Integrated Environmental Innovation in the German Automotive Industry: Policy Drivers and Consequences for Competitiveness, resent 21.12.2004

Ursula Triebswetter
Ifo Institute for Economic Research
Poschingerstr. 5
D-81679 Munich
(Triebswetter@ifo.de)

Johann Wackerbauer
Ifo Institute for Economic Research
Poschingerstr. 5
D-81679 Munich
(Wackerbauer@ifo.de)

Abstract

This paper examines the environmental innovation process in various branches of the German automotive industry. The focus is on the policy drivers of environmental innovation and how industry adapts and with which effects for the competitiveness of the industry. In particular, the development of integrated products and technologies is examined. According to the Porter hypothesis it was analysed whether regulation-driven innovation does stimulate win-win potentials for firms. In a regional case study approach, a sample of automotive firms in Southern Germany and their suppliers were interviewed. Essentially, integrated environmental innovation is driven by a mixture of factors internal and external to the firm: not only policy pressure, but cost pressure, competitive advantages, technological lead and customer pressure are important drivers. Policy pressure did not only comprehend sectoral policies like emission vehicle standards, but - among other things - also wider non-sectoral issues of energy conservation strategies both on a national and international level. EU Directives on future use of renewable energy as well as national goals for reaching the Kyoto protocol played an important role. Where policy formulation succeeded in establishing a dialogue with the automotive companies, it was particularly successful both environmentally and also from the competitiveness point of view of the firms.

Keywords: environmental innovation, Porter hypothesis, policy integration, automotive industry.

1. Introduction: Integrated environmental products and processes and their impact on competitiveness

During the last years the level of environmental investment as measured in the German census data has strongly decreased. While in 1996 the environmental investments still amounted to 2.5 billion Euro in the manufacturing industry, these investments were only 1.7 billion Euro in 2002. It is assumed that the reasons for this phenomenon cannot only be found in a generally lower level of economic activity, but also in the trend to integrated environmental protection measures. However, integrated products and processes are up to now not adequately measured in the official statistics. In Germany measurement of integrated environmental investment is planned only for the reporting year 2003 (see Grundmann and Becker, 2004).

In order to bring further insight into the field of integrated environmental investment, the focus of this paper is on the analysis of the development of integrated products and processes and their impact on competitiveness. Diverse empirical studies have found out that environmental innovation is the response to either regulatory pressure or is undertaken as the firm's own decision, e.g. following market pressure. E.g. it is found that increased abatement pressures appear to increase patents (Brunnermeier and Cohen, 2003). With respect to product-related eco-innovations a recent study by Türpitz (2004) shows that regulation is one of the main drivers for ecological product innovations, followed by new technology as second most important stimulus. Thus, in the field of integrated product policy environmental regulation spurs innovation and could be an example for the possibility of ”win-win” opportunities available through environmental regulation, where simultaneously pollution is reduced and productivity increased (”Porter hypothesis”, Porter and van der Linde, 1995). In contrast to this hypothesis, the traditional view fears that the private costs initiated through stringent environmental policy impair competitiveness and productivity (Palmer et al., 1995).

The differences between the traditional and the revisionist views can only be measured through empirical studies. In general terms, a negative impact of environmental regulation on the output and employment of firms will be the larger the rise in costs following compliance, the greater the differential cost penalty relative to domestic and foreign competitors, the more significant the compliance costs are in total costs and the greater the degree of price competition between firms and the greater the sensitivity of demand to price increases (OECD, 1993).

However, empirical studies taking labour productivity as the main indicator of competitiveness and firm performance come to at least mixed findings concerning the relationship between environmental regulation and competitiveness (Stewart, 1993; Gray and Shadbegian, 1995; Repetto, 1995; Boyd and McClelland, 1999). Gray and Shadbegian (2003) find that plants with higher pollution abatement costs have significantly lower productivity levels, with older and newer plants showing similar impacts. Clausen et al. (2004) find no significant impact of environmental initiatives on competitiveness of small and medium firms in a variety of countries in the European Union. Neither was competitiveness influenced by a positive environmental management culture. Clear proof of the Porter hypothesis is scarcely found (one example would be Murty and Kumar who examine upgrading of waste water technology in India (2001)). A shortcoming of all studies is that no systematic search for the impact of the type of environmental abatement measure was undertaken. In most cases the impacts of end-of-pipe technologies were measured, but not those of process-integrated or clean technologies. It should also be noted that much of the evidence has been US based, with only little attention paid to the European case.

Therefore this research was designed to cover the impact of European environmental policy and to examine the effects of integrated technology on competitiveness. Generally, the economic impact of clean technology is assumed to be more positive than that of end-of-pipe technology (see Coenen et al., 1995).

The automotive industry in the region of Munich was chosen as example for this study because it is not only known to be one of the most innovative industries in Germany, but it is also identified to be particularly innovative in the area of integrated environmental product and process innovations. Moreover, the automotive industry holds a high share of the total manufacturing output both in Bavaria and Germany (see Verband der Deutschen Automobilindustrie, 2001 and Industrie- und Handelskammer für München und Oberbayern und Bayerisches Staatsministerium für Landesentwicklung und Umweltfragen, 2001). Still, according to Nunnenkamp

(2004) the competitive pressure in this highly globalised industry is enormous. International cost differences play an important role for outsourcing and production abroad. In order to remain competitive, innovations are therefore of great importance.

2. Analytical framework

2.1 Key definitions: Innovations and environmental innovations

Regarding the general definitions of innovations the paper follows the guidelines laid out in the Oslo-manual which defines innovations as technological or organisational changes (OECD/EUROSTAT, 1997). Concerning technological innovations, product and process innovations are distinguished. Process innovations lead to decreased inputs, at a constant level of output. Product innovations lead to new or improved goods. Organisational innovations and new services have only recently been included in the Oslo-manual.

According to Klemmer (1999), we define environmental innovations as techno-economic, organisational, social and institutional changes leading to an improved quality of the environment. With respect to technological environmental innovations a difference is made between integrated and end-of-pipe production methods. Integrated methods can be of product or process character (Rennings, 2000). The focus of this paper is exclusively on these integrated technological methods.

2.2 Theories of environmental innovation: the development and diffusion of end-of-pipe technology vs. integrated technology

For a long time the determinants of general innovation activities were separated in supply and demand side components. In the view of the supply side it is assumed that knowledge and existing technological opportunities are decisive for the innovation activity of each individual entrepreneur (”technology push”). In the view of the demand side (”technological pull”) market demand is the essential factor for innovation. However, in the newer evolutionary theory of innovation both sides are a priori seen as important factors for innovation (see Nelson and Winter, 1977 and 1982). Within the evolutionary theory it has become state-of-the-art that innovations are developed in a process within networks of innovating firms and research institutions (Kurz, 1989). There are feedback processes between the different phases of innovations and exchange of experiences with the users.

According to Kemp (1993) environment-saving technological change should be perceived as regular technological change because clean technology issues cannot be regarded independent from general innovation motives. Recent studies have identified several key factors that are decisive for the general process of technological change and in particular the innovation phase which can also be applied to environmental innovation (see Strasser, 1997 for a review; Kemp, 1993). Also in the diffusion phase, when innovations are introduced into the market, certain key factors of success have been worked out (see Overview 2.1 below).

Overview 2.1 Determinants of innovation activities

Determinants of innovation activities	
Innovation phase	**Diffusion phase**
Technological opportunities	Cost-benefit-ratio of the innovation
Appropriability conditions like patents or first mover advantages	Transfer of knowledge and learning processes
Co-operative relationships, networks	Technical and economic risks of the innovation
Firm size and market structure	
Market demand (incl. regulation)	
Changes in market conditions	
Changes in consumer preferences	

Source: Sprenger et al. (1998) with own modifications.

In the sections 2.2.1 and 2.2.2 these key factors in the innovation and diffusion phase are analysed in detail. Special attention is paid to the development of integrated environmental technologies.

2.2. 1 Key factors in the innovation phase of integrated technologies

Technological opportunities to develop a particular technology are based on the pool of internal and external knowledge acquired in the company in the past. The external knowledge essentially consists of basic research in universities and institutes. Internal knowledge relies on the results of past research activities and the specific knowledge of the employees and also on the capability to draw on external knowledge (Cohen/Levinthal, 1989). Thus the capabilities to develop an innovation can vary among firms. They relate to the size and nature of the knowledge accumulated in the past which determines whether and how a company is prepared to introduce technological innovations for its products and processes (Erdmann, 1993). Concerning the development of clean technologies a growing affinity for science oriented approaches is to be expected because the solution of environmental problems requires early collaboration of many disciplines. However, the internal and external knowledge is not used to the same extent in all companies. Subsequently, process innovations are usually developed by special suppliers. Only the knowledge intensive sectors have the capabilities to develop environmentally friendly process innovations independently or together with special suppliers. Environmental product innovations are usually developed by the manufacturers of the product (Pavitt, 1984). R&D co-operations, e.g. between universities and companies, are of great importance for any type of innovation.

If a firm engages in the R&D process, it must be able to appropriate the benefits from the innovation. Usually the following *appropriability conditions* are distinghuished: patents, secrecy, technical lead on competitors, learning curve effects and the extent to which a strong market position can be built up. Dosi (1988) complements this list by scale economies. The appropriability conditions vary according to the type of innovation. A process innovation is more driven by learning curve effects, secrecy and technical lead, whereas a product innovation can be appropriated more easily by technical lead and learning curve effects along with additional marketing efforts (Levin, 1986). Patents are additional appropriability conditions in most cases. In the area of environmental technology patents have increased world wide since the 1980ies (Adler, 1997). However, this increase relates rather to end-of-pipe technologies than to clean technologies because the environmental relevance of a patent is not a classification criterion in the international patent statistics. Lanjouw and Mody (1993) find that increases in environmental compliance costs as a result of regulation lead to increases in the patenting of new environmental technologies with a one-to-two year lag.

In the innovation phase also *co-operative relationships and networks* play an important role. Feedback processes between the different phases of innovations and exchange of experiences with the users are preconditions for successful innovations. Also ecological innovation processes are influenced by the resources of network participants, their relationships and their spatial and social proximity (Minsch, 1996). During the development phase of an environmental innovation rather soft and co-operative factors like common perception of ecological pressure or the ecological image of a region play a dominant role.
Another important aspect during the innovation phase is *firm size and market*

structure. Innovation demands a continuous commitment for structured R&D work which might pose a problem for small firms. Concerning market structure and innovation an important question is whether entry to the market is open for new entrants with better technology.

The external or *market demand* for technological change will also be of relevance for a firm's decision to innovate. In the context of environmental technological change regulation and customer requirements are central reasons for the development of innovations. End-of-pipe technologies are usually geared to the reduction of specific pollutants or a group of pollutants and can therefore be transferred from one industry to another. Clean technologies are much more specific for certain processes in certain industries; thus the market potential is largely restricted. It can be expected that the market for clean technologies will focus on completely new installations or replacement of old plants.

Another influence on the demand for environmental technologies can be found in the elasticity of demand. Usually the suppliers of process technology can expect a price inelastic demand for those investments which have to be undertaken because of new regulation. A change in *market conditions* via price changes then shows little impact on demand. For green consumer goods, however, a price elastic demand reaction can be expected. Only if the green product shows an immediate benefit, e.g. health benefits, a higher willingness to pay reflects the *change in consumer preferences*.

2.2.2 Influencing factors in the diffusion phase of integrated technologies

Diverse empirical studies on the use of environmental technology have found out that environmental regulation is the decisive factor for their implementation (e.g. Adler, 1997; Halstrick-Schwenk et al., 1994; Bigleiser and Horrowitz, 1995; Newell et al., 1996). Jaffe and Stavins (1995) found that incentives for the invention and adoption of cleaner technologies are greater under emissions taxes and tradable emissions permits than under command and control regulations. For the analysis of diffusion and acceptability of new environmental technologies and products in the user sector various factors have an influence:

- transfer of information,
- costs,
- risk and uncertainty.

Knowledge and information on available techniques and newer developments is a key prerequisite, if a firm wants to implement environmental technology. Concerning clean technologies the immediate transfer of knowledge is difficult because they are very specific. Face-to-face relations between the special suppliers of the clean technology and the potential users must take place (Dielemann, de Hoo, 1993).

The *costs* and benefits of a certain innovation for the environment are determined by its price and quality. Costs can involve purchasing costs, implementation costs, financing costs, operating costs. Benefits can be found in better environmental performance, cost savings, increased demand and improved public image of the firm. The cost consequences of adopting clean technologies can differ enormously for firms. They do not only depend on the costs of purchasing, but also on the age and the nature of the production process. Hereby sunk costs play an important role. There is the tendency that existing installations invest in end-of-pipe technologies because of sunk costs (the capital costs of an existing installations which are fixed in the short and medium run). In an investment decision only the variable costs and the initial investment cost of an end-of-pipe technology are compared with the total costs of clean technology. Therefore the use of end-of-pipe technology may be a relatively more advantageous solution in terms of net present profits (Hartje, 1990). But the significance of the cost differences between end-of-pipe and clean technologies also depends on the R&D efforts of suppliers and the productivity increases of the users of environmental technologies. Clean technology might be cheaper, if suppliers can decrease costs through innovations and when users achieve cost reductions through e.g. energy savings during the use of clean technologies. The influence of sunk costs on existing installations also depends on both the regulator’s and the companies’ strategies for compliance with upcoming legislation. If companies can plan investment on a long term basis, the use of clean technology in replacement investment becomes more likely. Sunk costs, however, are not important in the case of a new installation or a replacement investment so that total costs of both end-of-pipe and clean technologies are compared. Clean technology is chosen when its costs are lower than the costs of a standard technology extended by end-of-pipe measures.

Another important cost factor is represented by the implementation costs related to the use of clean technology and there are also learning and scale effects which need to be taken into account. The implementation costs are the higher, the more process steps are involved in the innovation, the more basic the innovation is and the less experience is available (Maas, 1990). Thus, clean technologies may require a change in production routines (new jobs, rewards) and may meet both managerial and worker resistance (Kemp, 1993). Training is required and maybe even the hiring of new employees with special expertise. Adjustment costs of end-of-pipe technologies are expected to be much lower because only little amendments in the existing technology have to be made. However, learning effects in the use of clean technologies through improved routines over time can lead to a decrease of unit costs. These cost reductions can be the sooner realised the faster production grows due to increased demand. Thus, in the long term, cost structures of firms may change and the higher costs initially associated with clean technology may be overcome (Hemmelskamp, 1999; see Table 2.1 for an overall comparison of end-of-pipe and clean technologies).

Finally, because of the difficulties of obtaining an overview on all available environmental technology and due to the lack of complete information on their performance, users are faced with *technical and economic risks* (Kemp/Soete, 1990). Process-integrated clean technologies that lead to radical innovations, show a high risk (Hartje and Lurie, 1984). The more complex a technology is, the higher is the risk for frequent down time breaks. Also, if a technology is very new, no draw back on existing experience is possible (see Rogers, 1995). Personnel must gain knowledge of and experience with new machines. In particular smaller firms lack expertise in relation to clean technology, e.g. membrane technology (Kemp, 1993). The technical risks associated with clean technology are immediately related to economic risks. The higher the down-time, the greater the costs of non-production. If there is a problem in the use of an end-of-pipe technology, the standard technology can still be used to a certain extent (depending on the enforcement of environmental regulation). Since most companies would show a largely risk averse behaviour, end-of-pipe technologies seem to be advantaged over clean technologies.

Table 2.1 Comparison of end-of-pipe and clean technologies

Economic Parameter	End-of-Pipe Technology	Clean Technology
Total Productivity	Decrease of Productivity	Potential for Productivity Increase
Production Costs	Increasing	Potential for Cost Reduction
Investment Need	Lower	Higher
Sunk Costs	Generally: No	Potential
Information and Access Costs (For Example Licence Fees)	Higher	Lower
Adaptation Costs	Lower	Higher
Compatibility with Current Production Methods	Lower	Higher
Economic Risk (For Example Downtime Due to a Lack of Experience)	Lower	Higher
International Competitiveness of the Economy	Potential for Future Competitive Advantages	Tendency: Negative Influence

Source: Coenen et al., 1995, p. 47, modified.

2.3 Conclusion on environmental innovation processes

The above has shown that environmental technological change is on the one hand spurred by environmental regulation and on the other hand by a variety of influencing factors which will eventually also influence competitiveness. It became clear that in particular the type of environmental technology (clean vs. end-of-pipe technology) developed in response to regulation will have an impact on the final effect on competitiveness.

3. Research method and main hypothesis

Case study approach

The central aim of this research is to examine the impact of integrated environmental innovations on competitiveness in the automotive industry. For a robust testing of the potential effects of this kind of innovation the need for a detailed production of empirical data was recognised. Therefore an interview-based case study technique was selected as research method. The questionnaire was designed in a way that systematic comparisons of supply-side features of the firm after controlling for size, ownership and product type can be made. In the past, the technique has yielded robust measures of the importance of a range of factors influencing relative competitiveness in a variety of industries in intra-EU comparisons (e.g. Hitchens et al., 1990 and 1993; Mason et al.1994; for an extension to questions of environmental economics see e.g. Hitchens et al. 2002 and Triebswetter, 2004).

A case study approach allows access to sometimes confidential data on environmental costs and economic performance. This is particularly important since the focus of the study was on the cost and environmental effects of integrated or clean technology solutions which are not covered in the census data. Between June and October 2004 eighteen different environmental innovations could be analysed in five firms and suppliers of the automotive and railway industry in the region of Munich. Access to plants was easy, only one firm denied to participate in the study.

Main hypothesis and measurement of competitiveness impacts

The main hypothesis was that environmental regulation can trigger integrated environmental innovation both on the product and process side and that these clean technology solutions imply a win-win potential for firms, i.e. an improvement of the environment and a better competitive position in the market (Porter and van der Linde, 1995). To this end it was measured through which environmental innovations firms belonging or supplying the automotive industry have adjusted to environmental or other sources of innovation pressure, why they were put in place (legislation vs. market driven measures), at what costs and how their competitiveness was affected.

In the sample, in particular data on the effects of environmental innovation on output measures of competitive performance were analysed. As output indicators of competitive performance the effects of environmental innovations on market share, turnover, production costs, exports and the customer base were measured. Moreover, the ability to obtain patents from environmental innovations was examined. These output indicators illustrate the consequences of relative competitiveness of firms (see Jacobson and D., Andréosso-O'Callaghan, 1996).

4. Results

Altogether five enterprises of the automotive sector were interviewed in the region of Munich between May and October 2004. All of the sample firms were known to be strong environmental innovators and are prominent players in their specific industries and have a good economic record (see Table 4.1 for a distribution according to average employment and turnover growth, R&D expenditure and export shares). They are also known to have strong R&D capacities embodied both in their capital endowment and in the skills of their employees. These factors contribute to the likely explanations of competitiveness. Three of the sample firms are of large size, one is small (about 20 employees) and one is medium-sized (750).

Table 4.1 Sample description: Growth, R&D and exports

Industry branch	**Employment growth 2000-2003**	**Growth of turnover 2000-2003**	**R&D expenditure as % of turnover in 2003**	**Export share as % of turnover in 2003**
Cars	11	18	5.2	n.a.
Car industry suppliers	10	40	4.5	40
Commercial vehicles	- 4	2.2	2.6	65
Rail vehicles	- 15	2.3	8	40
Cargo vehicles	20	100	> 50	0

With the help of the data collected during the interviews and together with the analysis of enterprise documents 18 integrated environmental innovations could be analysed in detail (see Table 4.2 below). In the sample there were twelve product and six process innovations.

Table 4.2 Overview of environmental innovations in the sample

Industry Branch	Integrated Product Innovation (IPP), n=12	Integrated Process Innovation, n=6
Cars	Design for recycling	Alternative drive system: Hydrogen cars Production Process: Water solvent paints
Car industry suppliers	Downsizing of roller chains Replacement of metal parts by plastic components	
Commercial vehicles	Common rail diesel engine Training of truck drivers New software	Alternative drive systems: Natural-gas drive for busses and fuel cell busses Production Process: Water solvent paints
Rail vehicles	Oil-free compressor Pneumatic derailment detector Modular brake control system EP brake control Aluminium brake New software	-
Cargo vehicles	-	Alternative drive system: Fuel cell fork lifter

Four of the process innovations referred to alternative drive systems like hydrogen or fuel cell technologies, two of the process innovations were found in the use of water solvent paints during the production process.

4.1 Drivers of environmental innovation

Usually environmental innovations are developed with the explicit aim of environmental improvement. However, they are also motivated by general business considerations like cost reductions. Indeed, many environmental innovations connect an environmental with an economic benefit. Environmental goals are therefore ranked equally with other innovation goals, but never named by sample companies as first reason for innovation unless there is a legal requirement. In the following the main drivers for the environmental innovation found in the sample are analysed according to the type of innovation.

Concerning environmental product policy the main drivers for innovations were found to be customer and cost pressure as well as environmental legislation and company environmental policy (see Table 4.3 below). Environmental legislation is an important factor for the end producers of cars and vehicles, but not in the supplier industries. For the suppliers it is rather immediate customer pressure which pushes innovation. In particular, customer requirements for higher performance and less consumption of fuel play an important role.

The main reasons for process innovations like gas busses or hydrogen motors were said to be the opening of new markets and the gaining of competitive advantages as well as the saving of resources, reduction of emissions and CO_2 (company environmental policy as well as legal obligations under the Kyoto Protocol). One producer of commercial vehicles was also influenced by EU Directives, e.g. until 2020 20 % of all fuel shall be replaced by alternative fuel of which 10 % shall be gas. Also, the future Euro 4 and 5 emission limit values played an essential role in developing new environmentally friendly processes. In order to comply with the Euro 5 norms completely new technology is required.

Table 4.3 Main drivers of environmental innovations in the sample: Numbers of innovations

Main Drivers	Cars	Car industry suppliers		Commercial vehicles		Railway		
vehicles	Cargo vehicles		Total	Of which				
							IPP	
	Process							
Legislation	1		1	2		4	3	
	1							
Customer pressure		2		3		5	5	
Costs			2			2	2	
Competitive advantages/ new markets			1		2		1	
	4		4					
Environmental policy of the company						2		
	3	2						
Other	1					1		
	1							

4.2 Competitiveness impacts of environmental innovation

4.2.1 Overview of all effects

In the following the impact of environmental innovation on company competitiveness is measured by varying indicators. The effect on turnover, market share, production costs, long term employment and qualification levels of employees is measured. Moreover it is measured whether companies could enlarge their customer base and obtain patents on their developments (see Table 4.4).

As a consequence of two product and two process innovations sample firms could gain an increase in turnover. But most of the innovations did not touch upon turnover. About fifty per cent of the product innovations and a third of the process innovations have the capacity to increase market share for the firms. Furthermore three quarters of the product innovations lead to a reduction of production costs. Two of the process innovations trigger higher production costs because of more complex work. For two thirds of each kind of innovations intellectual property rights in the form of patents could be secured. Two of the process innovations led to success in broadening the customer base and three process innovations triggered higher exports. Five of the product innovations triggered new customers and seven led to an increase of exports. Two process and three product innovations created positive long term employment effects, most of the new employees have degrees in engineering or are apprentice-trained workers. Concerning process innovations, in one firm 20 - 50 engineers work on the development of the hydrogen motor, in another the production of the gas bus only led to small positive employment impacts. However, this firm also stated that the process innovations helped to secure employment, in particular in the segment of lower qualified workers. According to the management's own estimation all process innovations brought about a higher level of competitiveness and five product innovations had the same positive effect. The remaining innovations were needed to maintain competitiveness of the sample firms.

Table 4.4 Impact of environmental innovation on competitiveness in the sample: Numbers of effects

Indicators of Competitiveness: Direction of change caused by innovation	Integrated Product Innovation n=12		Integrated Process Innovation n=6	
	constant	increase	constant	increase
Turnover	10	2	4	2
Market share	7	5	4	2
Production costs	3	9*	2 2 x n.a.	2
Patent	4	8	2	4
New customers	7	5	4	2
Exports	5	7	1 2 x n.a.	3
Longterm employment	9	3	2 2 x negative	2
Skill levels of new employees		9	3	2 4
Management's own estimation of impact on competitiveness	6		7	5 0

* decrease

4.2.2 Competitiveness effects of environmental innovations according to drivers

It is particularly interesting to examine whether legislation driven innovations show any different competitiveness impacts than market driven innovations and to have a closer look at the type of policies which stimulate innovations. To this end, first of all, an overview of effects according to individual drivers of the environmental innovations is given. Moreover, some detailed examples are presented. The analysis is carried out separately for product and process innovations and special attention is paid to the type of policy measures driving the innovations.

Competitiveness effects of product innovations according to drivers

From the 12 integrated product innovations three were mainly legislation driven, five were undertaken due to customer pressure and four due to other reasons (cost reductions and company environmental policy). None of the legislation driven innovations triggers an increase in turnover and only one leads to a higher market share. However, just like the majority of the remaining, market-driven innovations, the innovations pushed by regulatory pressure imply a decrease in production costs and also lead to the creation of patents. In terms of broadening the customer base and increasing the export quota as well as stimulating employment growth the legislation driven measures seem to have less positive effects than innovations driven by market incentives. Still, according to the management's own estimation, two of the three legislation driven innovations show a positive impact on the overall competitiveness of the interviewed businesses (see Table 4.4). One of these innovations was design for recycling in the car industry for which the reason was the fulfilment of EU and from 2007 onwards national recycling quotas for used cars (see e.g. EU Directive on Used Cars). It was stressed by the interviewed company that design for recycling helps to optimise development and production processes and that this implies a competitive advantage for the company.

Table 4.4 Impact of environmental innovation on competitiveness in the sample: Numbers of effects concerning integrated product policy innovations

No. of effects	Legislation, n=3		Customer Pressure, n=5		Other n=4		All n=12	
	constant	increase	constant	increase	constant	increase	constant	increase
Turnover	3	0	3	2	4	0	10	2
Market share	2	1	3	2	2	2	7	5
Production costs	1	2*	1	4*	1	3*	3	9*
Patent	1	2	3	2	0	4	4	8
New customers	2	1	5	0	0	4	7	5
Exports	2	1	3	2	0	4	5	7
Long term employment	2	1	3	2	4	0	9	3
Skill levels of new employees	2	1	3	2	4	0	9	3
Management's view of effect on comp.	1	2	5	0	1	3	7	5

*decrease

Another legislation driven product innovation with a positive implication for competitiveness was the development of an oil-free compressor for brake systems in railway vehicles. The strict national requirements for the disposal of used oil stimulated this development. A detailed analysis of this innovation can be found in Box 1.

Box 1 Example of a legislative driven environmental product innovation: Oil-free piston compressors for rail vehicles

Piston compressors are more robust and easier to service than screw compressors. But in the past they were much less satisfactory in terms of noise and vibration levels. The new oil-free piston compressor combines the advantages of both types, with intrusive noise and vibration levels for passengers reduced to a minimum: innovative technology that offers the same high levels of comfort as a screw compressor. The oil-free compressor will be available in all performance categories from 70 l/min to 3500 l/min. While performance remains the same, the weight has been considerably reduced, energy consumption is much lower, and it operates more economically, efficiently and with less impact on the environment than traditional compressors. All the processes related to oil lubrication have disappeared: there is no need to top up, change, retrieve or collect oil, and no need to specially dispose of used oil and condensate. Components such as oil filters, oil separators and condensate collectors are things of the past. Customers can save up to 50 % of service and 20 % of energy costs. Due to these enormous advantages the company expects an increase in market share and in exports. The environmental innovation was primarily spurred by legislation, but also customer requirements and the company's own environmental policy played an important role. Since the new compressor is one of the most innovative products of the interviewed company, it highly contributes to its competitiveness.

A third legislation driven product innovation which just helped to maintain competitiveness was the so-called common rail diesel engine developed by the commercial vehicles industry in order to meet the Euro 4 exhaust emission norms. Consistent further development of the cooled exhaust gas recirculation technology was the basis for meeting the new Euro 4 NO_x standards which will be mandatory for all newly commissioned vehicles starting in fall 2006.
To comply with the new particle values, a catalysis process is added. It was stressed by the company that the Euro 4 norms were set by the authorities without a great deal of input or co-operation from industry and that industry therefore just looked for the most economical way to meet the Euro 4 norms.

Where policy formulation succeeded in establishing a dialogue with the automotive companies, it was particularly successful both environmentally and also from the competitiveness point of view of the firms. This was the case for the Euro 5 emission negotiation for which completely new technology is developed. Timely co-operation between regulators and industry is an important contribution to a successful implementation of environmental legislation from a competitive point of view.

Competitiveness effects of environmental process innovations according to drivers

Only one of the six process innovations found in the sample was driven by legislation. This innovation was the introduction of water solvent paints in the commercial vehicle industry.

The innovation was undertaken in anticipation of both EU and national stricter emission limit values for painting installations from 2008 onwards.

Four process innovations were driven by new markets and one by other reasons (problems with the neighbourhood; see Table 4.5 for an overview of effects). Interestingly, all innovations - irrespective of driver - imply according to the management's own estimation positive competitiveness effects for the sample firms. Even the legislation driven innovation was said to have a positive effect. Although it was an expensive installation, it was a necessary investment because the old installation was written off and had to be replaced. The new installation shows a higher efficiency than the old equipment.

However, concerning the individual competitiveness effects, process innovations due to companies' intentions to open new markets and to gain competitive advantages triggered more favourable effects for the businesses under concern than the legislation driven process measure. Especially in terms of positive impacts on turnover, market share, patents, new customers, exports and long term employment market-driven process innovations show a better performance than innovations pushed by legislation. One detailed illustration of a market-driven environmental process innovation, the natural-gas drive, is presented in Box 2.

Table 4.5 Impact of environmental innovation on competitiveness in the sample:

Numbers of effects concerning process innovations

No. of effects	Legislation n=1		New Markets n=4		Other n=1		All n=6	
	constant increase	increase	constant	increase	constant	increase	constant	
Turnover	1	0	2	2	1	0	4	
	2							
Market share	1	0	2	2	0	1	4	
	2							
Production costs		0	1	2 x n.a.	2*	0	1	
	2 2 x n.a.		2					
Patent	1	0		4	1	0	2	
	4							
New customers	1	0	1	3	0	1	2	
	4							
Exports	1	0	2 x n.a.	2	0	1	1 2 x n.a.	
	3							
Long term employment		0	1*	2	2	0	1*	
	2	2 2 x neg.						
Skill levels of new employees			0	1	2	2	0	
	1	2	4					
Management's view of effect on com-petitiveness					0	1	0	
	4	0	1	0	6			

* decrease

Box 2 Example of a market driven environmental process innovation: natural-gas drive

The interviewed company brought the natural-gas drive up to maturity for series production. Thanks to the latest engine and exhaust-gas technology both the (lambda= 1) induction engines and the lean-burn supercharged and intercooled engines already satisfy the EEV (Enhanced Environmentally friendly Vehicle) requirements with values that thus even fall below the EURO 5 limits envisaged for 2008. Thanks to a modular storage system a vehicle with any required operating range can be provided. Different types of pressurised storage systems are used. These differ according to their design, capacity, weight and price. A complete family of low-floor natural-gas buses for both urban and intercity operations is offered. The main reasons for this innovation were said to be the opening of new markets and the gaining of competitive advantages as well as the saving of resources, reduction of emissions and CO_2. There was also an influence by EU Directives, e.g. until 2020 20 % of all fuel shall be replaced by alternative fuel of which 10 % shall be gas. Also, the future Euro 5 emission limit values played an important role for the development of this new technology. The natural-gas drive is a clear competitive advantage for the company because it can claim technological leadership. Therefore the company could also increase its exports and broaden its customer base. Also, turnover and market share have increased. Production costs are higher than for a bus with conventional technology. The innovation mainly secures employment. Some few jobs in R&D were created.

5. Summary and conclusions

In the sample, three product innovations and only one process innovation were primarily legislation driven. Whereas regulatory pushed product innovations deliver a similarly high contribution to the competitive performance of sample companies, the legislation driven process innovation clearly shows a less positive competitive impact than those innovations carried out voluntarily. Thus, some clear, but anecdotal evidence of the Porter hypothesis can only be found on the side of product innovations. The anticipation of regulatory instruments was found to have an incentive effect for firms in looking for innovative solutions. Early search for new solutions can also alleviate economic and technical risks of environmental innovations, e.g. high investment costs and uncertain profitability. Within our sample it became clear that a co-operative policy style was particularly successful both environmentally and also from the competitiveness point of view of the firms. For the automotive sector, policy integration in the field of energy is a particularly important stimulus for environmental innovations.

However, both a wider interview sample and a postal survey geared to integrated environmental investment would be needed for further research. It would be particularly interesting to investigate on an internationally comparative basis, both within the EU and outside the EU, whether different environmental policy styles have an impact on the type of environmental technology developed.

Acknowledgement

The data used for this paper are part of a wider study entitled “The Environmental Sector in the Region of Munich” by J. Wackerbauer and U. Triebswetter, Ifo Institute for Economic Research, Munich, 2004. This study had been supported with funds of the City of Munich, Department of Labour and Economics. Its main focus was to analyse the structure of the environmental market in the region of Munich by means of a postal survey. One chapter of the study focused on the potential for environmental innovation in a variety of industry branches. Our special thanks are attributed to the interviewed facilities and the members of the advisory board to the study.

References

Adler, U. (1997), Integrierter Umweltschutz als Beispiel zukunftsfähiger Innovation, ifo Schnelldienst 17/18, 17. Juni 1997, S. 44 - 52.

Biglaiser, G., Horrowitz, J.K. (1995), Pollution Regulation and Incentives for Pollution Control Research. Journal of Economics and Management Strategy, Vol. 3, pp. 663-684.

Boyd, D.A., McClelland, J.D., 1999. The Impact of Environmental Constraints on Productivity Improvement in Integrated Paper Plants. Journal of Environmental Economics and Management, 38:121-142.

Brunnermeier, S.B., Cohen, M.A. (2003), Determinants of Environmental Innovation in US Manufacturing Industries. Journal of Environmental Economics and Management, 45: 278-293.

Clausen, J., Hitchens, D., Konrad, W., DeMarchi, B. (2004), Win-Win-Potenziale im Mittelstand? Zum Zusammenhang von Umweltleistung und Wettbewerbsfähigkeit im internationalen Vergleich. Zeitschrift für Umweltpolitik & Umweltrecht, 27(3):419 - 435.

Coenen, R., Klein-Vielhauer, S., Meyer, R. (1995), TA-Projekt Umwelttechnik und wirtschaftliche Entwicklung: Integrierte Umwelttechnik - Chancen erkennen und nutzen. Büro für Technikfolgenabschätzung beim Deutschen Bundestag. TAB-Arbeitsbericht Nr. 35, Bonn.

Cohen, W.M., Levinthal, D.A. (1989), Innovation and Learning: The two faces of R&D. The Economic Journal, 99: 569-596.

Dielemann, H., de Hoo, S. (1993), Toward a Tailor-made Process of Pollution Prevention and Cleaner Production: Results and Implications of the PRISMA Project, in: Fischer, K., Schot, J. (eds.) (1993), Environmental Strategies For Industry, International Perspectives on Research Needs and Policy Implications, Island Press, Washington D.C., pp. 245-275.

Dosi, G. (1988), Sources, Procedures and Microeconomic Effects of Innovation. Journal of Economic Literature, 26 (3): 1120-1171.

Erdmann, G. (1993), Elemente einer evolutorischen Innovationstheorie, Tübingen.

European Commission (EU) (Ed) (2001), Green Book on Integrated Product Policy, COM 68, Brussels.

Gray, W.B., Shadbegian, R.J. 1995. Pollution Abatement Costs, Regulation and Plant Level Productivity. NBER Working Paper no. 4994, National Bureau of Economic Research, Washington D.C.

Gray, W.B., Shadbegian, R.J. (2003), Plant Vintage, Technology and Environmental Regulation. Journal of Environmental Economics and Management, 46: 384-402.

Grundmann, T., Becker, B. (2004), Integrierte Investitionen für den Umweltschutz im Produzierenden Gewerbe - Das Erhebungskonzept ab Berichtsjahr 2003. Wirtschaft und Statistik 7:783-791.

Halstrick-Schwenk, M., Horbach, J., Löbbe, K., Walter, J. (1994), Die umwelttechnische Industrie in der Bundesrepublik Deutschland. Untersuchungen des Rheinisch-Westfälischen Instituts für Wirtschaftsforschung (RWI) (Hrsg.) Heft 12, Essen.

Hartje, V.J. (1990), Zur Struktur des ökologisierten Kapitalstocks: Variablen und Determinanten umweltsparender technologischer Anpassungen in Unternehmen, in: Zimmermann, K., Hartje, V.J., Ryll, A.: Ökologische Modernisierung der Produktion. Berlin, 135-198.

Hartje, V.J., Lurie, R.L. (1984), Adopting Rules for Pollution Control Innovations: End-of-pipe versus Integrated Process Technology. International Institute for

Environment and Society (IIUG), Berlin, WZB.

Hemmelskamp, J. (1999), Umweltpolitik und technischer Fortschritt, Eine theoretische und empirische Untersuchung der Determinanten von Umweltinnovationen, Physica Verlag, Heidelberg.

Hitchens, D.M.W.N., Wagner, K., Birnie, E., 1990, Closing the Productivity Gap: A Comparison of Northern Ireland, Britain and Germany. Avebury, Aldershot.

Hitchens, D.M.W.N., Wagner, K., Birnie, E., 1993. East German Productivity and the Transition to the Market Economy. Avebury, Aldershot.

Hitchens, D.M.W.N., Farrel, F., Lindblom, J., Triebswetter, U., 2002. The Impact of Best Available Techniques (BAT) on the Competitiveness of European Industry. Report EUR 20133 EN, Institute for Prospective Technological Studies, Seville.

Industrie- und Handelskammer für München und Oberbayern und Bayerisches Staatsministerium für Landesentwicklung und Umweltfragen (Hrsg.) (2001), ipp - Integrierte Produktpolitik - Instrumente aus der Praxis am Beispiel Automobil - Ein Projekt von Staat und Wirtschaft im Rahmen des Umweltpaktes Bayern, München.

Jacobson, D., Andréosso-O'Callaghan, B. (1996), Industrial Economics and Organisation, McGrawHill, Maidenhead.

Jaffe, A.B., Stavins, R.N. (1995), Dynamic Incentives of Environmental Regulation: The Effects of Alternative Policy Instruments on Technology Diffusion. Journal of Environmental Economics and Management, 30: 95-111.

Kemp, R. (1993), An Economic Analysis of Cleaner Technology: Theory and Evidence, in: Fischer, K., Schot, J. (eds.) (1993), Environmental Strategies For Industry, International Perspectives on Research Needs and Policy Implications, Island Press, Washington D.C., pp. 79-113.

Kemp, R. et al. (1994), Policy Instruments to Stimulate Cleaner Technologies, in: Opschoor, J.B. and Turner, R.K. (Eds.) Economic Incentives and Environmental Policies: Principles and Practice, Dordrecht, 1994.

Kemp, R., Soete, (1990), Inside the "Green Box": On the Economics of Technological Changes and the Environment, in: Freeman, C., Soete, L. (eds.), New Explorations in the Economics of Technical Change, London.

Klemmer, P. (1997), Umweltinnovationen - Institutionenökonomische Überlegungen, Vortrag im Rahmen des zweiten Workshops zum FIU-Projekt. Unveröff. Ms.

Klemmer, Paul (Hrsg.) (1999), Innovationen und Umwelt - Fallstudien zum Anpassungsverhalten in Wirtschaft und Gesellschaft. Berlin, Analytica Verlagsgesellschaft.

Kurz, R. u.a. (1989), Der Einfluss wirtschafts- und gesellschaftlicher Rahmenbedingungen auf das Innovationsverhalten von Unternehmen. In: Forschungsbericht Serie A, Nr. 50 des Instituts für angewandte Wirtschaftsforschung, Tübingen.

Lanjouw, J.O., Mody, A. (1993), Stimulating Innovation and the International Diffusion of Environmentally Responsive Technology: The Role of Expenditures and Institutions, mimeo.

Mason, G., van Ark, B., Wagner, K., 1994. Productivity, Product Quality and Workforce Skills: Food Processing in Four European Countries. National Institute Economic Review, 147: 62-83.

Minsch, J., u.a. (1996), Mut zum ökologischen Umbau: Innovationsstrategien für Unternehmen, Politik und Akteursnetze, Basel u.a.

Murty, M.N., Kumar, S., 2001. Win-win Opportunities and Environmental Regulation: Testing of Porter Hypothesis for Indian Manufacturing Industries. Delhi University Enclave, Institute of Economic Growth, India, mimeo.

Newell, R.G., Jaffe, A. B., Stavins, R.N. (1996), Energy-Saving Technology Innovation: The Effects of Economic Incentives and Direct Regulation, discussion paper, Harvard University, Cambridge, Mass.

North, D.C. (1991), Institutions. Journal of Economic Perspectives, 5(1): 97-112.

Nunnenkamp, P. (2004), Automobilstandort Deutschland unter Wettbewerbsdruck. ifo Schnelldients, 57 (7): 28-36.

OECD, 1993. Environmental Policies and Industrial Competitiveness. Organization for Economic Co-operation and Development, Paris.

OECD/EUROSTAT (1997), Oslo Manual. Proposed Guidelines for Collecting and Interpreting Technological Innovation Data.

Palmer, K., Oates,W., Portney, P., 1995. Tightening Environmental Standards: The Benefit-cost or the No-cost Paradigm? Journal of Economic Perspectives, 9: 119-132.

Pavitt, K. (1984), Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory. Research Policy,13:343-373.

Porter, M., van der Linde, C.,1995. Toward a New Conception of the Environment-Competitiveness Relationship. Journal of Economic Perspectives, 9: 97-118.

Rennings, K. (2000), Redefining Innovation - Eco-Innovation research and the Contribution from Ecological Economics. Ecological Economics 32: 319-332.

Repetto, R., 1995. Jobs , Competitiveness and Environmental Regulation: What Are the Real Issues? World Resources Institute, Washington, DC.

Rogers, E.M. (1995), Diffusion of Innovations, 4.Auflage, New York.

Stewart, R.B., 1993. Environmental Regulation and International Competitiveness. The Yale Law Journal,102:2039-2106.

Strasser, K. A. (1997), Cleaner Technology, Pollution Prevention and Environmental Regulation. Vol. IX, Fall 1997, No.1.

Triebswetter, U., 2004. The Impact of Environmental Regulation on Competitiveness in the German Manufacturing Industry - A Comparison with Other Countries of the European Union. Peter Lang, Frankfurt am Main, Berlin, Bern, Bruxelles, New York Oxford, Wien.

Türpitz, K. (2004), The Determinants and Effects of Environmental Product Innovations - An Analysis on the Basis of Case Studies, ZEW Discussion Paper No. 04-02, Mannheim.

Verband der Deutschen Automobilindustrie (2001) (Hrsg.), Auto Jahresbericht 2001, Frankfurt a.M.

Zapf, H. (1989), Über soziale Innovationen, Soziale Welt, Jg. 40, Heft ½, S. 170-183.