

When do Firms Benefit from Environmental Regulations? A Simple Microeconomic Approach to the Porter Controversy

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1. INTRODUCTION

In the economic analysis of environmental regulations the benefits of pollution reduction are usually weighed against costs, including those arising at the firm level. Resistance to environmental regulations stems from the fact that these costs are perceived as high. Michael Porter and others have recently claimed that such a perception may be mistaken. Using case-study evidence they argue that often environmental regulations induce firms to carry out innovations that are not only beneficial for the environment, but have additional positive effects, deemed innovation offsets, on productivity.¹ PORTER and VAN DER LINDE (1995a) distinguish between product offsets, that is, increases in product quality and process offsets, that is, reductions in production costs. Both elements were present in the adjustment of the electronics company Raytheon to the Montreal Protocol and the U.S. clean air act, in which Raytheon was forced to develop CFC-free cleaning processes for electronic circuit boards. Interestingly, application of these substitutes turned out to result in higher product quality and lower production costs. An example of pure process offsets is related to the introduction of new environmental standards in New Jersey: To comply with the new law, Ciba-Geigy had to reexamine the wastewater streams of a dyestuff plant, and as a consequence of two changes in the production process, yield was boosted by 40 percent and considerable cost savings were generated by elimination of wastes.

In itself, these examples are interesting, but not controversial. Porter would hardly have caused much reaction had he not claimed that such cases are more the rule than the exception, at least as long as environmental regulations are sufficiently flexible, that is, do not prescribe the use of specific technologies. Not surprisingly, these claims met with heavy criticism from mainstream environmental economists. Of course, they also advocate flexible instruments such as taxes or tradeable permits, because such instruments reduce the negative effects of regulation on productivity. However, they disagree with Porter's stronger claim that for flexible instruments the productivity effects of regulation tend to be positive in many or even most cases. For instance, in a response to

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1. For example, PORTER (1991), PORTER and VAN DER LINDE (1995a,1995b).

PORTER and VAN DER LINDE (1995a), PALMER et al. (1995, p. 120) concede that regulation has occasionally improved firm productivity, but they hasten to add that “with literally hundreds of thousands of firms subject to environmental regulations in the United States alone, it would be hard *not* to find instances where regulations have seemingly worked to a polluting firm’s advantage.”

Of course, this is a strong point: a clever selection of case studies can “prove” just about anything. On the other hand, the evidence against Porter is not overwhelming. For instance, in a survey of relevant empirical research on manufacturing firms, Jaffe et al. (1995) come to the conclusion that the effects of environmental regulations on productivity tend to be negative and fairly small, but highly variable inside the industrial sector.² In fact, Porter’s opponents seem to rely less on empirical observations than on an obvious theoretical argument. Imposing restrictions on optimizing agents generally makes them worse off. Therefore, no matter what kind of innovations environmental regulations induce, it will result in lower profits, as a rule and on average, at least if the fixed costs of innovation are taken into account properly. Important as this argument may be, it hardly is the whole story. While Porter remains vague about the mechanisms inducing innovation offsets, he is clearly thinking of firms that are not necessarily profit maximizers in a competitive world. There are several reasons why such firms might forego innovation possibilities that are or at least appear to be profitable. To evaluate Porter’s contribution, one should therefore argue why such instances are unlikely – and not rule them out a priori.

Accordingly, our main concern will not be to judge which of the two parties is right and which is not. Rather, we shall attempt to reconcile the different views by clarifying the underlying assumptions. To this end, we shall occasionally choose the assumptions in a fashion which is somewhat biased towards Porter’s position. We shall then see that, even under these assumptions additional conditions are necessary to support the view that environmental regulation could systematically induce innovations that are beneficial to firms. Depending on the particular explanation given, these conditions are more or less convincing. Understanding the conditions under which environmental regulation can be expected to lead to innovation offsets adds clarity and structure to a discussion that is not always sufficiently precise.

2. A SIMPLE MODEL – AND AN OUTLINE OF THE ANALYSIS

In much of the following, we shall use a simple analytical framework. We consider a firm that produces a fixed output level.³ Suppose the output price is fixed. Production costs in

2. Also empirical studies are necessarily mainly about regulation that is not highly flexible, simply because economists’ campaigns for flexible instruments have had very little real-world impact (so far); see HAHN (1989) for a slightly outdated survey.
3. The generalization to variable outputs is straightforward. The essential differences in this case will briefly be discussed in section 5.

the absence of environmental regulations and cost-reducing innovations amount to $C(0)$. Environmental regulations lead to compliance costs $R(0)$, including both the costs of improving environmental performance and additional costs of regulation, such as emissions taxes. Now suppose there is a pool I of innovation projects i . Each innovation can potentially affect production costs and compliance costs, which we therefore write as $C(i)$ and $R(i)$, respectively. Each innovation has fixed costs $F(i) > 0$. Three types of innovations are conceivable. Pure cost-reducing innovations satisfy $C(i) < C(0)$, but $R(i) \geq R(0)$. Pure environmental innovations satisfy $R(i) < R(0)$, but $C(i) \geq C(0)$. We are most interested in environmental innovations with cost-reducing effects, i.e. innovations such that both $R(i) < R(0)$ and $C(i) < C(0)$. Clearly, if environmental regulations are to induce cost-reducing innovations, they must be of the last type. In addition, the regulation must affect the firm's behavior in a fashion that directs its behavior towards the introduction of such projects. In all of the following, we assume that there are two periods. In period 1, investment takes place, in period 2, the firm produces. We suppose for simplicity that the firm can choose at most one innovation project.⁴ We abstract from discounting considerations.

The outline of the paper can be summarized with the three following questions, which we shall discuss in sections 3 and 4:

- (1) Suppose first that there is no environmental regulation. Under which circumstances might firms refrain from innovative activities, even when these activities have cost-reducing effects that would seem to make them worthwhile in the absence of regulation?
- (2) Under which circumstances might environmental regulations induce firms to carry out such innovations?
- (3) If environmental regulations induce firms to carry out cost-reducing innovations that would not have been carried out otherwise, under which conditions do the positive effects of these innovations dominate over the negative effects of regulations from the firms' point of view?⁵

Before pursuing this agenda, we first dispense with a trivial reason why environmental regulations might lead to cost-reducing innovations. If a firm minimizes total costs $C(i) + F(i) + R(i)$, it will be induced by environmental regulations to carry a cost-reducing innovation if and only if the following condition holds.

$$C(0) - C(i) < F(i) \quad \text{for all } i \in I \quad (\text{E1})$$

$$F(i) < C(0) - C(i) + R(0) - R(i) \text{ and } 0 < C(0) - C(i) \text{ for at least one } i \in I. \quad (\text{E2})$$

4. This is more general than it seems. An "innovation project" can be interpreted as a set of several projects.
5. We shall confine ourselves to positive effects due to improved productivity at the firm level. One strand of related literature discusses a possible "double dividend" of environmental policy arising from the correction of distortionary taxes (e.g. NORDHAUS 1993, BOVENBERG and DE MOOIJ 1994, BOVENBERG and GOULDER 1996); another literature argues that environmental policy might have positive strategic effects for home firms against foreign firms (e.g. BARRETT 1994).

Without regulation the possible cost-reducing effect of the innovation does not outweigh the fixed costs (E1), whereas with regulation there exists a cost-reducing innovation such that the combined effect on production and compliance costs does outweigh fixed costs (E2). Hence, in this case (1) and (2) can be answered affirmatively, (3) will be answered negatively. As has been pointed out elsewhere (PALMER et al. 1995) firms are perfectly rational not to carry out such innovations.⁶ Porter is not very definite about the role of fixed costs, but it seems that in many of the examples he believes those costs to be negligible, in which case it becomes more puzzling why (1) and (2) should hold simultaneously. In this paper, we want to deal with more interesting cases.

In section 3, we shall answer question (1), section (4) discusses questions (2) and (3). Section (5) concludes.

3. REASONS FOR UNDERINVESTMENT WITHOUT ENVIRONMENTAL REGULATION

In this paper we analyze under which circumstances environmental regulations correct underinvestment by inducing cost-reducing innovations that would otherwise not have been carried out. As a first step we therefore present answers to question (1), that is, we discuss familiar explanations of why cost-reducing activities might not occur without environmental regulations. In section, we shall then analyze whether environmental regulations might change this.

To understand why firms might refrain from activities that reduce costs, we shall distinguish between two completely different sets of issues. First, there are strategic arguments (subsection A). Firms will be reluctant to engage in cost-reducing innovations if the beneficial effects of the innovation mainly accrue to consumers or to competitors. They might be well advised to forego such opportunities – departures from rational behavior in case studies might therefore be more apparent than real. The innovating firms are actually better off without the innovation. Second, there are organizational arguments. Here, we shall mainly deal with incentive problems (subsection B); problems of bounded rationality will only be touched upon very briefly (subsection C).

3.1. Strategic Issues

Industrial organization theory provides a wide variety of reasons why rational firms might refrain from cost-reducing innovations, even when innovation costs are low, leading to inefficiently low investment levels from a social point of view, but not necessarily to inefficiently low investment levels from the firm's point of view. In the following, we

6. Also, without further information there is no reason to expect innovation levels to be suboptimal, except on environmental grounds.

shall mainly confine ourselves to the most convincing argument, namely to the existence of spillover effects.

Profit-maximizing firms will only carry out cost-reducing innovations if they can expect sufficient profit increases as a result. These profit increases will tend to be low if the knowledge generated in the process of innovation is likely to spill over to the competitor, for instance because knowledge-bearing employees change firms. Hence, the possibility of spillovers might in principle reduce the incentives to engage in cost-reducing innovations. Many theoretical papers emphasize this possibility (e.g., ARROW 1959, NELSON 1962, SPENCE 1984, D'ASPREMONT and JACQUEMIN 1988, KAMIEN et al. 1992, LEAHY and NEARY 1997).

Transferring this to the language introduced above, consider a simple game. We distinguish two cost-minimizing firms k and l . We suppose that, if firm k innovates, spillovers affect firm l 's production costs. To capture this, we write $C_l(i_l, i_k)$ for the costs of firm l , where $i_l(i_k)$ is the investment decision of firm $l(k)$. An innovation i_k of firm k creates spillovers if $C_l(i_l, i_k) < C_l(i_l, 0)$. In this setting, suppose the following condition holds.

$$C_k(0, 0) - C_k(i_k, 0) < F_k(i_k) \quad \text{for all } i_k \in I_k \quad (\text{A1})$$

$$C_k(0, 0) - C_k(i_k, 0) + C_l(0, 0) - C_l(0, i_k) > F_k(i_k) \quad \text{and } C_k(0, 0) - C_k(i_k, 0) > 0 \quad (\text{A2})$$

for at least one $i_k \in I_k$.

The cost-reducing effect does not outweigh the fixed costs of each firm (A1), whereas due to the spillover effect a reduction of the industry's total costs would result if firm k innovated (A2). In this setting, in equilibrium,⁷ no firm will innovate, whereas minimization of total industry costs would demand innovation. This is the sense in which there is underinvestment.

However, the negative incentive effects of such spillovers on innovation incentives should not be exaggerated. The empirical literature (e.g., GEROSKI 1995) emphasizes that, on the one hand, firms have many instruments to reduce the flow of knowledge to competitors, and, on the other hand, that obtaining knowledge from competitors is usually a costly matter. Hence, spillovers do not arise automatically: their extent depends on the activities of the firms involved. Also, to some extent the problem can be solved by using research joint ventures. However, entering a research joint venture has fixed costs itself and may therefore not be an option for fairly small innovations. In spite of these qualifications, the spillover argument is reasonable in principle – it may explain why firms sometimes forego innovations that are beneficial from a social point of view, even ignoring environmental effects.

There are other potential strategic explanations for too little cost-reduction. For reasons of space, we shall not discuss them in detail here. Examples include underinvest-

7. "Equilibrium" stands for Nash Equilibrium in the game where each firm k chooses investments simultaneously, with the goal of minimizing the sum of F_k and C_k .

ment as a means of obtaining second-mover advantages,⁸ underinvestment as a means of softening competition (ESWARAN and GALLINI 1996) and underinvestment as a means of avoiding misleading signals about product quality (STIGLITZ 1987).⁹ Most of them suffer from a problem that is all too familiar in Industrial Organization theory: they are not robust to minor changes in the way competition is modelled. For example, an argument for underinvestment under quantity competition might become an argument for overinvestment under price competition, and vice versa. This is not necessarily an indication of bad modeling; it may just reflect real world complexity. However, it is hard to derive a tendency towards too little innovation from such arguments.

Summing up, we have one strategic argument of unambiguous direction, but unclear strength, and a number of strategic arguments which suggest underinvestment in some situations, and overinvestment in others. The likelihood that spillover effects lead to underinvestment is influenced by the market environment. First, the nature of the market for skilled labor matters in this context inasmuch as spillover problems increase with managerial mobility. Second, according to GERSBACH and SCHMUTZLER (1998) the spillover problem disappears in product markets with intensive price competition, in a setting where spillovers arise endogenously.¹⁰

With respect to our discussion in section (4), note that even if regulation leads to innovations, their beneficial effects accrue to other agents, not to the regulated firms themselves. Explanations for cases where environmental regulations are beneficial for the firms themselves must use different arguments.¹¹ Therefore, we now turn to organizational explanations for insufficient innovation which rely on deviations from profit maximization. We distinguish between incentive and coordination problems.

3.2. *Incentive problems*

Decisions about innovations are usually not taken by firm owners, but by managers and other employees. Unlike the owners, these agents will usually be less concerned about the effects of their decisions on firm profits. Instead, they will probably consider the effect on their career chances, on their remuneration, and on their job quality (effort, etc.). Ra-

8. Such advantages could for instance arise if waiting for the investment of other firms carries an informational value about the chances of a project.
9. For a critique of the argument that signaling considerations can explain underinvestment, see SHIEH 1993.
10. Intuitively, when competition is strong, a firm gains very little from catching up with a competitor. If spillovers are costly to acquire (for instance, because it is necessary to hire the competitor's employees to obtain their knowledge), then the firm will not be prepared to incur these costs. The competitor therefore has little reason to fear that the benefits of innovation will accrue to the competitor.
11. FUNG and MAECHLER (1999) give an argument why environmental regulation might increase industry profits. However, in their case, there are no innovation offsets: costs increase as a result of regulation, but equilibrium profits go up. This is usually considered as possible, but unlikely in oligopoly models, but the authors provide empirical evidence for their argument.

tional owners can, in principle, try to align the employees' objectives with the goal of profit maximization. However, this is usually not simple. There are several reasons why there could be differences in innovation incentives. For instance, models of BRESNAHAN et al. (1991), STEIN (1988, 1989), and ZECKHAUSER and POUND (1990) have shown that, with asymmetric information, owners will find it difficult to give sufficient long-run incentives for managers. The arguments are variants of the following. Suppose rational managers can devote time to different activities that increase short-term profits and long-run profits respectively, and the relation between effort and short-term performance is easier to observe than the relation between effort and long-term performance. Then, an excessive allocation of efforts to short-term activities might result. This problem is compounded when managers have a limited time horizon. If a manager expects to retire or change employers soon, his incentives to engage in long-run investments will be particularly low (MILGROM and ROBERTS 1992, 432–433).¹² Alternatively, it has been argued that it may be hard to give managers sufficient incentives for carrying out risky investment projects (MILGROM and ROBERTS 1992, 429–432). While (risk-neutral) owners would be willing to carry out certain high-risk projects if the expected gains are sufficiently high, risk-averse managers might not be. Because of these incentive problems, managers are not likely to invest enough from the owners' point of view. In particular, they might refrain from innovative activities that can potentially improve productivity, even when they are likely to increase expected profits.¹³ Typically, such activities are likely to involve great coordination efforts and hence high (short-term) adjustment costs. Innovation offsets are likely to arise only in the long run. If managers are indeed biased towards short-term actions, they might therefore not carry out certain investments.

We now transfer these ideas to the model introduced above in the simplest possible way, abstracting from the precise origin of the incentive problem. We consider a firm where decisions are taken by managers who do not necessarily have cost-reduction as their prime goal. Instead, when they decide on the investment project, they maximize some objective function $\Gamma(i, P)$. As before, i stands for the investment project that is chosen; $i = 0$ if there is no innovation. P is a policy variable that takes values 0 if there are no environmental regulations, 1 if there are. In general, one should think of $\Gamma(i, P)$ as being positively related with the firm's profits, but it also depends on various private benefits for the manager.¹⁴ In this set-up, without environmental regulations we can speak of underinvestment if the following set of conditions holds.

$$\Gamma(i, 0) - \Gamma(0, 0) < 0 \quad \text{for all } i \in I \quad (\text{B1})$$

$$C(0) - C(i) > F(i) \quad \text{for at least one } i \in I. \quad (\text{B2})$$

12. Additional incentive problems might arise in multi-divisional firms if cost-reducing innovations in one division yield positive externalities for other divisions.
13. There are of course possible countervailing forces. For instance, managers may engage in excessive investments to have a "visible impact" on the firm.
14. The positive relation of managerial profits could for instance arise because managers of highly profitable firms have better career chances.

From the managers point of view it does not pay to innovate (B1), whereas it would be in the owner's interest (B2). The above arguments have shown that it is conceivable that conditions (B1) and (B2) are satisfied simultaneously.

The incentive argument can thus explain underinvestment, but again, it is not clear how important it is. Despite this problem, we can at least conjecture which aspects of the market environment determine whether incentive problems are likely to lead to underinvestment. Product markets, labor markets and financial markets all play a role here.

The nature of product market competition, for instance, influences how likely internal inefficiencies are. It is generally harder to measure managerial performance and thus to give appropriate incentives when there are few competitors in the market whose performance can serve as a yardstick for the performance of the own firm's managers (HOLMSTRÖM and TIROLE 1989). This is an informational effect of competition. SCHMIDT (1997) distinguishes two further effects: On the one hand, managerial effort increases with product market competition due to the threat of liquidation. On the other hand, more competition reduces profits, so it may also affect the value of cost reduction and thus the benefits of inducing a higher level of effort. Thus, while a relation between the intensity of product market competition and managerial effort is very likely, its direction is unclear.

The nature of the market for skilled labor also influences whether this kind of organizational inefficiency is likely to arise. As argued above, high managerial mobility makes it more likely that managers lack appropriate incentives to engage in long-run investments. Finally, well-functioning financial markets are often claimed to prevent deviations from profit maximization: a firm that deviates from profit maximization will be a likely target for takeovers. While this takeover mechanism is unlikely to be perfect (see SCHERER 1980), there should at least be a negative relationship between the effectiveness of the market for corporate control and the likelihood of innovation offsets.

3.3. *Coordination problems and bounded rationality*

Even ignoring incentive problems, achieving profit maximization is not a trivial matter when information processing and communication capacities are limited, i.e., coordination problems exist due to some kind of bounded rationality. In many of the examples discussed by Porter, environmental regulations sparked off internal communication, eventually leading to the discovery of innovation possibilities. For instance, waste management personnel detected pollutants; with the help of other experts the causes of pollution were then traced back to the process design (PORTER and VAN DER LINDE 1995b, p. 122). The processes could then be adjusted to alleviate the problem. Without environmental regulation, the necessary communication between waste management personnel and process engineers might never have taken place.¹⁵

15. Related arguments have been investigated in great depth by Aoki (1986,1990), who argues convincingly that a firm's ability to discover and implement different types of innovations may depend strongly on its organizational structure.

More generally, there seem to be many cases where environmental regulation makes firms aware of “low-hanging fruits”, i.e., possibilities to increase profits and improve their environmental performance at the same time with low investment costs, where it is hard to argue that incentive problems prevented the firms from choosing these opportunities before the introduction of regulation. Explaining why these things happen is hard to model, as it requires ideas of limited managerial attention, bounded rationality, etc. For serious attempts to approach these issues, the reader is referred to the work of GABEL and SINCLAIR-DESGAGNÉ (1998, 2000). These authors adapt organizational theories (e.g. CYERT and MARCH 1992) to the problems considered here. Essentially, they argue that firms must develop problem-solving routines that only let them consider a limited number of options for change – and possibly overlook some “low-hanging fruits”. These routines are hard to change even when they are no longer appropriate, except under external pressure, resulting for instance from environmental regulation.

To sum up, strategic and organizational arguments can, in principle, explain a lack of innovative activities. Such effects are particularly likely to appear for specific organizational structures and market environments. The presence of underinvestment, in itself, does not imply that environmental policy is preferable to no environmental policy from the firms’ point of view. Additional conditions need to be fulfilled for this to be the case, as we will now argue.

4. WHEN DO ENVIRONMENTAL REGULATIONS INDUCE COST-REDUCING INNOVATIONS AND WHEN DO THE BENEFITS FOR FIRMS EXCEED COSTS?

In the preceding section, we have seen that there are reasons why unregulated firms may forego cost-reducing investments that would, at first glance, seem worthwhile. We now turn to the more debatable point whether environmental policy might change this.¹⁶ The point is not just that environmental regulations might induce some kind of innovation. It has been debated at great length to which extent environmental regulations might induce firms to introduce new technologies that reduce the costs of compliance (DOWNING and WHITE, 1986; MILLIMAN and PRINCE, 1989). The benefits of such innovations are purely “environmental” – regulation does not reduce production costs. Hence, even if environmental policy induces innovations, these may not be identical to those innovations that would otherwise be the victim of organizational (or strategic) inefficiencies. In fact, empirical work of ROSE (1983) and GRAY and SHADBEGIAN (1998) has come to the conclusion that environmental investments may even crowd out productive investments. In any event, additional arguments are required to support the position that the induced innovations are indeed productive in some sense.

16. See question (2) and (3) in section 2.

To this end, we next show under which conditions environmental regulations induce innovations. We shall delineate the circumstances under which environmental regulations leads to cost-reducing investments and conditions under which the benefits from these cost reductions outweigh the costs of compliance, considering first strategic issues, then organizational issues. With respect to the latter, we shall only consider incentive questions, not problems of bounded rationality.¹⁷

4.1. Strategic Issues

Under which circumstances might environmental regulations induce cost-reducing innovations that would have otherwise fallen victim to spillover problems? The simplest way to state the result is the following.

Result A: Consider the two-firm framework of section 3A. Suppose conditions (A1) and (A2) are still satisfied. Suppose in addition that the following condition holds

$$\begin{aligned} C_k(0,0) - C_k(i_k,0) + R_k(0) - R_k(i_k) &> F_k(i_k) \text{ and} \\ C_k(0,0) - C_k(i_k,0) &> 0 \text{ for at least one of the } i_k \in I_k \text{ that satisfy (A2).} \end{aligned} \quad (\text{A3})$$

Then, even though “no innovation” is an equilibrium in the absence of environmental regulations, this is no longer true with environmental regulation.

The non-existence of the “no innovation” equilibrium in the presence of regulation is due to the reduction of abatement costs resulting from the innovation, which together with the decrease in production costs outweighs the fixed costs of innovation, even from the point of view of an individual firm. In this setting, however, if regulation induces only one firm to innovate, this will never result in higher profits (lower total costs) for this firm than in the absence of regulation. This is evident from (A1).

In principle, however, it is conceivable that regulation induces innovation by both firms and both firms have lower total costs after the regulation than before the regulation, i.e. regulation serves to destroy an equilibrium that is Pareto-inefficient even from the firms’ point of view. This may happen if innovations are strongly complementary. The precise conditions are straightforward to derive (see the Appendix). As this case does not appear to be very likely, we do not pursue this line of thought any further.

Apart from the general skepticism towards the spillover argument articulated in section 3, there are additional reasons why it may have little bite in our context. Innovations that simultaneously reduce costs and improve the environment are often specific to the firm under consideration. Consider for instance a large chemical company producing thousands of different products. Suppose that emissions arising in the production of one

17. For a related discussion of the relative impact of different environmental policy instruments on possible efficiency gains from innovations in pollution abatement technologies, see PARRY (1998).

such product (good 1) are reduced. Innovation offsets might for instance arise if the firm finds a way to use these emissions as inputs for the production of another good (good 2).¹⁸ These internal recycling possibilities might not exist in other firms that compete in the market for good 1, but not in the market for good 2. In such a case, an innovating firm will not face a serious spillover risk, and, accordingly, innovation incentives should remain high.

4.2. Incentive problems or firms with self-interested managers

Now consider the framework with self-interested managers laid out in section 3.2. Environmental regulations induce cost-reducing innovations that would otherwise not have occurred if the following result is satisfied.

Result B: In the framework of section 3.2., suppose condition (B1) is still satisfied, and in addition, the following two conditions hold.

$$\Gamma(i, 1) - \Gamma(0, 1) > 0 \text{ for at least one } i \in I \quad (\text{B3})$$

$$C(0) - C(i^*) > 0 \text{ for the } i^* \text{ that maximizes } \Gamma(i, 1) - \Gamma(0, 1). \quad (\text{B2}')$$

Then, environmental regulation affects incentives in such a fashion that the manager will choose a cost-reducing innovation under regulation even though he would not do so in the absence of regulation.

For this innovation offset to be strong enough to outweigh the costs of innovation must be replaced by

$$C(0) - C(i^*) - F(i^*) > 0 \text{ for the } i^* \text{ that maximizes } \Gamma(i, 1) - \Gamma(0, 1). \quad (\text{B2}'')$$

To add more meat to these conditions, it is useful to understand why they could be satisfied simultaneously. Most importantly, why should environmental regulations affect managerial behavior in the fashion described by conditions (B1) and (B3)? First note that the effect of innovation on abatement costs $R(0) - R(i)$ does not directly enter the above conditions. However, it is reasonable to assume that it enters in an indirect way. If we continue to assume that the managers' objective function is positively related to a firm's profit, other things being equal, we should expect $\Gamma(i, 1) - \Gamma(0, 1)$ to be greater than $\Gamma(i, 0) - \Gamma(0, 0)$: If there are environmental regulations, the innovation has greater beneficial effects for the firm than without regulation. The managers whose interests are partly (though not perfectly) aligned with the firm therefore also considers the innovation as more valuable when there is regulation than when there is not.

18. For a discussion of innovation offsets in the chemical industry, see FABER et al. (1994).

This can be made more specific if the nature of the incentive problem is known. First, environmental regulations could help to counteract managerial myopia: SCHMUTZLER (2000) clarifies under which conditions regulation might raise expected profits by inducing myopic managers to carry out cost-reducing investments with positive effects on the environment.¹⁹ Second, environmental regulations could induce risk-averse managers to carry out projects that risk-neutral owners might have wanted to be carried out even without regulation, because a possible unsuccessful innovation decision might be attributed to the regulation, rather than to the manager.

A more subtle point is whether these arguments could justify a *systematic* bias against environmental innovation. If managers are indeed too myopic and too risk-averse, this will be true if environmental innovations are long-run and risky, which is not implausible. However, as argued in footnote 13, there might also be countervailing effects: managers might derive personal satisfaction from carrying through environmental projects, which the owners might not share.

Another criticism against the idea that environmental regulation might help to overcome an incentive problem is the following: if the incentive effects resulting from regulation were beneficial to the owners, these owners could simply have provided the same incentives directly to the manager. While this criticism must be taken seriously, it is not entirely convincing. The typical justification for employing a manager is that the owner may not be able to collect all the information that is relevant for decision making himself. It may therefore be plausible that the owner does not know about some investment projects that the manager might pursue. For a case in point, consider various energy programs initiated by environmental agencies which made firms aware of considerable savings potentials, such as the EPA Green Lights Program. Such programs are successful, because the kind of program is potentially applicable to many firms, including small firms with limited resources for gathering information. The regulator on the other hand will typically supervise more than one firm, and may find it worthwhile to gather specialized knowledge, so unlike the principal he will know of certain options that are potentially available to the manager, and he can force him to apply those options, or at least inform him of their existence. Of course, the regulator does this for environmental reasons, not for the sake of firm profits.

4.3. *Does more flexibility of environmental policy make innovation offsets more likely?*

It is often claimed that the more “flexible” an environmental policy is, the more likely it is to lead to innovation offsets (PORTER and VAN DER LINDE 1995). While it is notoriously unclear what flexibility means in general (see SCHMUTZLER 1991), a rough defini-

19. However, this argument has one limitation: PORTER and VAN DER LINDE (1995a) themselves claim that, in several cases, the pay-back period of innovations induced by environmental regulations are very short, often only half a year. Managerial myopia is hardly able to explain why firms abstain from such innovations in the absence of regulation.

tion of a more flexible environmental policy would be that it leaves more options for the firms to react to. In this sense, there are various cases in which one instrument can be described as more flexible than another one. For instance, the regulation of emissions usually offers more possibilities to comply with than input regulation which itself offers more compliance opportunities than the prescription of particular processes. There is also a difference between emission taxes and emission standards: The former are more flexible because there is the possibility to substitute but also to pay for the use of the harmful input, whereas emission standards do not allow to exceed certain emission limits under any circumstances. Another example concerns a policy that forbids the use of a certain technology compared to a policy prescribing the use of a certain technology. The former is again more flexible than the latter.²⁰

At first glance, only relatively flexible policies would appear to be compatible with beneficial effects on firms: only these policies allow the firm's employees to search for innovative solutions. However, there is a caveat here. As argued before, at least in principle environmental policy might be beneficial for the owner precisely because it limits managerial discretion. Thus, with higher flexibility environmental policy may be less likely to solve incentive problems.

5. CONCLUSIONS AND EXTENSIONS

There are several reasons why environmental regulation might lead to cost-reducing innovations. We briefly discussed the trivial reason in which the combined effect on production and compliance costs outweighs the fixed costs of innovation. Strategic issues are a first non-trivial reason for underinvestment without regulation: with spillover effects, innovation might pay from the point of view of society, but not for the single firm. Organizational issues are a second and more convincing explanation for underinvestment. On the one hand, environmental regulations might ameliorate incentive problems between owners and managers and lead to cost-reducing innovations. On the other hand, environmental regulations might induce communication inside the firm or change the firm's information structure, which serves to solve coordination problems.

In some of these cases, environmental regulations might even benefit firm owners, but it seems unlikely as it requires "almost contradictory" conditions: In general, there must be some type of initial underinvestment, the environmental regulation must correct this, and it must do this at low compliance costs.

The conditions under which all this is likely relate to market structure, firm structure, the type of regulation and the technology. Without being more specific, it is hard to derive very general comparative statics results. For instance, even the effects of the flexibility of regulation are ambiguous: On the one hand, it means there is scope to search for innovative solutions rather than use costly prescribed technologies. On the other hand,

20. For a related discussion of instruments see SCHMUTZLER and GOULDER (1997).

flexibility might put insufficient pressure on management to change behavior in the desired way.

There are different possible extensions of the analysis: First, one can move away from the reduced form approach taken here and derive more primitive conditions under which firms are likely to benefit from regulation in specific settings. For instance, SCHMUTZLER (2000) shows that, when underinvestment arises from managerial myopia, innovations should have medium-size productivity effects for owners to benefit from regulation. On the one hand, innovations with very large positive productivity effects would have been introduced by the manager even without regulation. On the other hand, innovations with low productivity effects would be unlikely to be beneficial for the owners.

A second extension relates to the variability of output or price, in which case much of the present analysis carries over directly.²¹ The additional point with variable output consists in the fact, that even if innovations exist that reduce both production and abatement costs, environmental regulation might reduce the incentives to introduce such innovations. The reason lies in the existence of abatement costs that make lower output desirable and thus reduce marginal benefits from cost reduction.

Third one might consider the case that environmental regulations induce quality-enhancing investments. This would lead to an analysis analogous to the one above, so we did not pursue this line of thought any further.

The more general point of this paper is that it could be worthwhile for environmental economists to deal with the interior of firms. As we have seen in the discussion of the role of flexible environmental regulations, the existence of deviations from profit maximization might not lead to very different results than standard models. For instance, the present paper strengthens the view that flexibility of environmental regulations is desirable. Having more general robustness results of this type would be reassuring to assess the usefulness of environmental policy prescriptions.

21. The difference lies in the assumption of a profit-maximization instead of a cost-minimization.

APPENDIX

Under which conditions do environmental regulations induce beneficial innovation offsets in the case of strategic problems?

If only one firm innovates in equilibrium after environmental regulations are introduced, the innovating firm is definitely not better off than without regulation because of (A1). In principle, however, there could be an equilibrium where both firms invest after regulation is introduced, i.e. there exist $i_k \in I_k$ and $i_l \in I_l$ with $i_k, i_l \neq 0$ such that

$$C_k(0, i_l) - C_k(i_k, i_l) + R_k(0) - R_k(i_k) > F_k(i_k) \quad \text{and}$$

$$C_l(0, i_k) - C_l(i_l, i_k) + R_l(0) - R_l(i_l) > F_l(i_l).$$

This case would require complementarities between the different projects. In this equilibrium, both firms would end up in a better position than without regulation if for the relevant i_k and i_l

$$C_k(0, 0) - C_k(i_k, i_l) > F_k(i_k) \quad \text{and}$$

$$C_l(0, 0) - C_l(i_l, i_k) > F_l(i_l),$$

which is compatible with condition. In theory, therefore, environmental regulations could solve a coordination problem by destroying an inefficient equilibrium.

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SUMMARY

Michael Porter and others have recently argued that suitable environmental regulations are likely to induce cost-reducing innovations. We analyze under which conditions such arguments might be consistent with microeconomic analysis, and under which additional conditions the firms' benefits might exceed the costs. It turns out that this requires fairly specific conditions.

ZUSAMMENFASSUNG

Michael Porter und andere haben kürzlich die Behauptung aufgestellt, dass Umweltregulierung in vielen Fällen kostenreduzierende Innovationen auslöst. Im folgenden untersuchen wir, unter welchen Bedingungen diese Sichtweise mit mikroökonomischen Argumenten vereinbar ist, und unter welchen zusätzlichen Bedingungen die Nutzen für die Firmen aus der Regulierung die Kosten übersteigen. Es zeigt sich, dass sehr spezielle Bedingungen erforderlich sind.

RESUME

Michael Porter et d'autres ont avancé l'argument suivant lequel des réglementations environnementales provoquent souvent des innovations qui entraînent des réductions de coûts. Nous analysons ici sous quelles conditions cet argument s'applique également dans le cadre d'une analyse micro-économique, et sous quelles conditions additionnelles les bénéfices excèdent les coûts pour une entreprise. Il s'avère que des conditions assez spécifiques sont nécessaires.