# Welfare Implications of Environmental Policy; when consumers are Environmentally Conscious and have Future Considerations

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# Introduction

People nowadays understand that with the accumulated human impact on the environment, the future of the planet will be dark if proper actions are not taken. Humans have a long history of severely exploiting the environment leading to irreparable impacts on it. Prehistoric agricultural practices tended to significantly impact the forests mainly due to clearing by burning. Later, larger population started depleting forests through clearing for fields and intensive harvest of firewood and wild resources (Kohler 1992). Humans have also altered the ocean ecosystem through land-based activities (run-off of agricultural fertilizers and pesticides into oceans) and ocean-based activities (resource extraction and species composition alternation) (Halpern *et al.* (2008)). Through investigation of anthropogenic drivers of ecological change for marine ecosystems, Halpern *et al.* (2008) show that all areas are affected by human influence and a large fraction is affected by multiple drivers. In a case study on The Baltic Sea, Elmgren (2001) states that the sea population were found to carry large amounts of DDT, polychlorinated biphenyl, and mercury which tend to persist in the environment and within animals' body at the head of the food chain, making them unsuitable to eat for humans.

Such ongoing challenges to the environment and consequently hazards for mankind have been influential warnings to people. Consumers are now becoming more conscious about the potential immediate impacts of human actions on the environment and its inhabitants as well as potential longer term impacts. With higher awareness, consumers are more willing to pay higher prices for environmentally friendly products or green products[2]. For example, Roe *et al.* (2001) in their paper

[2] Durif, Boivin, and Julien (2010) provide a comprehensive set of definitions for green products from academic perspective, industrial perspective, and consumer perspective. The integrative definition they provide for academic perspective is: "A green product is a product whose design and/or attributes (and/or production and/or strategy) use recycling (renewable/toxic-free/biodegradables) resources and which improves environmental impact or reduces environmental toxic damage throughout its entire life cycle". According to the industrial

of “US consumers' willingness to pay for green electricity” find that US consumers value environmental benefits derived from green alternatives of traditional electricity generating methods and many population segments are willing to pay more for decreased air emissions. US firms on the other hand, have recognized this willingness to pay and are offering several products with different prices to capture consumers’ value. However, they also emphasize the importance of other policy instruments in the cases of rapidly increasing energy prices. Lin and Huang (2012) also demonstrate that consumers with high environmental concern support green products more, and show greater readiness to choose them. Therefore, it’s important to acknowledge consumers’ increasing tendency to purchase environmentally friendly products.

In this paper, our goal is to find the market equilibrium when consumers are heterogeneous in their preferences for the environmental preservation. Also, due to long term impacts of environmental pollutants, we need to account for consumers’ level of future considerations and the interpersonal differences in temporal orientation. Therefore, consumers in our model have two characteristics and are located on a two-dimensional space, based on their environmental preferences and time preferences. We also study the role of imposing a tax on (providing a subsidy for) the polluting (environmentally-clean) firm on market equilibrium, and more specifically on social welfare and environmental damage. The market we are interested in consists of two profit maximizing firms producing a good that is only different in its environmental quality. In other words, the goods produced by each firm have different environmental impacts. The environmental impacts take

perspective, a green product “must respect the "3 R": "reduce", "reuse" and "recycle"; that is certified by an official entity; and that is not tested on animals”, and is biodegradable. Consumers on the other hand, seem to be more concerned about the attributes of a green product affecting environmental preservation and personal health. From consumer’s point of view, “a green household cleaning product is non-toxic for nature, good for health, socially responsible, and good for the planet.” In this paper, we use green product and environmentally friendly product interchangeably which both stand against “brown product” which is not environmentally friendly and produces pollution either during production process or consumption process.

place during either the production or consumption process, and the two products are the same in any other attribute.

We should note that a green (environmentally friendly) product is usually more expensive than its brown (polluting) alternative (due to abatement costs, using a cleaner more advanced technology, cleaner inputs etc.). This means that consumers are facing a social dilemma, a situation in which there is a conflict between short term self-interest (paying a higher price for the green good) and long term collective-interest (a cleaner environment for everyone). Van Lange *et al.* (2013) review different types of social dilemmas and mention that short term self-interest can prevent people from investing their time and efforts for group benefits. Therefore, environmental behavior can be linked to social dilemma through time perspective and social values; two important human traits. Studies show that pro-socials tend to present higher pro-environmental behaviors and intentions than pro-selves (e.g. Joireman *et al* (2001)).

On the other hand, the extent to which consumers consider the future consequences of their behavior can have substantial impact on their decision making (including decisions impacting the environment). While considering future payoffs, it is important to note that all individuals do not value future payoffs the same. Strathman *et al* (1994) developed and validated a new construct called Consideration of Future Consequences (CFC) which refers to "the extent to which individuals consider the potential distant outcomes of their current behaviors and the extent to which they are influenced by these potential outcomes." This definition highlights an intrapersonal conflict between immediate consequences of one's actions and distant outcomes. They mention that this individual difference variable is relatively stable. With empirical experiments, they show that the CFC scale was strongly correlated with environmental behaviour (such that pro-environmental behaviors are higher among individuals scoring high in CFC) and also provide

strong support for significant predictive ability of CFC above other personality measures, including Stanford Time Perspective Inventory, Hope Scale, the Life Orientation Test, and the Conscientiousness dimension of the Big Five Personality Inventory. In other words, they show there is significant variance in human's behavior that can only be explained by CFC. Furthermore, in their book "Time Perspective Theory; Review, Research and Application", Stolarski *et al* (2014) cite several studies comparing time perspective with descriptions of traits in the Big Five model and finding several similarities which further supports that temporal orientation is a dispositional human trait (102). They also provide evidence that individuals are different in their consideration of the past, the present, and the future and that individuals emphasize the present or the future the most and they are least interested in the past.(118). These works suggest that to build a proper theoretical model to explain and predict individuals' decisions, we can only focus on the present and the future, and the effect of payoffs in the past are negligible in humans' choice of behavior.

One limitation of social value orientation approach in the literature is that it is within a few categories (usually prosocial vs. pro-self). For example, within the extended norm activation model of proenvironmental behaviour, Joireman *et al* (2001) integrate social value orientation and CFC in an empirical framework. They study the proenvironmental behavior when the behaviour has short-run negative consequences for the self and long-run positive consequences for the self and others. The decision is affected by two orientations: social orientation and temporal orientation and the utility of a certain decision depends on the actual outcomes for self and group and the weight the individual assigns to the each category of outcomes. Their results show that prosocials expressed stronger proenvironmental intentions compared to proselfs and individuals high in CFC (more focused on their distant consequences) expressed stronger proenvironmental intentions and behaviors. This emphasizes the importance of incorporating temporal orientation in modeling

human behavior. However, regarding social orientation, a more broad approach accounting for continuous spectrum of human values potentially improves the explanatory and predictive power of environmental studies (Milfont and Gouveia (2006)).

Milfont and Gouveia (2006) studies the combined empirical relations of time perspective and values to environmental attitudes. Their results show that future orientation and biospheric (self-transcendence's environmental items) are significantly positively and altruistic (self-transcendence's non-environmental items) is non-significantly positively correlated with environmental preservation. Moreover, by performing hierarchical multiple regression analyses they demonstrate that future perspective and biospheric orientation are predictors of the environmental preservation. Furthermore, both time perspective and values explained nearly the same amount of non-overlapping variance in environmental attitudes. In other words, the relationship between time perspective and environmental attitudes remain significant even when values are controlled for, and that the relationship between values and environmental attitudes remain significant even when time perspective is controlled for. These results further supports the distinction between the social and temporal conflicts in environmental social dilemmas and emphasize the importance of accounting for both social and temporal orientations –as two important psychological constructs- to achieve maximum accuracy in environmental preservation models.

Even though consumers are becoming more environmentally aware, various extinct species and endangered ecosystems teaches us that it might take decades for scientists to get to an unanimous agreement on the causes of environmental issues and proper counteractions, and it may take even longer for these actions to become effective and for the environment to recover. Hence, authorities

responsible for making decisions related to environmental preservation should not wait for scientific certainty and must take immediate actions to protect the nature (Elmgren (2001)).

Lin and Huang (2012) also emphasize role of government by provide subsidies or promotions for green producers, that would help them break even more easily. In that case, consumers are more likely to purchase green due to lower costs. This highlights the importance of analyzing potential welfare improving impacts of policy instruments. Several papers have studied how a tax or subsidy policy may impact consumers and producers behavior when we have negative externalities. However, taking into account the existence of environmentally friendly consumers is a relatively modern trend. Bansal and Gangopadhyay (2003) investigate welfare implications of different tax-subsidy policies with environmentally aware consumers. Assuming environmental friendliness is a quality attribute of the good, they use a vertical differentiation model to show different levels of consumers' willingness to pay for an environmentally friendly product. Their results show that while both a uniform and discriminatory subsidy policy improve environmental quality, a uniform or discriminatory tax policy on the polluting firm may do the opposite. Espinola-Arredondo and Zhao (2012) study impacts of tax (on the brown firm) and subsidy (for the green firm) policies on welfare and pollution in a horizontal differentiation setting with two types of consumers. One group of consumers have a strong preference for the pollution-free product while the other group are indifferent between clean products and conventional polluting products. They show that both a tax or subsidy policy will improve social welfare. However, the consumer in their model does not have any time considerations and they are located at the two endpoints of environmental preference spectrum.

In this paper, we aim to provide a theoretical framework to analyze welfare implications of tax/subsidy in a complete information setting in presence of environmentally conscious

consumers. The main contributions are adding consideration of future consequences to the consumer's utility function and integrating such considerations with a continuum of preferences for the environment. We also investigate the impact of government intervention on different components of social welfare with a focus on environmental damage. Welfare implications of changes in consumers' awareness and abatement costs are also analyzed.

## Model

There is a continuum of environmental preferences which is represented by $\theta$. We assume $\theta$ follows a standard uniform distribution, between 0 and 1. Low value of $\theta$ represents small willingness and ability to pay for the environmentally friendly product, while a large value of $\theta$ represents strong preference for the green product and thus, high willingness to pay for it. Consumers with high value of $\theta$ derive a high utility solely for consuming the green good. We represent consumer's consideration of future consequences with $\beta$. We assume people emphasize on future consequences at most as much as current payoffs; i.e. $\beta \leq 1$. We also assume $\beta$ follows a uniform distribution which with the former assumption sums up to $0 \leq \beta \leq 1$. For example, at the extreme left side end of this continuum, individuals do not even consider future consequences of their decision, while at the extreme right side end of the continuum for $\beta$, individuals care about future payoff as much as they care about current payoff.

Figure 1 shows the location of consumers in this model. The area below the square shows the location of consumers. We can see different combinations of consumers on horizontal and vertical axes.

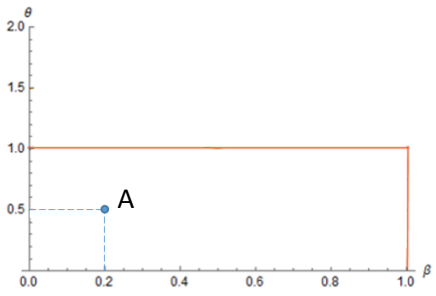

Figure 1; consumers with two attributes

For examples, A=(0.2,0.5) represents a person with a value of future consideration of 0.2 and a

value of 0.5 for willingness to pay for an environmentally friendly product. This person values future payoffs 0.2 of today's payoffs, while she derives moderate additional pleasure from consumption of an environmentally friendly product compared to the brown alternative.

The green firm –represented by firm 1- produces an environmentally friendly product that doesn't produce pollution. The utility of a consumer purchasing from firm 1 is[3]:

$$u = v - p_1 + \theta e + \beta\theta e = v - p_1 + \theta e(1 + \beta)$$

The brown firm –represented by firm 2- on the other hand produces a brown alternative of the green good. Either the consumption or production process of this product causes damage to the environment. The utility of a consumer purchasing from firm 2 is:

$$u = v - p_2$$

Here $v$ is the utility from consuming the good. $v$ is the same for both firms since we assumed the only difference between the goods produced by the two firms is their environmental quality. We also assume that $v$ is large enough that all consumers will buy from either of firms. $p_1$ and $p_2$ are the prices charged by green and brown firm, respectively. $\theta e + \beta\theta e$ is the extra utility derived from purchasing from the clean firm (firm 1). Here, $e$ represents "environmental awareness" and it represents the aggregate level of consumer concerns for the environment. Van Lange *et al* (2013) assert that cooperation requires the expectation that others will cooperate, too and cooperative act has an important impact on the behavior of other members of society. Hence, the aggregate level of public environmental awareness which leads to more cooperative acts in terms of environmental protection plays a crucial role in each individual's demand for the green product and needs to be

[3]Consumers considering purchasing green product as an act helping protect and preserve the environment experience positive feelings of doing good for themselves and for society at large (Lin and Huang (2012)). So we expect this entering into utility function as a form of positive parameter.

taken into account when modeling their utility. On the other hand, introducing $e$ simplifies our work as we can stick to a uniform $\theta$ between 0 and 1 throughout our analysis and it helps us keep the extra utility in the same scale as $v$ and price. Moreover, this enables us to easily study the impacts of an overall change in consumers' preferences for the environment by analyzing the impacts of change in $e$ (especially in the comparative statics section).

As mentioned earlier, individual differences play a crucial role in this component of extra utility from consuming the environmentally clean product. If an individual has a Low θ and a low β; i.e. individual cares about neither environment nor future, we will have a small $\theta e + \beta\theta e$. Also, for a Low θ and high β individual; i.e. a consumer who doesn't care about the environment but cares about future, again we will have a small $\theta e + \beta\theta e$. This means that if a consumer doesn't care about environment, they do not receive any extra utility from purchasing from firm 1, which is an intuitive expectation.

On the other hand, for a consumer with high θ and high β (consumer puts a high importance on both environment and future), this extra utility will be at its highest. This is also an intuitive expectation of the model because when someone cares a lot about the future consequences of their actions (high β) and they care about having a clean planet (high θ), they receive a large utility from consuming the green product. This is because they know this behavior will have positive outcomes for environment in the long run and they value long run outcomes.

Since the only difference between the product of firm 1 and form 2 is their environmental impact, we can normalize their production costs to zero and add an additional cost of $c$ for firm 1 for producing a green product[4]. Therefore, the profit function for the green firm (or firm 1) is:

$$\pi_1 = (p_1 - c) \times demand_1$$

And the profit function for brown firm (or firm 2) is:

$$\pi_2 = p_2 \times demand_2$$

Since only firm 2 is producing a product damaging the environment, the environmental damage would only depend on the production of firm 2, or in other words, the demand for firm 2, represented by $demand_2$. So environmental damage would equal to:

$$d \times demand_2$$

Where $d$ is the extent of damage that firm 2's production will impose on the environment.

## Demand

To find the demand for each firm, we need to find the indifferent consumer between firm 1 and firm 2:

$$v - p_1 + \theta e + \beta\theta e = v - p_2$$

$$\theta = \frac{p_1 - p_2}{e} \times \frac{1}{1 + \beta}$$

[4] This additional cost can be due to using a more expensive clean technology, cleaner inputs used in manufacturing process, or abatement efforts.

We can get a graphical representation of the demand for each firm by drawing the line $\theta = \frac{p_1 - p_2}{e} \times \frac{1}{1+\beta}$ in the $(\theta, \beta)$ graph, represented in Figure 2. The area below the graph represents the demand for firm 2 ($demand_2$), while the area above the graph shows the demand for firm 1 ($demand_1$). At this point, two cases may happen:

i) $p_1 \leq p_2 + e$, or $\frac{p_1 - p_2}{e} \leq 1$; blue and green lines in Figure 2

ii) $p_1 > p_2 + e$, or $\frac{p_1 - p_2}{e} > 1$; orange line in Figure 2

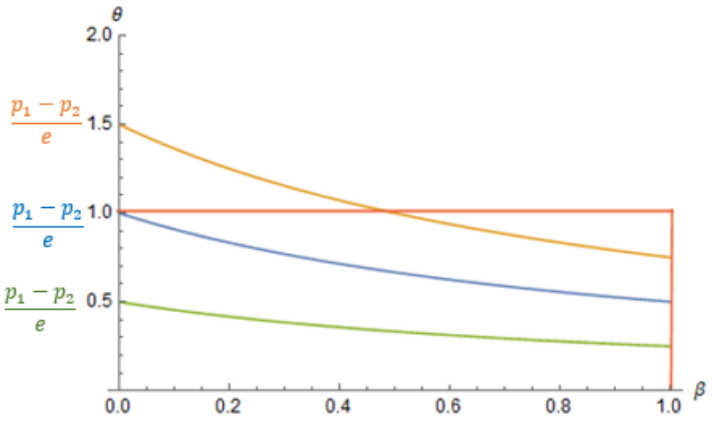


Figure 2

We first focus on the first case where $\frac{p_1 - p_2}{e} \leq 1$.

i) $\frac{p_1 - p_2}{e} \leq 1$

By taking the integral of the demand function and finding the area below the graph, we can find the demand for firm 2:

$$D_2 = \frac{p_1 - p_2}{e} Ln2$$

And since the area under the square equals $1 \times 1 = 1$ and we assumed a large enough $v$ so that consumers will buy from either of firms:

$$D_1 = 1 - D_2$$

## Results

By plugging $D_1$ and $D_2$ back into the profit functions, we have:

$$\pi_1 = (p_1 - c) \times (1 - \frac{p_1 - p_2}{e} Ln2)$$

$$\pi_2 = p_2 \times (\frac{p_1 - p_2}{e} Ln2)$$

By taking FOC w.r.t. $p_1$ and $p_2$ we find that:

$$p_1 = \frac{2(e + cLn2)}{3Ln(2)}, p_2 = \frac{e + cLn2}{3Ln(2)}$$

$$D_1 = \frac{2e - cLn2}{3e}, \; D_2 = \frac{e + cLn2}{3e}$$

$$\pi_1 = \frac{(-2e + cLn2)^2}{9Ln(2)}, \pi_2 = \frac{(e + cLn2)^2}{9Ln(2)}$$

It is worth noting that $\frac{p_1 - p_2}{e} \leq 1$ or $p_1 \leq p_2 + e$ simplifies to approximately $c \leq 1.56e$; meaning when the price of green firm is smaller than a certain value, then the cost of having a clean production is also smaller than a certain number.

## Government Intervenes: Optimum Tax/Subsidy

We define $SW_G = CS + PS - Env + G$ where $SW_G$ is social welfare with government intervention (social planner), $CS$ is consumer surplus, $PS$ is producer surplus, $Env$ represents environmental damage. $G$ is government expenditure in the case of providing subsidy for green firm, and is government revenue in the case of taxing the brown firm. Solving for either of these cases (tax or subsidy) yields the same level of tax/subsidy and social welfare. So here, we only explain the case of subsidizing the green firm, which is firm 1.

To solve for the optimizing value of $s$, we can do a change of variable in firm 1's profit function and replace $c \to c - s$.

Plugging back all the variables in $SW_G$, we will have:

$$SW_G = \frac{1}{36}(-12\,d + 4\,(s + 9\,v) + e\left(27 - \frac{2}{Ln2}\right)$$

$$- \frac{2(-5c^2 Ln2 + s(-6\,d + s)\,Ln2 + 2\,c\,(7\,e + s\,Ln4 + d\,Ln8))}{e})$$

Checking the second order condition, assures us that $SW_G$ is indeed a concave function which has a maximum:

$$\frac{d^2 SW_G}{ds^2} < 0$$

Taking FOC w.r.t. $s$, we will have:

$$\frac{dSW_G}{ds} = 0 \to s^* = \frac{e + 3\,d\,Ln2 - c\,Ln4}{Ln2}$$

Taking the difference between $SW_G$ (social welfare with government intervention) and $SW_{NG}$ (social welfare with No Government intervention) yields a welfare improvement equal to:

$$\frac{(e\ -\ c\ Ln4 +\ d\ Ln8)^2}{18eLn2} \geq 0$$

So by selecting the optimizing level of $s$, social planner can achieve a social welfare at least as big as the social welfare with no government intervention.

An interesting point here is that with big enough $d$ and $e$, the government may provide a subsidy for the green firm which is bigger than its cleaning costs; i.e. when the damage caused by the brown firm is large enough, or people on the aggregate level care a lot about the environmental quality, it may be optimum to reward the environmentally friendly firm and cover all their costs and even more.

ii) $\frac{p_1-p_2}{e} > 1$

This case where $\frac{p_1-p_2}{e} > 1$ is represented in figure 3. We are still under $1 \times 1$ area but part of the demand function ($\theta = \frac{p_1-p_2}{e} \times \frac{1}{1+\beta}$) is located outside of the box.

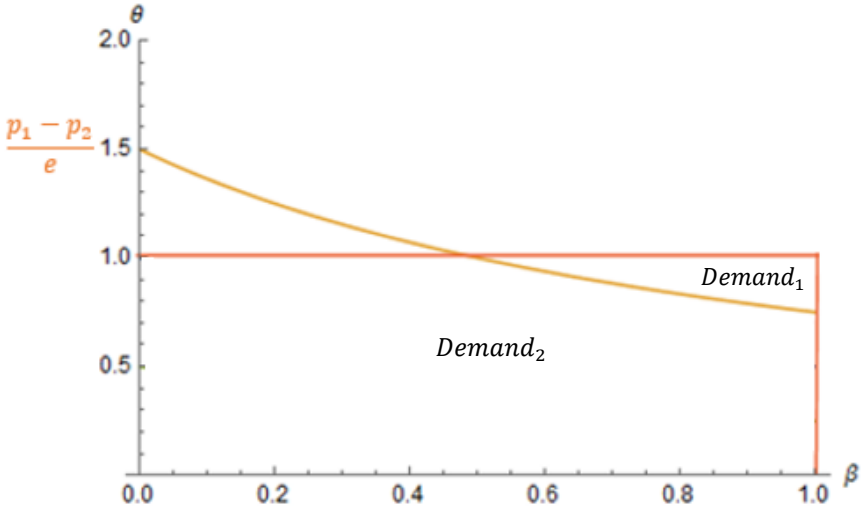


Figure 3, $\frac{p_1-p_2}{e} > 1$

To calculate the demand, we need to find the intersection of the demand function and the line $\theta = 1$:

$$1 = \frac{p_1 - p_2}{e} \times \frac{1}{1+\beta} \rightarrow \beta = \frac{p_1 - p_2}{e} - 1$$

$$D_2 = \left(\frac{p_1 - p_2}{e} - 1\right) \times 1 + \int_{\frac{p_1-p_2}{e}-1}^{1} \frac{p_1 - p_2}{e} \times \frac{1}{1+\beta} d\beta$$

$$= \frac{p_1 - p_2}{e} - 1 + \frac{(p_1 - p_2)\left(\text{Log}[2] - \text{Log}\left[\frac{p_1 - p_2}{e}\right]\right)}{e}$$

$$D_1 = 1 - D_2 = 2 - \frac{p_1 - p_2}{e} - \frac{(p_1 - p_2)(\text{Log}[2] - \text{Log}[\frac{p_1 - p_2}{e}])}{e}$$

By plugging $D_1$ and $D_2$ back into the profit functions and taking the F.O.C.s, we find:

$$\frac{\partial \pi_1}{\partial D_1} = 2 - \frac{p_1 - p_2}{e} - \frac{(-c + p_1)\left(\text{Log}[2] - \text{Log}\left[\frac{p_1 - p_2}{e}\right]\right)}{e} - \frac{(p_1 - p_2)\left(\text{Log}[2] - \text{Log}\left[\frac{p_1 - p_2}{e}\right]\right)}{e} = 0$$

$$\frac{\partial \pi_2}{\partial D_2} = \frac{p_1 - p_2}{e} - 1 + \frac{(p_1 - p_2)\left(\text{Log}[2] - \text{Log}\left[\frac{p_1 - p_2}{e}\right]\right)}{e} - \frac{p_2\left(\text{Log}[2] - \text{Log}\left[\frac{p_1 - p_2}{e}\right]\right)}{e} = 0$$

Unfortunately, with current math techniques, it is not possible to solve this system of equations. Thus, to solve the problem, we switch to discrete values of $\beta$. We assume $n$ discrete values for $\beta$ out of which $k$ values are greater than $\frac{p_1-p_2}{e}-1$; represented by $b_1, b_2, \dots, b_k$, with probability (density) of $y_1, y_2, \dots, y_k$, respectively. We also define $y \equiv y_1 + y_2 + \cdots + y_k$. The remaining $n-k$ values are smaller than or equal to $\frac{p_1-p_2}{e}-1$ and they are represented by $b_{k+1}, \dots, b_n$. The density of all these values together is $1-y$.

We will have:

$$D_2 = (1-y)\times 1 + \frac{p_1-p_2}{e}\left(\frac{y_1}{1+b_1}+\frac{y_2}{1+b_2}+\cdots+\frac{y_k}{1+b_k}\right)$$

$$D_1 = 1 - D_2$$

We plug $D_1$ and $D_2$ into firms' profit functions, take F.O.C.s and by using mathematical induction, we will have:

$$p_1 = \frac{e(1+y)+2c\sum_{j=1}^{k}\frac{y_j}{1+b_j}}{3\sum_{j=1}^{k}\frac{y_j}{1+b_j}}$$

$$p_2 = \frac{e(2-y)+c\sum_{j=1}^{k}\frac{y_j}{1+b_j}}{3\sum_{j=1}^{k}\frac{y_j}{1+b_j}}$$

## Government Intervenes: Optimum Tax/Subsidy

It also appears that government intervention can improve social welfare and reduce environmental damage.

The optimal subsidy for per unit production of green product will be:

$$s^* = \frac{-[e\times(1+b_1)\times\dots\times(1+b_k)\times\left(1+4y-6\sum_{j=1}^{k}y_j\right)+(2c-3d)\times(\sum_{j=1}^{k}y_j\prod_{i\neq j}1+b_i)]}{\sum_{j=1}^{k}y_j\prod_{i\neq j}1+b_i}$$

## Comparative Statics:

We analyze the comparative statics for case i and case ii. For case ii where a discrete $\beta$ was studied, I have not yet done the calculation for the general case of $k$ discrete values for $\beta$. But the results for $k = 1, k = 2, and\ k = 3$ are consistent.

Cost of cleaning: in both cases, we can see that with an increase in $c$, the prices that both firms charge would go up. This means that higher cost of producing a green product is transferred to consumers of both firms. As the cost of cleaning, c, goes up, demand for firm 1 goes down and demand for firm 2 goes up. The reason for an increase in $D_2$ is that price of firm 1 goes up more (twice as much). Therefore, some of the consumers of green firm would switch to the brown firm. When this happens, the environmentally friendly firm starts making less profit, while the profit of the brown firm increases. Since the demand and consequently the production of brown firm increases, the environmental damage would also increase. This has important policy implications since –as proven by comparative statics done for the value of subsidy ($s$)- when the cost of producing the green product goes up, we will end of with higher pollution for the environment. Therefore, subsidizing the green firm (or taxing the brown firm) can help us have a cleaner environment and improve consumer surplus. Without government intervention, social welfare is also higher with lower cleaning (or abatement) cost.

Overall level of consumer preference for green product: As consumers derive higher utility from consumption of the green product (or in other words, as consumers become more alert to environmental warnings and start attaching a higher weight to the green product), i.e. as $e$ goes up, demand for the green product goes up, and the demand for the brown product goes down. Since demand determines production, with a decline in production of brown product, the environmental damage also declines. The interesting point is when at the aggregate level consumers become more

willing to pay for a green product, both firms start taking advantage of this change in preferences and raise their prices. Even though, the direction of change in profit of brown firm is indeterminate, the green firm makes higher profit with higher values of $e$, and in case i where $\frac{p_1-p_2}{e} \leq 1$, both firms together also make higher profits with an increase in public awareness for the environment. On the other hand, with higher values of $e$, the consumer surplus may or may not increase. This is because as both firms raise their prices, consumers will end up paying more for the same goods.

## Comparative Statics for SW

Taking the derivative of social welfare with no government intervention with respect to costs of producing a clean product reveals:

$$\frac{dSW_{NG}}{dc} < 0$$

Also we have:

$$\frac{dSW_{NG}}{d\,d} < 0$$

So when the importance of environmental damage goes up, the social welfare goes down, which is an intuitive result.

Also, if $(c-d)Ln2 < e \rightarrow \frac{dSW_G^*}{dc} < 0$. A sufficient condition for this would be: $\frac{e}{8} < d$. This means that if people consider a relatively small importance on the environment, or, social planner assigns a relatively big weight on environment, an increasing cost would definitely lead to a smaller social welfare.

## Discussion

Two key points of our analysis are summarized below:

- Subsidizing green product has equal impact as taxing brown product
- Optimal subsidy is welfare-improving.
- Increase in cleaning costs increases the environmental damage.
- When consumers become more environmentally aware, environmental damage would decrease even though this may worsen their own surplus.

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