Milieu en innovatie

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Summary

The following general question is posed in this study: is it possible to reduce pollution to levels that do not degrade environmental qualities at socially acceptable costs? More specifically, this study tackles the question: what is the contribution of environmental technology and how can policies foster the introduction and diffusion of environmental innovations? The findings suggest that currently available technologies can already reduce present pollution levels by 70% to 90%, which means that technological improvements and innovations to increase effectiveness are not absolutely necessary to prevent environmental degradation. The effectiveness of the available technologies is not the main barrier to compliance with strict, environmental standards. The main problem is that costs involved in reducing pollution increase at high-percentage, pollution reduction.

The empirical data on material and resource use suggest that technological progress enables a reduction of use per unit of product and reduces the costs of use; pollution reduction being an indirect effect of the progress. As a result, resource prices decrease due to more efficient use. In analogy, it can be expected that it is possible to reduce pollution and pollution control costs per unit of product due to environment-oriented, technological progress. The problem is how to attain that progress. The scholars that follow the mainstream economic theory argue for higher price on pollution, which certainly encourages pollution reduction, but it is not the only factor that drives innovations, possibly not the major one. Based on evolutionary theory, it is argued that economic development is reinforced by a polluting pattern of technological development (path-dependency). Therefore, policy needs to create favourable conditions to break out of the current pattern that is often described as locked in. However, this interesting view has not been able to provide concrete guidelines for environmental and technology policies on how to do it.

This study focuses on decisions made in companies. On one hand, we find companies that cause pollution through materials and resource use (pollution sources). These are potential demanders of environmental technologies. On the other hand, there are suppliers of environmental technologies; both add technologies and integrated technologies. The suppliers research and develop innovative technologies and improve the existing ones. The improvements are adaptations of the available technologies whereas innovations are new technologies due to efforts in research and development.

The starting point in the study is the observation that external pressures invoke demand for environmental technologies, for example, through stricter environmental policy or by liability, whereas the suppliers realise new equipment only when they expect good possibilities for sales. The demand is central in our approach. Following that, we analyse what conditions favour environmental innovations that include reduction of the uncertainty about the costs of environmental policies and attractive innovations, strategies in decision-making on innovation and investments, methods of policy interventions and negotiations between stakeholders.

Environmental innovations to reduce costs

Presently, authorities prepare environmental standards based on proven environmental technologies. They take the costs of technologies into consideration because polluting companies should not be confronted with excessively high costs. However, the question remains: how can these costs be assessed during policy preparation if the companies are reluctant to apply the technologies before implementation of the standards and taking into account the fact that costs expand at high percentages of pollution reduction. The current preparation of environmental standards entails an inventory of possible technologies, selection of a few types of environmental technologies that are expected to be useful, followed by a number of demonstration projects to assess pollution reduction and costs at selected pollution sources. The standards are based on measurements at the selected sources and implemented in permits at many other sources. This is done on the assumption that the measured values at the selected sources are valid for those at many others. This process of policy making is expensive. It costs about 15% of total pollution control costs, growing twice as fast as all costs in the period 1980-1996, whilst it remains difficult to assess the costs for each single pollution source.

However, experience shows that the costs per unit for pollution reduction vary strongly at different sources. The costs of environmental technology depend very much on the type of pollution sources. At some sources the costs are manifold higher than at other ones. It is not certain at all that the demonstration projects provide cost data that are normative for many other sources. Yet despite this uncertainty, policy-makers must be capable of constructing marginal, pollution–control, cost functions for each problem that indicate the costs at various sources. The cost function is usually constructed from a combination of technologies with emission sources in ascending order of pollution control costs per unit of emission reduction

In chapter 3, we try to develop a method that enables one to estimate an increasing cost function with the help of a few empirical data. This is done per type of pollutant with a set of combinations between environmental technologies and pollution sources. Based on empirical data, we found that the cost functions can be defined by a formula $cr_{i+1} = cr_i * e^{kcr}$, where cr_i and cr_{i+1} are the costs per unit emission reduction for each combination in ascending order. The co-efficient kcr (as an exponent of natural logarithm) determines how steeply the costs increase. The co-efficient can be accounted for using the help of a few measurements, that is, by measuring the combinations with a very low marginal cost and those with a very high cost. Thus defined, cost function indicates how the marginal pollution control costs are distributed between various sources, albeit it does not link pollution reduction with the costs. To define the cost function, we need information about the number of possible source-technology combinations and cost at two combinations. These are the combinations with the lowest and highest marginal cost. With the help of the co-efficient, the test with 28 empirical cost functions has shown that the increase of cost per unit of emission reduction can be estimated for 27 cost functions with accuracy greater than 0.9 ($R>0.9$). Thus, it can be accurately estimated how the cost functions expand at increasing pollution reduction percentage. This is useful to assess the effects of economic instruments like charges or tradeable emission rights on costs. This lead to the conclusion that we can assess how sharply marginal costs will rise in cases of stricter standards.

We need much more information to construct the cost function that aims to link costs at individueal sources with percentage pollution reduction: we need the order of each combination and need to relate the order with total emission reduction. If this information is available then the estimated total costs deviate less than 30% below or above empirical data for 21 out of 28 cost functions. However, it is not possible to assess the cost at the invidual sources unless data are provided about the relation between costs and the scale of pollution reduction for many combinations in a set (in addition to the information about the combinations with lowest and highest marginal cost). This is difficult because we found no clear relation between scale of operations and marginal costs because costs depend on process conditions and product qualities. The results based on analyses of empirical cost functions imply that policy cannot forecast the pollution control costs at various sources caused by stricter environmental standards, as there is not enough information. It is only possible to assess the steepness of the cost function. This support the assessment of how much pollution can by reduced by a higher pollution price, for example, through a charge. Somewhat better cost approximation is reached for the sets with one type of technology and one type of process (homogeneous set), but there are still large differences between the empirical and assessed data because of varying resource and product specifications. The pollution control costs caused by stricter standards are largely determined by the possibility of matching environmental technology with specific process and product characteristics at the sources.

In chapter 4, we assess the areas for which it is worthwhile to put costly efforts into development of environmental technologies in order to innovate. This is done on the assumption that a large cost advantage to pollution sources indicates good sales opportunities. We distinguish between two types of progress in environmental technology: improvements and innovations. This distinction is relevant for investors and policy-makers because improvements are usually low cost and they can be invoked using stricter standards, whereas innovations need large investments in research, development, demonstration and sales that are usually heavily subsidised by authorities. In case of improvements, we assume cost reduction at the sources that make low costs if they apply available technology to comply with stricter standards. For innovations we assume cost reduction at the high-cost sources (that probably remain untouched by environmental policy because of cost considerations). We show that improvements are advantageous for the moderately steep cost functions which occurs in situations with technical alternatives that match with specific product- and process conditions. Vice versa, the innovations provide advantages in case of sharply increasing cost functions.

In this chapter we simulate how the co-efficient's size relates to cost reduction through innovations and improvements. The simulations are based on empirical cost functions described in chapter 3. The results show that innovations are attractive for the cost functions with an exponent larger than 0.25, whereas improvements are attractive in cases of less steep cost functions. Hence, the steepness of the cost function that is measured by the co-efficients indicates whether or not it is advantageous to put costly efforts into development of new environmental technologies in view of the future's stricter environmental standards. It is assessed that some environmental demands can be covered by improved available technologies because there are low-cost alternatives. Here, limited sales of innovations should be expected. This holds true for acidification by NOx and SO_2 emissions and reduction of fine dust. In this field, improvement is the most attractive supply strategy. The cost advantages for pollution source due to innovation can be found in new areas of environmental policy with limited alternatives such as pollutant-specific emissions (so-called POPs) and renewable energy to reduce CO_2. In these fields many opportunities for sales of innovations can be found. The assessment indicates that there are enough opportunities for sales of innovations to cover all annual expenditures connected with realisation of a new technology. It also suggests that it is often economical to foster improvements rather than embark on sponsoring new technologies.

In view of exponentially increasing pollution-control cost functions, the question remains: what are the effects of stricter environmental demands on productivity if progress in environmental technologies is taken into account? Much research has been done on the effects of environmental policy on productivity. It is argued that the negative effects dominate because environmental technology is assumed to be costly without contributing to companies' results. However, this argument does not consider the positive side effects of stricter environmental policies, such as lower energy and material use, increased export of environmental technology and improved quality performance in companies. As a result, many empirical findings indicate a slightly positive outcome or slightly negative effects. If cost function is strongly increasing then the negative effects predominate, but in reality there are cost-saving improvements and innovations as well. The decision-making process in which managers must balance environmental issues against many other issues included in companies' strategies can explain the finding that companies often do not use the most cost-effective options. Limited attention for cost-saving, environmental technologies in companies can be explained by the managerial focus on other topics assumed to be most important for corporate operations, such as a preoccupation with labour costs. Other impediments for good environmental management includes the high costs involved in obtaining information, negotiations with suppliers, uncertain future prices and so on.

The effect of a stricter environmental policy on companies' costs and results largely depends on the policy incentive to develop environmental technologies and companies' strategies vis-a-vis the policies. We illustrate this in chapter 5 using a model for environmental strategies. In the model, a company can decide to comply with demands through available technology that can cause high costs at strict future demands or it can anticipate strict future demands using innovations. The innovations are often not economical in the short-term but they can become attractive over a longer period of time. In cases of strict demands, innovations provide cost advantages in comparison with available technologies. However, anticipation by innovations is not economical when policies aim at moderate demands.

A flat, pollution-control, cost function is realistic. Empirical studies into environmental techniques suggest the cost-saving technological progress of 3% to 7% a year, which flattens all cost functions. It means that the progress of environmental technology is sufficient to limit the adverse effects of strict demands on pollution control costs. As a result, environmental innovations and improvements temper the negative effects of environmental policy on productivity. Using both statistical analyses and cases, our empirical studies support this argumentation. The statistical analyses of pollution control costs of acidification reduction and effluent treatment in several industrial sectors show that the costs per unit pollution reduction during the period 1980-1996 decreased with a gradually increasing pollution reduction percentage in the sector. In particular, the sectors that can anticipate stricter demands by new processes and products are capable of reducing the costs. These sectors have achieved on average 6% to 11% annual cost reducing technological progress. Case studies of companies suggest that the anticipation of stricter standards by environmental innovations in many cases contributes to corporate results. In addition, there are numerous opportunities to reduce pollution-control costs in the life cycle of products, which prevents an increase of consumer prices. Assurance of strict demands in the future largely determines cost-reducing innovations that flatten the pollution-control cost function.

There are technological possibilities to minimise the pollution-control costs of environmental policy with positive side effects on productivity. This can be achieved if demands are stringent and implementation is probable enough to invoke anticipation strategy by environmental innovations. It is economical to comply with available techniques without costly innovative efforts if companies deal with moderate demands. However, in the longer run, this policy causes unnecessary high compliance costs as it does not foster cost-saving innovation. There is a threat of creating a vicious circle in environmental policy because the social perception of high pollution-control costs enlarges resistance to the introduction of stricter demands that in turn impede efforts in environmental innovations and improvements. Far-reaching pollution reduction is not so much a technical problem, but rather an socio-economic and political question on how to formulate policy that triggers polluters to anticipate stricter demands and suppliers to invest in environmental innovations.

Conditions for cost-saving environmental innovations

The conditions that favour cost-saving innovations are discussed in chapters 6 and 7; first demands imposed on industries by authorities are discussed and then the demands put forward by private organisations are examined.

The present environmental policy imposes demands that are based not only on environmental criteria, but also take policy objectives and costs at pollution sources into consideration. The course of action in policy preparation is an inventory of available technological options followed by the selection of effective and low-cost alternatives. Policy preparation aims at authorisation of a standard or an agreement (a covenant) that is possible to attain with the help of available technologies. Strict demands that invoke environmental innovations are not a common practice, but vice versa, the availability of effective and cost-saving techniques enables the policies to prepare and authorise stricter demands. This is seldom recognised in studies looking at the effects of environmental demands on innovations. Scholars usually assume that strict environmental demands invoke innovations and focus on effectiveness of various instruments, particularly the comparison of direct regulations with economic instruments. In this book, we take the currently dominant practices for granted; that is environmental standards in direct regulations or agreement in covenants made during the last few decades. One needs to ask the question: what are the effects of current practices on the preparation and implementation of environmental policies and what are the suitable conditions for innovations in the course of policy-making?

The procedure to set an environmental standard takes many years; usually about six years are needed to reach a covenant agreement and more than eight years for authorisation. In this period, innovators must demonstrate the costs and effects of their new environmental technology in order to enter a shortlist of applicable technologies. The innovator must realise and demonstrate the technology at an early stage of policy preparation and then wait until a standard or an agreement is set. After the standard is set, it is implemented at various pollution sources through the installation of pollution-reducing equipment. Implementation also takes many years. During this period, the innovator must patiently watch sales as polluters are generally not eager to procure the equipment and usually only due so under pressure by an enforcing authority. The consequence of the waiting time linked to policy preparation and then gradual implementation of the standards is that costly efforts in research and development become less and less attractive as the present value of future sales revenues decreases over time. As the waiting time elongates, the present value is depressed and ultimately it does not offset the costs. Moreover, a long preparation and implementation period makes sales increasingly uncertain. The innovators must take into account an implementation process that is also tempered by decisions to integrate pollution controls with capital investment and by the division of competence between various authorities. Uncertainties are expressed by a higher discount rate that depresses the present value even further. We have assessed the revenues from sales of innovations in The Netherlands with help of the data in pollution-control cost functions that are presented in chapter 4. Under realistic assumption of 8 years waiting time, gradual implementation of demands over 15 years and a 10% discount rate, we have found that the present value of the new technologies' sales revenues hardly covers the costs currently made to develop the environmental technologies. The simulations suggest that it is generally not profitable to innovate under the current course of policy preparation and implementation although the potential market for sales is large enough, unless policies provide subsidies to the innovators. This result is caused by a long waiting period, sluggish implementation and uncertainties.

Making some changes in the course of policy action can create better sales conditions for environmental innovations. These include timely announcement and assurance that strict demands are going to be prepared and authorised, followed by fast implementation. Covenants have an advantage at the policy preparation phase because they shorten the waiting time, but implementation is uncertain. Economic instruments can achieve fast dissemination of environmental innovations during the implementation period. In general, the instruments that put a price on emissions foster investments in cleaner technologies, but policy preparation can be time-consuming because of social resistance to effective, environmental policy.

An alternative policy to invoke cost-saving innovations is self-regulation that involves negotiations between interest groups. In the case of self-regulation, the authorities' task is to create conditions for the negotiations between interest groups on pollution reduction, for example, an appropriate legal framework to set and enforce agreements. The expectation based on the Coase theorem can be that the division of property rights between pollution sources and harmed groups invokes negotiations between these two interest groups, which result in an optimal level of pollution reduction. However, the result of self-regulation largely depends on the basic preconditions for negotiations. One basic precondition is that only a few interests are directly involved in the negotiations in order to limit the transactions' costs, another one is that each negotiator can enforce its own interest, for example, by bringing the case to court. A supplier of environmental technology can also be an interest group in the negotiation process or it can participate as a third party by providing technologies that can comply with demands. It can also create an agreement on the development of effective or cost-reducing technologies. Self-regulation can be advantageous compared to time-consuming direct regulation due to faster agreements on the installation of cleaner technologies. This can foster innovations.

A limitation of self-regulation is that the basic conditions for effective negotiations rarely exist in reality. If the negotiations take off, they usually involve several negotiators who are expected to represent various interests, often without the commitment of the interest groups they represent. Thus, it is uncertain whether or not the negotiations provide results that are acceptable to various interests. It is also uncertain if the agreement will be implemented. The uncertainties impede innovations. In addition, there are high transaction costs. Although this market-based approach can potentially foster innovations, in practice, only minor adaptations are attained because of the negotiators' conflicting interests and unclear commitments by interest groups. This is illustrated by studies on negotiations in the packaging chain. It has been shown that a great deal of costs can be lowered and much packaging waste reduced in the chain due to innovations, but various interests in the chain have totally different perceptions about the feasibility of innovations. The differences are so large that agreement about priorities is difficult to reach, not to mention joint investments.

The possibilities to foster innovations through self-regulation are simulated in a model for negotiation between three interests: harmed groups, pollution sources and suppliers of innovations. The latter two interest groups must deal with uncertainty about the harmed groups' demands. In addition, the suppliers are confronted with uncertainty about the pollution sources' willingness to buy innovations or use available technologies. The conclusion is that the advantage of a shorter waiting time due to self-regulation is limited by the disadvantages connected with uncertainties about sales revenues. An innovation's advantage above available technology can be expressed by innovation-rent, that is, the sum of the cost advantage of pollution sources and the profit of suppliers. The uncertainty is expressed by a higher discount rate. Based on the negotiation model, it is simulated which policy instruments help foster innovations under self-regulation. This is done on the assumption that a large innovation-rent is a strong incentive to realise innovations. The simulations suggest that the innovations are feasible if the demand for pollution reduction among harmed groups is strong and reasonably certain. This makes procurement of innovation by pollution sources arguable. Hence, policy instruments that assure demands are most effective in support of technology development and sales; these are primarily emission rights, liability and take/bring-back regulations. The instruments to attract procurement of innovations also foster development of new technologies (like purchase- and quality guarantees), but they are somewhat less effective. The simulations also show that subsidies provide little support to innovations. A subsidy for research and development is the most effective one. The assessment of the innovation-rent under self-regulation based on empirical pollution–control cost functions (presented in chapter 4) is done on the assumption of no waiting time, compared with a waiting period of four to eight years in direct regulations. The result is that environmental innovations remain profitable at a discount rate that is more than 7% higher than the discount rate under direct regulation. The conclusion is that innovations under self-regulations are only possible in cases of reasonably certain demand for pollution reduction.

This study set out to examine whether or not it is possible to reduce pollution substantially at socially acceptable costs. The answer is positive. The available environmental technology is effective to tackle many environmental problems. The cost can be reduced by steady improvements in the available technologies based on experiences during use at various pollution sources. Cost-saving innovations can be invoked by stringent, environmental demands. The precondition is certainty about introduction of the demands and incentives to speed up implementation. Environmental policy that embarks on innovations and improvements is capable of steadily reducing pollution at hardly any additional cost and in many cases at net cost savings.