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Can Stricter Environmental Standards Benefit the Industry and Enhance Welfare?

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ABSTRACT. – This paper argues that the industrialists' claim that stricter environmental standards reduce the industry output, competition, and hence social welfare rests solely on the "cost" effect of a stricter standard and ignores its "demand" effect. It considers situations where firms' pollution abatement increases the industry demand, but, because of inability to coordinate their emissions reductions, and thus free-riding problem, they can not act in their own *collective* interest. The paper examines the effects of a stricter standard in such situations both at the individual firm and industry levels and when entry/exit is free as well as when the number of firms is fixed. It identifies conditions under which a stricter standard leads to a *larger* number of firms in the industry, a *greater* industry output, and a *lower* total pollution in the long-run; and to *higher* levels of firms' profits *and* output in the short-run. It also shows that for the industry to survive, a *minimum* pollution standard may be necessary. Further, it analyzes the welfare effects of a stricter standard and indicates situations in which the regulator may prefer *no* standards to weak ones.

Une réglementation environnementale plus stricte peut-elle favoriser une industrie et améliorer le bien-être ?

RÉSUMÉ. – Dans cet article, nous montrons que l'assertion des « industrialistes » que des normes environnementales plus strictes réduisent la production industrielle, la concurrence et donc le bien-être collectif, repose uniquement sur l'effet sur les coûts de ce durcissement de la réglementation et ignore l'effet sur la demande. Nous étudions des situations dans lesquelles la réduction des émissions polluantes augmente la demande de produits industriels, mais où à cause de l'incapacité de coordonner leurs réductions de substances polluantes, les entreprises ne peuvent agir dans le sens de leur intérêt collectif. Le papier examine les effets d'une réglementation plus rigoureuse à la fois au niveau de la firme individuelle et au niveau de l'industrie dans son ensemble, soit quand le nombre de firmes est fixe, soit quand il y a libre entrée dans l'industrie. Nous identifions les conditions sous lesquelles une réglementation plus rigoureuse conduit à un plus grand nombre de firmes dans le secteur, une production industrielle accrue, et une pollution totale plus faible à long terme, ainsi que des profits et une production plus élevés à court terme. Nous montrons également qu'il peut être nécessaire à la survie d'une industrie, que soit instaurée une norme minimale. De plus, nous analysons les effets de bien-être d'un durcissement de la réglementation et les situations dans lesquelles l'autorité publique préfère qu'il n'y ait pas de réglementation à une réglementation laxiste.

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1 Introduction

Industrialists widely claim that by raising abatement costs, stricter environmental standards raise the polluting firms' overall production costs, thus rendering them uncompetitive and forcing them out of business. On this basis, they argue that the consequent reductions in the industry output, employment, and competition will be against public interest. Ironically, when it comes to negotiations for higher international or global environmental standards, governments also often resort to similar arguments.

It is, of course, remembered that even when the industrialists' argument about the adverse effects of stricter standards on the industry are valid, still that does not necessarily mean that the government should not raise the standards if there is a net social welfare gain from doing so. The central point of the present paper, however, is to show that there are situations in which the very adverse effects that the industrialists attribute to stricter standards may *not* hold. Specifically, such situation arise when firms are unable to coordinate their actions to reduce emissions, so that even though doing so would be in their *collective* interest, *individually* they have incentive to free ride. I show that in such situations a stricter standard can enhance the industry's profitability, and hence output, and at the same time reduce total pollution.

To this end, I analyze a simple oligopoly model of an industry in which the production of a good by identical firms inflicts a negative environmental externality. A stricter standard implies that at any given output level firms should abate a greater portion of their pollution. This, as industrialists correctly argue, increases the abatement cost of the representative firm and therefore its overall production cost. This effect, which I call the "cost" effect of a stricter standard, is too familiar and basic to almost all economic analyses of environmental standards. What is, however, novel is what I call the "demand" effect of a stricter environmental standard.

This effect accounts for the fact that environmental quality can be directly or indirectly a complement to the consumption of the polluting good, so that enhancing the environmental quality increases the demand for the good. Tourism industry presents a good example. Higher quality standards for urban air, water, and land (*e.g.*, beaches) practiced by firms can attract a larger population to touristic and recreational sites and therefore boost the demand for tourism services. Another example is when agricultural chemical run-offs from upland farms into a river stream which serves as source of fishing, drinking water, and irrigation inflict costs on downland fishing and farming communities. Directly by reducing fish and crops harvesting rates and indirectly by reducing labor and land productivity, the use of polluted water causes loss of income by downland communities, which in turn reduces the demand for outputs of upland farms. A third example is the remarkable growth in recent years of the demand for agricultural products (foods and fibers) that are grown and processed according to a defined set of standards that certify them as organic. This growth draws partly from the higher standards of food safety and hence lower risks of health hazards that consumers attribute to organic products, and partly from the beneficial environmental effects (*e.g.*, protection of topsoil, protection of water resources, and preservation of biodiversity) that they associate with organic farming.

An important point in these examples is the presence of externalities and the associated free-riding problem. Firms' reduction of pollution has a *positive* feedback effect on the industry demand, but since all firms in the industry benefit from this, in the absence of coordination among firms, none has incentive to reduce pollution as much as it should. The firms' failure to coordinate their pollution reductions for collective benefit and the free-riding problem call for a mandatory pollution standard.[1,2] By requiring greater reductions in pollution, the regulation can actually benefit the industry.[3]

Under free entry/exit assumption, the cost effect of a stricter standard tends to reduce the number of firms in the industry whereas its demand effect does the opposite. So, the effect of a stricter standard on the number of firms and the industry output depends on which of the two effects dominates. The demand effect, however, has been completely ignored in the empirical studies of the effect of environmental regulations (*e.g.*, PASHIGIAN [1984], HAZILLA and KOPP [1990]) and by large has also gone unnoticed in the theoretical literature on environmental economics. For example, in an insightful paper, BESANKO [1987] compares a "performance" standard (one that restricts a firm's total pollution) with a "design" standard (one that mandates a specific level of pollution control technology) with respect to their effects on individual firms' output level and profits as well as their social welfare effects. However, his models differs in structure and assumptions from the present model, particularly by abstracting from the demand effect of a stricter environmental standard and hence from firms' entry decisions. Similarly, the theoretical works in CARRARO *et al.* [1995] and the papers by KATSOULACOS and XEPAPADEAS [1995] and by CONRAD and WANG [1993] explore the effect of environmental policy on market structure and welfare, but none allows for the effect of environmental quality on industry demand. Furthermore, while, in one form or the other, standard setting is the predominant mode of environmental regulation, this literature is primarily concerned with the effects of environmental *taxes*. Moreover, it examines the effects of environmental taxes when the polluting industry is imperfectly competitive or when other distortionary taxes pre-exist in the economy (see, *e.g.*, GOULDER [1995], and BOVENBERG and GOULDER [1996] for the latter case). As such, most of the results in the literature are essentially of the "second-best" nature (see particularly the original works of SEADE [1985] on the effects of taxation of oligopolistic industries and DIXIT [1986] on comparative statics for oligopoly).

1. See KLIBANOFF and MORDUCH [1995] for a formal explanation of why in a large range of cases involving externalities and private information, private coordination fails to occur, or to improve efficiency despite common knowledge of gains from agreement.
2. The issue somewhat resembles that of expenditures on advertising, particularly for 'search' goods. If by enhancing consumers' information, advertising benefits all firms in the industry, then, in the absence of regulation, a firm may not have incentive to provide enough information because it is unable to fully appropriate the benefits of its own advertising (see, *e.g.*, NELSON [1970], SCHAMALENSEE [1972], and COMANOR and WILSON [1974]).
3. That when firms are unable to coordinate their private actions to their own collective benefit, mandatary regulation of industry, in one form or the other, can make all firms better off is well known (see, *e.g.*, the classical works of OLSON [1965] and SCHELLING [1978]) . Regulation of the "commons" is a prime example in the literature. However, whereas the literature has been typically concerned with cases of negative externality on *production* side (so that regulation causes the production function to shift out, or, equivalently, lowers the present and/or future marginal costs), the cases studied in this paper are marked by positive externality on the *demand* side, so that regulation makes the industry demand to shift out.

Of the existing literature, the paper by CARRARO and SOUBEYRAN [1995] is the only one that comes close in spirit to the present work. However, although it allows the industry demand to depend on environmental quality, it differs sharply from the present work in several important respects. (i) It analyzes the effects of environmental taxation and not of standards. (ii) By assuming that the number of firms is *fixed*, it abstracts from the effect of environmental regulation on the industry size. (iii) It assumes that *no* abatement technology is available to firms, so that the only way the firms react to the environmental regulation is by changing their output levels. (iv) It considers the case of asymmetric firms which differ in the marginal and fixed costs, whereas in the present paper firms are assumed to be identical. CARRARO and SOUBEYRAN show the conditions under which the introduction of an emissions tax, or a raising of the tax rate to the *optimal* level, may benefit *some* firms while hurting others. Further, as a consequence of (ii) and (iii), in their model a tax increase always leads to a reduction in firms' and hence industry output levels, implying in turn an inevitable trade-off between industry output and environmental quality. As we shall see later in this paper, relaxing either of these assumptions, can alter these results. Specifically, in this model, a tightening of the environmental standard need not cause the typical firm's output level to fall, and, in any event, due to entry of new firms to the industry, the industry output may in fact increase. Moreover, the increase in industry output can be accompanied by a *reduction* in total net emissions.

In a different context, PORTER [1991] and PORTER and VAN DER LINDE [1995a][1995b] have argued that the conception of an inevitable tradeoff between industrial competitiveness and environmental regulations derives from of a *static* view of environmental regulations whereas by promoting innovations more stringent environmental standards can yield *dynamic* benefits which more than offset the initial higher cost of compliance and therefore enhance industrial competitiveness and profitability. PORTER also suggest that regulation can create demands for environmental products and so gives countries a head start in those products. They, however, do not provide an explicit theoretical basis for their claim, which has come to be known as "PORTER's hypothesis". And, unfortunately, partly because of this, their claim has been dismissed by some economists (*e.g.*, PALMER *et al.* [1995], and SIMPSON and BRADFORD [1996]. It should be noted, however, that, despite similarity of the main conclusion, the model presented in this paper is very different from PORTER's hypothesis in that (i) it is a static model whereas PORTER's hypothesis rests on dynamic cost effects, and (ii) the "demand" effect in this model is very different from that suggested in PORTER's hypothesis.

The rest of the paper is organized as follows. Section 2 develops the basic model. Adopting a positive analysis approach, it derives conditions under which, with free entry and exit, a stricter environmental standard leads to a *larger* number of firms, a *greater* industry supply, and a *lower* total net pollution. These industry effects, which are often of most concern to policy makers, are different from the standard results of models that do not incorporate the demand effect of a stricter regulation. Section 3.1 sharpens the main results in the context of a specific example and illustrates them for some assumed parameters values. This example shows that for the industry to survive, a *minimum* pollution standard may be necessary, and that this minimum standard will be higher, the *less* efficient the industry is in producing the good or abating pollution, or the *smaller* the market demand is in the absence of standards. For a fixed number of firms in the short-run, Section 3.2 examines the effects of a stricter standard on profitability, output, and pollution emissions both at the individual firm and industry levels, and compares these effects with those obtained under free entry condition. Here too, it is shown that the individual firm's effects can be different from the standard ones and that the industry's short-run and long-run effects of a stricter standard may conflict, thus suggesting a partial explanation for why some industries may contest stricter standards that can be in their own interest.[4] Section 4 illustrates the welfare effects of a higher standard by incorporating into the model of Section 3.1 linear and quadratic sets of specifications of the cost functions associated with pollution damages and standards enforcement. Interestingly, it shows situations where weak standards reduce welfare, while the standards that enhance welfare may be too high to be politically feasible, suggesting that the regulatory agency may prefer *no* standards to weak standards. Concluding remarks are given in section 5.

2 The Basic Model[5]

Consider an industry with n identical firms that produce a homogeneous good and generate pollution as a by-product. For simplicity it is assumed that pollution emissions is a constant proportion of each firm's output, x, so that, by appropriate choice of units, emission and output levels are equal in the absence of abatement. The industry output is $X = nx$. Each firm's production cost is given by $C = C(x)$, with $C' > 0$ and $C'' \geqslant 0$. The regulator sets the environmental standard uniformly, requiring that all firms, both the existing ones and potential new entrants, abate a fraction, $0 \leqslant \alpha \leqslant 1$, of their pollution emissions. Accordingly, the environmental standard does not pose a barrier to entry. The industry demand is taken to depend both on the price of the good, P, and the environmental quality standard, α. It is given generally by the inverse demand function $P = P(X,\alpha) = X^{-1}(X,\alpha)$, where $P_X = \partial P(X,\alpha)/\partial X < 0$ and $P_\alpha = \partial P(X,\alpha)/\partial\alpha > 0$. The first inequality simply indicates that, for any given environmental standard, the industry demand is downward sloping. The second inequality states that a higher environmental standard induces the industry demand to shift out and to the right. Stated differently, for any quantity demanded, consumers are willing to pay a higher price for the good if its production, distribution, or consumption is associated with improved environmental quality. I assume a large constant population ($M > 0$) of identical consumers, which, for simplicity and without loss of

4. Another explanation could be the firms' inability to accurately assess the industry's benefits from a higher standard; for example, by underestimating the positive demand effect and/or overestimating the cost effect. Also, when firms in the industry are heterogenous, it is possible that a more stringent regulation increases profits of some firms while reducing those of others, thus the latter's opposition to the regulation (*e.g.*, see CARRARO and SOUBEYRAN [1996]).

5. The model of this section, which is essential to the analyses in sections 3 and 4, draws heavily on FARZIN [2003].

generality, is normalized at unity ($M = 1$) so that the market demand, X, is identified with the representative consumer's consumption. In Appendix 1, I show that the demand effect, $P_\alpha > 0$, derives generally and in a theoretically consistent way from individual utility maximization where the representative consumer derives utility $U = U(X,Z,Y)$ from the consumption of the polluting good X and of a composite of all other goods, Y, but incurs disutility from the net pollution (after abatement), $Z = (1-\alpha)X$. The industry demand is divided equally among the firms, so that each firm's market share is $1/n$.

To monitor firms and enforce the standard, the regulator incurs cost, E, which is assumed to rise with the number of firms monitored, and at nondecreasing rates; that is, $E = E(n)$, with $E' > 0$, $E'' \geqslant 0$ and $E(0) = 0$. The reason for incorporating monitoring and enforcement costs into the analysis is to reflect the important fact that in deciding about the optimal levels of environmental standards, the regulatory agencies are also concerned about implementation costs. Thus, for example, in a setting where the number of firms is fixed, the regulator's information is incomplete, and the enforcement cost depends on the degree of cleanness of the technologies that firms choose, the regulator may be willing to trade the stringency of the standards for reduced enforcement cost (*e.g.*, AMACHER and MALIK [1996]). In the present model, however, it is assumed that the regulator has complete information about firms so that they fully comply, but that the number of firms in the industry and hence the monitoring and enforcement costs depend on the stringency of the standard set by the regulator.

To be compliant, each firm incurs pollution abatement costs, A, which are assumed to rise with the amount of pollution abated, αx, and at increasing rates; that is, $A = A(\alpha x)$, with $A' > 0$, $A'' > 0$, and $A(0) = 0$. Thus, for a given level of output, and hence pollution, a firm's abatement cost rises with the standard, α, as more expensive capital equipment, embodying a more efficient abatement technology, and/or greater amounts of other relevant inputs will be required.[6] Notice that, to keep the model tractable, the pollution abatement and the production of the good are taken to be separate activities within each firm, so that a higher environmental standard raises the abatement cost, but leaves production cost unchanged. This will be the case, for example, when the inputs used in pollution abatement are specific to that activity, so that the changes in demand for them resulting from a change in environmental standard do not affect the demand for inputs used in production of the good. This seems to be more or less supported by the existing empirical evidence (BARBERA and MCCONNELL [1990] which shows that such indirect effects, if present at all, are likely to be insignificant and can be either positive (improving the productivity of factors employed in the production sector) or negative.

Although mandating a standard that requires complete elimination of pollution (*i.e.*, $\alpha = 1$) can be very costly, such a possibility is not ruled out. However, for values of $\alpha < 1$, it is assumed that the residual pollution inflicts social damage which, although unknown to the representative consumer, is

6. Here abatement technology is interpreted as installation of end-of-the-pipe equipment to reduce pollution after it is generated, thus leaving the emission-output ratio at the source unchanged. It may, however, also be interpreted as changes in production processes resulting in a lower emission-output ratio at the source by enhancing the efficiency of (polluting) input use.

fully known to the regulator and is taken into account when setting the optimal abatement standard.[7] The cost of social damage is assumed to be given by the function $D(Z)$, where $D' > 0$, $D'' \geqslant 0$ and $D(0) = 0$.

It is important to emphasize that the central focus of this model is to investigate the effects on the industry and social welfare of higher environmental standards when the free-riding problem and lack of coordination by firms necessitates a mandatory industry standard. Accordingly, the assumptions that a homogeneous good is produced by identical firms and consumed by the representative consumer are deliberately made to abstract from situations where, for variety of reasons, which are principally strategic in nature, firms may voluntarily choose pollution abatement standards (for the case of voluntary abatement and different motives behind it, see ARORA and GANGOPADHYAY [1995], ARORA and CASON [1995], BAGNOLI and WATTS [1995], and MAXWELL *et al.* [2000], among others). Here, without public regulation, the voluntary abatement effort of a typical firm (if it is warranted at all) will be less than the collectively efficient or socially optimal level. In other words, in the absence of a mandatory standard, if a typical firm were to choose its abatement level, it would have an incentive to free ride on other firms' abatement efforts, so that the non-cooperative abatement level would fall short of the industry efficient (or socially optimal) level. So, a standard set by the regulator above the non-cooperative level will solve the free-riding problem and will be binding.

Let us now analyze the effect of a change in environmental standard on the industry equilibrium under the free entry condition. Taking as given the environmental standard set by the regulator and the output levels of other firms, each firm plans its own output so as to maximize its profits, which under the assumption of free entry and exit, will be zero in the long-run equilibrium. That is, each firm chooses x to

$$\operatorname*{Max}_{x} \pi(x,n,\alpha) = xP(X,\alpha)\ A(\alpha x)C(x)$$

The first-order conditions for an interior optimum are

$$P(X,\alpha)\left[1 - \frac{1}{\varepsilon(X,\alpha)}\right]\ \alpha A'(\alpha x)C'(x) = 0 \tag{1}$$

and,

$$P(X,\alpha) - [A(\alpha x) + C(x)]/x = 0 \tag{2}$$

where $\varepsilon(X,\alpha) \equiv -P(X,\alpha)/X.dX/dP > 0$ denotes the absolute value of the price elasticity of market demand and the zeroprofit condition (2) determines the equilibrium number of firms in the industry. Thus, both x and n depend generally on the emissions standard, α. Of particular interest is the question

7. This reflects the fact that for obvious reasons the individual consumer usually does not possess full information about *all* current and future harmful effects of pollution, particularly when such effects are latent and unobservable by current consumers until after a long period of consumption or perhaps even only observable in their offsprings.The introduction of uniternalized social costs of pollution is only relevant, though not essential, to the welfare analysis in section 4.

of how the equilibrium number of firms, the representative firm's output level, and therefore the industry's supply would respond to a change in the standard.

To carry out these comparative statics, let $\xi(\alpha x) \equiv \alpha x A''/A' > 0$ denote the elasticity of the marginal abatement cost and $\varepsilon_p \equiv \partial\varepsilon(X,\alpha)/\partial P = \partial\varepsilon(X,\alpha)/\partial X.\partial X/\partial P \equiv \varepsilon_X/P_X$ and $\varepsilon_\alpha \equiv \partial\varepsilon(X,\alpha)/\partial\alpha$ the partial derivatives of the demand elasticity with respect to P and α, where $dX/dP = 1/[dP/dX] < 0$. Differentiating (1) and (2) with respect to α, using these notations and suppressing the arguments of the functions for notational ease, one has

$$\left[P_X\left(1-\frac{1}{\varepsilon}\right)+\frac{P}{\varepsilon^2}\varepsilon_X\right]\frac{dX}{d\alpha}(\alpha^2 A''+C'')\frac{dx}{d\alpha} + P_\alpha\left(1-\frac{1}{\varepsilon}\right)+\frac{P}{\varepsilon^2}\varepsilon_\alpha - A' - \alpha x A'' = 0 \tag{3}$$

$$\frac{dn}{d\alpha} = \frac{(P_\alpha - A')n\varepsilon}{P} \tag{4}$$

Recalling that $X = nx$, one has

$$\frac{dX}{d\alpha} = n\frac{dx}{d\alpha} + x\frac{dn}{d\alpha} \tag{5}$$

Substituting for $\frac{dX}{d\alpha}$ from (5) and for $\frac{dn}{d\alpha}$ from (4) into (3) and solving for $\frac{dx}{d\alpha}$, yields, after simplification

$$\frac{dx}{d\alpha} = \frac{A'(\xi + 1/\varepsilon) + P/\varepsilon^2[(P_\alpha - A')\varepsilon_p - \varepsilon\alpha]}{nP_X(11/\varepsilon + P\varepsilon_p/\varepsilon^2)(\alpha^2 A'' + C'')} \tag{6}$$

Equation (4) reveals that the effect of a change in the environmental standard on the number of firms is generally *ambiguous*, so that, contrary to what common intuition might suggest, raising the environmental standard need *not* necessarily cause a reduction in the number of firms. This is because a rise in the environmental standard has two opposing effects. First, for a given level of the firm's output, it entails a greater amount of emission abatement and therefore raises the unit abatement cost by the extent of $\frac{\partial}{\partial\alpha}[A(\alpha x)/x] = A'$. This effect, which is the cornerstone of the industrialists' opposition to stricter environmental standards, tends to reduce the number of firms. Second, for a given quantity of the good demanded, a higher standard induces consumers to pay a higher price for the good. This demand side effect, which is captured by P_α and has been ignored, tends to induce entry. Thus, $(P_\alpha - A')$ measures the effect of a change in the environmental standard on the firm's unit profit.

It is then clear that in the presence of the demand effect, a stricter standard has in general an ambiguous effect on firm profitability and hence on entry. In turn, this ambiguity opens up a number of interesting questions. For example, one would like to know under what conditions the demand effect is strong enough to give rise to situations where the effects of a more stringent standard are in contrast to those claimed by industrial lobbyists, thereby providing some light on the political economy of environmental regulation. Further, in the literature, the effect of a more stringent regulation (especially a higher pollution tax) is either conventionally to lower both firms' output and profitability (as, for example, when each firm faces a perfectly elastic demand), or, when the demand facing each firm is downward sloping, to increase firms' profitability by inducing them to *reduce* their output levels and therefore raise the price to a level which more than outweighs the increase in the unit production cost (see, BUCHANAN and TULLOCK [1975], MALONEY and MCCORMICK [1982], SEADE [1985], DIXIT [1986], CONRAD and WANG [1993], and CARRARO and SOUBEYRAN [1995], among others).[8] In contrast to conventional models, through its demand effect, a stricter standard could render firms more profitable and at the same time *increase* their output level.

From equation (4) it follows that:

PROPOSITION 1: *In an oligopoly industry with identical firms and free entry/exit, a stricter standard leads to a larger (smaller) number of firms if it raises (lowers) the representative firm's unit profit, i.e.,* $\frac{dn}{d\alpha} \gtreqless 0$ *as* $(P_\alpha - A') \gtreqless 0$. *The rate of entry/exit will be greater the larger the price elasticity of the industry demand.*

Although rather obvious, the insight from this proposition can be valuable for public policy when assessing the effects of a higher environmental standard. It emphasizes the importance of paying due attention to consumers'

TABLE 1.A
Signs of $\partial x/\partial \alpha$ ***when*** $P_\alpha - A' \geqslant 0$

		ε_α		
		0	-	+
ε_p	0	<0	<0	?
	-	?	?	?
	+	<0	<0	?

8. CARRARO and SUBEYRAN's paper differs from the others by allowing for the effect of environmental quality on the industry demand. Analyzing an asymmetric oligopoly, however, they show that while a higher emission tax may raise profits of some of the firms it lowers those of the others and that it reduces firms' outputs, and hence, industry's total supply.

preferences and their willingness to pay higher prices for goods that promote environmental quality, and cautions against limiting attention only to increased costs of compliance with higher standards.

To determine the sign of $dx/d\alpha$, it is noted from (6) that $A'' > 0$, $C'' \geqslant 0$, and $\varepsilon > 1$ for all $X > 0$ and positive marginal revenues, so that the sign of $dx/d\alpha$ depends crucially on the signs of $(P_\alpha - A')$, ε_P, and ε_α. Possible signs of $dx/d\alpha$ are presented in Tables 1.a and 1.b, and the result is summarized in the following proposition:

TABLE 1.B
Signs of $\partial x/\partial\alpha$ ***when*** $P_\alpha - A' < 0$

		ε_α		
		0	**-**	**+**
ε_p	**0**	<0	<0	?
	-	?	?	?
	+	?	?	?

PROPOSITION 2: *When* $P_\alpha - A' \geqslant 0$, *a stricter standard unambiguously leads to a lower firm's output level only if the price elasticity neither decreases with the price nor increases with the standard (i.e., if* $\varepsilon_P \geqslant 0$ *and* $\varepsilon_\alpha \leqslant 0$*); otherwise, the effect is ambiguous. When* $P_\alpha - A' < 0$, *only if the price elasticity is constant (*$\varepsilon_P = 0$*)* <u>*and*</u> *does not increase with the standard (*$\varepsilon_\alpha \leqslant 0$*), will a stricter standard unambiguously lead to a lower firm's output level.*

It is therefore seen that stricter standards will unambiguously lower firms' output only under a particular configuration of demand characteristics and in particular that they may increase firms' output as long as the demand elasticity is *either* a *decreasing* function of the price ($\varepsilon_P < 0$) *or* an *increasing* function of the environmental standard ($\varepsilon_\alpha > 0$).[9] These conditions are not implausible. The former may occur when, by virtue of some particular technological or geographical characteristics, the existing substitutes for the good in question have traditionally had the market to themselves, but a lowering of the good's price expands its market share and brings it increasingly into competition with its substitutes. Few examples make this clear. A prime

9. It can be verified from (6) that when a stricter standard causes firms to exit the industry in the long-run, *i.e.*, when $P_\alpha - A' < 0$, and $\varepsilon_p \geqslant 0$, then the smaller $\xi > 0$ or the larger $\varepsilon_\alpha \geqslant 0$, the more likely it is that $dx/d\alpha > 0$.

example is the demand for organically grown agricultural products. At lower prices, the demand for these products become more elastic as they make an inroad into the markets traditionally taken up by conventionally grown products. Another example is the demand for private touristic and recreational services where prices are deliberately set so high as to make these services available exclusively to a segment of the market (for example only to members) whose demands are relatively less price elastic. Lowering the prices of such services will bring them in closer competition with rival services (some of them may also be publicly provided), therefore making their demands more price elastic. As another example, consider the demand for coal which becomes more elastic at lower prices as coal becomes a more competitive energy source and takes a larger share of energy market at the expense of substitutes such as natural gas and crude petroleum. The same is also true with the demand for domestic goods that are kept out of foreign markets by imposition of import tariffs. At sufficiently low prices, such goods will be brought increasingly into competition with foreign goods, thus rendering their demands more price elastic.

Whether the price elasticity of the industry demand increases or decreases as the environmental standard becomes more stringent is an open empirical question. On purely theoretical grounds, both possibilities seem equally likely, depending on the manner in which a stricter standard causes the demand for the industry in question to shift. Thus, for example, in the case of food products grown conventionally, subjecting the use of chemical inputs to stricter standards is likely both to increase the demand and, by rendering the products closer substitutes for the organically produced food, the price elasticity also increases at any consumption level, $\varepsilon_\alpha > 0$; graphically, the demand curve shifts upward and becomes flatter. Similarly, raising the standards for use of coal in electricity generation (*e.g.*, tougher standards on coal cleaning to reduce its contents of sulphur and other toxic chemicals) would both increase the level of coal demand and its price elasticity.

Perhaps of the most concern to the regulator are the effects of a stricter standard, not on the individual firm's output or pollution level, but on the *industry* output and total pollution. Interestingly, as propositions 1 and 2 together imply, for the industry output to be unambiguously adversely affected, more stringent conditions than those just noted about the effect on an individual firm's output need to be satisfied. More specifically, from (5), (4) and (6) one has:

COROLLARY 1: *A stricter standard unambiguously lowers the industry output ($dX/d\alpha < 0$) if (a) it does not increase the number of firms (i.e., $P_\alpha - A' \leqslant 0$), (b) the price elasticity is constant (i.e., $\varepsilon_p = 0$), and (c) the elasticity does not increase with the standard (i.e., $\varepsilon_\alpha \leqslant 0$). Otherwise, the effect is ambiguous.*

Assuming that the conditions needed for a stricter standard to bring about a larger industry output are met, the question arises as to whether this would lead to a degraded or improved environmental quality. The following proposition provides the answer.

COROLLARY 2: *Beyond a certain level, a stricter abatement standard always reduces the total net pollution (improves the environmental quality) even when it increases the industry's output.*

PROOF: Differentiating $Z = (1-\alpha)X$ w.r.t. to α one has $dZ/d\alpha = X(\alpha)$ $[(1-\alpha)/\alpha\eta(X,\alpha) - 1]$, so that

$$dZ/d\alpha < 0 \text{ iff } \eta(X,\alpha) \equiv \alpha/X\, dX/d\alpha < \alpha/(1-\alpha) \tag{7}$$

where $\eta(X,\alpha)$ is the elasticity of industry demand with respect to the standard. Focusing on the more interesting case where a stricter standard raises the industry output, $dX/d\alpha > 0$, it is noted that $dZ/d\alpha < 0$ as $\alpha \longrightarrow 1$. This is because as $\alpha \longrightarrow 1$ the RHS of the inequality rises to infinity, whereas η obtains a finite limit. The latter follows from the assumption that the abatement cost is convexly increasing in α, which in turn implies that X and $dX/d\alpha$ and hence $\eta(X,\alpha)$ all approach finite limits as $\alpha \longrightarrow 1$. Thus, there exists some $\alpha = \hat{\alpha} > 0$ such that $dZ/d\alpha < 0$ for all $1 \geqslant \alpha > \hat{\alpha}$.

The regulator in turn chooses the abatement standard to maximize the net social welfare, which, recalling that firms' long-run equilibrium profits are zero, for consumption level $X(\alpha)$, is

$$\begin{aligned}&\underset{\alpha\in[0,1]}{\text{Max}}\ W(\alpha) = \\ &\int_0^{X(\alpha)} P(X(\alpha),\alpha)ds - X(\alpha)P(X(\alpha),\alpha) - D((1\ \alpha)X(\alpha)) - E(n)\end{aligned} \tag{8}$$

Differentiating (9) with respect to α and using $X\ P_X = -P/\varepsilon$ yields the necessary condition for an optimum

$$\begin{aligned}W'(\alpha) = \int_0^{X(\alpha)} &[P_X\frac{dX}{d\alpha} + P_\alpha]dX\ [(1-\alpha)D' - P/\varepsilon]\frac{dX}{d\alpha} \\ &- (P_\alpha - D')X - E'\frac{dn}{d\alpha} = 0\end{aligned} \tag{9}$$

where the first term on the RHS measures the change in consumers' willingness to pay for an incremental increase in the standard, the second term in bracket is the net loss (benefit) from an incremental increase in industry output at a *given* standard (a larger marginal damage but a lower price), the third term is the net loss (benefit) from an incremental increase in the standard at a *given* total output (a higher price but also a lower marginal damage), and the last term is the increased cost of enforcement. Condition (9) simply states the requirement that the marginal social benefit of a higher standard should equal its marginal social cost.

At the level of generality we have been analyzing the issue, this is almost as far as one can go. To proceed, we need to obtain explicit solutions for the industry equilibrium. This is done in Section 3.1 below.

3 A Specific Example

3.1 Industry Effects of a Stricter Standard With Free Entry/Exit

Let us consider a simple example in which the industry faces a linear demand function given by $X(P,\alpha) = a(1+\alpha) - bP$, where $\alpha \in [0,1]$ and $0 \leqslant P \leqslant (1+\alpha)a/b$. Accordingly, for any quantity demanded/output, X, a reduction in the *amount of pollution*, $(1-\alpha)X$ (or equivalently, an increase in the environmental standard, α) leads to *parallel* and *outward* shifts of the industry demand curve.[10] For all $X > 0$, this demand function has the following properties;

(10a) $$\varepsilon(X,\alpha) = a(1+\alpha)/X - 1 > 0$$

(10b) $$\varepsilon_\alpha(X,\alpha) = a/X > 0$$

(10c) $$\varepsilon_p(X,\alpha) = ab(1+\alpha)/X^2 > 0$$

(10d) $$P = [a(1+\alpha) - X]/b$$

(10e) $$P_X = -1/b$$

(10f) $$P\alpha = a/b$$

Both for simplicity and to highlight the role of the demand side effects rather than costs as the driving force in the model, it is assumed that the representative firm's production cost is given by $C(x) = cx$, implying constant marginal (=unit) cost, $C'(x) = C(x)/x = c > 0$, and $C''(x) = 0$. The firm's total abatement cost is assumed to take the form $A(\alpha x) = A(\alpha x)^3 - d(\alpha x)^2 + k(\alpha x)$, where A, d, and k are all positive constants, and which by normalization (setting $A \equiv 1$) can be rewritten as $A(\alpha x) = (\alpha x)^3 - d(\alpha x)^2 + k(\alpha x)$. This implies a U-shaped unit cost of abatement, which not only seems plausible, but more importantly, as we will see presently, is a feature necessary for the existence of an interior industry equilibrium. The unit and marginal abatement cost (with respect to the firm's *output* level) are:

(11) $$AC(\alpha x) \equiv A(\alpha x)/x = \alpha^3 x^2 - d\alpha^2 x + \alpha k$$

10. It is easily verified that consistent with the consumer optimization problem in Appendix 1, the linear demand function used here is derived from a utility function of the form $U(X,Z,Y) = 2a/bX - 1/2bX^2 - a/bZ + Y$, and using the first-order condition (A.4') when the consumer internalizes pollution $Z = (1-\alpha)X$. Alternatively, it can be interpreted to be derived from the utility function $U(X,Y,\alpha) = a/b(1+\alpha)X - 1/2bX^2 + Y$, and using (A.4″) when the consumer does not internalize the disutility of pollution but her marginal utility of consumption increases *exogenously* with the environmental standard α set by the regulator.

$$MC(\alpha x) \equiv \partial A(\alpha x)/\partial x = \alpha A'(\alpha x) = 3\alpha^3 x^2 - 2d\alpha^2 x + \alpha k \tag{12}$$

which, since firms are identical, are also the industry's average and marginal costs.

Note that for a solution with $x > 0$ to exist, certain constraints on parameters must hold. First, one must have $AC(\alpha x) + c \geqslant 0$ for all $x > 0$ and $\alpha > 0$, which implies that $\alpha k + c > \alpha d^2/4$. Second, since the unit aggregate cost curve is U-shaped, for any $\alpha > 0$, the demand's "choke" price, $P(0,\alpha) = (1+\alpha)a/b$, should not exceed the unit aggregate cost of production and pollution abatement as $x \longrightarrow 0$; that is, one must have $k\alpha + c > (1+\alpha)a/b$, or $\alpha(k - a/b) + (c - a/b) > 0$, and *a fortiori* that $c > a/b$ for $\alpha \longrightarrow 0$. Importantly, the condition that $c > a/b$ implies the necessity of a minimum standard for the industry to survive, for otherwise the environmental quality would be so poor, and the demand facing the industry so little, that even with no abatement cost, the representative firm's unit production cost would exceed the choke price, thus causing the industry to go out of business. Formally, for $\alpha = 0$ and $x > 0$, one would have $AC(\alpha x) + C(x)/x = c > P(0,0) = a/b$, implying that no firm will stay in business without some amount of pollution abatement. We shall shortly determine this minimum abatement standard.

Substituting into (1) and (2) from (10d)(10e), (11) and (12) and solving for x and n yields:

$$\begin{aligned} x^2 &= [\alpha(k - a/b) + (c - a/b)]/\alpha^3 \\ &\Longrightarrow x = [\alpha(k - a/b) + (c - a/b)]^{1/2}\alpha^{-3/2} \end{aligned} \tag{13}$$

$$n = b\alpha^2(d - 2\alpha x) \tag{14}$$

where, as noted above, the inequality condition $\alpha(k - a/b) + (c - a/b) > 0$ ensures that $x > 0$ and where for $n > 0$ the additional condition that $d > 2\alpha x$ must also hold.[11] Writing this inequality as $d^2/4 > \alpha^2 x^2$ and substituting for x^2 from (13), we can combine the relevant parameter restrictions for the existence of an interior solution, $n > 0$ and $x > 0$, as

$$\alpha d^2/4 > [\alpha(k - a/b) + (c - a/b)] > 0 \tag{15a}$$

or, equivalently

$$\alpha d^2/4 + (1+\alpha)a/b > \alpha k + c > (1+\alpha)a/b > \alpha d^2/4 \tag{15b}$$

11. This latter inequality reconfirms the inadmissibility of abatement cost functions for which $d = 0$, and hence the choice of the specification used here. Also, since a smaller value of d corresponds to an upward shift in the unit abatement cost curve, the inequality echoes the simple fact that for an equilibrium to exist the unit abatement cost should not be unduly high.

An immediate implication of condition (15a) is that

$$\text{(15c)} \quad n > 0 \text{ and } x > 0 \Longrightarrow \alpha > \underline{\alpha} = (c - a/b)/[d^2/4 - (k - a/b)]$$

where the condition $d^2 > 4[(k - a/b) + (c - a/b)]$ ensures that $0 < \underline{\alpha} < 1$. Further, it is easy to verify from (15c) that $\partial\underline{\alpha}/\partial c > 0$, $\partial\underline{\alpha}/\partial d < 0$, $\partial\underline{\alpha}/\partial k > 0$ and $\partial\underline{\alpha}/\partial(a/b) < 0$. Thus,

PROPOSITION 3: *In order for the polluting industry to survive, a minimum abatement standard is necessary. This minimum standard will be higher the larger the unit cost of production or of abatement and the smaller the industry demand in the absence of any standards.*

This result is appealing because, although in reality one can readily find unregulated industries that have survived, it questions the perception that *any* environmental regulation would be against industry's interest. Particularly so when adopting a minimum necessary (or higher) standard renders benefits to the entire industry, which, because of firms' failure to coordinate and the free-riding problem, would not materialize without public intervention.

The rather counter-intuitive comparative statics results in Proposition 3 have a simple explanation: in order to survive, an industry that is characterized by a relatively high unit cost and/or a small market size needs to offset these deficiencies by becoming relatively cleaner as a means of boosting its market. The proposition provides a useful insight for standard-setting policy in situations where the regulator deems it more desirable to limit the standard to the minimum level necessary for the industry's survival. As we shall see later in section 4, such a situation may arise when *optimal* regulation of an industry entails setting so high a standard that is politically infeasible but at the same time setting too weak a standard would reduce welfare.

Next, we determine the effects of a stricter standard on each firm's output level, the number of firms in the industry, the industry's total output and total pollution. In particular, of great concern to policy makers are the effects on industry output and total pollution. Interestingly, we show that even when the effects of a higher standard at the firm level appear to be standard, its industry effects can be very different from those obtained in models that abstract from the demand effect of a higher standard.

In Appendix 2 we show that for the present model,

(a) $dx/d\alpha < 0$: a stricter standard causes a *reduction* in the individual firm's output level,
(b) $dn/d\alpha > 0$: a stricter standard *increases*, rather than decreases, the number of firms,
(c) As a result of (a) and (b), and as an application of Corollary 1, we have

COROLLARY 1': *Even when a stricter standard leads to a lower individual firm's output level, it may well lead to a larger industry output ($dX/d\alpha > 0$).*

(d) It would also be interesting to see the effect on total pollution, since the argument for a stricter environmental standard will be particularly strong if it can reduce total pollution and hence improve environmental quality at the same time that it increases the industry output. As as an application of Corollary 2, we show in Appendix 2,

COROLLARY 2': *While, at the individual firm level, a stricter standard reduces pollution, at the industry level, it leads to a* larger total pollution at low standards *but a* smaller total pollution at sufficiently high standards, *even though the industry output (and hence gross emission) increases with the standard* .

The observation that for very small values of α, total pollution initially rises with the standard derives from the fact that at too low standards there will be relatively too rapid entry into the industry but too little abatement per unit of output/emission, so firms entry raises industry outputs sufficiently to overwhelm reductions in emissions per unit output. It is important to note that here the increased pollution is *not* because the firm increases its output to dilute the pollution and hence lower its emissions per unit of output; as firm's output *falls*. Rather, the increased pollution is due to the entry decisions which in turn derives from the demand side effect of a stricter standard.[12] Perhaps to the surprise of the environmentalists, Corollary 2' has the interesting implication that from *their* perspective weak standards may be worse than no standards. As such, it illustrates two points. First, that regulation can lead to unintended consequences, a point that economists have consistently tried to point out. Second, it is a stark reminder that firm level effects are not always equivalent to industry level effects.

To give a quantitative feeling for the various effects analyzed above, we have simulated the model for parameter values of $a = 100$, $b = 1$, $c = 101$, $d = 25$, and $k = 102$, chosen conveniently and consistent with (15b). Figure 1 depicts the industry's equilibrium values of x, n, X and Z (on the left-hand vertical axis) and P (on the right-hand vertical axis) as a function of α. For these parameter values, the minimum standard is negligible, 0.6 percent, but rises to nearly 10 percent and 24 percent as the value of d is lowered respectively to 7 and 5. This is in line with Corollary 2; a smaller value of d corresponds to an upward shift in the firm's abatement cost curve, while leaving its production cost unchanged.[13] In the long-run equilibrium, this would force the firm out of market unless the industry demand and hence price is increased by mandating a higher minimum standard.

As Figure 1.A shows, through its positive effect on the demand for the good, which in turn reflects the consumers' willingness to pay for improved environmental quality, a sricter standard may very well encourage more firms to the industry, and, despite lowering each firm's output level, expand the

12. Increased pollution is likely to result also from a *performance* standard restricting the firm's total emission. In fact, perhaps this is even more likely since the effect on the firm's profitability could be stronger (because restricting total emission has a greater effect on abatement cost at the margin but a smaller effect inframarginally) and so generates even more entry.

13. Note from (13) that the equilibrium level of firm's output, x, is independent of d.

FIGURE 1.A
Long-run Industry Equilibrium for Different Environmental Standards

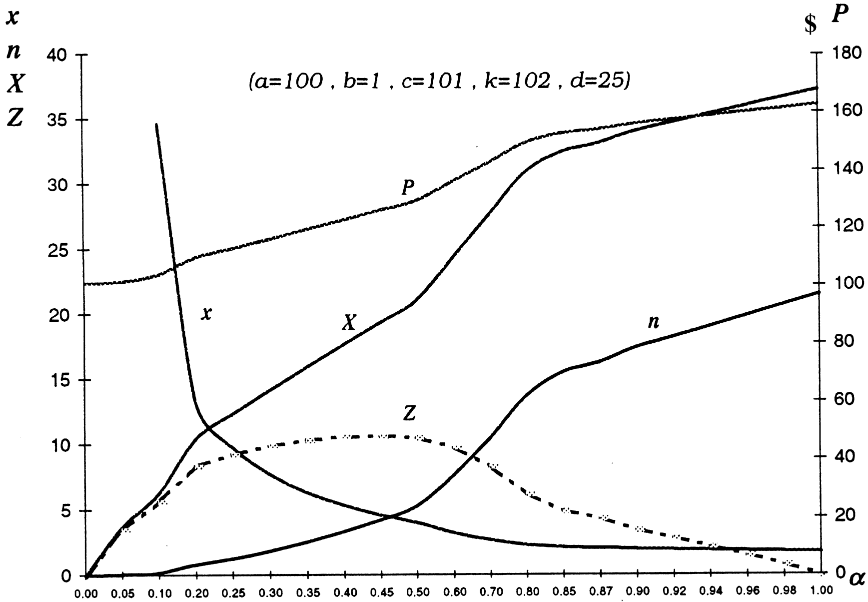
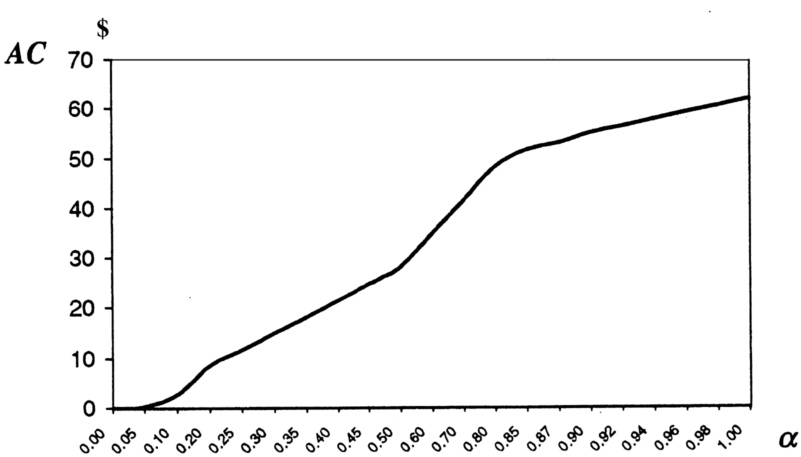


FIGURE 1.B
Unit Abatement Cost in Long-Run Equilibrium



industry's supply. Further, despite increasing the industry's total output, it is seen that for standards exceeding 44 percent pollution reduction, raising the standard reduces total pollution and hence improves environmental quality too. It is important to note that it is the demand effect rather than costs characteristics that is the driving force behind these industry effects. For, as Figure 1.B shows, the equilibrium unit abatement cost is monotonically increasing in α, thus supporting the industry claim that stricter standards are costly but also supporting the present paper's claim that demand side effects are dominating here.

3.2 Industry Effects of a Stricter Standard With Fixed Number of Firms

The previous results show clearly that the effect of regulation on firms' output and profitability, and hence on industry size, output, and net pollution is ambiguous. It depends on the relative strength of the offsetting cost and demand effects. This section concentrates on the short-run effects where the the number of firms in the industry is fixed. It identifies conditions under which the short-run and long-run interests of the environmentalists and industrialists conflict, thus permitting some insight into political economy aspects and a sense for whether there is a ground for the industry opposition to regulation. To this end, let $n = n_0$ denote the original equilibrium number of firms before the standard is raised.

Differentiating $\pi(x,n,\alpha) = xP(X,\alpha) - A(\alpha x) - C(x)$ w.r.t. α and using the first-order condition (1), gives

(16a) $$\left.\frac{d\pi}{d\alpha}\right|_{n=n_0} = x[P_\alpha - A'(\alpha x)]$$

So that

(16b) $$\left.\frac{d\pi}{d\alpha}\right|_{n=n_0} \underset{<}{\overset{>}{=}} 0 \quad \text{as} \quad P_\alpha - A'(\alpha x) \underset{<}{\overset{>}{=}} 0$$

Thus, in general, with a fixed number of firms, the net effect on profitability is *ambiguous*: firms will earn positive profits/rents (incur a loss) if an increase in the standard raises the price more (less) than it raises the unit abatement cost.

To see the effect on a firm's output, differentiate the first-order condition (1) w.r.t. α, holding n fixed at $n = n_0$, to get after simplification

(17) $$\left.\frac{dx}{d\alpha}\right|_{n=n_0} = -\frac{[P_\alpha(1 - 1/\varepsilon)] - A'(1+\xi)] + P/\varepsilon^2\varepsilon_\alpha}{nP_X(1 - 1/\varepsilon + P\varepsilon_p/\varepsilon^2) - (\alpha^2 A'' + C'')}$$

Also, to compare the effect of a stricter standard on the firm's scale when the industry size is fixed with that when entry or exit is free, subtract (6) from (17) to obtain

$$(18)\quad \left.\frac{dx}{d\alpha}\right|_{n=n_0} - \frac{dx}{d\alpha} = -\frac{(P_\alpha - A')[(1-1/\varepsilon) + P\varepsilon_p/\varepsilon^2]}{nP_X(1-1/\varepsilon + P\varepsilon_p/\varepsilon^2) - (\alpha^2 A'' + C'')}$$

Finally, to simplify the analysis and to be able to illustrate the general results in the context of the parameterized model of section 3.1, we assume that $\varepsilon_p \geqslant 0$. This is a sufficient (but not necessary) condition to ensure that the denominators in (17) and (18) are negative, so that the signs of the expressions are determined by those of respective numerators. We can distinguish two broad cases:

Case I : $P_\alpha - A' \longrightarrow 0$

According to (16b), in this case the barrier to entry in the short-run generates rents for incumbent firms. As is clear from (17), whether the existing firms increase their scales or not depends crucially on the magnitudes of the elasticities of the demand ($\varepsilon > 0$) and the marginal abatement cost ($\xi > 0$), as well as on the sign and magnitude of ε_α, which measures the change in the *price elasticity* of demand resulting from an increase in environmental standard. To proceed further, we assume that the magnitude of ε_α is sufficiently small so that the sign of (17) is predominantly determined by that of the bracketed tem in the numerator. The following proposition then follows from (16b) and (17):

PROPOSITION 4(I): *With the number of firms fixed, if a stricter standard raises the price more that it raises the unit abatement cost, then it makes firms* more *profitable. Furthermore, if the industry demand is sufficiently elastic (ε large) and the marginal abatement cost is sufficiently inelastic (ξ small), a stricter standard can also lead to a* larger *output by each firm and hence to a larger industry output in the short-run.*

Clearly, despite increasing the industry output, a higher standard can reduce the total amount of pollution if the standard exceeds a certain level.

Proposition 4(I) is important because, assuming that the required conditions hold, it implies that either industry pundits are unduly alarmist, perhaps due to being ill-informed about the possible net effects of higher standards, or unlike policymakers, they are more worried about the *long-run* effects of a stricter environmental regulation than its immediate effects.[14] It also contrast the results in the literature that a more stringent regulation (especially a higher pollution tax) either reduces both firms' output and profitability or increases firms' profitability by inducing them to *lower* their output levels. In the present model, due to the demand effect of a stricter standard, firms can become more profitable and at the same time *increase* their output level. In fact, as can be verified from (17), the present model generalizes the literature results for the special case where $P_\alpha = \varepsilon_\alpha = 0$.

14. Alternatively, when the industry consists of heterogenous firms, industry pundits may represent a fringe of firms who undergo losses as a result of stricter regulations.

Next, we compare the effect on firms' output in the short run and long run. Maintaining the conditions of Proposition 6, we have $\left.\frac{dx}{d\alpha}\right|_{n=n_0} > 0$ and, from (18), $\left.\frac{dx}{d\alpha}\right|_{n=n_0} - \frac{dx}{d\alpha} > 0$. So, there are two possibilities: either (i) $\left.\frac{dx}{d\alpha}\right|_{n=n_0} > \frac{dx}{d\alpha} > 0$, or (ii) $\left.\frac{dx}{d\alpha}\right|_{n=n_0} > 0 > \frac{dx}{d\alpha}$.

In the first case, each firm expands its scale to the point where the marginal revenue associated with its share of increased market demand equals the increased overall marginal cost of production and abatement. In the long-run, as new firms enter the industry, the share of each firm from the market demand shrinks, thus forcing each firm to reduce its output from the no-entry, profit-maximizing level to the free-entry, zero-profit level. However, this latter level is still larger than that prevailing before the standard is raised. So, in this case, a more stringent standard leads to a higher *industry* output *both* in the short-run and in the long-run. But, since it raises the individual firm's output more in the short-run than in the long run, whether the increase in the industry output is greater in the short run or in the long run depends on how much each firm has to lower its output to accommodate new entrants and on how large is the inflow of new firms. Clearly, this case should not generate tension between environmentalists and industrialists except if the increased standard is still weak $(\alpha < \hat{\alpha})$, causing net pollution to rise.

In the second case, as the demand for each firm shrinks with new firms' entry, firms are forced to reduce their scale from the no-entry, profit-maximizing level by such an extent that their new zero-profit output level is less than that before raising the standard. Thus, in this case, while a stricter standard causes incumbent firms to expand their scale in the short run, it reduces firm' output level in the long run. This is an interesting case because it highlights the tension between environmentalists and industrialists: one that sees the immediate effects of regulation and one that sees the latent effects. While the industry's total output increases in the short run, it *may* or *may not* increase in the long run. The former situation is indeed the one that holds for the specific example of the industry analyzed in Section 3.1, namely, a higher standard leads to a larger industry output in the long-run equilibrium. Table 2.A summarizes the comparisons of the short-run and long-run effects when $P_\alpha - A' > 0$.

TABLE 2.A

$$P_\alpha - A' \longrightarrow 0$$

	Case (i)		**Case (ii)**	
	$\left.\frac{dx}{d\alpha}\right\|_{n=n_0} > dx/d\alpha > 0$		$\left.\frac{dx}{d\alpha}\right\|_{n=n_0} > 0 > dx/d\alpha$	
	SR	*LR*	*SR*	*LR*
x	↑	↑	↑	↓
X	↑	↑	↑	$\Updownarrow$
Z	$\alpha > \hat{\alpha}$ ↓	↓	$\alpha > \hat{\alpha}$ ↓	↓

Case II : $P_\alpha - A \longleftarrow 0$

According to (16b), $\left.\frac{d\pi}{d\alpha}\right|_{n=n_0} < 0$, implying *negative* profits for firms. Further, by (17), *for all* values of the elasticities ε and ξ, we have $\left.\frac{dx}{d\alpha}\right|_{n=n_0} < 0$. This is so because to minimize short-run losses, every firm reduces its output to the point where the marginal revenue from its increased share of market demand equals its increased overall marginal cost of production. We therefore have:

PROPOSITION 4 (II): *With the number of firms fixed, if a stricter standard raises the unit abatement cost more that it raises the price, then firms incur losses in the short-run, and both the output level of each firm and hence the industry output decline as a result of a stricter standard. Total pollution emission, however, also declines in the short-run.*

Further, for this case, we note from (18) that $\left.\frac{dx}{d\alpha}\right|_{n=n_0} - \frac{dx}{d\alpha} < 0$, which together with $\left.\frac{dx}{d\alpha}\right|_{-n=n_0} < 0$ implies two possibilities: (i) either $\left.\frac{dx}{d\alpha}\right|_{n=n_0} < 0 < \frac{dx}{d\alpha}$, (ii) or $\left.\frac{dx}{d\alpha}\right|_{n=n_0} < \frac{dx}{d\alpha} < 0$.

In the former case, as eventually some of the loss-incurring firms exit the industry, the market demand facing each one of the remaining firms increases, thereby encouraging them to expand their output levels until the price covers the overall unit cost and the zero-profit equilibrium prevails again. Under case (i), a more stringent standard leads to a new long-run equilibrium output by each firm that is larger than the original one. This is another interesting case where the interest of environmentalists who focus on the long-run effects of a sticter standard conflicts with that of industrialists who worry about the immediate effects. In this case, while a stricter standard causes the individual firm's scale and hence the industry output to decline in the short run, in the long run it leads to an industry characterized by fewer firms, each producing at a larger scale, and by a total output that may be larger than that before the standard is raised. Other things being equal, the industry's output is more likely to be larger the smaller is the elasticity of the marginal abatement cost, ξ, and the greater is the price elasticity of demand, ε. It can be verified from (6) that a smaller ξ, and hence a smaller A'', implies a larger $dx/d\alpha > 0$, and from (4) that a larger ε implies a smaller magnitude of $dn/d\alpha < 0$.

Under case (ii), although the exit of some of the firms and the resulting larger demand for each remaining firm encourages it to expand its scale to the zero-profit equilibrium level, this level is, however, less than that in the original equilibrium. Therefore, under this case, a more stringent standard reduces each firm's as well as the industry's output both in the short run and long run.

Obviously, except for the resulting reduction in net pollution, this case conforms to standard results. It indicates the situation where the demand effect is dominated by the cost effect of a stricter standard, thus giving credibility to industrialists' claims. Table 2.B summarizes the comparison of the effects of a stricter standard in the short run and long run when $P_\alpha - A' \longleftarrow 0$.

TABLE 2.B

$$P_\alpha - A' \longleftarrow 0$$

	Case (i)		**Case (ii)**	
	$\frac{dx}{d\alpha}\Big\vert_{n=n_0} < 0 < dx/d\alpha$		$\frac{dx}{d\alpha}\Big\vert_{n=n_0} < dx/d\alpha < 0$	
	SR	*LR*	*SR*	*LR*
x	$\downarrow$	$\uparrow$	$\downarrow$	$\downarrow$
X	$\downarrow$	$\Updownarrow$	$\downarrow$	$\downarrow$
Z	$\downarrow$	$\downarrow$ ($\forall$ or $\alpha > \hat{\alpha}$)	$\downarrow$	$\downarrow$

4 Social Welfare and Environmental Standard

Can stricter environmental standards at the same time enhance social welfare? To answer this question, it is noted from (8) that besides its effect on the sum of consumer's and producer's surpluses, a higher standard reduces the social cost of damages from unabated pollution, $D[(1-\alpha)x]$, on the one hand, and raises the regulator's monitoring and enforcement costs, $E(n)$, on the other.[16] To see how for the industry parameterization of section 3, a higher standard affects social welfare, two different sets of specifications are stipulated for the functional forms of the damage and enforcement costs: a linear set where $D[(1-\alpha)x] = \delta(1-\alpha)x$ and $E(n) = \gamma\, n$, and a quadratic set where $D[(1-\alpha)x] = \delta/2[(1-\alpha)x]^2$ and $E(n) = \gamma/2n^2$, with δ and γ as positive constants. Inserting these specifications in (8) and (10d), and simplifying yields:

(19a) $$W(\alpha) = 1/2bX^2 - \delta(1-\alpha)X - \gamma n$$

and

$$W(\alpha) = 1/2bX^2 - \delta/2[(1-\alpha)X]^2 - \gamma/2n^2 \tag{19b}$$

respectively for the linear and quadratic cases, where $X(\alpha) = x(\alpha)n(\alpha)$ and the latter are given by (13) and (14). Since $W(\alpha)$ is a complicated nonlinear function of α, its behavior is investigated numerically. For assumed common values of $\delta = 1,3,5$ and 10, the results for the linear case are depicted in Figures 2.A and 2.B respectively for the values of $\gamma = 20$ and 35, and for the quadratic case in Figure 3 for the value of $\gamma = 5$.[15]

First, for small values of the marginal enforcement cost (*e.g.*, $\gamma = 20$), as Figure 2.A shows, in the linear case, when the marginal cost of pollution damage is also rather small (*e.g.*, $\delta = 1$), welfare rises *montonically* as the standard is raised above the industry's minimum level, *i.e.*, for $\alpha > \underline{\alpha}$. The explanation is simple: with the assumed linear industry demand, total surplus is $1/2bX^2$ which increases with the standard since $dX/d\alpha > 0$ for all $\alpha > \underline{\alpha}$, in our example. This would leave the regulating agency with a relatively wide range of welfare enhancing standards.

But, when the marginal cost of damage is relatively large, for example when δ takes values of 5 or 10, or larger, even the standards in the range of $\underline{\alpha}^s \geqslant \alpha \geqslant \alpha$ will be *too low* from social welfare perspective. Only for the standards exceeding $\underline{\alpha}^s$ (*e.g.*, those above $\underline{\alpha}^s \cong 47\%$ when $\delta = 10$) will social welfare increase as standards are further tightened. The intuition for this case is that, as noted earlier, at too low standards, total pollution rises with the standard as relatively little of the emissions is abated, so too much pollution remains unabated. This, coupled with a large marginal cost of pollution damage, leads to too large damage and hence negative social welfare. On the other hand, at sufficiently high standards, total pollution will always fall with stricter standards (see Corollary 2 and Corollary 2′), thus reducing damages and increasing social welfare. In fact, since pollution damages vanish for $\alpha = 1$ regardless of the magnitude of δ, so long as γ is not unduly large to render welfare negative, welfare would always rise with the standard as the latter is raised above a certain critical level (*i.e.*, for all $\alpha > \underline{\alpha}^s$). Of course, this critical level will be higher the larger is δ. This is no surprise, as it is usually for the industries generating very harmful pollution that the socially desirable levels of standards far exceed those that are necessary for mere industry survival. What is, however, contrary to public opinion is the finding that for such industries setting standards that are too low may well reduce welfare while setting standards that are sufficiently high may well enhance it. This has an important implication for the political economy of standard setting. If for whatever reason, such as industry groups' political opposition,

15. These values are selected to illustrate the typical features of the welfare function in each case. From the figures the reader can readily deduce how the welfare function would behave for alternative values of γ and δ. The behavior of the welfare function presented in the linear case for the values of γ will qualitatively also apply to the quadratic case.

FIGURE 2.A
Social Welfare: Linear Case, γ **= 20**

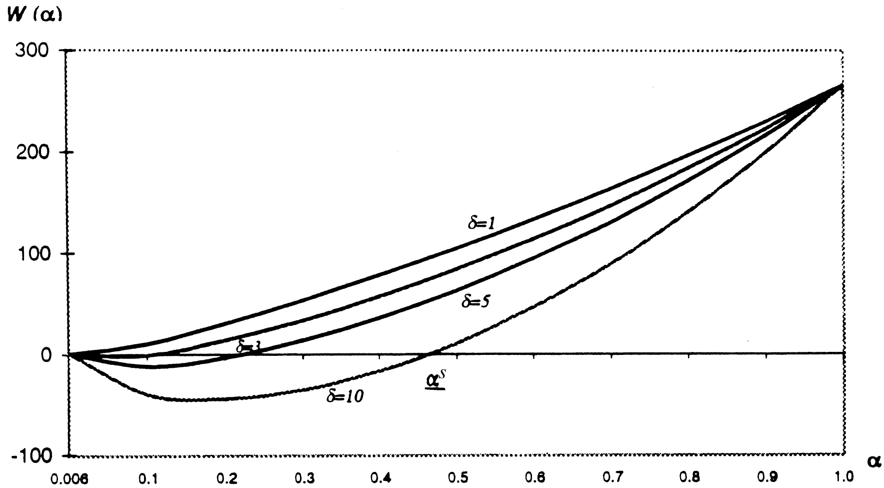
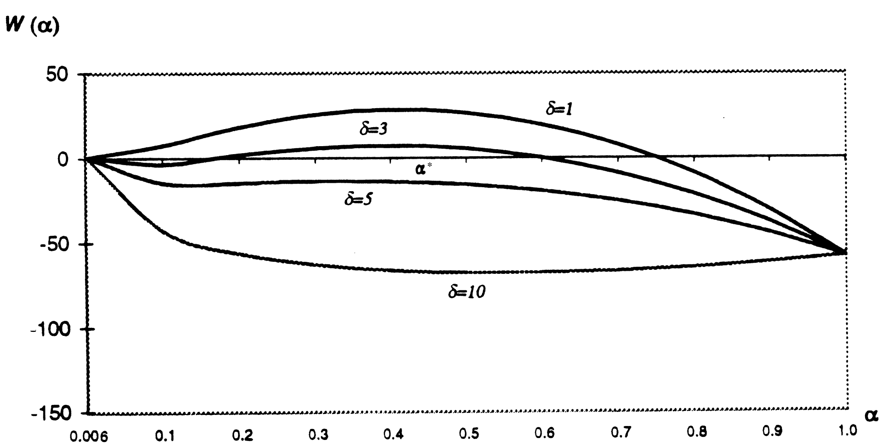


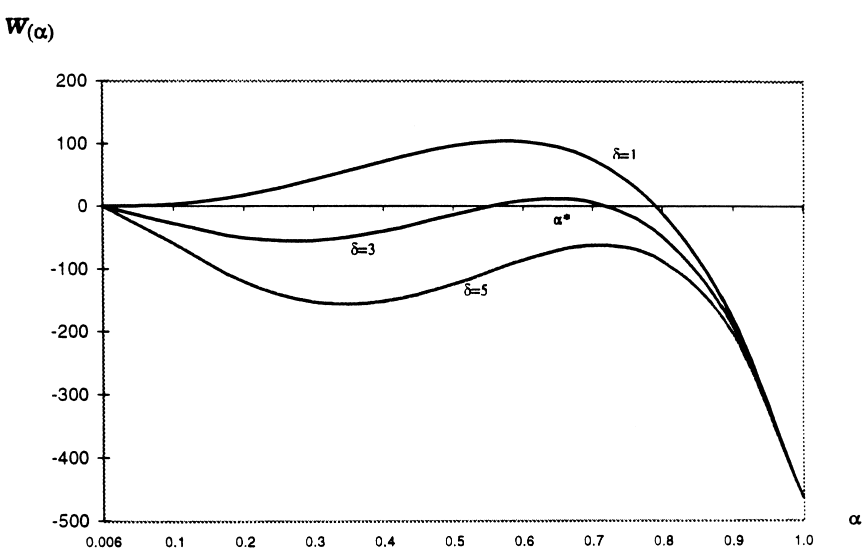
FIGURE 2.B
Social Welfare: Linear Case, γ **= 35**



the regulator is unable to set standards at sufficiently high levels to enhance social welfare, then since setting weak standards may be worse than no standards, she may prefer to negotiate an agreement with the industry whereby she would forego imposing standards provided that unregulated firms individually volunteer to undertake sufficient amount of abatement. Alternatively, since the source of the problem is too much entry if the standard is raised, there may be a role for entry licences to capture the gains from increasing firm and industry output while limiting monitoring costs.

Second, as Figure 2.B shows, in the linear case, when the marginal enforcement cost is rather large (*e.g.*, $\gamma = 35$), but not too large to result in negative welfare, welfare function behaves very differently from the previous case. For small marginal damages (*e.g.*, $\delta = 1$), there will be a unique optimal standard ($\alpha^* = 41\%$). Further, for a larger marginal damage, the optimal standard can be higher or, perhaps contrary to intuition, *lower* depending on whether the optimal standard already is greater or less than $\hat{\alpha}$, the standard for which unabated pollution is at maximum (see Appendix 3 for proof). The explanation becomes easy once we recall the behavior of total pollution as the standard is raised (see the path of $Z = (1 - \alpha)X$ in Figure 1 and recall Corollary 2′): thus, while in the former case ($\alpha^* > \hat{\alpha}$) total pollution and hence damage is reduced by raising the standard further, in the latter case (when initially $\alpha^* < \hat{\alpha}$) this is achieved by *lowering* it. In our numerical example, however, it is the latter case that prevails, so, as Figure 2.B shows, for $\delta = 3$, the optimal standard falls to $\alpha^* = 39\%$. For sufficiently large marginal damages, however, welfare becomes negative at all standards, implying that the optimal decision would be to disband the industry's operation.

FIGURE 3
Social Welfare: Quadratic Case, $\gamma = 5$



Third, turning to the quadratic case, it is seen from Figure 3 that for values of the marginal enforcement cost that are not too large to result in negative welfare at all standards (*e.g.*, $\gamma = 5$), if the marginal pollution damage is also sufficiently small (*e.g.*, $\delta = 1$), then there will be a unique optimal standard ($\alpha^* = 58\%$ for $\delta = 1$) so that beyond which raising the standard would cause welfare to decline as the industry becomes overly crowded. But, for moderate values of the marginal damage cost (*e.g.*, $\delta = 3$), both the standards that are set too low (below $\underline{\alpha}^s \cong 56\%$) and those that are set too high (above 72%) will result in negative social welfare: too weak standards leave too much pollution unabated and too strong standards lead to too crowded an industry to monitor. Finally, while the optimal standard will be higher the larger the marginal pollution damages, when the latter is too large (*e.g.*, $\delta = 5$), the optimal policy is to disallow the polluting industry altogether.

5 Concluding Remarks

This paper has focused on situations where reductions of pollution by all firms boost the industry demand, but, because firms are unable to coordinate actions to reduce emissions, *individually* free ride on each other's pollution abatement, and therefore fail to act in their own *collective* interest. It has shown that, contrary to industrialists' arguments, in such situations a stricter standard can lead to a *larger* number of firms in industry, a *greater* industry output, and *less* total pollution. We have examined the short-run (fixed number of firms) effects of a stricter standard on profitability, output, and pollution emissions both at the individual firm level and the industry level, and compared these effects with those obtained under free entry/exit condition. It turns out that the firms' effects emerging from this model are also different from the standard ones; for example, here a stricter standard may well increase both the firms' short-run profits *and* output levels. We have identified the conditions under which the short-run and long-run interests of the environmentalists and industrialists conflict, thus providing some insight as to why the stricter standards that appear to environmentalists to benefit the industry may nevertheless be contested.

As an implication of the coordination failure and free-riding problem inherent in the model, it is shown that in order for the industry to survive, a minimum pollution standard may be necessary. Perhaps interestingly, the analysis of the welfare effects of a higher standard indicates situations where weak standards are welfare reducing, while at the same time the welfare enhancing standards may be too high to be politically feasible, suggesting that the regulatory agency may prefer *no* standards to weak standards, provided, of course, that firms individually undertake some abatement.

To focus on the question at hand, the paper has considered only the demand-side externality. A stricter environmental standard may also have positive *cost-side* externalities: for instance, the pool of workers from which firms draw is healthier, and hence more productive, the cleaner is the environment firms provide them, but each firm is unable to fully appropriate the benefits of the health improvements of all workers. More generally, the results of the paper can be expected to extend to a general equilibrium treatment in which each agent might be both a producer and consumer of pollution, but each free-rides on pollution reductions by others. Another general-equilibrium aspect from which the paper has abstracted is the secondary effects of a stricter environmental standard adopted by one industry on other industries. Whether these effects are positive or negative depends, of course, on whether the output of the industry in question is a complement or a substitute for other industries' outputs. They are also likely to be more significant if the output of the industry in question is an essential intermediate input, such as energy, than a final consumer good. In any case, the direction and significance of these effects are open empirical questions.

The present model can be extended also by relaxing one or more of the assumptions of identical firms, homogenous goods, and consumer preferences. Whereas the theoretical literature on environmental regulation when firms act strategically has been large and growing, there has been little theoretical or empirical research on how heterogeneity of consumers with respect to preferences, income, or other attributes may affect environmental regulations.[16] It would be also interesting to investigate how the results of this paper may be affected by considering (a) other market structures than Cournot competition and (b) pollution taxes instead of standards and comparing their efficiencies as instruments of environmental regulation. This latter question, of course, requires that firms be allowed to choose their own abatement standards. Finally, of great value will be empirical research into the direction and extent by which the market demand for specific products may be affected by environmental quality improvements and into the conditions, noted in this paper, under which an industry may or may not contest stricter standards. ▼

16. An exception is the paper by Arora and Gangopadhyay [1995] which considers a duopoly model of firms where consumers value environmental quality and can identify the firms' degree of environmental cleaners, but they differ in their income levels. They show that differences in affordibility for clean products leads a cleaner firm to voluntarily over-comply with the environmental standard.

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APPENDIX 1

Let $U = U(X, Z, Y)$ denote generally the representative consumer's utility function, where X is the consumption of the industry's good, $Z = (1 - \alpha)X$ is the net pollution, and Y is a composite of all other goods which serves as numerairé. The utility function U is assumed to have the regular properties; in particular, it is assumed to satisfy the following plausible conditions (subscripts denote partial derivatives):

(A.1) $$U_1 > 0,\ U_{11} < 0,\ U_{12} = U_{21} < 0,$$

(A.2) $$U_2 < 0,\ U_{22} \leqslant 0$$

(A.3) $$U_3 > 0,\ U_{31} = U_{13} \geqslant 0,\ U_{32} = U_{23} = 0,\ U_{33} < 0$$

Condition $U_{12} = U_{21} < 0$ indicates that a reduction in the amount of pollution renders the consumption of good X more valuable, and *vice versa*. Condition $U_{22} \leqslant 0$ states that the disutility of pollution increases with the amount of pollution, or, stated differently, pollution becomes more unpleasant as its amount increases. Condition $U_{31} = U_{13} \geqslant 0$ implies that X and the composite good are either unrelated or weakly complements, while $U_{32} = U_{23} = 0$ implies that the pollution does not affect the marginal utility from consumption of the composite good (*i.e.* utility function is additively separable in Y and Z). Denoting by I, the representative consumer's income, her decision problem is

$$\operatorname*{Max}_X U(X, (1 - \alpha)X, Y) \text{ s.t. } PX + Y \leqslant I.$$

We consider both the case where the representative consumer takes into account (internalizes) the disutility of pollution from her choice of consuming X and when she does not internalize the pollution externality. In the former case, forming the Lagrangean, differentiating it with respect to X and Y, and eliminating the Lagrangean multiplier from the first-order necessary conditions, routinely yields

(A.4)

$$U_1(X, (1 - \alpha)X, Y) + (1 - \alpha)U_2(X, (1 - \alpha)X, Y) = U_3(X, (1 - \alpha)X, Y)P$$

This simply states that at the optimum, the marginal utility of consuming an extra unit of the good *net* of the marginal disutility of the associated pollution, $(1 - \alpha)U_2$, should equal its opportunity cost in terms of foregone utility from spending P dollars on Y. Recalling that for an interior optimum $Y = I - PX$ and substituting this in (A.4) one obtains the demand for X, with I fixed, as an implicit function of P, X and α.

Differentiating (A.4) w.r.t X and P and simplifying gives

$$\text{(A.5)} \quad \begin{aligned} \partial P/\partial X = {} & [U_{11} + 2(1-\alpha)U_{12} + (1-\alpha)^2 U_{22} - 2P(1-\alpha)U_{32} \\ & - 2PU_{31} + P^2 U_{33})]/\{U_3 + X[U_{13} + (1-\alpha)U_{23} - PU_{33}]\} \end{aligned}$$

which, upon using (A.1),(A.2), and (A.3), reduces to

(A.5')

$$\begin{aligned} \partial P/\partial X = {} & [U_{11} + 2(1-\alpha)U_{12} + (1-\alpha)^2 U_{22} - 2PU_{31} + P^2 U_{33}] \\ & /[U_3 + X(U_{13} - PU_{33})] < 0 \end{aligned}$$

Similarly, differentiating (A.4) w.r.t P and α yields

$$\text{(A.6)} \quad \begin{aligned} \partial P/\partial \alpha = {} & -\{U_2 + X[U_{12} + (1-\alpha)U_{22} - PXU_{32}]\} \\ & /\{U_3 + X[U_{13} + (1-\alpha)U_{23} - PU_{33}]\} \end{aligned}$$

which, upon using (A.1), (A.2), and (A.3), one has

(A.6')

$$\partial P/\partial \alpha = -\{U_2 + X[U_{12} + (1-\alpha)U_{22}]\}/[U_3 + X(U_{13} - PU_{33})] > 0$$

Note that when there is no income effect, *i.e.* the utility function is linear in Y, then U_3 will be a constant, which by normalization can be set to unity, $U_3 \equiv 1$, implying in turn $U_{31} = U_{13} = U_{32} = U_{23} = U_{33} = 0$. For this case, (A.4), (A.5') and (A.6') simplify to

$$\text{(A.4')} \quad U_1(X,(1-\alpha)X,Y) + (1-\alpha)U_2(X,(1-\alpha)X,Y) = P$$

$$\text{(A.5'')} \quad \partial P/\partial X = U_{11} + 2(1-\alpha)U_{12} + (1-\alpha)^2 U_{22} < 0$$

$$\text{(A.6'')} \quad \partial P/\partial \alpha = -\{U_2 + X[U_{12} + (1-\alpha)U_{22}]\} > 0$$

Next, we consider the case where the consumer does *not* internalize the pollution externality, so that $U_2 \equiv 0$. If, in addition, there is no income effect, then for this special case, (A.4'), (A.5''), and (A.6'') will further simplify to

$$\text{(A.4'')} \quad U_1(X,(1-\alpha)X,Y) = P$$

$$\text{(A.5''')} \quad \partial P/\partial X = U_{11} + 2(1-\alpha)U_{12} < 0$$

$$\text{(A.6''')} \quad \partial P/\partial \alpha = -XU_{12} > 0$$

APPENDIX 2

Sign of $dx/d\alpha$: Given that $\varepsilon_\alpha > 0$, $\varepsilon_p > 0$, and $P_\alpha - A'(\alpha x) > 0$, from Table 1.A, it appears at first that the sign of $dx/d\alpha$ is in general ambiguous. However, differentiating (13) with respect to α yields

$$dx/d\alpha = -\{[\alpha(k - a/b) + (c - a/b)] + (c - a/b)/2\}x\alpha^4 < 0,$$

by (15.a) and $c - a/b > 0$.

Sign of $dn/d\alpha$: The sign of $dn/d\alpha$ is determined by that of $P_\alpha - A'(\alpha x)$. From (10f) and (12), one has $P_\alpha - A'(\alpha x) = a/b - [3\alpha^2 x^2 - 2d\alpha x + k]$ $= a/b - [-2\alpha x(d - 2\alpha x) - \alpha^2 x^2 + k]$, which upon substituting for x^2 from (13) simplifies to $P_\alpha - A'(\alpha x) = 2\alpha x(d - 2\alpha x) + (c - a/b)/\alpha$. Recalling that $c > a/b$ and, from (14), that $d - 2\alpha x > 0$ for $n > 0$, we have $P_\alpha - A'(\alpha x) > 0$ and hence, by (4), $dn/d\alpha > 0$.

Sign of $dz/d\alpha$: differentiate $Z = (1 - \alpha)X$ with respect to α to obtain $dZ/d\alpha = -X + (1 - \alpha)dX/d\alpha$. It can readily be verified from (13) and (14) that for $\alpha = 1$, $x(1) = [(k - a/b) + (c - a/b)]^{1/2} > 0$ and $n(1) = b\{d - 2[(k - a/b) + (c - a/b)]^{1/2}\} > 0$, by (15a), so that $X(1) = n(1)x(1) > 0$ and therefore $Z(1) = 0$, and that for $\alpha = \underline{\alpha} = (c - a/b)/[d^2/4 - (k - a/b)]$, $n(\underline{\alpha}) = 0$, by substitution in (14) and $x(\underline{\alpha}) > 0$, by substitution in (13), so that $X(\underline{\alpha}) = 0$ and hence $Z(\underline{\alpha}) = 0$. Further, using these information, it can readily be checked that $\lim_{\alpha \to \underline{\alpha}} dZ/d\alpha = (1 - \underline{\alpha})(c - a/b)b/\underline{\alpha} > 0$ and $\lim_{\alpha \to 1} dZ/d\alpha = -X(1) < 0$, so that by the continuity of Z in α it follows that there must exist some $\hat{\alpha}, 1 > \hat{\alpha} > 0$, for which $dZ/d\alpha = 0$. This means that the curve of the total pollution function Z is a parabola with a maximum at $\alpha = \hat{\alpha}$ and zero values at $\alpha = \underline{\alpha}$ and $\alpha = 1$.

APPENDIX 3

Formally, we show that $\partial\alpha^*/\partial\delta \gtreqless 0$ as $\alpha^* \gtreqless \hat{\alpha}$, where $\hat{\alpha}$ is the standard at which the total unabated pollution $(1-\alpha)X$ is maximum. Note that at $\alpha = \hat{\alpha}$ one has $(1-\alpha)dX/d\alpha - X = 0$ and $\partial/\partial\alpha[(1-\alpha)dX/d\alpha - X] < 0$. Also, at the optimal standard, $\alpha = \alpha^*$, one has $W'(\alpha) = 0$, so that $X\ dX/d\alpha - \gamma\ dn/d\alpha = \delta\,[(1-\alpha)dX/d\alpha - X] \gtreqless 0$ as $\alpha^* \gtreqless \hat{\alpha}$, and $W''(\alpha) < 0$, so that $\partial/\partial\alpha\ [XdX/d\alpha - \gamma\ dn/d\alpha] - \delta\partial/\partial\alpha[(1-\alpha)dX/d\alpha - X] < 0$. Noting that α^* depends on δ, differentiating the foregoing necessary condition for welfare maximization and solving for $\partial\alpha^*/\partial\delta$ yields $\partial\delta^*/\partial\alpha = [(1-\alpha)dX/d\alpha - X] / \{\partial/\partial\alpha[XdX/d\alpha - \gamma dn/d\alpha] - \delta[(1-\alpha)dX/d\alpha - X]\}$. Since the denominator's sign is negative, by the sufficiency condition for welfare maximization, and $\partial/\partial\alpha[(1-\alpha)dX/d\alpha - X] < 0$ for all α, it then follows that . $\partial\alpha^*/\partial\delta \gtreqless 0$ as $\alpha^* \gtreqless \hat{\alpha}$.