumption of products with emission taxes. Eco-labels provide information to consumers, unlike emission taxes or permits, where consumers may unknowingly purchase taxed products. Our approach highlights the challenges that government eco-labels face as a policy. At the same time, we find evidence of a disparate effect in their absence, the creation of additional "certification" by firm. We acknowledge that our framework includes the intrinsic benefit consumer feel from purchasing environmentally friendly products, which alters social welfare. Nevertheless, eco-labeled products are ubiquitous and the resulting consumption changes are far from trivial.

We are unaware of any research indicating that consumers' willingness-to-pay for a product adjusts in response to an emission tax. Firms subject to taxes and permits can (and often do) campaign their cleanliness to consumers, but it is unclear if the results would be as effective. If we evaluate the political feasibility of each policy (feasible meaning socially preferred), the factors that determine the most favored policy are the consumer surplus, social environmental damage, and firm profit. This essentially represents the following interest groups: non-market participants, consumers, and producers. Evaluating social welfare would yield the same results; however, by examining each component separately, we can gain greater insight into each groups' preference.

Our analysis shows that supporting a policy by each group tends to move similar directions. With high demand products, consumers, producers and non-market participants prefer voluntary eco-labels. Lower demand increases the social costs of voluntary eco-labels relative to emission taxes ($D^V > D^T$), thus making taxes more politically feasible and attractive due to the appeal to non-market participants. Under the same circumstances, producers unequivocally support eco-labeling instead of emission taxes. However, in the event marginal damage from production is higher, both sides of the market (consumers and producers) agree on the preferred policy, which is sub-optimal. This result is likely to hold for "non-priority" markets, where production and environmental damage are relatively lower, and likely not already subject to environmental regulation. Importantly, this implies that the preferred policy is not socially optimal.

[20] As correctly pointed out by a reviewer, a Pigouvian tax creates an efficient outcome, i.e., the revenue generated by the tax could be redistributed to consumers, firms, or used to reduce other taxes that are distortionary.

5. Concluding remarks

In this paper, we present a model of duopolistic competition to analyze differences in implications between eco-certification and emission tax policies for the environment, the clean-technology investment, and social welfare. We find scenarios where both policies have merit, but that the best policy is dependent on the regulatory objective, environmental damage, and overall product demand. For eco-certification, we find that it reduces total damage to the environment, increases consumer benefits, and is socially desirable. However, if the government sets the standard, polluting firms will not voluntarily subject themselves to eco-certification at the socially optimal level. There are still levels that the firms will voluntarily agree to the standard, but they occur at a level below that requested by the government. As an alternative to emission taxes, we find that eco-certification policies can improve social welfare, but it depends crucially on overall product demand.

When market demand is relatively low, social welfare is relatively higher under the emission tax policy. From an environmental standpoint, the presence of more serious environmental damage implies that an emission tax would be more effective. However, a market that is relatively limited in production and consumption is unlikely to influence a critical number of consumers or the general public to support a non-voluntary regulation such as taxation or permits, even if it is market-based. In the context of low marginal damage, we would expect consumers to be "egoists" or be more concerned with the private benefits of purchasing eco-labels, as discussed by Grolleau et al. (2009). Additionally, the use of voluntary policies like eco-labels is easily implemented thus explaining the vast expansion of eco-labels as an environmental tool.

On the other hand, when demand is high, social welfare is relatively higher under the easily implemented eco-certification program. Unsurprisingly, many currently used eco-labels fall into this category. However, in the case of more serious environmental damage, the public concern would be greater and hence much more widespread. Therefore, regulatory action (like permits or emission taxation) is more likely to occur, resulting in a welfare loss. The public concern could thus negatively impact the market outcome by indirectly supporting the use of substandard environmental policies such as tradable permits or emission taxes.

As noted by Tews et al. (2003), concern with competitiveness lowers the "political feasibility" of certain environmental taxes, while eco-certification has seen rapid spread in certain countries. Since emission taxes require a significant level of social concern to muster enough political clout to pass, we would expect this type of action to occur when production causes substantial environmental damage and can shift public opinion. However, in markets with significant environmental damage from production, we have shown that using emission taxes as a regulatory approach yields a better environmental outcome.

These results illustrate a regulatory quandary in the context of eco-labels and emission taxes. We have shown a scenario where the selected policy is likely to be both optimal and political feasibility. Eco-certification programs require considerably less political leverage to enact and, as a result, they are easier to impose in markets where production causes significant environmental damage. Unfortunately, in these types of markets, traditional environmental policies are more likely to be enacted, yielding a sub-optimal outcome. Our findings provide some guidance in identifying the optimal policies when deciding between eco-labels or emission taxes while also highlighting the political obstacles hindering enactment.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix. Mathematical appendix

A.1. To make the eco-standards voluntary to polluting firms, each firm's profit with the standard (denoted as π_i^V) must be at least as high as its profit (π_i^N)without the standard. That is, $\pi_i^V \geq \pi_i^N$, where $\pi_i^N = a^2/9$ and $\pi_i^V = [(a-2s)(a+4s)]/9$ as shown in Eqs. (1a) and (2a), respectively. A comparison between these two profit functions indicates that eco-certification is voluntarily accepted by each polluting firm if the standard satisfies the following condition: $0 \leq s^V \leq \frac{a}{4}$. Setting $s^V = \frac{a}{4}$, we find that

$$s^E - s^V = \frac{(4a - 3d + 3ad)}{2(7 - 3d)} - \frac{a}{4} = \frac{(a - 6d + 9ad)}{4(7 - 3d)} > 0.$$

This implies that $0 < s^V < s^{Eco}$.

A.2. A comparison between the emission abatement under an eco-standard (r^{Eco}) and an emission tax (r^T) reveals that

$$r^{Eco} - r^T = \frac{Z_1}{2(7 - 3d)(9 - 2d^2)}$$

where $Z_1 = 36a - 27d + 4ad^2 - 6ad^3 - ad + 28d^2 - 6d^3 > 0$.[21] This implies that $r^{Eco} > r^T$.

[21] The positivity of Z_1 follows from the constrained condition for environmental damage that $0 < d < \frac{1}{3}(\sqrt{37} - 3)$ (see footnote 3) and the restriction that $a \geq 3d/2$ (see footnote 1).

A.3. Calculating the difference in the equilibrium output yields

$$q_i^{Eco} - q_i^T = \frac{Z_2}{2(7-3d)(9-2d^2)} > 0$$

where $Z_2 = 12a + 33d - 12ad^2 + 2ad^3 + 9ad - 18d^2 + 2d^3 > 0$. This indicates that $q_i^{Eco} > q_i^T$.

A.4. To compare consumer surplus, we calculate the following:

$$CS^{Eco} - CS^T = \frac{Z_3}{2(7-3d)^2(9-2d^2)^2}$$

where

$$Z_3 = (12a + 33d - 12ad^2 + 2ad^3 + 9ad - 18d^2 + 2d^3)(96a - 51d - 12ad^2 + 2ad^3 - 27ad + 18d^2 + 2d^3).$$

It can also be verified that $Z_3 > 0$, which implies that $CS^{Eco} > CS^T$.

A.5. With respect to firm profits, we have

$$\pi_i^{Eco} - \pi_i^T = -\frac{Z_4}{(7-3d)^2(9-2d^2)^2}$$

where

$$\begin{aligned} Z_4 = &-(351ad^2 + 351a^2d + 338ad^3 - 156ad^4 + 60ad^5 - 20ad^6 + 227a^2d^2 - 156a^2d^3 \\ &- 128a^2d^4 + 36a^2d^5 + 8a^2d^6 - 1125ad + 36a^2 + 603d^2 - 378d^3 - 187d^4 + 168d^5 - 28d^6). \end{aligned}$$

Evaluating Z_4 at the critical point where $a = 3d/2$ yields

$$Z_4 = d^2(3753d + 3323d^2 - 1668d^3 - 904d^4 + 204d^5 + 72d^6 - 4014)/4.$$

There are two points of interest that can be obtained from our analysis. First, for a low value of d (say, $d = 0.1$), we have $Z_4 < 0$, which implies that $\pi_i^{Eco} > \pi_i^T$. Second, for a high value of d (say, $d = 1.0$), we have $Z_4 > 0$, which implies that $\pi_i^T > \pi_i^{Eco}$.

A.6. Comparing total environmental damage reveals that

$$D^{Eco} - D^T = \frac{Z_5}{2(7-3d)^2(9-2d^2)^2}$$

where

$$\begin{aligned} Z_5 = &\, d(1512a + 4158d - 4686ad^2 + 42a^2d + 2016ad^3 - 96ad^4 - 112ad^5 + 24ad^6 + 99a^2d^2 + 720a^2d^3 \\ &- 204a^2d^4 - 56a^2d^5 + 12a^2d^6 + 2268ad - 1944a^2 - 4293d^2 + 1476d^3 - 108d^4 - 56d^5 + 12d^6) \end{aligned}$$

Evaluating Z_5 at the critical point where $a = 3d/2$ yields,

$$Z_5 = d(-21060d - 21834d^2 + 12555d^3 + 5680d^4 - 2460d^5 - 360d^6 + 108d^7 + 25704)/4$$

There are two possibilities. (i) When the value of d is low (say, $d = 0.1$), we have $Z_5 > 0$, which implies that $D^T < D^{Eco}$. (ii) When the value of d is high (say, $d = 1.0$), we have $Z_5 < 0$, which implies that $D^{Eco} < D^T$.

A.7. Finally, we look at the difference in social welfare:

$$SW^{Eco} - SW^T = \frac{Z_6}{2(7-3d)(9-2d^2)}$$

where

$$Z_3 = -(30ad^2 - 24a^2d - 24ad^3 + 4ad^4 + 7a^2d^2 + 2a^2d^4 - 4ad - 16a^2 + 47d^2 - 24d^3 + 2d^4).$$

Evaluating Z_3 at the critical point where $a = 3d/2$, we have

$$Z_3 = -d^2(-132d - 73d^2 + 24d^3 + 18d^4 + 20)/4.$$

There are two possibilities. (i) When the value of d is low (say, $d = 0.1$), we have $Z_6 < 0$, which implies that $SW^T > SW^{Eco}$. (ii) When the value of d is high (say, $d = 1.0$), we have $Z_6 > 0$, which implies that $SW^{Eco} > SW^T$.

A.8. We first look at the difference in the equilibrium output:

$$q_i^V - q_i^T = \frac{9a + 36d - 10ad^2}{12(2d^2 - 9)}.$$

When demand is low ($a = 3d/2$), we have

$$\frac{9a + 36d - 10ad^2}{12(2d^2 - 9)} = -\frac{d(10d^2 - 33)}{8(2d^2 - 9)} < 0.$$

Note that for all possible values of d, we have $9 - 2d^2 > 0$. When demand is high ($a = 9/2d$), we have $\frac{9a+36d-10ad^2}{12(2d^2-9)} = -\frac{3}{8d} < 0$. These results imply that

$$q_i^V < q_i^T,$$

regardless of market demand (size).

Next, comparing firm profits yields

$$\pi_i^V - \pi_i^T = \frac{d(162a - 81d - 72ad^2 + 4a^2d^3 + 36d^3)}{9(9 - 2d^2)^2}.$$

When demand is low ($a = 3d/2$), the numerator of the expression is positive since

$$(162a - 81d - 72ad^2 + 4a^2d^3 + 36d^3) = 9d(18 - 8d^2 + d^4) > 0$$

When demand is high ($a = 9/2d$), the numerator of the expression continues to be positive since

$$(162a - 81d - 72ad^2 + 4a^2d^3 + 36d^3) = 9(2d^2 - 9)^2/d > 0.$$

We thus have $\pi_i^V > \pi_i^T$, regardless of the market demand. As for consumer surplus, we see that

$$CS^V - CS^T = \frac{(9a + 36d - 10ad^2)(81a - 36d - 10ad^2)}{72(9 - 2d^2)^2}.$$

When demand is low ($a = 3d/2$), we have

$$\frac{(9a + 36d - 10ad^2)(81a - 36d - 10ad^2)}{72(9 - 2d^2)^2} = \frac{d(10d^2 - 33)(10d^2 - 57)}{32(2d^2 - 9)^2} < 0,$$

where the negative sign is due to the restrictions on d. This implies that

$$CS^V < CS^T.$$

But when demand is high ($a = 9/2d$), we have

$$CS^V - CS^T = \frac{(9a + 36d - 10ad^2)(81a - 36d - 10ad^2)}{72(9 - 2d^2)^2} = \frac{81}{32d^2} > 0,$$

which implies that $CS^V > CS^T$. The difference in total damage to the environment is:

$$D^V - D^T = \frac{d(324a + 1296d - 1008ad^2 + 288a^2d + 80ad^4 + 180a^2d^2 - 20a^2d^4 - 405a^2)}{24(9 - 2d^2)^2}.$$

When demand is low ($a = 3d/2$), this yields:

$$D^V - D^T = \frac{-d(45d^6 - 120d^5 - 405d^4 + 864d^3 + 911.25d^2 - 1782d)}{24(2d^2 - 9)^2} > 0,$$

and when demand is high ($a = 9/2d$), this yields:

$$D^V - D^T = \frac{1080d - 1215}{63d^3} > 0,$$

for all possible values of d. These results imply that the policy that reduces environmental damage the most depends on the marginal damage from a unit of output. Finally, a welfare comparison indicates that

$$SW^V - SW^T = \frac{135a^2d + 120ad^3 - 82a^2d^2 - 30a^2d^3 + 36ad + 81a^2 - 288d^2}{72(9 - 2d^2)}.$$

When demand is low ($a = 3d/2$), this gives:

$$SW^V - SW^T = \frac{(30d^5 + 2d^4 - 135d^3 + 23d^2)}{64d^2 - 288},$$

which can be both positive (high d) or negative (low d). When demand is high ($a = 9/2d$), this gives:

$$SW^V - SW^T = \frac{(-56d^2 + 135d + 81)}{32d^2} > 0,$$

for all value of d. We thus have that the optimal policy depends on market demand and environmental damage.

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