Fondazione Eni Enrico Mattei

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NOTA DI LAVORO 138.2006

NOVEMBER 2006

ETA – Economic Theory and Applications

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Summary

In a duopoly industry with environmentally differentiated products, we examine the effects of introducing a mandatory environmental quality standard on firms' environmental quality choices, profits, and the average environmental quality offered by the industry. We show that at low standard levels, both firms choose to overcomply regardless of the standard level. At intermediate levels, the mandatory standard can reduce the profit of the low-cost firm while increasing that of the high-cost firm, and that it can lower the industry's average environmental quality below what it would be without the standard.

Keywords: Duopoly, Environmental Quality, Mandatory Environmental Standard, Overcompliance, Product Differentiation

JEL Classification: Q58, L13, l51, D43

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1. Introduction

The past three decades have witnessed two broad trends in concerns about environmental quality. On the one hand, consumers have become increasingly concerned about the environmental quality and impact of products they consume. They have often expressed these concerns both by showing willingness to pay a price premium for the so called "green" or environmentally-friendly products and by pressuring policymakers to subject the polluting industries to environmental quality standards. On the other hand, responding to the consumers' preferences and public pressure for environmental regulations, producers have more than ever become environmentally proactive.[1] At the same time, firms have been increasingly competing with one another on the basis of environmental quality either directly, by adopting more environmentally friendly technologies to improve the environmental quality of their production processes and products, or indirectly, by engaging in, or supporting, pro-environment activities in general to enhance their environmental image or reputation (see, for example, Videras and Alberini (2000) and Antona *et al.* (2004)). In these fashions, firms have been increasingly tending to environmentally differentiate their brands and public image from those of their rivals. Examples indicating these trends abound and include agricultural products differentiated by the degree of their genetically modified (GM) content, or by the degree of their organic content (organic versus conventionally produced product), or the extent of their bio-degradability (recyclability). Gasolines of different octane or lead content, electricity generated by different processes (fossil fuel-based, solar based, hydro or thermal based) or inputs (coal, oil, natural gas, biomass), and cars driving on different mixes of bio-fuel (ethanol) and gasoline, or electricity, are all few among numerous other examples. In this last respect, it is perhaps interesting to note that to further differentiate itself environmentally from its rival auto companies such as Toyota,

[1] For an interesting historical account of corporate environmentalism, see Hoffman (1997). For an economic and financial view of corporations' environmental pro-activism, see Heal (2005), who presents several interesting examples of the corporations (such as British Petroleum (BP), Dow Chemical, and Heniz) whose pro-environment actions have benefited them both financially and in reputation, thereby giving them a competitive edge over their rivals, and those (such as Shell oil company, McDonalds, and Monsanto) whose less environmental-friendly approaches have harmed their public image and profitability.

Honda Motor Co. has just announced that it “is to mass-produce compact cars that run solely on bioethanol, becoming the first Japanese automaker to do so.” Bioethanol has attracted attention as a carbon-neutral fuel that does not contribute to global warming. Furthermore, Honda R&D Co. and Japan’s Research Institute of Innovative Technology for the Earth “have developed a new process to efficiently produce ethanol fuel from soft biomass, a renewable resource derived from plants” (*The Daily Yomiuri*, Tokyo, Friday, September 15, 2006, p.8).

The trends noted above raise several important questions. For example, what factors determine the firms’ choice of environmental quality of their brands if they are left to freely compete by differentiating their products? More importantly, faced with a mandatory quality standard, do firms have an incentive to overcomply? How does the introduction of a mandatory standard affect the firms’ degree of environmental differentiation, their profitability, and the average environmental quality provided by the industry? This paper explores these questions by adopting a simple differentiated duopolistic model of a polluting industry that faces a mandatory standard set exogenously by a regulating agency. We take a purely positive approach and as such do not deal with social welfare effects of either the regulator’s choice of the standard level or the industry’s choice of environmental quality. The two firms are assumed to differ only with respect to their costs of environmental quality, perhaps due to having access to different pollution abating technologies. Each of the firms produces a brand of a commodity that consumers deem to be different only in their environmental quality attribute.

Although there is an extensive literature dealing with various aspects of interaction between corporations and environmental regulations [see, for example, one or two references here], rather few theoretical economic research have explored the specific question of firms’ environmental quality choice in a differentiated industry facing a mandatory standard. Maloney and McCormick (1982) study the effect of a mandatory environmental quality regulation on profits in an atomistic competitive industry where the regulation increases a typical firm’s costs but has no direct effect on industry demand. They show that with restricted entry to the industry, the regulation can result in increased profits for all firms in the industry creating a scarcity rent from the right to use the environmental assets. Further, they show that when the firms differ in their production costs, the environmental regulation may increase the profits of the low-cost firms while lowering those of the high-cost firms, and that this intraindustry transfer can happen even if entry is not restricted. Farzin (2003) examines the effect of a mandatory pollution standard on a polluting oligopolistic industry with identical firms where a higher environmental quality standard raises both the firms' compliance costs and the demand for the industry's output. He shows the conditions under which a stricter standard leads to a larger profit in the industry, a larger number of firms, a greater industry output, and a lower total pollution in the long run. However, none of these studies considers strategic environmental quality differentiation and possibility of voluntary overcompliance with the standard. On the other hand, Arora and Gangopadhyay (1995) analyze a model in which firms overcomply in order to attract high-income consumers, and thereby raise consumers' welfare.[2] As such, in their model overcompliance derives from the demand side due the heterogeneity of consumers' willingness to pay for environmental quality, which arises from differences in income levels. In contrast, our model explains overcompliance from the supply side by considering heterogeneity of firms' pollution control technologies, which lead to differences in their unit costs of environmental quality improvement.

Salop and Scheffman (1983) (1987) consider a dominant firm-competitive fringe model of an industry where a lower-cost dominant firm acts as price leader. They show that a cost-raising action controlled by the dominant firm, which could be interpreted as controlling product standards or other government regulations, or expenditures on advertising or research and development, can increase the dominant firm's profit at the expense of the fringe's profit and possibly consumer welfare.[3] Interestingly, however, in our model of environmental-quality differentiated duopoly, raising the mandatory quality standard can increase the profits of the

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[2] A strand of literature on motives for corporate environmentalism has emphasized self-regulation as a strategic means of preempting otherwise higher future government regulations. For a survey of this literature, see Lyon and Maxwell (2000).

[3] For a review of the literature on the use of regulation as a cost-raising strategy, see McCormick (1984). In a related but different model, Lutz *et al.* (2000) consider situations where a high quality firm in the industry takes the role of quality leader by credibly committing to a quality level that is higher than the anticipated standard to be set by the regulator. They show that by such a strategic action, the high-quality firm can influence the regulator to set lower standards, thereby leading to a *lower* social welfare than would be the case if the regulator were to lead in setting the industry standard.

high-cost firm while lowering those of the low-cost one.

The rest of the paper proceeds as follows. In section 2 we set out the model and present the firms' equilibrium choices of environmental quality of their products in the absence of regulation. Section 3 examines the effect of introducing a mandatory environmental quality standard on the firms' quality choices, where we show that depending on the level of the standard, either both, or only one, or none of the firms may overcomply with the standard. Sections 4.1 and 4.2 respectively examine the effects of the mandatory standard on the firms' profits and the average environmental quality offered by the industry. We show that for intermediate levels of the standard the mandatory standard can reduce the profits of the low-cost firm while increasing those of the high-cost firm, and that it can lower the industry's average environmental quality below what it would be without regulation. Concluding remarks are presented in section 5.

2. The Model: Environmental Quality in the Absence of Regulation

Consider an industry consisting of two firms, labeled $i = 1$ and 2, each producing a brand of a product. From consumers' perspective, the products are different only with respect to their environmental quality attributes but are identical in all other respects. Let $\alpha_i \geq 0$ denote the environmental quality and $q_i \geq 0$ the quantity of firm i's product.

In general, each firm's revenue is a function of the quantity demanded of the firm's own product and that of its rival firm's product. It also is a function of both firms' choices of environmental quality. Formally, the revenue function of firm *i* can generally be represented by $R_i = R_i\left(q_i, q_j, \alpha_i, \alpha_j\right) = p_i\left(q_{i,} q_j, \alpha_i, \alpha_j\right) q_i$. To concentrate on firms strategic behavior with regard to the choice of environmental quality, and their responses to the environmental standard set by an environmental regulatory agency, we abstract from firms' strategic behavior with regard to the choice of output quantity. This simplification can be justified, for example, by considering situations where consumers' aggregate income spent on the products is large enough and the firms make short-run decisions, so that consumers' demand for each product is determined by the firm's available output capacity, which is assumed to be fixed at $\bar{q}$ in the short run. Thus, the revenue function of each simplifies to $R_i = R_i\left(\overline{q}_i, \overline{q}_j, \alpha_i, \alpha_j\right) = p_i\left(\alpha_i, \alpha_j\right)\overline{q}_i = R_i\left(\alpha_i, \alpha_j\right)$.

The environmental quality of the firm in our model can be interpreted broadly so that it not only can represent the environmental quality associated with any stage of production of the final products (that is, from input acquirement to production processing, packaging, and distribution). It can also represent a firm's environmental activities which may not necessarily be related to its product *per se*, but could be pro-environment activities which, for example, improve the firm's environmental reputation in general. The firm's incentive to engage in such activities is to attract consumers who support its pro-environment stance by their willingness to pay a premium price for the firm's product. In other words, α_i in our model can be interpreted broadly enough to encompass the notion of firm's environmental responsibility. We are thus treating α_i in our model as firm's environmental reputation which can from consumers' perspective be distinct from how much of the firm's product they may consume. Accordingly, our notion of the environmental standard set by the regulator may also be interpreted broadly. It may not only represent the environmental standard that firms have to observe in production of their products. It can more generally be viewed as a composite index of a firm's environmental friendliness.

To simplify the model, and without much loss of generality, we make two further assumptions. First, we assume that the choice of environmental quality by a firm does not affect its output level. That is, the firm's environmental quality activity is like end-of-pipe pollution abatement and as such is separate from the firm's production process, so that there is no spillover effect from environmental quality activity into the production activity and vice versa. An implication of this assumption is that the production cost is not affected by choice of environmental quality. This is consistent with the assumption of constant unit production costs of the products that we shall also be making shortly. Second, we assume that inputs employed in production and environmental activities are specific to each activity. An implication of this assumption is that a firm can not by reallocating some of the inputs from production into environmental quality activity reduce the level of its output to improve the environmental quality of its product, thereby obtaining a higher price for its product.

To be able to proceed analytically, we assume the following quadratic revenue functions:

$$R^i(\alpha_i, \alpha_j) = -\frac{1}{2}a\alpha_i^2 - b\alpha_i\alpha_j + r\alpha_i,\ i = 1,2,\ j \neq i,\ a,b,r > 0, \qquad (1)$$

where $\partial^2 R^i(\alpha_i, \alpha_j)/\partial\alpha_i^2 = -a < 0$ and $\partial^2 R^i(\alpha_i, \alpha_j)/\partial\alpha_i\partial\alpha_j = -b < 0$. The first inequality indicates that for each firm there are diminishing marginal returns from choosing higher environmental quality levels. The second inequality indicates that an increase in one firm's environmental quality lowers the rival firm's marginal revenue, implying that from firms' perspectives the environmental qualities are strategic substitutes.

It is plausible to assume that a firm's marginal revenue is more sensitive to a change in its own environmental quality than to a change in the rival's; that is

$$a > b \qquad (2)$$

In fact, for a given value of a, the magnitude of b indicates the degree to which the consumers' perceive the two products are differentiated, or inversely, how close strategic substitutes the two products are from the firms' perspectives. In the extreme case of $b = a > 0$ (*i.e.*, $a - b = 0$) the two products become homogeneous (zero degree of differentiation or strategically perfect substitutes) and the firms' profits would drop to the lowest level. In the other extreme case, when $b = 0$ (*i.e.*, $a - b = a$), the degree of product differentiation is the highest, and the two products become independent of each other. In this case, each firm behaves like a monopolist in choosing its level of environmental quality. As such, one could consider ($a - b$) as an index of product differentiation or the inverse of it as a degree to which the two products are strategic substitutes.

To focus on the role of environmental quality differentiation, we assume that the unit production costs of products are the same, and normalize them to be zero. Let A_i be the constant unit cost of achieving environmental quality α_i.[4] We assume that the two firms differ only with respect to this cost, for example, due to differences in their pollution abatement technologies. More specifically, we assume that firm 1 has an advantage over firm 2 in cost of environmental quality, *i.e.*,

$$A_2 > A_1 > 0. \tag{3}$$

Then, the profit functions are expressed as [5, 6]

$$\pi^i(\alpha_i, \alpha_j) = \left(-\frac{1}{2} a\alpha_i^2 - b\alpha_i\alpha_j + r\alpha_i \right) - A_i\alpha_i \quad (i, j = 1, 2, \ \ i \neq j) \tag{4}$$

To ensure that both firms can coexist in the market, we need to assume that

$$r > A_2. \tag{5}$$

Otherwise, the profit of firm 2 will always be negative and thus not entering the market.

The two firms play a Nash-Cournot game in environmental qualities of their products. The problem of firm $i = 1, 2$ is

$$\max_{\alpha_i} \pi^i(\alpha_i, \alpha_j) = -\frac{1}{2} a\alpha_i^2 - b\alpha_i\alpha_j + r\alpha_i - A_i\alpha_i, \quad \alpha_j \ (j \neq i) \text{ given.} \tag{6}$$

Suppose that in the absence of any environmental regulation, there exists an equilibrium $\left(\alpha_1^*, \alpha_2^*\right)$.[7] At equilibrium, the following equation holds:

$$\begin{bmatrix} a & b \\ b & a \end{bmatrix} \begin{pmatrix} \alpha_1^* \\ \alpha_2^* \end{pmatrix} = \begin{pmatrix} r - A_1 \\ r - A_2 \end{pmatrix}. \tag{7}$$

With condition (2) one has $a^2 - b^2 > 0$, which ensures that a Nash equilibrium is unique and

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[4] A_i can also be interpreted, for example, as a constant unit cost of pollution abatement.

[5] Strictly speaking, π^i represents the profit margin (price minus unit cost) for each firm. To simplify the analysis, we focus on the profit margin, instead of profit levels, which depend on $\overline{q}_i$, $i = 1, 2$.

[6] We could more generally write the profit function to include a constant term c_i, as $\pi^i(\alpha_i, \alpha_j) = R^i(\alpha_i, \alpha_j) - A_i\alpha_i - c_i$, where c_i can be interpreted either as a unit cost of production or as a tax or subsidy per unit of output respectively when c_i is positive or negative. This generalization would not affect the results as long as both firms remain in the market.

[7] It is shown below (see (10)) that the firms' profits at equilibrium are positive. Therefore, both firms can coexist under laissez faire.

stable.[8] The firms' equilibrium choices of environmental quality are

$$\alpha_1^* = \frac{a(r-A_1)-b(r-A_2)}{a^2-b^2} > 0 \text{ (by (2) and (3))}, \tag{8.a}$$

$$\alpha_2^* = \frac{a(r-A_2)-b(r-A_1)}{a^2-b^2} \tag{8.b}$$

Notice that whereas α_1^* is always positive, to ensure that α_2^* is positive we need the condition

$$\frac{b}{a} < \frac{r-A_2}{r-A_1} < 1, \tag{9}$$

that is, the adverse effect of an increase in the rival's quality on the firm's marginal revenue should not be too large, or, equivalently, the two products should be sufficiently differentiated.

As to be expected, from (8.a) and (8.b) it is seen that the equilibrium choice of the quality by each firm varies inversely with its own cost of environmental quality and directly with that of its opponent.

The associated profits at the equilibrium are calculated as

$$\pi^i(\alpha_i^*, \alpha_j^*) = \frac{a}{2}\left(\frac{a(r-A_i)-b(r-A_j)}{(a^2-b^2)}\right)^2 > 0, \quad i=1,2, \quad j \neq i, \tag{10}$$

which ensures that both firms will coexist in the market.

An interesting finding here is (from (8.a) and (8.b))

$$\alpha_1^* - \alpha_2^* = \frac{A_2 - A_1}{a-b} > 0 \tag{11}$$

which enables us to state the following proposition:

Proposition 1: *In the absence of any environmental quality regulation, in a differentiated duopoly, (i) the firm with the lower environmental quality cost (* $A_1 < A_2$ *) adopts a higher environmental quality than that chosen by its high-cost rival (* $\alpha_1^* > \alpha_2^*$ *), and (ii) the extent of environmental quality differentiation in the market varies directly with the environmental cost differential and the degree to which the products are strategic substitutes.*

This result parallels that of output quantity choices in a differentiated duopoly (see, for example, Dixit, 1979, Singh and Vives, 1984, and Shy 1995.) As we shall see in the next

[8] See Dixit (1986).

section, when a mandatory environmental standard is introduced, the asymmetric equilibrium quality choices, (8.a) and (8.b), give rise to a situation where one of the firms complies with the standard whereas the other overcomplies.

3. Mandatory Standard and Duopoly Choices of Environmental Quality

In this section we analyze the equilibrium quality choices of the duopoly facing an environmental quality standard. Let $\hat{\alpha} > 0$ denote the minimum environmental quality standard mandated by the environmental regulatory agency. Taking this standard and the rival firm's choice of environmental quality as given, the profit maximization problem for firm i is written as

$$\max_{\alpha_i} \left(\frac{-1}{2} a\alpha_i - b\alpha_j + r - A_i \right) \alpha_i, \quad \text{subject to } \alpha_i \geq \hat{\alpha}, \;\; \alpha_j \, (j \neq i) \text{ given.} \tag{12}$$

At equilibrium $\left(\alpha_1(\hat{\alpha}), \alpha_2(\hat{\alpha})\right)$, it holds that

$$-\begin{bmatrix} a & b \\ b & a \end{bmatrix} \begin{pmatrix} \alpha_1(\hat{\alpha}) \\ \alpha_2(\hat{\alpha}) \end{pmatrix} + \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix} = -\begin{pmatrix} r - A_1 \\ r - A_2 \end{pmatrix},$$

$$\left(\alpha_1(\hat{\alpha}) - \hat{\alpha}\right)\mu_1 = 0, \;\; \left(\alpha_2(\hat{\alpha}) - \hat{\alpha}\right)\mu_2 = 0 \tag{13}$$

where $\mu_1, \mu_2 \geq 0$ are the Lagrange multipliers. Notice that for now we have left aside the possibility that the standard may render production by one or both firms unprofitable. Later, we will take this possibility into account and analyze how the standard affects the market structure.

Using the Kuhn-Tucker conditions (13), the equilibria are classified into three types:

(a) *Both firms overcomply*: In this case, $\mu_1 = \mu_2 = 0$, implying that $\alpha_1(\hat{\alpha}) = \alpha_1^* > \hat{\alpha}$ and $\alpha_2(\hat{\alpha}) = \alpha_2^* > \hat{\alpha}$, where, as before, α_1^* and α_2^* are given by (8.a) and (8.b). The equilibrium exists if $\min[\alpha_1^*, \alpha_2^*] = \alpha_2^* \geq \hat{\alpha}$. We term the interval $[0, \alpha_2^*)$ as *Interval I*. Thus,

Proposition 2: *Over Interval I, (i) both firms overcomply, (ii) they choose equilibrium quality levels that are the same as those in the absence of any standard, implying that within this interval the mandatory standard has no effect on the firms' voluntary choices of environmental quality, and (iii) the low-cost firm overcomplies by a larger extent than the high-cost firm does. (See Figure 1).*