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Green consumerism and pollution control[☆]

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ABSTRACT

In this paper, we show that collective action by environmentally aware/green consumers, who derive benefits from consuming environmentally cleaner products, can reduce pollution and improve social welfare in the same manner as pollution taxes or subsidies for reducing pollution can. We construct a model with two competing firms each producing a good of different environmental quality and two types of consumers with high and low preferences for environmental quality and characterize a benchmark equilibrium in which each consumer acts individually and disregards that his decision to buy a good may affect the level of pollution. We then show that, compared to the benchmark equilibrium, collective action by consumers with high preference who take into account the impact of their combined decision to buy a good on pollution will result in an equilibrium with not only lower pollution and higher social welfare, but also higher prices and profits for the firms.

1. Introduction

Consumption of certain goods generates both *private* and *public* benefits. For instance, a consumer benefits directly from consuming organic food because it is more nutritious and healthier with fewer risks to personal health from pesticides and herbicide residues. However, organic farms are also more sustainable and environmentally better than conventional farms because they do not release synthetic pesticides or herbicides into the environment. Thus, consumption of organic food not only directly benefits a consumer, but also helps indirectly in preserving and sustaining the ecosystem which benefits all consumers.[1] The same positive relationship between private and public benefits also holds if the consumers *perceive* the quality of goods produced with cleaner technologies and inputs to be higher, though there may be no *real* difference. For instance, electricity produced from renewable energy may be perceived as better than that produced from coal, though there is no real difference in its quality when consumed. More generally, a consumer may drive additional utility (i.e., private

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[1] Other interesting examples include coffee grown under the canopy of tropical forests, rather than in open deforested fields, which tastes better as well as helps preserve forests. Some additional examples are discussed in the concluding section.

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benefits) from the consumption of a good simply from knowing that it will contribute less to pollution. This is known as the "warm glow" effect (see Andreoni (1990) and Ribar and Wilhelm (2002)).

It is well-known that higher private benefits from the consumption of a good, whether real as in the case of organic food or altruistic as in the case of green electricity, can induce consumers to pay more for it and firms to invest in cleaner technologies, see e.g. Arora and Gangopadhyay (1995).[2]

A number of authors including Cremer and Thisse (1999), Bansal and Gangopadhyay (2003), and Erikkson (2004) among others consider models of price competition and product differentiation when consumers are environmentally aware. These models address many important questions concerning the impact of green consumerism on market equilibrium and the role of various economic instruments such as pollution taxes or subsidies for reducing pollution. But all of them are concerned with *individual* action by consumers and accordingly assume that each consumer takes the pollution level as given exogenously. However, if some consumers come together and decide *collectively* which good to buy, then they can influence the pollution level. For instance, if all consumers sharing a common economic-ecological system decide collectively to buy only organic food, then, besides the private benefits from the consumption of organic food, each consumer will also benefit from a better preserved and more sustainable ecosystem which is free from pesticides and herbicides.[3] The Organic Consumers Association (OCA) in the US is one such example of mobilization of hundreds of thousands of consumers who buy only organic food.[4]

Economic implications of collective action by green consumers have not been studied previously. In this paper, we construct a model for analyzing the impact of collective action by green consumers on prices, pollution, and social welfare. The model consists of two competing firms each producing a good of different environmental quality and two types of consumers with high and low preferences for environmental quality. A consumer – of either type – acting individually disregards that his action may affect how a good is produced, while when some consumers act collectively they may influence upon production, e.g. which technologies are used and which goods are produced, which in turn affects the pollution level. We first characterize a benchmark equilibrium in which consumers act individually and even the consumers with high preference choose to buy the cheapest product leading to highest pollution. We then characterize another equilibrium in which the consumers with high preference for environmental quality form a coalition and decide collectively which good to buy taking into account the combined impact their decision will have on pollution. Accordingly, we treat pollution level as a choice variable in the individual utility maximization problems of the consumers who decide collectively which good to buy and show that in the resulting equilibrium they buy the higher-priced good with higher environmental quality leading to lower pollution and equilibrium prices such that no member of the coalition *individually* will have incentive to leave the coalition and "free-ride". Thus the coalition once formed, will remain formed and not collapse. In fact, as will be shown, if some consumer with high preference for environmental quality did not join the coalition initially, he will have incentive to join it later after the new equilibrium is established.

Our analysis shows further that collective action by consumers with high preference for environmental quality reduces competition and leads to higher equilibrium prices for goods of both qualities. That is because the firm producing the good of higher environmental quality can charge a higher price if the consumers who form a coalition take into account the favorable impact their combined decision to buy the good of higher environmental quality will have on pollution. As a result the firm producing the good of lower environmental quality can also charge a higher price. Overall, we show that collective action by consumers with high preference for environmental quality not only leads to lower pollution, but also improves social welfare in the same manner as can pollution taxes or subsidies for reducing pollution. In fact, as will be shown, collective action may even lead to optimal control of pollution if the difference in the preferences of the two types of consumers is sufficiently large.

The paper is organized as follows. Section 2 describes the model. Section 3 motivates and characterizes the benchmark equilibrium under the assumption that each consumer acts independently and each firm maximizes its profit, taking the price of the other firm as given. Section 4 motivates and characterizes the equilibrium when consumers with high preference for environmental quality form a coalition and decide collectively which good to buy taking into account the combined impact their decision will have on pollution. Section 5 compares the two equilibria and studies how collective action by consumers impacts the market equilibrium, pollution, and social welfare. Section 6 draws the conclusion.

2. The model

A simple model of preferences for a vertically differentiated product was developed by Mussa and Rosen (1978) and applied to the analysis of vertically differentiated product markets by Gabszewicz and Thisse (1980) among others. An abundant literature developed from these applications. The model in the present paper is an extension of the Mussa-Rosen model in that it introduces the idea that some agents may form a coalition and decide *collectively* which product to buy.

The model consists of two firms each producing a good of different environmental quality. The environmental quality of a good is positively related to cleanliness of the technology and inputs used to produce it – the cleaner the technology

[2] See also Arora and Cason (1996) and Cornes and Sandler (1996).

[3] The underlying assumption here is that the consumers share a common environment in which both consumption and production take place.

[4] It is an association of consumers with an explicitly stated goal to promote a more responsible and sustainable approach to food production.

and inputs, the higher the quality of the good. To keep matters simple, we assume that goods can be produced in only two environmental qualities: high, to be denoted by $S_H > 0$ and low: to be denoted by $S_L > 0$. Let c_H and c_L with $c_H > c_L$ denote the costs of producing one unit each of the goods of high and low environmental qualities, respectively. We assume that firm 1 produces the good of low quality and firm 2 of high quality.

We consider a population of consumers (who share the same economic-ecological system) with different preferences for goods available in different environmental qualities. We assume that each consumer buys at most one unit of one of the goods. The consumers are environmentally aware and willing to pay a higher price for a good of higher environmental quality.

The utility of a consumer who buys one unit of good of environmental quality s is $U = \theta_s - p + \alpha S$ where p is the market price of one unit of good of quality s, θ is consumer's preference for environmental quality, S is the amount of pollution abated and α is the preference for pollution abated. To keep matters simple, we assume that there are only two types of consumers with preferences θ_H and θ_L for environmental quality where $\theta_H > \theta_L > 0$. We shall refer to them as the *H*-consumers and the *L*-consumers, respectively.

Let λ denote the proportion of *L*-consumers and thus $1 - \lambda$ the proportion of *H*-consumers. To minimize notation, we assume henceforth that the population of consumers is normalized to 1 so that λ and $1 - \lambda$ also denote the actual numbers of *L*- and *H*-consumers, respectively. If r and t are the qualities of the goods purchased by the *L*- and *H*-consumers, respectively, then the amount of pollution abated is $S = \lambda r + (1 - \lambda)t$. The amount of pollution abated is thus determined by the aggregate consumption of all consumers, but the impact of an individual consumer's consumption of a product on it is negligible. By assumption, $r,t \in \{S_L, S_H\}$. Let $u_H = \theta_H t - p + S$ and $u_L = \theta_L r - p + \varepsilon S$ denote the utilities of the *H*- and *L*-consumers, respectively. The variable S appears in the utility of each consumer as it represents a public good. To highlight the generally low concern for the environment of *L*-consumers, we assume that $0 \leq \varepsilon < 1$.

In one of the equilibria that we characterize below the *H*-consumers act *collectively* and take into account the impact of their decision on the amount of pollution abated, while each *L*-consumer, as in all other equilibria, acts *independently* and takes the amount of pollution abated as exogenously given. Thus, the utility of each *L*-consumer who buys one unit of good of quality r, can be taken to be equal to $\tilde{U}_L \equiv \theta_L r - p$. But since the *H*-consumers decide collectively which good they should each buy, the utility of a *H*-consumer who buys one unit of good of quality t is $U_H = \theta_H t - q + S = \theta_H t - q + (1 - \lambda)t + \lambda r$ where r is the quality of the good bought by each *L*-consumer. Since the *H*-consumers have no control over the decisions of the *L*-consumers, each *H*-consumer must take r as exogenously given. Thus when the *H*-consumers decide collectively to buy a unit each of a good of quality t, we can take the utility of a *H*-consumer to be equal to $\tilde{U}_H \equiv \theta_H t - q + (1 - \lambda)t$. We do not drop the term $(1 - \lambda)t$ from the utility of a *H*-consumer, since the *H*-consumers decide collectively which good to buy and take into account the impact of their decision on pollution abatement, taking as given the environmental quality of the good bought by the *L*-consumers.

In sum, we can take the utility of a *L*-consumer who decides independently to buy one unit of good of quality r simply as $\tilde{U}_L = \theta_L r - p$ and that of a *H*-consumer when the *H*-consumers decide collectively to buy one unit each of a good of quality t as $\tilde{U}_H = (\theta_H + 1 - \lambda)t - q$, where p and q are the market prices of the goods of qualities r and t, respectively.[5] Comparing the simplified utilities of the *H*- and *L*-consumers, we can interpret collective action by *H*-consumers as equivalent to each *H*-consumer having a higher preference $\theta_H + 1 - \lambda$ instead of θ_H. The higher the proportion $1 - \lambda$ of *H*-consumers, the higher the simplified preference $\theta_H + 1 - \lambda$.

3. Individual actions and equilibrium prices

In this section, we adopt the standard assumption in the related previous literature that each consumer acts *independently* and takes the amount of pollution abatement as given. Though consumption of a good by a consumer may generate both private and public benefits, each consumer thinks that the impact of his consumption on pollution is negligible – it is the aggregate rather than his own individual consumption that affects the pollution level. A consumer's decision to buy a good is then motivated entirely by his own private benefit from consumption of the good. Accordingly, in this section, we ignore the amount of pollution abatement S from the utility maximizing exercise of both *H*- and *L*-consumers.

Let p_L and p_H denote the market prices of the low and high environmental quality goods, respectively. We assume that each firm sets the price of the good produced by it so as to maximize its profit, given the price of the other firm and preferences of the consumers. Several types of equilibria are possible. There are nine possible types in total. E.g., there is one in which no consumer buys a good of either quality. To rule out such uninteresting equilibria, we make the following assumption:

A1. $\theta_L s_L - c_L > 0$ and $\theta_L s_H - c_H > 0$.

Since $\theta_H > \theta_L$, the assumption also implies $\theta_H s_L - c_L > 0$ and $\theta_H s_H - c_H > 0$. The assumption rules out equilibria in which no consumer buys a good of either quality or only one of the two goods is sold.[6] Furthermore, if $\theta_L s - p \geq 0$, then $\theta_H s - p \geq 0$, i.e., if a *L*-consumer is willing to buy a good of quality s at price p, then so is a *H*-consumer. Thus, it is never the case that a *L*-consumer buys a good of some quality, but a *H*-consumer does not buy a good of any quality. Since $\theta_H > \theta_L$ and $s_H > s_L$ the

[5] For welfare comparison, of course, we take into account impact of both r and t, i.e. of $S = \lambda r + (1 - \lambda)t$.
[6] It also ensures greater competition among the two firms.

two inequalities $\theta_L s_H - p_H > \theta_L s_L - p_L$ and $\theta_H s_L - p_L > \theta_H s_H - p_H$ cannot hold at the same time for any prices p_L and p_H Thus, it is never the case that a L-consumer buys the high quality good, but a H-consumer buys the low quality good. All in all, assumption A1 rules out all but three types of equilibria: (1) both H- and L-consumers buy the low quality good, (2) the L-consumers buy the low quality good and the H-consumers the high quality good, and (3) both H- and L-consumers buy the high quality good.

Our modeling strategy is to take the type 1 equilibrium as a benchmark and show that collective action by H-consumers results in an equilibrium of Type 2. Accordingly, we make an additional assumption.

A2.1.

$$\theta_H \leq \lambda\theta_L + (1-\lambda)\frac{c_H - c_L}{s_H - s_L}.$$

Since $\theta_H > \theta_L$, assumption A2.1 is satisfied *only* if $\theta_H(s_H - s_L) < c_H - c_L$ and thus $\theta_L(s_H - s_L) < c_H - c_L$,i.e., the difference in the unit cost of producing the two goods of different qualities is higher than the difference in the willingness-to-pay for them. We show that assumption A2.1 is sufficient for ruling out types 2 and 3 equilibria and ensure existence of a unique type 1 equilibrium.

Lemma. *Suppose assumptions A1 and A2.1 hold. If the consumers act independently, then the equilibrium, if one exists, cannot be of type 2 or 3.*

The proofs of this lemma and all following propositions can be found in the Appendix to the paper.

Proposition 1. *Suppose Assumptions A1 and A2.1 hold. If the consumers act independently, then there exists a unique equilibrium* $(\bar{p}_L, \bar{p}_H)$ *which is of type 1, i.e., both H- and L-consumers buy the low quality good.*

Notice the role played by assumption A2.1, which implies $(c_H - c_L) > \theta_H(s_H - s_L)$, in the proof of Proposition 1. The assumption implies a relatively high equilibrium price ($\bar{p}_H = c_H$) for the good of quality s_H such that the price-quality tradeoff offered by the good of quality s_H is not good enough even for the consumers with higher preference for environmental quality. This intuitively explains why, under assumptions A1 and A2.1 only type 1 equilibrium may exist.

4. Collective action and equilibrium prices

Having characterized the equilibrium for the case when consumers decide independently which good to buy, we consider next the case in which some consumers may form a coalition and decide collectively which good to buy taking into account the combined impact of their decision on pollution. In particular, if the H-consumers form a coalition and decide collectively which good to buy, then each of them realizes that their buying the high quality good would reduce pollution. If each of them takes that into account, then each of them would be willing to pay a higher price for the high quality good and the firm producing the high quality good will be able to charge a higher price.

To keep matters simple, we assume that while the H-consumers form a coalition and engage in collective action, the L-consumers, in view of their generally low concern for the environment, continue to act independently. We show that the resulting equilibrium prices are such that the H-consumers will have no incentive to leave the coalition. In other words, the coalition, once formed, will remain formed and not fall apart. In fact, if a H-consumer somehow did not join the coalition initially, he will have incentive to join it later after the collective action results in new equilibrium prices.

It was noted in Section 2 that collective action by H-consumers is equivalent to each H-consumer having a higher preference $\theta_H + 1 - \lambda$ instead of θ_H. This interpretation of collective action by H-consumers motivates the following assumption.[7]

A2.2.

$$\lambda\theta_L + (1-\lambda)\frac{c_H - c_L}{s_H - s_L} < \theta_H + 1 - \lambda.$$

Since collective action by H-consumers is equivalent to each H-consumer having a higher preference $\theta_H + 1 - \lambda$ instead of θ_H, assumption A2.2, unlike assumption A2.1 which implies $\theta_H(s_H - s_L) < c_H - c_L$, does not rule out existence of a type 2 equilibrium as it does not imply $(\theta_H + 1 - \lambda)(s_H - s_L) < c_H - c_L$, In other words, a type 2 equilibrium may now exist, since collective action is equivalent to each H-consumer having a higher preference $\theta_H + 1 - \lambda$ which does not satisfy the inequality in A2.1. As a result, Firm 1 can no longer compete with Firm 2 and profitably set a price which is low enough such that the H-consumers will continue to buy the low quality good produced by it. Thus, it reorients its price strategy and raises the price of the low quality good such that it is just low enough for preventing Firm 2 from profitably inducing the L-consumers also to switch to the high quality good. Similarly, firm 2 sets a price for the high quality good which is just low enough for preventing Firm 1 from profitably inducing the H-consumers also to buy the low quality good. Indeed, the next two

[7] It is easily verified that the set of parameters satisfying assumptions A1, A2.1, A2.2, is non-empty. E.g., all three assumptions are satisfied if $\lambda = 1/2$, $\theta_L = 2$, $\theta_H = 3$, $c_H = 5.2$, $c_L = 1$, $s_H = 3$, and$s_L = 2$.

propositions show that there exists a unique type 2 equilibrium in which the H-consumers buy the high quality good and the L-consumers the low quality good at prices which are higher than those in type 1 equilibrium.

Proposition 2. *Suppose assumptions A1, A2.1, and A2.2 hold. If the H-consumers form a coalition and decide collectively which good to buy taking into account the combined impact of their decision on pollution, then there exists a unique type 2 equilibrium* (p_H^*, p_L^*) *in which the L-consumers buy the low quality good and the H-consumers the high quality good.*

While Proposition 1 implies that in equilibrium the price-quality tradeoff offered by the high quality good is not good enough for the H-consumers if they do not take into account the impact of their *independent* consumption decisions on pollution, Proposition 2 implies that it is good enough if the H-consumers form a coalition and take into account the combined impact of their *collective* decision on pollution. Recall from Proposition 1 that $(\bar{p}_L, \bar{p}_H)$ are the equilibrium prices when there is no collective action.

Proposition 3. *Suppose assumptions A1, A2.1, and A2.2 hold. Then collective action by H-consumers leads to higher equilibrium prices for goods of both qualities, i.e.,* $p_L^* > \bar{p}_L$ *and* $p_H^* > \bar{p}_H$.

When the H-consumers decide collectively which good to buy, they internalize the externality associated with their consumption of the good. This impacts the market equilibrium in two different ways. First, it allows the firm producing the high quality good to charge a higher price. Accordingly, firm 2 earns (compared to zero profit in the type 1 equilibrium) a positive profit equal to $(1-\lambda)(p_H^* - c_H)$, as shown in the proof of Proposition 2. Second, it reduces competition and as a result the firm producing the low quality good is also able to charge a higher price. However, the impact of this on the profit of firm 1 is ambiguous. On the one hand, the profit of firm 1 is higher because the price of the good produced by it is now higher, but on the other hand, the profit is lower because fewer consumers now buy it. In particular, the profits of firm 1 in the two cases are $\bar{\pi}_1 = (\bar{p}_L - c_L) = (c_H - c_L - \theta_H(s_H - s_L))$ and $\pi_1^* = \lambda(p_L^* - c_L)$. Substituting from (17) and after some algebra, it is seen that $\pi_1^* - \bar{\pi}_1 = [\theta_H - \lambda\theta_L - (1-\lambda)(c_H - c_L)/(s_H - s_L)] + \lambda(1-\lambda)^2/(s_H - s_L)$. Since $\lambda < 1$, $\pi_1^* - \bar{\pi}_1 > 0$ if $\theta_H = \lambda\theta_L + (1-\lambda)(c_H - c_L)/(s_H - s_L)$ in conformity with assumptions A2.1 and A2.2.[8] It was shown that collective action by the H-consumers leads to a positive (i.e., higher) profit for firm 2. Thus both firms stand to gain if the H-consumers decide collectively to buy the high quality good and $\theta_H = \lambda\theta_L + (1-\lambda)(c_H - c_L)/(s_H - s_L)$.

Note that Propositions 2 and 3 as such do not show that formation of coalition by the H-consumers and collective action by them can be sustained in equilibrium. We now show that this is indeed the case if the preference of H-consumers for environmental quality is sufficiently high as no individual H-consumer will then have incentive to "free ride" and buy instead the low quality good. Thus, the coalition of H-consumers once formed will remain formed and not collapse.

Proposition 4. *Suppose assumptions A1, A2.1, and A2.2 hold and* $\theta_H \geq \theta_L + \lambda$. *Then, the equilibrium prices* p_L^* *and* p_H^* *under collective action are such that* $\theta_H s_H - p_H^* > \theta_H s_L - p_L^*$, *i.e., each H-consumer individually prefers to buy the high quality good.*[9]

The proposition also implies that if the two competing firms set their prices assuming that the coalition of H-consumers will remain formed then in the resulting equilibrium it will indeed remain formed as no H-consumer will have incentive to leave the coalition and "free ride".

Proposition 4 may appear contradictory to Proposition 1, but it is not. That is because if $\theta_H \geq \theta_L + \lambda$, then $\bar{p}_H - \bar{p}_L > p_H^* - p_L^*$, i.e., the price-quality tradeoff offered by the low quality good in the equilibrium under collective action is not as good as in the type 1 equilibrium in the absence of collective action. In other words, the equilibrium price of the low quality good goes up relatively more under collective action if preferences of the H- and L-consumers differ sufficiently. Note that this argument implicitly assumes that each H-consumer believes that his deviation will have no impact on the equilibrium prices (p_H^*, p_L^*).

Proposition 4 has two additional implications. First, it also implies that if a H-consumer somehow did not join the coalition initially, he will have incentive to join it later in the new equilibrium. Second, it also implies that not only each individual H-consumer, but also no coalition of many H-consumers will have incentive to leave the coalition of all H-consumers and buy instead the low quality good. That is so because unlike an individual H-consumer a coalition of many H-consumers may take into account the adverse impact of its deviation on pollution. Therefore, the incentive to leave the coalition of all H-consumer is stronger for an individual H-consumer than for a coalition of many H-consumers.[10] It is therefore sufficient to rule out deviations by only individual H-consumers as the proposition indeed shows.

Finally, note that in Propositions 2–4 we assume that *all* H-consumers form a coalition. But these propositions still hold if not all but a large fraction $1-\lambda' < 1-\lambda$ of them do such that the inequality in assumption A2.2 holds for $1-\lambda'$ in place of $1-\lambda$. This is seen by replacing λ' for λ such that $1-\lambda' < 1-\lambda$ in Eqs. (12)–(14) and solving for p_H^*, p_L^*, π_1^* and π_2^*. Clearly, the proofs of Propositions 2–4 are not affected if assumption A2.2 holds for $1-\lambda'$ in place of $1-\lambda$.

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8 Note that λ close to 1 is not a sufficient condition because then for assumption A2.1 to be satisfied θ_H must be close to θ_L and as a result the equilibrium prices p_L^* and $\bar{p}_L$, by definition, must also be close to each other.

9 Note that the set of parameters in fn. 9 which satisfy assumptions A1, A2.1, A2.2 also satisfy the condition $\theta_H \geq \theta_H + \lambda$.

10 Moreover, deviations by coalitions, unlike those by individuals, can be observed and taken into account both by the firms and the other consumers.

5. Collective action and social welfare

As shown, if the H-consumers decide collectively, then the prices as well as the profits of both firms are higher, especially if the proportion of the low-type consumers is sufficiently high. However, since the H-consumers switch to the high quality good, pollution is lower. This raises the question whether the resulting fall in pollution is sufficient to outweigh the increase in prices and improve social welfare.

Since in the absence of collective action by the H-consumers only the low quality good is produced and consumed, the amount of pollution abated $S = s_L$. The utility of a L-consumer is then $\bar{U}_L \equiv \theta_L s_L - \bar{p}_L + \varepsilon s_L$, and that of a H-consumer is $\bar{U}_H \equiv \theta_H s_L - \bar{p}_L + s_L$. Substituting for $\bar{p}_L$, $\bar{U}_L = \theta_L s_L + \theta_H(s_H - s_L) - c_H + \varepsilon s_L$ and $\bar{U}_H = \theta_H s_L + \theta_H(s_H - s_L) - c_H + s_L = \theta_H s_H - c_H + s_L$.

If the H-consumers form a coalition and decide collectively, then, as shown, the H-consumers buy the high quality good and the low-type the low quality good. Thus, the equilibrium pollution level then is $S = \lambda s_L + (1-\lambda)s_H$ and the utility of a L-consumer is $U_L^* \equiv \theta_L s_L - p_L^* + \varepsilon(\lambda s_L + (1-\lambda)s_H)$, where $p_L^* > \bar{p}_L$, as shown. Similarly, the utility of a H-consumer is $U_H^* = \theta_H s_H - p_H^* + \lambda s_L + (1-\lambda)s_H$, where $p_H^* > \bar{p}_H (= c_H)$, as shown.

Proposition 5. *Suppose assumptions A1, A2.1, and A2.2 hold. If the H-consumers form a coalition and decide collectively which good to buy taking into account the impact of their decision on pollution, then the sum of utilities of the consumers and profits of the two firms is higher than when there is no collective action, i.e.,* $\lambda U_L^* + (1-\lambda)U_H^* + \pi_1^* + \pi_2^* > \lambda \bar{U}_L + (1-\lambda)\bar{U}_H + \bar{\pi}_1 + \bar{\pi}_2$.

What is the maximum welfare gain from collective action? If $\theta_H \geq \theta_L + 1$, then the resulting type 2 equilibrium under collective action is in fact optimal. To prove this, we only need to show that any outcome in which both L- and H-consumers buy the high quality good is not optimal, since we already know from Proposition 5 that outcomes in which both H- and L-consumers buy the low quality good is not optimal. This is indeed so if the following inequality is true

$$\lambda(\theta_L s_L - c_L) + (1-\lambda)(\theta_H s_H - c_H) + (\varepsilon\lambda + (1-\lambda))(\lambda s_L + (1-\lambda)s_H) > \lambda(\theta_L s_H - c_H) + (1-\lambda)(\theta_H s_H - c_H) + (\varepsilon\lambda + (1-\lambda)s_H)).$$

This inequality is equivalent to

$$\lambda(c_H - c_L) > \lambda\theta_L(s_H - s_L) + (\varepsilon\lambda + (1-\lambda))s_H - (\varepsilon\lambda + (1-\lambda))(\lambda s_L + (1-\lambda)s_H).$$

Since $0 \leq \varepsilon < 1$, $(\varepsilon\lambda + (1-\lambda))s_H - (\varepsilon\lambda + (1-\lambda))(\lambda s_L + (1-\lambda)s_H) < \lambda(s_H - s_L)$. Therefore, by assumption A2.1, the inequality is indeed true if $\theta_H \geq \theta_L + 1$ This shows that the welfare gains from collective action can be substantial and it can even lead to optimal control of pollution if the preference of the H-consumers for environmental quality is sufficiently higher.[11]

For comparison purposes, note that setting environmental standards can also lead to pollution control. But in the present model if the standard is set low, it may have no impact on the benchmark type 1 equilibrium and therefore pollution and if the standard is set high then either the low quality good or both low and high quality goods may not be produced and consumed leading to over control of pollution and loss in welfare. In contrast, the more familiar tax/subsidy policies can achieve at least the same pollution control as collective action. Indeed, imposing a per unit tax $t = p_L^* - c_L$ on the low quality good – where p_L^* is the price of the low quality good in the type 2 equilibrium under collective action – would lead to exactly the same equilibrium outcome as collective action, though with different welfare implications. The same is true if the high quality good is given a per unit subsidy $b = p_H^* - c_H$. But, unlike collective action, tax/subsidy policies may be costly to enforce.

6. Conclusion

This paper begins analysis of collective action by green consumers in a vertically differentiated duopoly. It shows that collective action by green consumers can reduce pollution, improve social welfare, and lead to higher profits for the firms. Thus, as a policy, regulators and firms may promote rather than oppose collective action by green consumers.

Our analysis can be applied to many instances of vertically differentiated duopoly involving a good with public good characteristics. E.g., to the case in which two firms produce electricity using different technologies and fuels and set prices competitively in the presence of green consumers. Another example is that of an antibiotic which can control a contagious disease *faster*. Such an antibiotic not only directly benefits the individual patients being treated, but also indirectly the entire population as its use by individual patients reduces others risk of exposure to the infection. However, such an antibiotic may not be produced and consumed unless a large enough proportion of patients decides collectively to purchase it taking into account the public benefit of their collective decision. Thus, promoting collective decision to consume the antibiotic may lead to better control of the infection and improve social welfare. An additional example is the problem of choosing among networks that differ in quality. Agents with higher preference for quality of a network can be more easily induced to join a

[11] That more divergent preferences can lead to more efficient outcomes has been also noted in other contexts of voluntary provision of public goods by Bardhan et al. (2007).

more costly, but higher quality network if they can be persuaded to decide collectively which network to join and take into account the positive spillover effect their collective decision will have on the quality of the network.[12]

Our results are driven by the difference in the preferences of consumers for environmental quality and the relative size of the two types of consumers. If the difference is small, the reduction in pollution and improvement in welfare due to collective action highlighted in Proposition 5 may not be large. We assumed that consumers take the prices of the two goods as exogenously given. It is not unreasonable to think that the consumers who decide collectively which good to buy will also have some buyers' power in terms of negotiating the price. If so, the effect of higher equilibrium prices we discovered in Proposition 3 may be mitigated to some extent. But collective action would still lead to lower pollution and higher social welfare. The same is true if there are more than two firms each producing a product of different quality as that too would increase price competition.

Appendix.

Proof of the Lemma. Since each firm maximizes its profit given the price of the other firm, existence of a type 3 equilibrium implies $p_L = c_L$, $\theta_L s_H - p_H \geq \theta_L s_L - p_L \geq \theta_L s_L - c_L$ or $\theta_L(s_H - s_L) \geq p_H - c_L \geq c_H - c_L$, which is clearly ruled out by assumption A2.1. We show that assumption A2.1 also rules out existence of type 2 equilibria.

A type 2 equilibrium, if one exists, is a pair $(\tilde{p}_L, \tilde{p}_H)$ such that

$$\theta_L s_L - \tilde{p}_L \geq 0, \quad \theta_H s_H - \tilde{p}_H \geq 0, \quad \tilde{p}_L - c_L \geq 0, \quad \tilde{p}_H - c_H \geq 0 \tag{1}$$

$$\theta_H s_H - \tilde{p}_H \geq \theta_H s_L - \tilde{p}_L, \tag{2}$$

$$\theta_L s_L - \tilde{p}_L \geq \theta_L s_H - \tilde{p}_H. \tag{3}$$

Inequalities (1) denote the participation constraints of the consumers and the firms. Inequalities (2) and (3) represent the self-selection constraints of the *H*- and *L*-consumers, respectively.

Since $(\tilde{p}_L, \tilde{p}_H)$ is an equilibrium, it should not be possible for firm 1 to lower its price such that, besides the *L*-consumers, the *H*-consumers also prefer to buy the low quality good and the profit of firm 1 is higher. Thus, if $p'_L < \tilde{p}_L$ and $\theta_H s_L - p'_L = \theta_H s_H - \tilde{p}_H$, then $p'_L - c_L \leq \lambda(\tilde{p}_L - c_L)$. This means that $(\tilde{p}_L, \tilde{p}_H)$ must be such that

$$\theta_H s_H - \tilde{p}_H \geq \theta_H s_L - \lambda \tilde{p}_L - (1-\lambda)c_L. \tag{4}$$

Similarly, firm 2 should not be able to lower its price such that the *L*-consumers will also buy the high quality good and its profit is higher. That is, if $p'_H < \tilde{p}_H$ and $\theta_L s_H - p'_H \geq \theta_L s_L - \tilde{p}_L$, then $p'_H - c_H \leq (1-\lambda)(\tilde{p}_H - c_H)$. This means that $(\tilde{p}_L, \tilde{p}_H)$ must be such that

$$\theta_L s_L - \tilde{p}_L \geq \theta_L s_H - (1-\lambda)\tilde{p}_H - \lambda c_H. \tag{5}$$

Inequality (2) is weaker than inequality (4), since $\tilde{p}_L \geq c_L$. Similarly, (3) is weaker than (5), since $\tilde{p}_H \geq c_H$. Since each firm maximizes its profit, taking the price of the other firm as given, (4) and (5) must hold with equality in equilibrium. However, equalities (4) and (5) admit a unique solution which is

$$\tilde{p}_L = \frac{(s_H - s_L)((1-\lambda)\theta_H - \theta_L) + (1-\lambda)^2 c_L + \lambda c_H}{1 - \lambda + \lambda^2}, \tag{6}$$

$$\tilde{p}_H = \frac{(s_H - s_L)(\theta_H - \lambda\theta_L) + (1-\lambda)c_L + \lambda^2 c_H}{1 - \lambda + \lambda^2}. \tag{7}$$

Therefore, if $(\tilde{p}_L, \tilde{p}_H)$ is indeed a type 2 equilibrium, then it must satisfy inequalities (1), and equalities (6) and (7). However, substituting from (7), $(\tilde{p}_H - c_H) = [(s_H - s_L)(\theta_H - \lambda\theta_L) - (1-\lambda)(c_H - c_L)]/[1 - \lambda + \lambda^2] < 0$, by assumption A2.1. Thus, $(\tilde{p}_H, \tilde{p}_L)$ cannot be an equilibrium as it does not satisfy the inequality $\tilde{p}_H \geq c_H$. This rules out existence of a type 2 equilibrium.

Proof of Proposition 1. Define $\bar{p}_H \equiv c_H$ and $\bar{p}_L \equiv c_H - \theta_H(s_H - s_L)$. By definition, a pair (p_L, p_H) is an equilibrium of type 1 only if

$$\theta_L s_L - p_L \geq 0, \quad \theta_H s_L - p_L \geq 0, \quad p_L \geq c_L, p_H \geq c_H. \tag{8}$$

$$\theta_L s_L - p_L \geq \theta_L s_H - p_H \quad \text{and} \quad \theta_H s_L - p_L \geq \theta_H s_H - p_H. \tag{9}$$

We show that $(\bar{p}_L, \bar{p}_H)$ satisfies inequalities (8) and (9). Since $\theta_H > \theta_L$ and $s_H > s_L$, it is easily verified that $(\bar{p}_L, \bar{p}_H)$ satisfies inequalities (9). Replacing p_H by c_H in (9) and using assumption A1, it follows that $\theta_L s_L - p_L > 0$ and $\theta_H s_L - p_L > 0$. Furthermore, assumption A2.1 implies $\bar{p}_L > c_L$. Hence, $(\bar{p}_L, \bar{p}_H)$ also satisfies inequalities (8).

To prove that $(\bar{p}_L, \bar{p}_H)$ is indeed an equilibrium, we need to show further that neither firm 1 nor firm 2 can obtain a higher profit by raising its price, given the price of the other firm. This is clearly true in case of firm 2, since any $p_H > \bar{p}_H (= c_H)$ will

[12] Public announcement of how many and what type of agents will join the network can help.

not induce either type of consumer to buy the high quality good, if the price of the low quality good is $\bar{p}_L$. We show that firm 1 also cannot obtain a higher profit by raising its price. Since at prices $(\bar{p}_L, \bar{p}_H)$ both types of consumers buy the good of low quality, the profit of firm 1 is $\bar{\pi}_1 = \bar{p}_L - c_L = c_H - \theta_H(s_H - s_L) - c_L = c_H - c_L - \theta_H(s_H - s_L) > 0$, by assumption A2.1. From the definition of $\bar{p}_L$ it is seen that if the price of high quality good is $\bar{p}_H$, then for any price $p_L > \bar{p}_L$ the H-consumers will switch to the high quality good and at most the L-consumers will buy the low quality good. Thus, if the price of high quality good is $\bar{p}_H$, then for any price $p_L > \bar{p}_L$ the profit of firm 1 is at most $\lambda(p_L - c_L)$. We show that $\lambda(p_L - c_L) \leq \bar{p}_L - c_L$ for any $p_L > \bar{p}_L$. Define p'_L such that $\theta_L s_L - p'_L = \theta_L s_H - c_H$. Since $s_H > s_L$ and $\theta_H > \theta_L$, $p'_L > \bar{p}_L$. By definition, p'_L is the highest price at which the L-consumers will buy the low quality good, if the price of high quality good is $\bar{p}_H (= c_H)$. It is thus sufficient to show that $\lambda(p'_L - c_L) \leq \bar{p}_L - c_L$. Substituting for p'_L and $\bar{p}_L$ this inequality is equivalent to $\lambda(\theta_L s_L - \theta_L s_H + c_H - c_L) \leq \theta_H s_L - \theta_H s_H + c_H - c_L$. That is, $(\theta_H - \lambda\theta_L)(s_H - s_L) \leq (1 - \lambda)(c_H - c_L)$. Assumption A2.1 implies that this inequality is indeed true.

Finally, it is straightforward to see that neither firm 1 nor firm 2 can obtain a higher profit by lowering its price, given the price of the other firm. This proves that $(\bar{p}_L, \bar{p}_H)$ is an equilibrium in which both types of consumers buy the good of low quality.

We now prove that $(\bar{p}_L, \bar{p}_H)$ is the unique equilibrium. For this we only need to show that there exists no other type 1 equilibrium. Suppose contrary to the assertion that $(\hat{p}_L, \hat{p}_H) \neq (\bar{p}_L, \bar{p}_H)$ is also an equilibrium of type 1. Since $\bar{p}_H = c_H, \hat{p}_H \geq \bar{p}_H$. If $\hat{p}_H = \bar{p}_H = c_H$, then, as just shown above, profit of firm 1 is maximized only if $\hat{p}_L = \bar{p}_L$. Thus, if $\hat{p}_H = \bar{p}_H$, then $\hat{p}_L = \bar{p}_L$, which contradicts our supposition that $(\hat{p}_L, \hat{p}_H) \neq (\bar{p}_L, \bar{p}_H)$. If $\hat{p}_H > \bar{p}_H$, then since firm 1 maximizes profit, $\hat{p}_L$ must be such that $\theta_H s_L - \hat{p}_L = \theta_H s_H - \hat{p}_H$ and therefore $\theta_L s_L - \hat{p}_L > \theta_L s_H - \hat{p}_H$, since $\theta_H > \theta_L$ and $s_H > s_L$. Thus, there exists a price p_H such that $\hat{p}_H > p_H > \bar{p}_H$ and $\theta_H s_L - \hat{p}_L < \theta_H s_H - p_H$. This means that given the price of firm 1, firm 2 can obtain a positive (i.e., higher) profit by lowering its price such that the H-consumers will switch to the high quality good. This contradicts our supposition that $(\hat{p}_L, \hat{p}_H)$ is an equilibrium. This shows that our supposition is wrong and $(\bar{p}_L, \bar{p}_H)$ is the unique type 1 equilibrium.□

Proof of Proposition 2. By definition, if (p_L, p_H) is a type 2 equilibrium then it must satisfy

$$\theta_L s_L - p_L \geq 0, \quad p_L - c_L \geq 0, \quad p_H - c_H \geq 0, \tag{10}$$

$$\theta_L s_L - p_L \geq \theta_L s_H - p_H, \tag{11}$$

$$\theta_H s_H - p_H + (1 - \lambda)s_H \geq \theta_H s_L - p_L + (1 - \lambda)s_L. \tag{12}$$

Inequality (12) highlights the fact that the H-consumers who decide collectively which good to buy take into account the impact of their decision on pollution, taking as given the environmental quality of the good bought by the L-consumers.

Since the firms engage in price competition, if (p_L, p_H) is an equilibrium then firm 2 should not be able to lower its price such that, besides the H-consumers, the L-consumers also prefer to buy the high quality good and its profit is higher. Thus, if p'_H is such that $\theta_L s_H - p'_H > \theta_L s_L - p_L$, then $p'_H - c_H \leq (1 - \lambda)(p_H - c_H)$. Thus, the equilibrium prices (p_L, p_H) should be such that

$$\theta_L s_L - p_L \geq \theta_L s_H - (1 - \lambda)p_H - \lambda c_H. \tag{13}$$

Similarly, it should not be possible for firm 1 to lower its price such that, besides the L-consumers, the H-consumers would also decide collectively to buy the low quality good and its profit would be higher, that is, if p'_L is such that $\theta_H s_L - p'_L + (1 - \lambda)s_L > \theta_H s_H - p_H + (1 - \lambda)s_H$, then $p'_L - c_L \leq \lambda(p_L - c_L)$. Thus, the equilibrium prices (p_L, p_H) should be such that

$$\theta_H s_H - p_H + (1 - \lambda)s_H \geq \theta_H s_L - \lambda p_L - (1 - \lambda)c_L + (1 - \lambda)s_L. \tag{14}$$

Clearly, inequalities (11) and (12) are weaker than inequalities (13) and (14), respectively. Thus, an equilibrium of type 2 must satisfy inequalities (10), (13) and (14). Since the firms maximize profits, inequalities (13) and (14) must hold with equality in equilibrium. However, equalities (13) and (14) have a unique solution (p^*_L, p^*_H) such that

$$p^*_L = \frac{(s_H - s_L)((1 - \lambda)(\theta_H + 1 - \lambda) - \theta_L) + (1 - \lambda)^2 c_L + \lambda c_H}{1 - \lambda + \lambda^2} \tag{15}$$

$$p^*_H = \frac{(s_H - s_L)((\theta_H + 1 - \lambda) - \lambda\theta_L) + (1 - \lambda)c_L + \lambda^2 c_H}{1 - \lambda + \lambda^2}. \tag{16}$$

It is easily verified that p^*_L and p^*_H also satisfy the participation constraints (10). Assumptions A2.1 and A2.2 imply $p^*_H > p^*_L > 0$. Substituting from (15) and (16), the profit of firm 1 is

$$\pi^*_1 = \lambda(p^*_L - c_L) = \lambda \frac{(s_H - s_L)((1 - \lambda)(\theta_H + 1 - \lambda) - \theta_L) + \lambda(c_H - c_L)}{1 - \lambda + \lambda^2} > 0, \tag{17}$$

by assumption A2.1, and that of firm 2 is

$$\pi^*_2 = (1 - \lambda)(p^*_H - c_H) = (1 - \lambda)\frac{(s_H - s_L)((\theta_H + 1 - \lambda) - \lambda\theta_L) - (1 - \lambda)(c_H - c_L)}{1 - \lambda + \lambda^2} > 0,$$

by assumption A2.2. Hence, (p^*_L, p^*_H) is the unique type 2 equilibrium.□

Proof of Proposition 3. Using assumption A2.1,

$$p_L^* > \frac{(s_H - s_L)((1-\lambda)(\lambda\theta_L + (1-\lambda)(c_H - c_L/s_H - s_L)) - \theta_L) + (1-\lambda)^2 c_L + \lambda c_H}{1-\lambda(1-\lambda)}$$

$$= \frac{(1-\lambda)^2(c_H - c_L) - (1-\lambda(1-\lambda))\theta_L(s_H - s_L) + (1-\lambda)^2 c_L + \lambda c_H}{1-\lambda(1-\lambda)} = c_H - \theta_L(s_H - s_L) > c_H - \theta_H(s_H - s_L) = \bar{p}_L.$$

Thus, $p_L^* > \bar{p}_L$. Similarly, using assumption A2.2,

$$p_H^* > \frac{(1-\lambda)(c_H - c_L) + (1-\lambda)c_L + \lambda^2 c_H}{1-\lambda(1-\lambda)} = c_H.$$

Thus, $p_H^* > \bar{p}_H = c_H$.□

Proof of Proposition 4. Substituting for p_L^* and p_H^* from (15) and (16), the inequality $\theta_H s_H - p_H^* > \theta_H s_L - p_L^*$ is equivalent to

$$\theta_H - \frac{\theta_H + (1-\lambda) - \lambda\theta_L - (1-\lambda)\theta_H - (1-\lambda^2) + \theta_L}{1-\lambda(1-\lambda)} > \frac{(1-\lambda)c_L + \lambda^2 c_H - (1-\lambda)^2 c_L - \lambda c_H}{(s_H - s_L)(1-\lambda(1-\lambda))}.$$

After some algebra and rearranging the terms, this inequality is equivalent to

$$\theta_H - \theta_L - \lambda + \lambda\left[\frac{c_H - c_L}{s_H - s_L} - \theta_H\right] > 0.$$

This inequality is true, since $\theta_H \geq \theta_L + \lambda$ and $(c_H - c_L)/(s_H - s_L) > \theta_H$ by assumption A2.1.□

Proof of Proposition 5. Substituting for $U_L^*, U_H^*, \bar{U}_L, \bar{U}_H, \pi_1^*, \pi_2^*, \bar{\pi}_1$, and $\bar{\pi}_2 = 0$, we need to show that $\lambda(\theta_L s_L - p_L^* + \varepsilon(\lambda s_L + (1-\lambda)s_H)) + (1-\lambda)(\theta_H s_H - p_H^* + (\lambda s_L + (1-\lambda)s_H))\lambda(p_L^* - c_L) + (1-\lambda)(p_H^* - c_H) > \lambda(\theta_L s_L - p_L + \varepsilon s_L) + (1-\lambda)(\theta_H s_H - c_H + s_L) + \lambda(p_L - c_L)$. This inequality is equivalent to $\varepsilon\lambda s_H + (1-\lambda)s_H > \varepsilon\lambda s_L + (1-\lambda)s_L$ which is clearly true, since $s_H > s_L$. This completes the proof.□

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