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Discussion Paper

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Environmental Policy Intruments and their Effects on Innovation

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ZEW

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Environmental Policy Instruments and their Effects on Innovation

by

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Summary

The influence of environmental policy on innovative behaviour of companies has so far recieved little attention in scientific discourse. Based on recent literature, the paper analyses the impact of requirements, levies, permits, liability laws, and the EC-eco-audit regulation with respect to the generation of environmentally benign innovations. Most theoretical studies come to the conclusion that direct requirements provide little incentives for dynamic effects and that emission taxes and permits are better instruments to promote innovations. However, the empirical studies show that the dynamic effects of environmental policy instruments in practice partly differ from the ideal instruments analyzed in theoretical studies.

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[1] Forthcomming in European Planning Studies. The article is based on a ZEW/SEO-study commissioned by the European Commission, DG XII (cf. HEMMELSKAMP et al. 1995).

1 Introduction

Environmental pollution caused by human beings has always been a considerable problem in Europe. In the Middle Ages, for example, rivers and lakes were contaminated because faeces of humans and animals were dumped into them. These water reserves served as drinking water reservoirs at the same time, so that illnesses (e.g. the plague) were able to spread easily and to take on epidemic proportions. Technical innovations in the course of the industrial development helped to improve these conditions. The invention of the steam engine, for instance, made it possible to get clean water from deep wells and to supply the population with uncontaminated drinking water.

At the same time, however, it became clear that technical progress can create new or solve and reduce existing environmental problems. Parallel to increasing industrialisation, the development of modern technologies and the ever-more intensive use of the environment, new environmental and resource problems were created, since the environment was the supplier of non-renewable and renewable natural resources, the direct recipient of pollutants from the production process and the indirect recipient of pollutants generated by product distribution, use and disposal (cf. FABER et al. 1983; DUCHIN/LANGE 1994; KEMP/SOETE 1990).

Therefore "some people regard technological developments as one of the greatest threats to nature and the environment. Others, by contrast, see them as a possible salvation" (WETERINGS/OPSCHOOR 1992:3). If the latter are right, then technological progress must result in companies being able to generate innovations which make it possible to:

- come up with new possibilities for the substitution of natural resources,
- reduce specific impacts on the environment,
- improve resource productivity or
- improve the reversibility of environmental damage.

Issues related to innovation research have been examined in a host of studies during the past few years. The emphasis was placed, amongst other things, on investigating innovation objectives or measuring innovation success. Little attention has been paid to the impact of environmental policy instruments on innovation. This article explores whether the effects of environmental policy instruments on innovation analysed in a merely theoretical manner differs from results of empirical studies. The paper begins in Chapter 2 with definitions. Chapter 3 analyzes the dynamic effects of environmental policy instruments. The Chapter 4 presents some empirical studies firstly concerned with the influence of specific environmental instruments on innovations and secondly dealing with industry-specific effects of environmental policy. Chapter 5 presents some conclusions.

2 Some Definitions

In political and scientific discussions the term "innovation" is interpreted in many different ways. If a narrow definition is chosen, innovations merely denote technological novelties. Used in a broader sense, innovations refer to novelties resulting in the first-time application of newly acquired know-how, of new methods or new products as well as to novelties where no new technologies are used, but where, for example, only changes in the product design are made. So the definition of "innovations" is a very personal one and consequently it is hard to come up with an exact delimitation in empirical studies. Following the OECD'S Oslo-Manual (1992), product innovations are taken as meaning creation of new, hitherto unknown or fundamentally altered products (basic innovations) and improvements concerning product quality (incremental improvement innovations). Process innovations refer to a company's gradual shift to new or substantially improved production methods, i.e., methods making it possible to produce a given quantity at a lower cost or a larger quantity at the same cost.

On the basis of the general description of the term "innovation" environmental innovations can be defined as innovations which aim at reducing the negative environmental impacts caused by production methods (process innovations) and products (product innovations). Environmental innovations serve to:

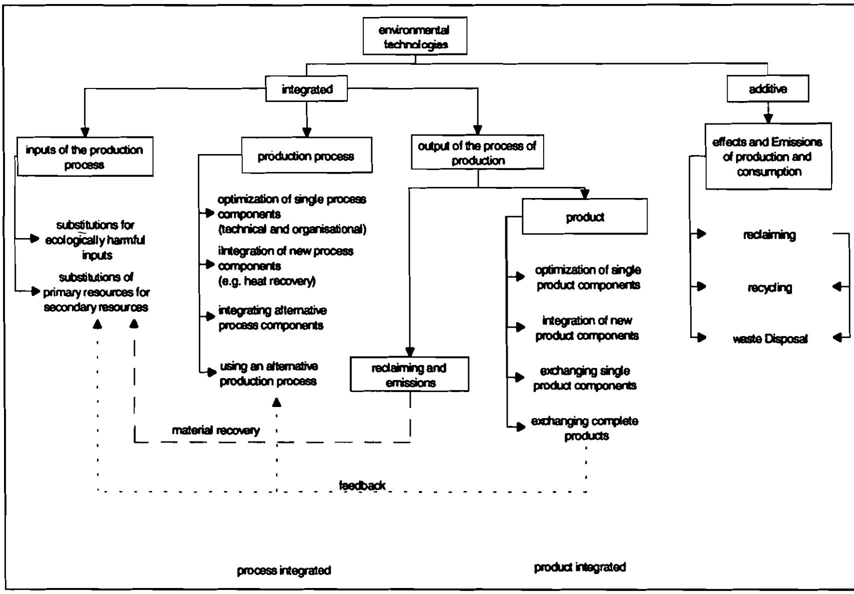
- avoid or reduce emissions caused by the production, use or consumption and disposal of goods,
- reduce resource input,
- clean up environmental damage done in the past,
- identify and control pollution.

Environmental technologies in the field of production-related environmental protection can basically be subdivided into two lines of development (paradigms): end-of-pipe technologies and integrated technologies (cf. Figure 1).

Additive or end-of-the-pipe technologies are disposal methods and recycling technologies that follow the actual production and consumption process. They dispose of or modify the gross accumulating emissions in such a way that they become less polluting or less environmentally-harmful or can be better stored, but there is no emission reduction in terms of quantity.

Instead, what is triggered off is a shift of emissions to an environmental medium which is not yet subject to regulations and is still classified as a medium able to stand emissions, for instance soil (disposal depots) or water. With regard to innovations, end-of-pipe-technologies only call for incremental improvements of the original production process, not for fundamental changes in the production process.

Figure 1: Overview of environmental technologies



Source: HOHMEYER/KOSCHEL 1995:6

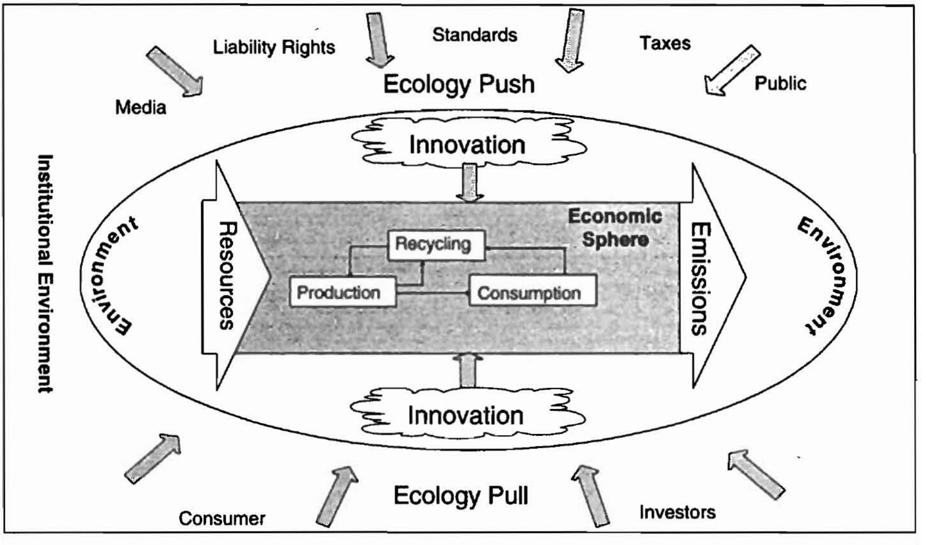
Unlike additive solutions, integrated environmental protection starts directly at the source of the emissions, i.e., at the production process or at the product. It comprises all measures that lead to a reduction in input materials, energy input and emissions during the process. This includes reducing or replacing environmentally-harmful inputs by environmentally-friendly inputs (e.g. solvent-free lacquers) or producing more environmentally-friendly products that release less noxious residual substances. By applying "clean" production methods that use less input materials or generate less residual substances (e.g. by optimising individual process components or by taking technological measures such as energy-saving process control systems) integrated technologies are able to achieve emission reductions across the board.

In addition to that HARTJE (1990) describes a cross between end-of-pipe and integrated technologies which includes recycling technologies that are integrated in the production process and make it possible for part of the emissions generated in the production process to be used directly as manufacturing supplies. However, in the following this hybrid form is subsumed under integrated technologies.

3 Innovation effects of environmental policy instruments

The scale and direction of a company's innovative behaviour is generally determined by a large number of supply and demand factors. Theoretical and empirical studies on the factors of influence primarily deal with their effects on innovations in general (cf. inter alia MAAS 1990; SCHWITALLA 1993). So far the literature on economics has given comparatively little attention specifically to the determinants of environmental innovations (cf. BECHER et al. 1990). Various external factors can be identified as triggers of environmentally-friendly innovations in companies (cf. Figure 2).

Figure 2: Factors determining environmental innovations



Social and market-related groups are intensifying their demands that companies behave in an increasingly environmentally-sound manner. On the one hand, such "ecology-push-factors" consist of government environmental policy instruments that confront companies with requirements (e.g. standards) that have to be met or with levies. On the other hand, they include demands made by residents pressing for, for example, a reduction in the emissions released into the atmosphere or in the noise level or demands made by environmental groups choosing certain environmental problems as a central theme and calling on companies to rectify the situation. Market-related groups (customers, consumer associations, wholesalers/retailers, investors) as "ecology-pull-factors" may find fault with excessive product packaging and demand that the packaging be taken back or investors may demand that companies comply with certain ecological standards[2] .

Most companies are still characterized by passive environmentally-oriented behaviour that consists of adapting to environmental legislation or regulations (cf. inter alia CARRARO/SINISCALDO 1994; Williams et al. 1993)[3]. The actual effects depend mainly on the environmental regulatory instrument that is applied. Regulatory instruments in terms of environmental policy can be subdivided into two categories:

- Non-market solutions in the form of juridical commands and bans that merely differentiate between admissible and inadmissible use of the environment.

- Instruments conforming to the market that indirectly control the economic process by means of the information and control function of prices. They include, among other things, permits, levies, subsidies, compensations, residual pollution levies or the privatisation of environmental media.

The effects of environmental policy instruments are assessed in the relevant literature by applying various, sometimes different criteria. ENDRES (1985), for example, analyses an instrument according to the criteria "efficiency" (minimal cost to achieve emission objective), "ecological accuracy" (ecological attainment of the objective) and "dynamic stimulating effect". The criterion of a dynamic stimulating effect means that the following question is examined: To what extent does an environmental policy instrument provide an impetus for the development and introduction of progress in terms of environmental technology? In the process as a rule only the effect of the instrument on the reduction of a specific pollutant is taken into account. The sort of technology, i.e., the distinction between additive and integrated environmental protection is usually not considered (cf. HOHMEYER/KOSCHEL 1995).

In the economic process environmental policy instruments may in principle "lead firms to adopt existing cleaner technologies which are not currently used ..." or they stimulate "firms' R&D through which new environment-friendly technologies can be developed" (CARRARO/SINISCALDO 1994:549). The companies have three innovation options to choose from:

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[2]Reference should be made to the so-called ethics or eco-funds, which guarantee the investors compliance with certain standards.

[3]Although other factors of influence, environmentally-oriented consumer behaviour in particular, are increasingly important, their influence is still comparatively modest and restricted to certain industries. Having said that, the influence exerted by eco-labels shows that consumers are increasingly attaching importance to environmentally-friendly products and production methods. For instance, a study by BROCKMANN et al.(1996) proved that certifying sustainably-grown tropical timber causes sales of products made of this raw material to go up.

- replacing input factors (by less scarce or by renewable resources or by inputs that are less harmful to the environment),

- enlarging the existing or planned installation by means of an end-of-pipe-technology i.e., the production method remains unchanged,

- the partial or complete replacement of an old installation by a new technology integrating environmental protection, which makes it possible to economize on resource inputs and/or causes less emissions.

In the following, by way of example, five instruments - requirements, levies, permits, liability law and the eco-audit-regulation- will be analysed on the basis of the existing theoretically-oriented literature and an evaluation of these instruments regarding their effects on technology will be made.

3.1 The effects requirements have on innovation

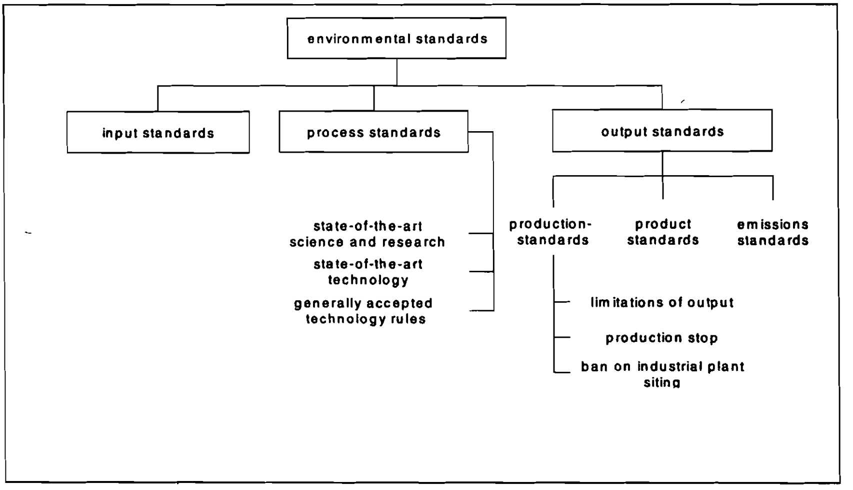
Environmental requirements in the form of commands and bans are regulations directly related to the environment with the help of which certain environmental objectives are meant to be achieved (cf. Figure 3). They are generally complemented by rules of conduct for authorities. For example, emission requirements state limits which may not be exceeded and serve as a basis for the environmental protection authorities when they grant a permit for new installations or issue retroactive directives for existing ones. Commands seek to reduce certain environmental impacts, whereas bans stop certain activities. Compliance with these provisions is checked by the government and failure to comply is penalised.

With regard to innovation generation a theoretical analysis with the help of a model of environmental standards and requirements STEPHAN (1987) showed that these instruments provide incentives to innovate and to introduce new, environmentally-friendly technologies. However, the effect, i.e. the extent, the speed of implementation and the nature of the environmental measures, depends, as Stephan points out, on the adaptability of the production system.

Usually technological progress is based on improving efficiency in the field of end-of-pipe-technologies. There is largely a consensus among researchers that the influence requirements have on progress concerning environmental technology is minor (cf. on this and the following remarks inter alia: FABER et al. 1989; ENDRES 1987; HANSMEYER/SCHNEIDER 1990; WALTER 1989). But CORFEE-MORLOT/JONES (1992:17) commented, that "`command and control` systems do not always have negative impacts on technological progress. For example, regulatory `bans` have sometimes `forced` the development and penetration of new pollution control technologies".

However, mostly it is pointed out that requirements constitute the most expensive option with regard to environmental policy instruments, since all polluters are treated on an equal basis, irrespective of their individual avoidance cost structure. Thus, economic efficiency can only be achieved with this instrument in the (unrealistic) event that the marginal avoidance costs of all affected emitters are the same.

Figure 3: Overview of environmental requirements



Source: FABER et al. 1989.

Compared with other instruments, requirements are considered to be rather innovation-impeding, since residual emissions, i.e., emissions below the fixed level, do not result in costs for the emitter and consequently the emitter is no longer interested in more far-reaching emission-reducing measures. Such an incentive would only exist if through innovations in the field of environmental technology which decrease operating cost, emissions would fall short of the limit. This, however, could turn out to be a disadvantage for companies. The reductions achieved could indicate to the authorities that further emission reductions are technically feasible and further tightening of the requirements possible, so that other installations, too, have to comply with the more stringent requirements and further costs ensue (cf. WEIMANN 1991; GEORGE et al. 1992). If, as is typical of the German-speaking area, requirements hinge the permit to exploit the environment on compliance with certain technical standards (as a rule, process standards based on state-of-the-art technology[4]) to thus make new installations adapt to technological developments and to dynamise the effect of instruments,

[4]ENDRES (1987:61) describes "state-of-the-art technology" as " [...] an advanced method of emission avoidance whose applicability must be ensured and of which the regulation-issuing authority must have knowledge".

this has a formative influence on technological progress. The technological standard has to be complied with by all emitters and therefore a tightening of standards makes a steady development of new and further development of the applied technologies possible. Since, however, the companies' individual costs and different adaptation intensities are not taken into account and marginal costs of avoidance rise as efficiency improvements increase, the inefficiency of the measures also increases over time.

The threat of more stringent requirements and of an updating of state-of-the-art technology may also lead to "chartered rights to pollute" for a given installation being taken advantage of as long as possible. For instance, the construction of a new production installation may be subject to lower limiting values or to new technology standards that have been adjusted to the current level of development, and thus entail additional costs. New installations and hence innovations will not be used until the cost advantages for the polluter gained from "technological progress" exceed the cost disadvantages resulting from more stringent provisions on emissions. That is why WEIMANN (1991) calls requirements an instrument which slows down structural change towards more environmentally-sound technologies.

Furthermore, issuing an ordinance defining state-of-the-art technology and its updating require a lengthy procedure, because information on the advanced methods being applied has to be compiled and the general applicability of new methods has to be discussed in consultation with experts. Hence, an efficient policy of requirements presupposes knowledge on the part of the authorities of numerous products and activities linked to emissions. The administration would have to know all possibilities of bringing about reductions, calculate a policy of avoidance with minimal cost and prescribe the appropriate requirements. Finally, changes in these data would constantly have to be taken into consideration and provisions that have been issued would have to be checked. Therefore, state-of-the-art technology may have lost some of its progressiveness by the time its introduction is binding or, as ENDRES (1987:62) remarks, instead of being "today's state-of-the-art technology" it may rather "correspond to the colloquial expression `yesterday's state-of-the-art technology`".

With respect to innovation, a direct intervention by means of environmental policy which seeks to bring about a technological adjustment by determining reference systems in the form of "state-of-the-art technology" promotes technological progress through a reactive adjustment to established standards, but no dynamic technological progress. This effect is intensified by the need of the authorities, due to the already described lack of information and the deficits concerning decision-making and amendment, to define "state-of-the-art technology" in cooperation with the emitters. Therefore, the effect on innovation is limited in so far as for the emitters involved in the decision-making process state-of-the-art technology is an endogenous quantity, i.e., it is to be expected that the cost of emission avoidance and of changes in "state-of-the-art technology" will be taken into account by the emitters involved and that consequently no tough demands will be made (cf. on this inter alia WEIMANN 1991; HEISTER/MICHAELIS 1990).

Besides, as juridical measures increase in number, there are ever-more enforcement problems which lead to companies exceeding the stipulated emission ceilings due to the low risk of inspection and to minor penalties. As a result, the effect on innovation is weakened.

Owing to the weaknesses of juridical instruments, the exploitation of the market's technological development dynamics and the use of corresponding regulatory instruments is pushed. In Denmark negotiations and agreements between the authorities and industry with the aim of lessening specific environmental problems have been introduced as a new regulatory instrument (cf. GEORGE et al. 1992). In particular the introduction of environmental taxes and charges ranks high on the academic and political agenda. In the Netherlands "covenants" are an important regulatory instrument and the "political debate about taxation and environmental policy has intensified" (OECD 1994:31). In Norway and Sweden, for example, CO_2 taxes were introduced in 1991 (cf. HAUGLAND et al. 1992) and in Germany new environmental taxes are recommended as a more efficient solution (for an overview of the German discussion cf. for example, KOSCHEL/WEINREICH 1995).

3.2 The effect of environmental levies on innovation

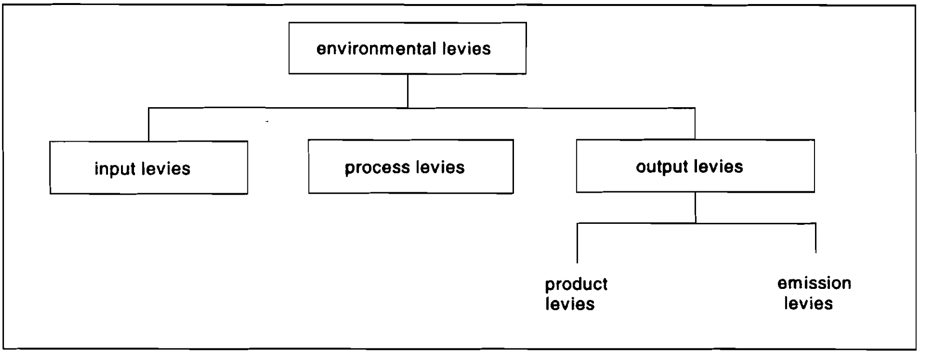
Environmental levies are defined as payments the government demands in order to tackle environmental issues. Environmental taxes, environmental charges and contributions and special environmental levies are subsumed under the generic term environmental levies (cf. on this HOHMEYER/KOSCHEL 1995).

Unlike juridical solutions environmental levies do not prescribe binding standards, instead, by means of a fixed price for the exploitation of the environment they may serve to provide revenue to the government to fund environment-related measures on the one hand, or may on the other hand, aim at offering a financial incentive for voluntary and individual adaptations to prevent or reduce environmental impacts. Amongst other things, the emission level, input and product output are used as bases for assessment (cf. Figure 4).

Unlike juridical measures, levies make an allocation possible that is efficient in terms of the overall economy. Each emitter can assess in accordance with his individual marginal avoidance costs, to what extent he will take environmental protection measures. He will respond by adapting if the necessary investment is more cost-effective than the payment of levies. The liability to pay the costs encourages the search for solutions that keep costs, levies and the exploitation of the environment as low as possible, i.e. as a rule it encourages directly environment-conserving technological progress, which reduces both emissions and pollution (cf. CORFEE-MORLOT/JONES 1992). The bigger the cost advantage, the greater the incentive to invest in new technologies.

In real life levies are used in environmental policy with a view to attaining a set political objective (standard-price-approach). However, fixing the rate of levies through a political process is hardly possible. The establishment of an incentive-efficient rate of levies presupposes information on the marginal avoidance costs of all polluters, information which in real life does not exist. Consequently, the rate has to be fixed according to a trial-and-error method, thus creating the danger that excessively high rates tie up capital which can no longer be employed for R&D activities. Excessively low rates, on the other hand, may result in existing and economically desirable methods never becoming competitive (cf. WEIMANN 1991).

Figure 4: Overview of environmental levies



Source: FABER et al. 1989 (modified)

3.3 The effects environmental permits have on innovation

Environmental permits are issued by a government authority and may be traded among companies. Each permit consists of an emission entitlement limited in terms of quantity and period of validity, allowing the owner to emit pollutants in specified environmental media. The sum of the issued emission entitlements is equivalent to the total volume of emissions the government wants. Permits - just like other environmental policy instruments - thus require knowledge of the desired goals in terms of environmental quality and hence knowledge of the total emissions permissible. In particular in the area of prevention of air pollution government authorities have built up such knowledge during the last twenty years. For sulphur dioxide and other air pollutants emission reduction goals can be deduced for European countries. In other areas, however, such as waste or soil contamination, there is a lack of information. Here, there is a risk of issuing too many permits and therefore of limiting the ecological effectiveness and of generating only minor innovation impulses.

The trading of permits leads to the formation of a price, reflecting the scarcity of the environmental medium and, if the market is in equilibrium, also the marginal avoidance costs for each individual emitter and for the overall economy (Laffont/Tirole 1994). Emitters whose marginal avoidance costs are lower than the market price of the permits will reduce emissions until permit price and marginal avoidance costs correspond.

Permits produce - in analogy to the levies described above - a permanent innovation incentive and thus incentives for technological improvements. Permits that are no longer needed owing to the introduction of new emission-reducing technologies can be sold in the marketplace. Emitters with marginal avoidance costs above the market price of permits legalise their emissions by buying permits. The avoidance behaviour of the emitters always changes in accordance with the price for a permit. Ultimately, the market price will find its level and will roughly correspond to the aggregate economic marginal avoidance costs.

Marginal avoidance costs, however, are not permanently fixed, rather, they may be changed due to technological progress. New, more efficient and cheaper avoidance technologies may be introduced or emission quantities may decrease by further developing production installations or substituting inputs while (production) output remains unchanged. In connection with increased avoidance activities and the further development of technologies, however, demand for permits declines and hence their price deteriorates, so that in a unchanged ecological framework the dynamic incentive provided by this instrument is lost in the long run (LAFFONT/TIROLE 1994). Technological progress is therefore produced through permits if a certain emission standard can be achieved with new technologies at lower overall costs (see inter alia Endres 1985 and 1991). However, dynamic emission reductions are only possible in a stable ecological framework if the economy grows or in the case of canging ecological framework by devaluing the permits.

The policy of permits is criticized for making it possible to create barriers to market entry by hoarding emission entitlements. Since in such a case new and potentially innovative companies with modern production installations or environmentally-friendly products cannot buy any emission entitlements or their price is too high owing to artificially scarce supply (WEIMANN 1991).

Finally the permits´ period of validity also has an impact on the permits´ innovation effects. For example, permits valid for a limited period make for greater flexibilty on the part of the authorities when it comes to responding to new political objectives or to changed ecological parameters. The ensuing insecurity for the companies concerned, however, results above all in innovations that can be implemented quickly and/or in economical innovations, which makes it seem likely that in the field of technology primarily end-of-pipe environmental measures will be taken. Permits with an unlimited period of validity provide a better basis for planning, with the authorities being to achieve new ecological goals by means of taking devaluation measures that were announced in time. Companies can then either purchase additional permits or try to reduce their pollutant emissions by means of innovation efforts.

3.4 The effects liability law has on innovation

The objectives of liability law are based on the concepts of damage compensation and damage prevention. With regard to the question of its effect on innovation it is primarily the aspects of prevention that are of importance. Liability law attempts to have a preventive effect via financial incentives (cf. HEMMELSKAMP/ NEUSER 1993).

Liability law is linked with the prospect that economic agents are obliged to provide financial compensation in the event of damage if their production or insufficient preventive measures are responsible for the occurrence of damage and for its extent. It is hoped that in this way those that may cause damage take the effects their actions have on third parties into account when making a decision and that these people take measures to reduce or avoid such risks, i.e. introduce innovations.

Liability law leaves it up to the economic agents to choose the measures to be taken according to their preparedness to take risks. Thus, an economic agent willing to take risks will be prepared to keep prevention at a lower level than a risk-averse one. Just how the individual will adapt and therefore the scale of the preventive effect is not known. Hence, the efficiency of this civil law instrument cannot be clearly determined. Instead only the framework can be provided in which the innovative effects of liability law can unfold.

The current liability system is characterised by the co-existence of two liability principles: liability based on fault and liability regardless of fault. In the case of liability for fault the person in question will only be charged with the damage which he or she caused. Concerning the risks inherent in the application of technologies, the blame is usually put on someone saying that the necessary duty to take due care when dealing with the situation in question was neglected. The incentives for innovation which liability for fault provides tend to be of a static nature. In practice the standard of due care concerning the case at issue is determined in the form of judicial decisions. If the standard was complied with, no claims are expected in the case of liability for fault. These incentives are thus related to those of juridical instruments. Liability regardless of fault takes account of the fact that using modern technologies involves specific risks in each case. On the one hand, utilizing this technology entitles the user to benefit in terms of profits and income, on the other hand he or she is obliged to assume responsibility for the risks concerned. If the realisation of these risks causes damage, this is sufficient reason for attribution to his or her liability obligation. Therefore, an economic agent cannot, like in the case of liability for fault, refer to the compliance with decrees or to permits granted by the authorities, i.e., there is a latent residual risk providing a continuous incentive to reduce known and unknown dangers (cf. inter alia NICKLISCH 1992). Liability regardless of fault can give rise to a general and dynamic interest in innovations if one assumes that as prevention inceases damage costs decrease. R&D activities to avoid or limit damage can then reduce the likelihood of costs due to damage.

The innovative effects have to be qualified, however, since in juridical practice the scope of liability is often limited. For example, the German Product Liability Act excludes liability for development risks. This encompasses damage resulting from the realisation of a risk which was not discernible when the product was sold. This exclusion means that the preventive effect of the German Product Liability Act is restricted to the compilation of the hitherto known risk factors of a given product in order to assess the liability risk and to take measures to avoid these risks. However, there is no incentive to include those risks that have not yet been borne out in experiments (cf. TASCHNER/FRIETSCH 1990). On the contrary, the failure to investigate safeguards the standard concerned of the known risks and thus the corresponding liability level.

The risk of unlimited liability for damage caused may lead to innovations, since it is to be expected that economic agents reduce the risk of damage through further and new developments or avoid the danger altogether by discontinuing the use of high-risk methods. Limiting liability to the assets or restricting it to personal injury and damage to property may result in third parties having to pay for that part of the damage that exceeds the liability ceiling. In that case, economic agents will take precautionary measures in their company in accordance with possible damages and not with the expected damage. If the damage exceeds this amount, the person that caused it only has to bear part of the costs. It is unlikely that a complete internalisation can be brought about, and the innovative effects will not be achieved in full either.

In reality there is the problem that a contested claim for damages has to be proved by the injured party before a civil court. To that end, especially the causality between the potentially damaging action and the damage incurred has to be proved. In particular regarding the dangers of modern technologies, the information needed for such a proof is scant. Companies and authorizing bodies may possess the information, the injured party as a rule does not. As for the topic at issue, innovative effects of liability law, these developments concerning the proof of causality play an important role. If the allocation of damage in accordance with the party that caused it can be improved through facilitating evidence, the "actual" cost burden could become visible to the companies and potential environmental users could be prompted to avoid damage and to reduce the likelihood of incidents and accidents by means of improved measuring and inspection methods, amongst other things.

In the current German Environmental Liability Act the difficulties concerning proof of evidence are meant to be reduced with the help of a presumption of cause inherent in the law. It stipulates that an installation caused the damage in question if the installation is suited to cause it. The suitability of an installation to have caused the damage incurred has to be proved in each case. So as to reduce the lack of information needed to prove the injured party's basis of presumption und thus facilitate the enforcement of a claim, the injured party has the right to demand information from the party that allegedly caused the damage and from authorities. However, by facilitating proof of evidence in this manner, companies may be liable for damage for which the company is not responsible. This counterproductive effect could also impact on the technological control of liability law, since liability based on presumption means liability covers any damage and individual activities to avoid damage do not matter any longer. The facilitation of proof of evidence laid down in the German Environmental Liability Act in the form of presumption of cause has to be seen against this background. It does not apply if an installation has been operating in accordance with the regulations, i.e., if the licensing provisions under public law have been complied with and no breakdowns have occurred, nor does it apply if in the case at issue other things could also have caused the damage. This favours compliance with the technological standard and innovations, which would be possible in the case of binding liability, are thus severely restricted (cf. NICKLISCH 1992).

3.5 The effects of eco-audits on innovation

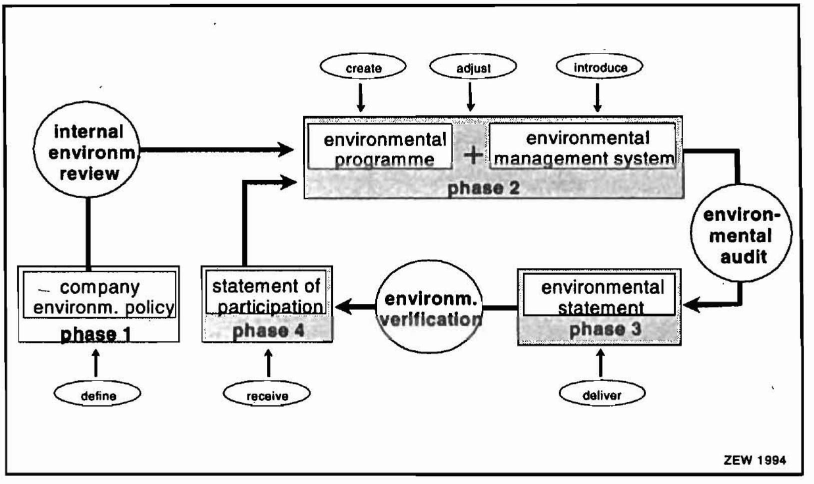
Eco-audits are evaluations with which the set of instruments to protect the environment and business activities relevant to the environment can be checked, appraised and developed further at regular intervals. From the point of view of innovative effects, eco-audits can result in the management, but also departments of the company such as R&D, procurement, production, distribution and waste disposal or recycling being directly integrated in environmental policy. The thus improved transparancy of company functions may make it possible to identify hitherto unnoticed starting points for environment-relieving measures and lead to more economically-efficient environmental protection measures, in particular to production-integrated ones. For instance, in the purchasing department a selective environmentally-oriented choice of material already eliminates a lot of the environmental impacts involved in production and consumption. Or in the production department eco-audits in connection with the implementation of the concept of "lean production" and the concomitant orientation towards efficiency can ensure an economical and therefore environmentally-sound input of production factors. R&D could already take aspects like recyclability into consideration during product development.

Due to these advantages and to the positive experience many European companies have had using eco-audits, the European Council adopted an eco-audit regulation on June 29, 1993, which has been in force since April 1995 (cf. COUNCIL OF THE EUROPEAN COMMUNITIES 1993). A flow chart for the EC-eco-audit is shown in Figure 5. One of the main concerns of the EC-regulation is to promote a steady improvement in environmental protection at company level. In the following individual aspects of the EC-eco-audit-regulation will be examined against this background (cf. HEMMELSKAMP/NEUSER 1994).

1. Companies taking part in the EC-eco-audit procedure may use a certificate stating their participation for public relations if a review carried out by an expert yields a favourable result. This way the instrument of the audit-procedure could undergo a considerable change in meaning and lose a lot of its innovative capacity. In the past it was used by companies as an in-house instrument, which can be considered to have been the more successful the more hitherto unidentified weak points it pinpointed or the

more risk potentials of existing weak points were able to be quantified fairly precisely. Under the EC-regulation an eco-audit could be presented as a result-oriented final programme which only seeks a result that does not harm business interests.

Figure 5: EU-eco-audit flow chart



2. The environmental management system provided in the regulation is, amongst other things, to ensure that environmental audits of the companies are carried out at regular intervals. Nature and scope of the audit reviewing the tasks of the environmental management system, however, are not clearly described in the regulation, and therefore when it comes to implementing the environmental audit the regulation leaves room for extremely different interpretations. If the scope of the audit is interpreted in a narrow sense taking advantage of the discrepancy between audit criteria and depth of the investigation, superficial measures are sufficient. For example, the regulation's criteria may be formally met by compiling manuals, instructions or similar documents without the necessary in-depth reviews of the actual situation being carried out. However, if the scope of the audit is seen in the context of the regulation's objective, i.e., a steady improvement of environmental protection at company level, then it has to be interpreted in a broader sense and go beyond a system audit. A possible methodological aid for a comprehensive overview of the ecologically-relevant effects are company eco-balance sheets. Eco-balance sheets make it possible to document and evaluate all

the material input and energy quantities as well as the entire real estate, all the installations and equipment and changes thereof[5] .

3. The EC-eco-audit-regulation provides that companies participating in the system must not only comply with all the relevant environmental provisions, but also have to achieve an appropriate, steady improvement in environmental protection in their company "as can be brought about through the economically-justifiable application of the best technology available" (Article 3 of the regulation). The compliance with all relevant environmental provisions demanded can be called an objective yardstick for the audit, since these standards have to be met by all companies. Obviously the companies assume that the national environmental standards, effective in the business location in question, apply. In view of the different environmental standards in the EU this results in audit standards differing substantivally and is something representatives of the Federal Republic of Germany in particular continually criticized while the regulation was being drafted. Apart from this, checking the compliance with environmental provisions presupposes that the company concerned knows which provisions apply to the location. However, on account of the increasing complexity not even the competent environmental authorities immediately know the relevant standards (cf. LÜBBE-WOLF 1993). The procedure provided for in the regulation shifts the problem of knowing the relevant standards to the companies. However, already implemented internal audit procedures showed that the comparison between target and actual situation, which aims at compliance with environmental standards (compliance audit), would have been too expensive and time-consuming and should therefore be phased in in the future (cf. HEUVELS 1993). Defining the scope of the appropriate, steady improvement in environmental protection in the company by applying the best technology available is entirely up to the entrepreneur as it is linked to "economically justifiable". This yardstick can be called subjective, for it is the company that has to compile a catalogue of measures for the location and has to fix deadlines for the implementation of the individual measures (cf. Article 2 lit c of the regulation). In that case the yardstick applied in the audit consists in determining the degree to which measures planned and measures implemented coincide (cf. on this Appendix II.F.2.b. of the regulation). This results in odd constellations. For instance, a company possessing innovative technologies that have already been installed can merely point to relatively minor improvements, whereas a company which has just started taking such measures can record dramatic improvements without, however, ultimately attaining the standard of its counterpart. Or a situation arises where a company that is prepared to introduce advanced technologies and organizational innovations and is willing to bear the risk involved and/or has fixed short periods for implementation, which, for example, could only be met to 75 % by the end of the period under review, does worse in terms of the "overall mark" it is given than a company that merely wants to achieve the environmental objectives typical of its industry, but succeeds 100%. In such a case this regu-

[5]However, the question of environmental accounting is still in the discussion stage, in particular in companies that have adopted a holistic approach.

lation almost constitutes an invitation to do without innovations. A technological leap from the prevailing utilization of additive technologies to an increased application of process-integrated technologies is hardly encouraged.

4. Profit-oriented small and medium-sized enterprises (SMEs) will be forced to take part in the EC-eco-audit procedure in order to remain competitive or due to demands made by their customers. So far small and medium-sized enterprises in particular hardly possess elements like quality assurance, which environmental management systems can build on. Initial experience with the introduction of environmental management systems in the Netherlands showed that in large companies the development of environmental management systems had made a lot of progress, whereas in small enterprises due to lack of time and capacity shortages the establishment of the system had not made sufficient headway. "Small enterprises usually do not have separate environmental departments, which can initiate such an introduction (of an environmental management system) and support it" (SOMEREN van 1994:49). That is why in these enterprises in particular the regulation could produce effective impacts on innovation regarding a steady improvement in environmental protection.

4 Some results of empirical studies

In the previous section an overview of the effects of different environmental policy instruments on innovation was given. The overall conclusion theoretical studies draw is that in general economic instruments like levies are more likely to prompt innovations than juridical measures such as requirements. Juridical measures favour innovations in end-of-pipe-technologies whereas economic instruments mostly promote innovation in the field of integrated technologies.

In this section empirical studies on the effects of environmental instruments will be discussed. The aim is to look what innovation effects different environmental instruments have in practice. There are only a limited number of empirical studies on the effects of environmental regulations on innovative behaviour. In the process we will firstly draw on studies concerned with the influence of individual regulations (levies, standards, subsidies), and secondly on studies dealing with industry-specific effects (packaging, chemical, textile and foundry industry).

4.1 Emission levies: The effluent levy in Germany

At an industry level FABER/STEPHAN (1987) conducted a case study in Germany examining the adaptation processes in a large chemical company in the field of prevention of water pollution. The company managed to drastically reduce the amount of effluents by cutting the production of effluent-intensive goods and establishing a closed cycle, amongst other things, as well as by introducing new production methods. The shorter the period was to adapt to the new regulations, the greater the financial burden of the company was.

Considerable influence on environmental protection measures in the field of effluents has been exerted in Germany by the Water Pollution Control Levy Act (Abwasserabgabengesetz, AbwAG). Effluent levies have been charged in Germany since 1981 and have been modified in four amendments. The adoption of the AbwAG coincided with an amendment of the Water Resources Management Act (Wasserhaushaltsgesetz, WHG) providing that minimum standards in accordance with the generally accepted state-of-the-art technology must be met when discharges are authorized (MEYER-RENSCHHAUSEN 1990).

In an ex-ante empirical study prior to the effective date of the Water Pollution Control Levy Act, companies and municipalities were asked about their reactions (cf. EWRINGMANN et al. 1980). While making the qualification that apart from instruments of anti-water pollution policy, other factors, too, influenced the adaptive behaviour of the sample, the study came to the conclusion that the mere announcement of the laws had triggered off responses. The effluent levy was a special case in this connection, since it was a new instrument and consequently it was difficult to obtain information on the available technologies. There was uncertainty concerning the cost burden small and medium-sized enterprises in particular had to expect. Nonetheless it became evident that the companies surveyed were improving effluent treatment in the run-up phase. The reduction of the harmfulness of effluents was largely achieved by means of physico-mechanical methods. Some companies changed their product range or externalized areas of production. The fact that on the whole the effluent levy has had a positive effect is also stressed by FABER et al. (1989).

However, FABER et al. (1989) criticize the combination of the effluent levy and the juridical instrument of the Water Resources Management Act, since they feel that taking into account state-of-the-art technology waters down the actual economic effect of the effluent levy. This effect was further intensified by the recent amendments (cf. GAWEL/EWRINGMANN 1993). In her criticism JASS (1990) even attributes merely enforcement-enhancing functions to the effluent levy and puts the actual effects on innovation down to requirements. She finds that in particular in the area of residual pollution, no reduction in emissions was accomplished, i.e. that the effluent levy failed to have any dynamic innovative effects (cf. also MEYER-RENSCHHAUSEN 1990).

4.2 An empirical analysis of an environmental law: The German Toxic Substances Control Act

The German Toxic Substances Control Act covers dissemination of new chemical compounds outside the company premises, protection of the workforce during production, use of hazardous substances and instructions. The Association of the Chemical Industry (VCI) and BASF PLC cite this act as an example of the existing excessive regulations, which to their mind prevent innovations in the chemical industry (cf. VCI 1993; BASF 1994).

A study on the impact of the Toxic Substances Control Act conducted by STAUDT et al. (1993) came to the conclusion that with regard to the innovation activities the act has lead to R&D projects on new substances being discontinued, to them being shifted abroad and to an increased use of traditional substances. Staudt's study furthermore concluded that compliance, depending on company-specific factors, entails delays and cost increases for the companies, amongst other things due to belated market entry. Thus, the companies, with a view to reducing costs and time, chiefly respond by improving their internal organisational structures. The direction of the attempts at innovation is not solely determined by the Toxic Substances Control Act, rather it depends on the interrelationship of various parameters.

However, one has to question the general validity of these findings. GLOEDE (1994), for example, criticizes the fact that the study is based on technical interviews and case studies which are not sufficiently representative. The delays in market entry discovered by Staudt are deemed insignificant by Gloede in view of the overall period needed for new developments. At the same time Gloede emphasizes that many substances on the list of traditional substances are more like new substances, because not much is known about their properties and the substances in question have hardly been marketed to date.

4.3 Subsidies: Lessons learnt from the Danish "Clean Technology Development Programme"

GEORGE et al. (1992) analysed how environmental innovations take place when polluters, their suppliers or consultants are engaged in the development processes initiated through the Danish Clean Technology Development Programme. Therefore the five cases contained in the study focus on the impact of subsidies on the development of clean technologies[6].

The Danish Clean Technology Development Programme (launched in 1986 with a three-year term) supported surveys on clean technologies and their potential use in different industries, the construction of a prototype of a computer-based information system covering clean technologies, as well as development and implementation projects.

GEORGE et al. concluded that most of the clean technology solutions resulting from the payment of subsidies were process-oriented. The programme is considered a success, for in most projects substantial improvements in terms of environmental protection were made without placing any financial burden on the companies. Some companies even managed to cut costs by substituting inputs. Some of the results were patented or

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[6]They defined clean technologies as technologies which "seek to prevent pollution by input-substitution, process changes, encouraging recycling, lengthening product durability and developing cleaner consumer products" (GEORGE et al.1992:548).

introduced in the market. The success is largely put down to the fact that firstly only projects aiming at solving specific environmental problems were supported and secondly the eligibility criteria took into consideration that often it is not just the polluter who is the innovator, but that solutions are found through cooperation between polluters, their customers, their suppliers and consultants.

4.4 Environmental innovation in the packaging industry

Retailers often point to an environmentally-oriented range of goods in connection with their eco-marketing. Here the packaging of the products plays a decisive part.

Against this background COTTICA (1994) looked at innovations in the packaging industry that reduced environmental impacts. The term "packaging industry" encompasses companies producing the packaging (or intermediate products) or the corresponding processing technology.

On the basis of company surveys he describes specific activities in the framework of individual strategies (elimination of packaging, weight reduction, reusability, recycling and material substitution) which reduce negative effects on the environment caused by packaging. From the talks the following hypotheses are deduced:

- Environmental innovations constitute a steady growth process which starts off from the existing technology
- Environmental innovations are characterized by vertical cooperation in the packaging industry.

These hypotheses were tested in an econometric analysis based on data on successful innovations in the packaging industry[7].

The statement on cooperation behaviour is borne out. It also becomes evident that the environmental innovations in question go hand in hand with cost cutting. The extent to which environmental innovations are technology- or market-induced, are stimulated by a legal framework or have to be seen as a comprehensive change of technology cannot be determined clearly owing to insignificant or missing data. Some statements on these questions are made on the basis of plausibility considerations.

To conclude with, Cottica suggest that there are a great many environmental innovations in connection with the existing technology. They are usually associated with industry-specific advantages (e.g. cost savings through reduction in packaging). However, there was no comprehensive technological re-orientation as a result of the inno-

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[7]Successful innovations are defined as innovations that won awards in mostly national competitions in the packaging industry.

vation activities. Far-reaching innovations are prevented by uncertainties about the kind of packaging and disposal solutions that are to be viewed as environmentally-friendly and socially desirable.

4.5 Effects of environmental regulations in the titanium-dioxide industry

Titanium dioxide is a pigment which is chiefly used in the paint and lacquer industry, in the plastics processing industry and in the paper industry. KOSCHEL (1994) in an empirical study examined the impact of environmental regulations on technological change in the production of titanium dioxide[8].

When producing titanium dioxide by sulphate pulping, which is prevalent in Europe, amongst other things dilute acid is obtained. Up until the late 80ies this dilute acid was dumped on the high seas. In the early 70ies this practice of disposal was already coming in for increasing criticism. The discussion prompted juridical environmental policy measures, which in the case of the titanium industry lead to environmental innovations at the process level. Regarding old installations, these consist in end-of-pipe- and recycling solutions complementing sulphate pulping. These retrofitted sulphate installations presently dominate titanium dioxide production in Europe. The study showed that environmental innovations greatly hinged on the introduction of legal regulations. Koschel also points out the possibility of pioneer profits through early innovations. As a result of complying with environmental regulations, a German company was considerably burdened in the 80ies with expenditure on R&D for titanium dioxide production, causing the company to be at a disadvantage compared with its foreign competitors. Following the introduction of a European-wide directive on avoidance of pollution caused by the titanium industry in 1989, the company benefited from its technological lead.

In the US environmental regulations also induced innovations in the titanium dioxide industry. These, however, lead to an almost complete phase-out of sulphate pulping and to the introduction of the chloride method, which had been developed more recently. Koschel does not attribute the differences in terms of the technology chosen between European and American companies to the environmental instruments applied, rather, in Europe the good supply with raw materials for sulphate pulping was a major reason. Another reason is to be found in the fact that the best technology, developed by an American company, was unavailable in Europe, as no licenses were granted for it. The production of titanium dioxide specialities for export, which was important in Europe, required the broader product specification of sulphate pulping.

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[8]The findings of the study are based on an in-depth analysis of the literature and on numerous talks with experts from the titanium dioxide industry.

4.6 The effects environmental regulations have on innovation in the foundry and textile industry

In a written survey of companies belonging to the German gray cast iron foundry industry the link between environmental protection and innovation was examined (cf. THEIßEN 1987). The foundry industry is among the contracting industries in Germany and produces in a relatively environmentally-intensive manner. To start with the study analysed the company features which are believed to influence innovative behaviour. They are: size of the company, location, number of R&D staff, share of university graduates, R&D expenditure, production technology, water requirements and effluents as well as environmental regulations. Among the relevant environmental regulations are environmental requirements concerning effluent temperature, noise emission and air pollution control in accordance with the Technical Instructions for Air (TA-Luft). Large companies were not found to be harder hit by regulations. However, smaller enterprises tend to spend a larger proportion of their turnover on environmental protection. The companies examined primarily chose end-of-pipe-solutions as environmental protection measures, dust extraction plants for example. On the whole the production process in the gray cast iron foundry companies has become more productive, more energy efficient and more environmentally-friendly over the past years.

The study is restricted to descriptive analyses of the above mentioned factors influencing innovative behaviour. Links between the factors are not established. The extent to which innovations are a consequence of the environmental regulation intensity in this industry is not a central theme.

MAAS (1987) conducted a written survey along the same lines in the German textile industry. This industry is equally faced with requirements to reduce effluents, outgoing air or noise. The most important innovations in the textile industry aimed at automating production. The measures primarily served to rationalize, however, almost automatically, they resulted in an improvement of the environment due to a more efficient use of resources. Environmental innovations were primarily implemented because of environmental regulations concerning effluents, but also concerning noise and air. The measures adopted included both integrated and end-of-pipe-measures. For example, a reduction in air pollution was achieved by limiting the use of fuel oil in favour of gas or by means of automatic apportioning of dyes which reduces water pollution caused by dyes.

5 Conclusions

The technological know-how a company has gained over time determines the future choice and application of processes and products. A fundamental change in the direction of innovation efforts entails at least a partial loss of acquired knowledge on the part of the company. That is why innovations as a rule build on experiences gained in the past, resulting in continuous and successive improvements of an existing product or a production process. Radical innovations, on the other hand, which make it possible to gain a lead in terms of know-how in new areas of technology, are rarely attempted. By shaping the parameters external to companies, the government can exert a significant influence on the direction of innovation. One important influence on innovation processes are environmental policy measures. However, the impact of environmental measures on a company's innovative behaviour has hitherto received little attention in the research community and in the political debate.

Most theoretical studies comparing innovative effects of individual environmental regulations come to the conclusion that direct requirements provide little incentives for dynamic effects and that emission taxes and permits are better instruments to promote innovations. However, the empirical studies show that the dynamic effects of environmental policy instruments in practice partly differ from the ideal instruments analyzed in theoretical studies.

One reason could be that the real design of environmental instruments is influenced by the environmental policy process. The way environmental regulations are worded and introduced is usually determined by the interaction between the legislator, federations of business enterprises, trade unions and the public and their corresponding interests. This potential discrepancy between theoretical assumptions and practical implementation regarding the design of environmental regulations became evident in the case of the German effluent levy.

Another reason is that environmental policy instruments merely constitutes one of many innovation-relevant determinants. Modern theoretical as well as empirical innovation research makes distinctions between numerous economic, social, legal or technological factors influencing the scope and the direction of R&D activities as well as the generation of innovations, their market launch and diffusion. Such factors are:

- company size and market structure,
- demand pull,
- technological opportunities,
- appropriability conditions (like patents),
- certain company characteristics and
- legal and administrative framework under which environmental policy can also be subsumed.

The impact of an environmental policy instrument on innovations strongly depends on the influence of these factors. Consequently, studies on the innovative effects of environmental policy instruments should take these innovation-relevant factors into account and examine them closely.

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