

# **Do Lower Prices For Polluting Goods Make Environmental Externalities Worse?**

Timothy J. Brennan

Discussion Paper 99-40

May 1999



1616 P Street, NW  
Washington, DC 20036  
Telephone 202-328-5000  
Fax 202-939-3460  
Internet: <http://www.rff.org>

© 1999 Resources for the Future. All rights reserved.  
No portion of this paper may be reproduced without  
permission of the author.

Discussion papers are research materials circulated by their  
authors for purposes of information and discussion. They  
have not undergone formal peer review or the editorial  
treatment accorded RFF books and other publications.

# **Do Lower Prices For Polluting Goods Make Environmental Externalities Worse?**

Timothy J. Brennan

## **Abstract**

Lower prices for polluting goods will increase their sales and the pollution that results from their production or use. Conventional intuition suggests that this relationship implies a greater need for environmental policy when prices of "dirty" goods fall. But the economic inefficiency resulting overproduction of polluting goods may fall, not rise, as the cost of producing those goods falls. While lower costs exacerbate overproduction, they also reduce the difference between private benefit and the total social cost--the sum of private and external costs--associated with that overproduction. We derive a test, based on readily observed or estimated parameters for conditions in which the latter effect outweighs the former. In such cases, making a dirty good cheaper to produce may reduce the need for pollution policy. This test, with minor modifications, can be applied where the dirty good is not competitive, demand rather than supply drives the increase in output, and abatement in production can reduce pollution. The analysis may speak to whether stricter air pollution regulations should accompany policies to reduce electricity costs by making power generation more competitive.

Key Words: environment, regulatory policy, externalities, electricity restructuring

JEL Classification Numbers: Q28, L51, L94

## **Table of Contents**

Diagramming the Trade-Off .....	4
More Formal Representations .....	7
Cases When Reducing the Costs of "Dirty" Goods Reduces the Need for Environmental Policy .....	11
Similar Effects from Changes in Demand .....	12
Incorporating Abatement in Production .....	15
Conclusion .....	17
Appendix .....	18
References .....	20

## **List of Figures**

Figure 1	Welfare losses from externalities in a competitive market .....	5
Figure 2	The change in welfare loss from a decrease in $z$ .....	6
Figure 3	Welfare gain from a reduction in private costs, when demand is inelastic at the market price .....	11
Figure 4	Welfare gain from a reduction in private costs, when supply is inelastic at the market price .....	12
Figure 5	Welfare loss effects from a shift in the demand curve .....	14
Figure 6	Welfare losses from externalities in a competitive market with too little abatement .....	16

## **DO LOWER PRICES FOR POLLUTING GOODS MAKE ENVIRONMENTAL EXTERNALITIES WORSE?**

Timothy J. Brennan\*

Environmental externalities, or any other negative externality, reflect a failure of prices of the associated good to embody costs imposed on third parties. When private negotiations are precluded by transaction costs of one sort or another (Coase, 1960, the standard remedy for externality problems is to create a cost for the externality that producers or consumers have to bear. Two standard theoretical approaches are either to impose a tax on the externality such as pollution fines (Baumol and Oates, 1988), or to let potential polluters bid for rights to pollute (Teitenberg, 1980; Portney, 1990 at 74; Peirce and Turner, 1990 at 110-19).<sup>1</sup> These approaches are equivalent when the size of the externality and abatement costs are known (Weitzman, 1974) and enforcement costs are negligible (Downing and Watson, 1974). A second-best substitute for these policies--first-best if abatement costs are prohibitive and pollution-related damages are proportional to output--is a tax on the good itself (Spulber, 1989 at 366).

An output tax, emissions tax, or requirement to buy a marketable permit all would address the concern that, in the absence of a market reflecting pollution costs, there will be too much of the "dirty" good produced. These familiar concerns with overproduction may engender a belief that the bigger the polluting industry, the bigger the pollution problem. In particular, if the cost of producing a "dirty" good falls, so will its market price, increasing the quantity produced and sold. This increases the level of associated pollution, hence increases the need for policy to do something about it. Such a belief may affect debates over policy. For example, if current efforts to deregulate electricity lead to lower generation costs and power prices, a belief that output and the need for environmental policy are correlated will add weight to a position that deregulation must be accompanied with commitments to stronger environmental protection.<sup>2</sup>

---

\* Senior Fellow, Quality of the Environment Division, Resources for the Future, and Professor, Policy Sciences and Economics, University of Maryland Baltimore County. Thanks go to Karen Palmer and Molly Macauley for helpful comments. The author bears sole responsibility for errors.

<sup>1</sup> Giving away permits, as with EPA's recent sulfur dioxide emissions trading programs, may be an inferior solution. Using the revenues raised by pollution fees or permit auctions to cut existing taxes may be necessary for these policies to increase net welfare when distortions from those taxes would warrant subsidizing complements, including pollution-causing goods. See Goulder, Parry, and Burtraw (1997).

<sup>2</sup> Deregulation may make environmental regulations more effective. For example, a regulated, franchised utility may treat a pollution tax as something merely to be passed on to ratepayers, while a deregulated power provider would have an incentive to cut pollution in order to reduce tax payments. For an extensive discussion of the ways regulation could limit the effectiveness of incentive-based environmental policies, see Bohi and Burtraw (1992).

But the premise of a correlation that output and the need for environmental policy need not be sound. Reducing the private, nonexternal cost of supplying a commodity, or increasing demand for it, will typically increase output and the *size* of the environmental damage created by its production. However, the *inefficiency* attributable to overproduction--the basis for an efficiency argument in support of intervention--need not increase. To oversimplify only a bit, the economic loss from uninternalized pollution is essentially the difference between the total social cost of supplying the good--private production cost plus environmental damage--and the value consumers place on getting the good produced, but evaluated over only the amount of the overproduction that occurs because the market does not reflect this damage. By increasing output, a fall in production costs or an increase in demand generally will reduce efficiency, because more overproduction makes environmental matters worse.<sup>3</sup> But reductions in cost or increases in demand also reduce the difference between social cost and consumer value, reducing the size of the inefficiency.

In other words, this "difference reduction" effect creates a counterintuitive possibility that dirty good output and environmental policy are substitutes rather than complements. A numerical example of the effect may be useful. Suppose that electricity is the dirty good in question, and that the value of a particular kilowatt-hour (kWh) to its user is 10¢, and that the private production cost of the kWh is 8¢. Absent environmental externalities, this generates 2¢ in consumer surplus. Suppose, however, that this kWh generates 5¢ in environmental cost. Social costs are now 13¢, and the economic loss from its production is 3¢.

Suppose that opening the electricity market to competition reduces the private production costs of this kWh from 8¢ to 6¢. The social cost of producing this kWh falls from 13¢ to 11¢. It still is part of the overproduction of electricity, since consumer benefits are less than production cost, but the size of the loss falls from 3¢ to 1¢ (11¢ - 10¢). It is this 2¢ reduction in the size of the loss associated with overproduction of dirty goods that leads to the possibility that falling prices could reduce the net economic loss associated with pollution, despite the increased output that exacerbates that inefficiency.

If this "difference reduction" effect outweighs the "output overproduction" effect, the need for policy to address the environmental problem may also fall, perhaps dramatically. As an extreme but not unrealistic example, assume that the costs of addressing an environmental policy problem include fixed administrative and legal costs associated with devising and imposing remedies. If price reductions or increases in demand for a dirty good reduce the inefficiency from environmental damages associated with its production, these fixed costs may no longer be worth incurring. Policy changes such as restructuring the electricity industry could take some environmental concerns off the policy agenda that were present and justifiable before.

---

<sup>3</sup> The "reswitching" controversies of the 1950s serve as a reminder that growth in output theoretically could create a scale effect justifying an industry switch to a new technology that happens to pollute less. For purposes of the analysis here, we assume the "normal" case in which the level of environmental damage associated with the good in question is a monotone increasing function of the level of output of that good.

Of course, the reverse effect on efficiency may hold. If the "output overproduction" effect outweighs the "difference reduction" effect, cost reductions could warrant environmental policies to address concerns that were, and should have been, previously neglected. However, that intuitive result is only a possibility, not a certainty.

It is important to note two different aspects of the environmental policy problem associated with cost reductions or demand growth *not* at issue here. First, we are not questioning whether cost reductions as a whole are a good thing in polluting industries. Such a comparison would involve comparing the increase in the marginal external cost from the increased output to the *total* cost reduction, rather than only to the reduction in the cost of supplying the excess output. This tradeoff, too, may be ambiguous, but in that case both aspects of the ambiguity seem fairly obvious.<sup>4</sup>

Second, we recognize an increase in the output of a polluting good normally increases total environmental damages. This increase in damages may warrant public support for research and development programs into abatement technologies, to change the relevant private and social costs of electricity production. In this respect environmental costs are not entirely unique. Taking electricity as an example, suppose that the costs of generation were to fall because new power plants were able to get more power from the same amount of fuel, but that the amount of labor per kilowatt-hour produced remained fixed. As a result of the cost reduction, there might be a stronger case for publicly funded research and development into labor-saving electricity generation technologies.<sup>5</sup> Aside from the overproduction inefficiency, the argument that increased output warrants an increase in damage-reduction research would be similar. But these arguments apply to any cost of production, not only to those that might be externally rather than internally borne.<sup>6</sup> Hence, R&D arguments do not warrant policies to deal with environmental *externalities*, and it is the case for externality control policy that is the subject under discussion here.

We begin that discussion with a diagrammatic exposition of the different effects arising from cost reductions to illustrate the tradeoffs affecting the need for environmental output control policies. This illustration reflects an assumption that pollution can be abated only by reducing output rather than by switching technologies; this assumption is lifted later. We can use this analysis to derive a relationship between supply and demand elasticities, external costs, and overproduction that indicates when cost reductions increase the size of the externality-related inefficiency. This relationship has some ready interpretations when output

---

<sup>4</sup> In the interest of completeness, an appendix analyzes the net welfare effects of a change in costs, using notation developed in the text below. See Freeman and Harrington (1990) for similar measurement of the gross effects of changes in production technology.

<sup>5</sup> I ignore labor market failures, political forces, or social considerations that might make using more labor a benefit of the economic process rather than a cost.

<sup>6</sup> Clearly, if generation companies do not bear environmentally related costs, they generally will not have the incentive to undertake research and development to mitigate them. They may have an incentive to undertake such research directly or give grants to universities or research laboratories to do it if doing so generates "goodwill" that they can capitalize on in the marketplace.

markets are competitive, and it generally applies unless the dirty good market is insufficiently competitive to ensure that the output level is greater than it would be if it were competitive and producers took external costs into account in their supply decisions. We derive and apply a general test for when cost reductions increase or decrease the need for policy to analyze noncompetitive markets. Specifically, we analyze settings where the equilibrium price is a constant markup over cost (as in Cournot models with constant demand elasticity) and for Cournot oligopolies with linear demand and constant marginal cost.

With those derivations in hand, we display examples of cost reductions that reduce the net welfare loss from uninternalized externalities. The factor leading to beneficial outcomes in these examples that supply or demand is inelastic (perfectly, in the examples) at the market equilibrium (assuming no internalizing of these externalities). Inelastic demand or supply is not a necessary condition; we invoke it only to make obvious the possibility that cost reductions and environmental policy are substitutes. It is not difficult to show that qualitatively similar results for cost reductions follow when demand for the output increases. The analysis concludes with a lifting of the restriction that abatement of pollution within the production process is not possible. This turns out to be a qualitatively unimportant restriction, in that we can readily incorporate net abatement benefits into the criteria for correlating the case for policy intervention with reductions in costs overall.

The models illustrated here should provide a counterweight to the intuition connecting lower prices of dirty goods to a greater need for environmental policy. Our analysis indicates how formal or informal empirical estimates of costs and elasticities would indicate whether externality-related inefficiencies increase or decrease following a change in policy regarding dirty goods markets, such as restructuring of the electricity industry. Policy makers could use it to improve the judgments they have to make as to whether changing economic conditions warrant more or less attention to environmental externalities.

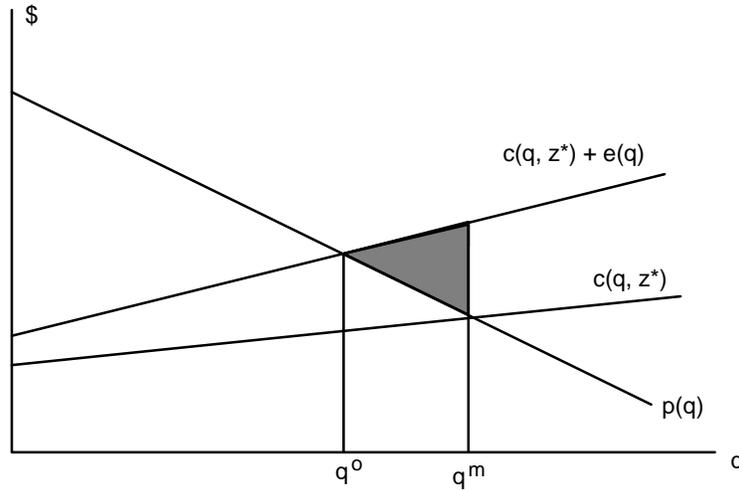
## DIAGRAMMING THE TRADE-OFF

Modeling the effect of cost reductions on the need for environmental policy is easiest when the output market is competitive. Once that is done, it is not hard to generalize to situations when the output market is less than fully competitive.

Using a conventional partial equilibrium setting, let  $q$  be output and  $p(q)$  be the demand curve;  $p' < 0$ . Private marginal costs of production are  $c(q, z)$ , where  $z$  is a parameter of interest, e.g., the price of one of the production inputs. Let  $z^*$  be the initial value of  $z$ . We assume that  $c_q \geq 0$  and  $c_z > 0$ , where subscripts indicate partial derivatives. Marginal external costs associated with the production of  $q$  are measured by  $e(q)$ , assumed positive for all  $q$ . The normal assumption is that  $e' \geq 0$ , but that assumption is not crucial to the analysis. Finally, let  $q^m$  be the quantity of output sold in the market and  $q^o$  be the optimal quantity of  $q$ .

Figure 1 displays the familiar graph of the welfare costs of an externality. The competitive market output,  $q^m$ , is the level where willingness to pay,  $p(q)$  just equals private marginal cost,  $c(q, z^*)$ . The social optimum  $q^o$  is where willingness to pay just equals marginal social cost, which is the sum of those private costs and marginal external costs  $e(q)$ .

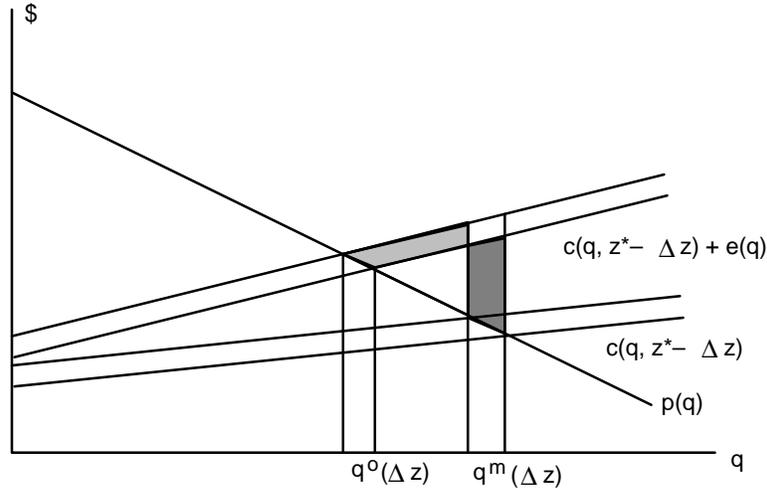
For all levels of production between  $q^o$  and  $q^m$ , the willingness of consumers to pay for the good is less than the social marginal cost of producing the good. The shaded area indicates the social welfare losses from the externality, equal to the difference between social marginal cost and willingness to pay.



**Figure 1: Welfare losses from externalities in a competitive market**

Now, consider a reduction  $\Delta z$  of  $z$ . This will shift both private and social marginal costs downward by  $c_z \Delta z$ , affecting  $q^o$ ,  $q^m$ , and the size of the welfare loss. Let  $q^o(\Delta z)$  and  $q^m(\Delta z)$  be the new optimal and market output, and define  $q^o(0)$  and  $q^m(0)$  as the original optimal and market outputs. To see the effects of reducing  $z$  by  $\Delta z$ , we superimpose the new private and social cost curves on Figure 1 to generate Figure 2. The darker area reflects the expected increase in the externality-induced welfare loss, arising because the fall in costs results in a fall in prices and an increase in output. Defining  $\Delta q^m = q^m(\Delta z) - q^m(0)$ , the approximate size of this added welfare loss is  $e(q^m) \Delta q^m$ --the marginal external loss times the increase in output.

However, there is a countervailing benefit, indicated by the lighter area. This change reflects the fact that as costs fall, the difference between marginal social cost and willingness to pay--that is, the marginal inefficiency from overproduction--falls. If we let  $\Delta c$  be the absolute value of the average fall in cost over the range of inefficient overproduction between  $q^o(0)$  and  $q^m(0)$ , the fall in  $z$  contributes to a reduction in the externality-related welfare loss, approximately equal to  $\Delta c [q^m - q^o]$ .



**Figure 2: The change in welfare loss from a decrease in z**

The net effect on welfare loss from the reduction in costs, notated by  $\Delta WL$ , is therefore

$$\Delta WL \approx e(q^m)\Delta q^m - \Delta c[q^m - q^o].$$

Accordingly, the welfare loss, and thus the need for environmental policy, increases with a fall in costs if and only if

$$\frac{\Delta q^m}{q^m q^o} > \frac{\Delta c}{e(q^m)}. \tag{1}$$

We derive more explicit conditions below. However, equation (1) suffices to indicate that if demand or supply is sufficiently inelastic to keep market output from changing much if costs fall, i.e., if  $\Delta q^m$  is sufficiently small, the welfare loss from inefficient overproduction of the dirty good will fall as its production costs fall. In that case, the need for environmental policy would fall, not rise, with a reduction in the cost of producing the polluting good.

It is not difficult to generalize this to the noncompetitive case. Equation 1 continues to describe the condition for when cost reductions increase welfare loss, although in practice the relationship between  $\Delta q^m$  and cost reductions will be more complex in the absence of competition. In the absence of competition, two cases can arise, depending on whether  $q^m$ , the market output, is greater than or less than  $q^o$ , the social optimum. In the absence of competition, the latter becomes a possibility.

- If  $q^m > q^o$ , as under competition, there remains a welfare loss due to overproduction, although the welfare loss is smaller than it would have been had there been competition setting market price equal to private marginal cost. The only qualitative difference between this case and the case displayed in Figure 2 is that  $q^m$  is not simply determined by the intersection of the private marginal cost and demand curves. However, it is still a function of the overall demand curve  $p(q)$  and the cost parameter  $z$ . Since reductions in cost lead to reductions in price even in the absence of competition,  $\Delta q^m$  will still rise as costs fall.

- If  $q^m < q^o$ , the loss from underproduction due to the lack of competition<sup>7</sup> overwhelms the overproduction because producers and consumers do not bear the external cost. If so, policies to internalize the externality will reduce  $q^m$ , exacerbating the welfare loss associated with market power.<sup>8</sup>

**MORE FORMAL REPRESENTATIONS**

A more formal derivation of the conditions under which falling costs increases the inefficiency associated with externalities allows more specificity in ascertaining when environmental policy is more or less warranted by cost reductions. It is helpful to represent the effects of the cost parameter  $z$  on market and optimal output as  $q^m(z)$  and  $q^o(z)$  respectively. Externality-related welfare losses  $WL(z)$ , where  $q^m(z) > q^o(z)$ , are given by

$$WL(z) = \int_{q^o(z)}^{q^m(z)} [c(x, z) + e(x) - p(x)]dx .$$

The effect of a change in  $z$  is

---

<sup>7</sup> Regulation that sets price above marginal cost may also lead observed prices in the market to be less than the optimum, even taking environmental externalities into account.

More generally, a reason that costs may fall could be because of a move from inefficient cost-of-service regulation to a setting in which firms have an incentive to cut costs. If such cost savings are present, such a policy change can have significant welfare benefits, even if the underlying monopoly problem persists (Brennan, 1996). Estimating the net effects of a change from regulation to competition, where increased output under the latter could increase pollution, should include those benefits as well as any net effects on welfare as outlined by Equation (1).

<sup>8</sup> One can use diagrams similar to Figure 2 to examine whether a fall in costs, in the presence of an externality, exacerbates or mitigates the welfare loss associated with market power. As in the case described in the text, there are two effects, but with reversed implications. The  $\Delta q^m$  from the fall in costs now leads to a benefit, as we are producing  $p(q^m)$  in marginal benefits that, because  $q^m < q^o$ , must be greater than  $c(q^m, z) + e(q^m)$ . However, the reduction in cost  $\Delta c[q^o - q^m]$  also has a reversed effect, increasing the welfare loss by increasing the difference between willingness to pay and marginal social cost, including the external costs. Equation (1) thus becomes the condition for when a change in costs *reduces* the need for antimonopoly policy, rather than indicating when there is an increase in the need for environmental policy.

$$WL'(z) = \int_{q^o(z)}^{q^m(z)} c_z(x, z) dx + q^{m'}[c(q^m, z) + e(q^m) - p(q^m)] - q^{o'}[c(q^o, z) + e(q^o) - p(q^o)]. \quad (2)$$

Let the function  $h(q)$ , treating  $z$  as a parameter, be the marginal harm generated by additional output, i.e., the marginal difference between social cost and willingness to pay at the market output:

$$h(q) = c(q, z) + e(q) - p(q).$$

By inspection,  $h' > 0$ . By definition of  $q^o$  as the social optimum,  $h(q^o) = 0$ . Suppressing some notation, this allows us to eliminate the third term in equation (2) and rewrite it as

$$WL'(z) = \int_{q^o}^{q^m} c_z(x, z) dx + q^{m'} h(q^m). \quad (3)$$

The first term is the reduction in cost over the range of overproduction, positive since  $c_z > 0$ . The second term is the product of the change in market output resulting from a change in the cost parameter ( $q^{m'}$ , typically negative) times  $h(q^m)$ , positive since  $q^m > q^o$ . Welfare losses fall with a reduction in  $z$  if and only if the cost savings represented by the first term exceed the increase in the externality costs represented by the second term.

The key results follow from analyzing  $q^{m'}$ . The derivative of  $q^m$  with respect to  $z$  can be represented as a succession of partial derivatives:

$$q^{m'} = \frac{dq^m}{dz} = \frac{\partial q^m}{\partial p} \frac{dp}{dc} \frac{\partial c}{\partial z},$$

where all of the derivatives are evaluated at  $q^m$ . Consequently, we can rewrite  $q^{m'}$  as

$$q^{m'} = -\varepsilon_d \varepsilon_{p/c} \frac{q^m}{c(q^m, z)} c_z(q^m, z),$$

where

$$\varepsilon_d = -\frac{\partial q^m}{\partial p} \frac{p}{q^m}$$

is the absolute value of the elasticity of demand for  $q$  at  $q^m$ , and

$$\epsilon_{p/c} = \frac{dp}{dc} \frac{c}{p}$$

is the observed elasticity of market price with regard to changes in cost.<sup>9</sup>

If  $c_z(q, z) = c_z(q^m, z)$  for all  $q$  between  $q^o$  and  $q^m$ , i.e., the reduction in marginal cost is constant over the range of overproduction, the integral in equation (3) becomes  $c_z[q^m - q^o]$ . Consequently, increases in private cost increase externality-related inefficiency, and decreases in cost reduce it, if and only if

$$\frac{q^m - q^o}{q^m} > \epsilon_d \epsilon_{p/c} \frac{h(q^m)}{c(q^m, z)}. \quad (4)$$

This equation can be simplified further if marginal cost is constant and price is a constant multiple  $k$  of it, i.e.,  $p = kc(z)$ . When this holds,  $\epsilon_{p/c} = 1$ , eliminating a term from equation (4), making the condition the simpler

$$\frac{q^m - q^o}{q^m} > \epsilon_d \frac{h(q^m)}{c(q^m, z)}. \quad (5)$$

This gives us our basic policy rule: For an increase (decrease) in costs to increase (decrease) externality-induced inefficiency, the percentage of output that is overproduced has to exceed the ratio of the marginal external cost to the marginal private cost, times the elasticity of demand, measured at the market output. This relationship holds in two simple cases:

- the standard case of competitive, constant cost markets, when price equals marginal cost.
- in constant cost monopolies or symmetric Cournot oligopolies, with constant demand elasticity, where price is given by

$$p = \frac{n\epsilon_d}{n\epsilon_d - 1} c,$$

when  $n$  is the number of firms in the oligopoly and  $\epsilon_d > 1/n$ .

Two somewhat more complex cases are also of interest:

- In the linear demand ( $p(q) = a - bq$ ) symmetric Cournot case with constant marginal cost, and where all firms costs depend identically on  $z$ , it is not difficult to show that

---

<sup>9</sup> This is not just the elasticity of a competitive supply curve, but will depend on that as well as on the degree of competition and the elasticity of demand.

$$\epsilon_d \epsilon_{p/c} = \frac{c(z)}{a - c(z)},$$

where  $c(z)$  is defined as  $c(q, z)$  when marginal cost  $c$  is constant for all  $q$ . This substitution allows us to rewrite condition (4) as

$$\frac{q^m - q^o}{q^m} > \frac{h(q^m)}{a - c(z)}.$$

This condition is noteworthy because, except for its effect on  $h(q^m)$ , the slope of the demand curve  $b$  does not matter. The slope affects both  $q^m$  and  $q^o$  in the same proportions, leaving the left-hand side independent of  $b$ . The direction of a change in the value of policy depends only on the difference between maximum reservation price and marginal cost.

- The general competitive case when marginal cost is not constant over all levels of output. It is easier to begin directly by computing  $q^{m'}$ . To do this, implicitly differentiate the market equilibrium condition

$$p(q^m) = c(q^m, z)$$

to find that

$$q^{m'} = \frac{-c_z}{c_q - p'}.$$

Redefining the absolute value of demand elasticity  $\epsilon_d$  as  $-p/p'q$ , and using the equality of price with marginal cost at  $q^m$  to define supply elasticity  $\epsilon_s$  as

$$\epsilon_s = \frac{p}{c_q q}$$

allows us to find that

$$q^{m'} = -c_z \frac{q^m}{c(q^m, z)} \frac{\epsilon_d \epsilon_s}{\epsilon_d + \epsilon_s}.$$

Because  $c(q^m, z) = p(q^m)$  under competition,  $h(q^m) = e(q^m)$ . If, as before,  $c_z(q, z) = c_z(q^m, z)$  for all  $q$  between  $q^o$  and  $q^m$ , then  $WL'$  is positive if and only if

$$\frac{q^m - q^o}{q^m} > \frac{\epsilon_d \epsilon_s}{\epsilon_d + \epsilon_s} \frac{e(q^m)}{c(q^m, z)} \tag{6}$$

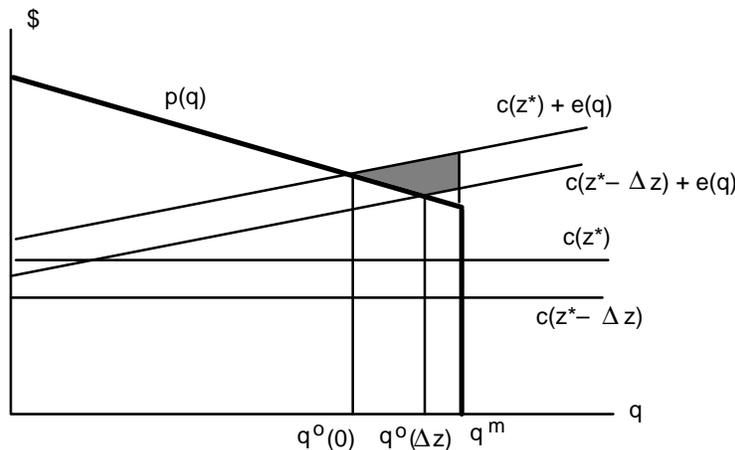
This implies equation (4) as a special case, since under perfect competition

$$\epsilon_{p/c} = \frac{\epsilon_s}{\epsilon_d + \epsilon_s}.$$

In addition, if supply elasticity  $\epsilon_s$  is infinite--the constant cost case--equation (6) reduces to equation (5). Note also that the last fraction on the left in equation (6) is the ratio of marginal external cost to market price.

**CASES WHEN REDUCING THE COSTS OF "DIRTY" GOODS REDUCES THE NEED FOR ENVIRONMENTAL POLICY**

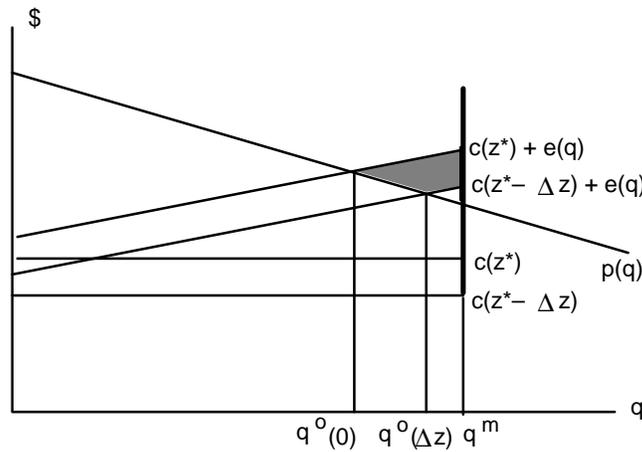
Equation (3), the condition for when reducing production costs reduces the size of the externality, tells us that environmental regulation will be less necessary if the effect on market output of a reduction in costs,  $q^m$ , is sufficiently small. Following equation (6), we can make use of this to construct a couple of simple situations in competitive markets, based on inelastic demand or supply, to exemplify the possibility that regulation becomes less necessary with lower costs. Using the notation from the earlier diagrams, Figure 3 illustrates an inelastic demand case.



**Figure 3: Welfare gain from a reduction in private costs, when demand is inelastic at the market price.**

Demand is displayed using a heavier line, to indicate more clearly that it is inelastic at the market output  $q^m$ . The shaded area indicates the welfare gain caused by the reduction in private costs from  $c(z^*)$  to  $c(z^*-\Delta z)$ . But because demand is inelastic, market output does not change, i.e.,  $q^m(0) = q^m(\Delta z)$  (following the above notation). The reduction in price does not lead to more output to exacerbate the externality. The reduction in costs reduces the size of the inefficiency from overproduction, reducing the need for policy intervention.

A similar story can be told for when supply is inelastic at the market output, as in Figure 4.



**Figure 4: Welfare gain from a reduction in private costs, when supply is inelastic at the market price.**

The heavier line indicates that marginal private cost, hence marginal social costs, becomes infinite past the market output. A reduction in costs brought about by a fall in  $z$  has no effect on  $q^m$ . That reduction brings about the same reduction in the welfare loss attributable to the externality as in Figure 3, with no output increase that might counteract it. Inelastic supply leads to the same conclusion as inelastic demand--reducing private costs reduces rather than exacerbates the need for environmental policy.

**SIMILAR EFFECTS FROM CHANGES IN DEMAND**

Identical results follow if the exogenous change is an increase in demand rather than a reduction in costs. Showing this requires only a slight modification of the above model. Eliminate the  $z$  parameter, leaving marginal cost  $c(q)$  depending only upon output. Let  $y$  be a parameter affecting demand, which is now  $p(q, y)$ , where  $p_q \leq 0$  and  $p_y \geq 0$ . The optimal and market output will now depend on  $y$  instead of  $z$ , as all else is held equal. Consequently, the welfare loss function becomes

$$WL(y) = \int_{q^o(y)}^{q^m(y)} [c(x) + e(x) - p(x, y)]dx .$$

The effect of a change in  $y$  on welfare is

$$WL'(y) = \int_{q^o(y)}^{q^m(y)} -p_y(x, y)dx + q^m[c(q^m) + e(q^m) - p(q^m, y)] - q^o[c(q^o) + e(q^o) - p(q^o, y)].$$

As before, representing the marginal net harm by the function  $h$ , modified in this context to be

$$h(q) = c(q) + e(q) - p(q, y);$$

and because  $h(q^o) = 0$ , we obtain

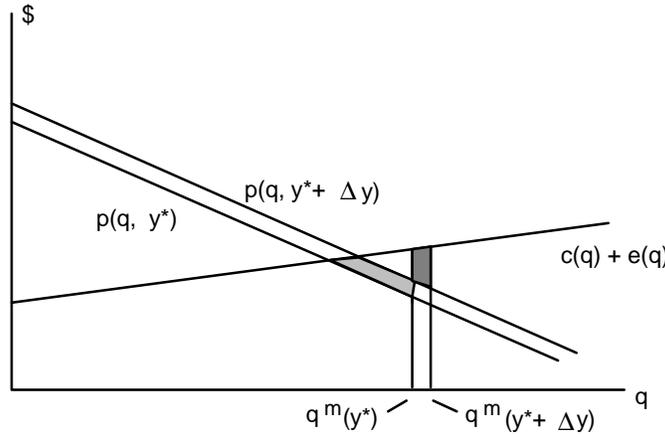
$$WL'(y) = \int_{q^o}^{q^m} -p_y(x, y)dx + q^m h(q^m). \tag{3*}$$

where  $q^m$  is now the derivative with respect to the demand parameter  $y$  rather than the cost parameter  $z$ . The asterisk indicates similarity to the equations in the derivation of the effect of changes in private cost on welfare losses.

Unlike the cost case, the integral is negative. Increasing  $y$  acts to reduce the welfare loss, because increasing demand for the "dirty" good decreases the difference between total social cost and willingness to pay. This is the "difference effect" discussed above for changes in costs. In competitive markets, in monopoly markets where the demand effect  $p_y$  is constant over  $q$ , and in other circumstances we would regard as "normal," increasing  $y$  by  $\Delta y$  will typically increase  $q^m$ .<sup>10</sup> Figure 5 illustrates these effects. The lightly shaded area indicates the reduction in welfare loss from the increase in willingness to pay for the dirty good, and the darkly shaded area indicates the increase in externality-related inefficiency loss from the increase in output.

---

<sup>10</sup> If the sellers of the dirty good have market power, it is possible that shifting out the demand curve could result in a reduction in market output, depending on the magnitude of the shift inframarginally relative to the shift at the margin. For example, if the seller is a monopolist,  $q^m$  can fall with an increase in  $y$  if  $p_{qy}$  is sufficiently negative, i.e., that increasing  $y$  has less effect the farther out the demand curve one goes.



**Figure 5: Welfare loss effects from a shift in the demand curve**

Effects of increases in demand will be similar to those from decreases in cost. The analysis of  $q^{m'}$  is more difficult to generalize than in the cost case. Since  $y$  affects  $p$  directly, we cannot decompose  $q^{m'}$  to derive general elasticity-based relationships as in the cost case. However, if the dirty good market is competitive, it is not hard to derive similar relationships, in the case where  $p_y$  is constant between  $q^o$  and  $q^m$ . When demand rather than supply is parameterized, the competitive market equilibrium condition is

$$p(q^m, y) = c(q^m).$$

As before, implicit differentiation yields

$$q^{m'} = \frac{p_y}{c' - p_q}.$$

If  $p_y$  is constant between  $q^o$  and  $q^m$ , the integral in equation (3\*) becomes  $-p_y[q^m - q^o]$ . Substituting the above expression for  $q^{m'}$  into equation (3\*) and dividing both terms by  $p_y$  shows that the welfare loss falls as demand increases if and only if

$$q^m - q^o > \frac{h(q^m)}{c' - p_q}.$$

As in the cost case, transforming the denominator on the left hand side into elasticity terms, and recognizing that under competition  $h(q^m) = e(q^m)$ , allows us to rewrite this condition for increasing demand to reduce welfare loss as

$$\frac{q^m - q^o}{q^m} > \frac{e(q^m)}{p(q^m, y)} \frac{\epsilon_d \epsilon_s}{\epsilon_d + \epsilon_s} . \quad (6^*)$$

Because  $p(q^m, y)$  equals market price in the demand case, and because  $c(q^m, z)$  equals market price in the cost case, this expression is identical to equation (6), the condition for when a uniform decrease in costs (rather than demand) reduces the welfare loss associated with externalities.

## INCORPORATING ABATEMENT IN PRODUCTION

The models so far have treated pollution as an ineradicable byproduct of production. But the absence of environmental policy can create a second inefficiency. In addition to excess output of the dirty good, the social costs of producing that good will be too high if producers do not face an appropriate incentive to substitute away from relatively pollution-intensive inputs. Taking electricity as an example, the first inefficiency, and that exclusively discussed so far, would be that people consume too much power if the price does not reflect the marginal environmental damages associated with its production. The second inefficiency is without having to cover the cost of these damages, electricity generators as a whole will use too much "dirty" coal to produce electricity and not enough cleaner fuels, such as natural gas.

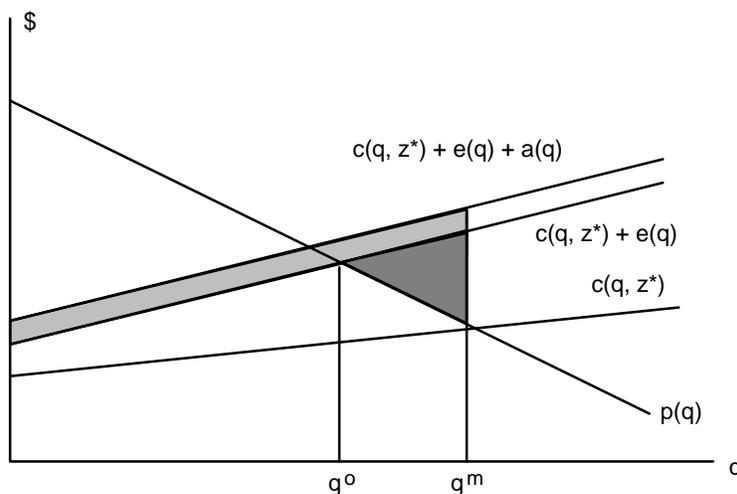
Full modeling of the interaction between changes in the private cost of producing a commodity and efficient abatement of external social cost is beyond the scope of this paper. But simple estimates, based on the assumption that actual change in the private cost would have little significant effect on optimal substitution away from pollution-intensive inputs or technologies, do allow us to incorporate into our measures the inefficiencies from having no incentive to abate.<sup>11</sup> Those simple estimates allow us to use the tests already derived with only a slight revised interpretation of the emissions damages measure.

As with the no-abatement case, a diagram illustrates the relative effects. Figure 1 above reflected the assumption that the social marginal cost curve was itself independent of policy choice. However, the absence of policy that leads to too little incentive to abate in the production process implies that the social costs incurred are too high at every level of output. We can show this by amending Figure 1 to include losses from excessive costs, as well as excessive output, as follows:

The lightly shaded area reflects the addition of  $a(q)$ , the extra social cost of producing  $q$  associated with the lack of efficient abatement in the production process. The optimal level of output,  $q^o$ , remains at the intersection of the (original) social marginal cost curve and the demand curve, since the former reflects the minimum social cost of producing  $q$ , taking efficient abatement into account.

---

<sup>11</sup> The results of precise estimates are probably an order of magnitude beneath the noise level of quantitative cost data (or informal estimates) available to those who decide when changes in environmental policy are appropriate.



**Figure 6: Welfare losses from externalities in a competitive market with too little abatement**

The effect of a change in the private cost of producing  $q$  from a change  $\Delta z$  from the original value  $z^*$  of the cost parameter would now be measured by a change in both shaded areas. The analysis above covered changes in the darkly shaded area alone. Diagrammatically, and using the earlier notation, the lightly shaded area just expands out from  $q^m$  to  $q^m(\Delta z)$ . Mathematically, the added cost is just  $a(q^m(\Delta z)) - a(q^m(0))$ .<sup>12</sup> Assume that a change in  $z$  would have little significant effect on the per-unit inefficiency associated with suboptimal abatement, and designate  $a'$  as the constant marginal inefficiency from too little abatement. The added cost is then  $a'\Delta q^m$ , i.e., the marginal inefficiency times the change in output in the absence of environmental policy to take external costs into account.

Incorporating the costs of abatement into the analysis of the need for policy becomes a matter of adding  $a'$  to the external marginal cost function  $e(\cdot)$  and marginal net welfare function  $h(\cdot)$  in the formal representations. An even simpler way is to recast  $e(\cdot)$  and  $h(\cdot)$ , not in terms of the *counterfactual* external cost with efficient abatement in the production process. Rather, we only have to interpret and estimate these based on the *actual* external cost, combining both the external cost with efficient abatement and the added cost when producers lack the incentive to abate. Recognizing inefficient abatement than makes  $e(\cdot)$  and  $h(\cdot)$  larger, and in that sense will tend to tilt balance more in favor of intervention when costs fall. However, the possibility that the need for intervention will fall, e.g., with highly inelastic demand for the commodity in question remains, with a qualitatively if not quantitatively identical test. Even recognizing that policy could lead to more efficient abatement, we should

<sup>12</sup> In more complex settings where changes in the private cost change the per-unit inefficiency due from too little abatement,  $a(\cdot)$  would itself become a function of  $z$  as well as  $q$ .

still be cautious in inferring a change in the *incremental* need for policy when private costs fall or demand increases.

## CONCLUSION

The common intuition is that private cost reductions (or increases in demand) for dirty goods and environmental policies are complements. According to this view, as the supply of the former increases, the demand for environmental latter goes up. We have shown here that cost reductions and environmental policy may be substitutes, not complements. Making a dirty good cheaper to produce, or increasing demand for it, may reduce the externality-related inefficiency underlying the economic case for corrective environmental policy. We have illustrated the tradeoffs, derived conditions when cost reductions or demand increases reduce the welfare loss, and displayed cases where the externality-related inefficiency clearly shrinks. While constructed assuming no substitution possibilities in the production process itself, the analyses readily accommodate the possibility of abatement.

We also hope to go beyond theoretical claims and provide practical policy guidance. In principle, if the size of the marginal externality, the amount of overproduction, market price, and demand and supply elasticities are known, the direction in the change of the inefficiency following marginal changes in costs or demand can be predicted, for a fairly wide variety of cases. Ideally, empirical assessments based on these parameters should accompany any policy change likely to increase demand or reduce production costs for dirty goods, e.g., expanding competition in markets for electric power.

## APPENDIX

Decreases in cost or increases in demand for dirty goods may reduce welfare overall economic welfare because of externality-related inefficiencies. Using notation from the paper, if cost is affected by an exogenous parameter  $z$ , total welfare  $W$  is

$$W = \int_0^{q^m(z)} [p(x) - c(x, z) - e(x)] dx .$$

Recalling that  $h(q) = c(q, z) + e(q) - p(q)$ , differentiating with respect to  $z$  gives

$$W' = - \int_0^{q^m(z)} c_z(x, z) dx - h(q^m) q^{m'}$$

For reductions in cost to increase welfare,  $W' < 0$ . Let  $c_{z(avg)}$  be the average *reduction* in cost from a from a reduction in  $z$ , i.e.,

$$c_{z(avg)} = \frac{1}{q^m} \int_0^{q^m(z)} c_z(x, z) dx .$$

The condition for a reduction in  $z$  to increase welfare becomes

$$-c_{z(avg)} q^m < h(q^m) q^{m'}$$

Dividing through by  $-c(q^m, z) q^m$  gives

$$\frac{c_{z(avg)}}{c(q^m, z)} > \frac{h(q^m)}{c(q^m, z)} \frac{-q^{m'}}{q^m} . \tag{A1}$$

The term on the left-hand side of equation (A1) is essentially the percentage reduction in cost from a decrease in  $z$ . The first term on the right hand side is the ratio of the marginal inefficiency at market output to marginal production cost. Note again that in the competitive case,  $h(q^m) = e(q^m)$ , which would make the first fraction in the right hand side of equation (A1) equal to the ratio of marginal external cost to marginal private cost. The third fraction is essentially the percentage increase in output from a fall in  $z$ .

For a cost reduction to increase welfare when externalities are present, the average percentage reduction in costs must be greater than the ratio of external to private cost times the percentage change in output brought about by that cost reduction. If this does not hold, e.g., if demand and supply are sufficiently elastic to make  $-q^{m'}/q^m$  sufficiently large, a reduction in cost could reduce overall welfare. The analysis for the welfare consequences of changes in demand is similar, with a percentage change in willingness to pay replacing the percentage reduction in costs on the left-hand side of equation (A1).

**REFERENCES**

- Baumol, William J. and Wallace E. Oates. 1988. *The Theory of Environmental Policy* (Cambridge: Cambridge University Press).
- Bohi, Douglas R. and Dallas Burtraw. 1992. "Utility Investment Behavior in the Emission Trading Market," *Resources and Energy*, 14, pp. 129-156.
- Brennan, Timothy J. 1996. "Is Cost-of-Service Regulation Worth The Cost?" *International Journal of the Economics of Business*, 3, pp. 25-42.
- Coase, Ronald H. 1960. "The Problem of Social Cost," *Journal of Law and Economics*, 3, pp. 1-44.
- Downing, Paul B. and William D. Watson, Jr. 1974. "The Economics of Enforcing Air Pollution Controls," *Journal of Environmental Economics and Management*, 1, pp. 219-236, reprinted in Wallace Oates, ed., 1992, *The Economics of the Environment* (Aldershot, UK: Edward Elgar Publishing Ltd.), pp. 507-524.
- Goulder, Lawrence H., Ian W. H. Parry, and Dallas Burtraw. 1997. "Revenue-Raising vs. Other Approaches to Environmental Protection: The Critical Significance of Preexisting Tax Distortions," *RAND Journal of Economics*, 28, pp. 708-731.
- Freeman, A. Myrick III, and Winston Harrington. 1990. "Measuring Welfare Values of Productivity Changes," *Southern Economic Journal*, 56, pp. 892-904.
- Peirce, David W. and R. Kerry Turner. 1990. *Economics of Natural Resources and the Environment* (Baltimore, Md.: The Johns Hopkins University Press).
- Portney, Paul R. 1990. "Air Pollution Policy," in P. Portney, ed., *Public Policies for Environmental Protection* (Washington, D.C.: Resources for the Future), pp. 27-96.
- Spulber, Daniel F. 1989. *Regulation and Markets* (Cambridge, Mass.: MIT Press).
- Teitenberg, Thomas H. 1980. "Transferable Discharge Permits and the Control of Stationary Source Pollution: A Survey and Synthesis," *Land Economics*, 56, pp. 391-416.; reprinted in Wallace Oates, ed., 1992, *The Economics of the Environment* (Aldershot, UK: Edward Elgar Publishing Ltd.), pp. 212-237.
- Weitzman, Martin L. 1974. "Prices vs. Quantities," *Review of Economic Studies*, 41, pp. 477-491.