Determinants of Environmental Innovation – New Evidence from German Panel Data Sources

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Summary

In most cases, empirical analyses of environmental innovations based on firm-level data relied on survey data for one point in time. These surveys, especially designed for the analysis of environmental innovations, are useful because they allow for the inclusion of many explanatory variables such as different policy instruments or the influence of stake-holders and pressure groups. On the other hand, it is not possible to address the dynamic character of the environmental innovation process. This paper uses two German panel data bases, the establishment panel of the Institute for Employment Research (IAB) and the Mannheim Innovation Panel (MIP) of the Centre for European Economic Research (ZEW), to explore the determinants of environmental innovations. These data bases were not specifically collected to analyze environmental issues, but they contain questions that allow the identification of environmental innovations. We use discrete choice models for each of the data bases to analyze hypotheses derived from the theoretical (environmental) innovation literature. The econometric estimations show that the improvement of the technological capabilities ("knowledge capital") by R&D or further education measures triggers environmental innovations – this result is confirmed by both data bases and both methods to measure environmental innovation. The hypothesis that "Innovation breeds innovation" is confirmed by the analysis of the MIP data. General and environmental innovative firms in the past are more likely to innovate in the present. Environmental regulation, environmental management tools and general organizational changes and improvements trigger environmental innovation, a result that has also been postulated by the famous Porter-hypothesis. Environmental management tools especially help to detect cost-savings (specifically material and energy savings). Following our econometric results, cost-savings are an important driving force of environmental innovation.

Keywords: Environmental innovation, Panel data analysis, Discrete choice models

JEL Classification: Q55, O33, O38, C25

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1 Introduction

According to a widespread definition, „Environmental innovation consists of new or modified processes, techniques, systems and products to avoid or reduce environmental damage“ (Kemp et. al. 2001). In contrast to other innovations, environmental innovations may lead to a so-called ‘win-win’ situation characterized by both economic and environmental benefits (Carraro 2000, Frondel et. al. 2004) due to the characteristic positive spill-overs of these innovations that are accompanied by the internalization of negative environmental effects.

Therefore, it is particularly important to learn more about the driving forces of environmental innovations, which may differ from “traditional” innovations. There are several empirical studies in the literature that primarily analyze these driving forces in a static context (see e.g. Frondel et. al. 2004, Rehfeld et. al. 2004). This is due to the fact that all the respective surveys were only related to one point in time. Consequently, the role of economic performance in the past as a possible precondition for (environmental) innovation or the inclusion of innovation activities in the past, which is an indicator for the path dependency of environmental innovation can not be explored. This paper tries to overcome these shortcomings by using panel data instead of one point in time sources.

The paper is organized as follows: Section 2 provides a short overview of the environmental innovation theory used to derive empirically provable hypotheses. In Section 3, we continue with the main results from the empirical environmental innovation literature, whereas Section 4 contains new econometric estimations based on two German panel data bases, the establishment panel of the Institute for Employment Research (IAB) and the Mannheim Innovation Panel (MIP) of the Centre for European Economic Research (ZEW). Section 5 provides a summary and conclusion.

2 Environmental Innovation Theory

In the following, a short overview of the main elements of an environmental innovation theory is provided to derive empirical provable hypotheses for the determinants of environmental innovations. These theories are mainly based on explanations of general innovations, but there are also environmentally-specific determinants such as institutional and political factors. The general innovation theory stresses the relevance of technology push and market, or demand pull factors for the explanation of innovation activities (Hemmelskamp 1999). There is a consensus that technology push factors are especially important during the initial phase in developing a new product, whereas demand factors become more important during the diffusion phase (Rehfeld et. al. 2004, Pavitt 1984). Most environmental problems represent negative external effects so that there is no clear economic incentive to develop new environmentally benign products and processes. Therefore, the general innovation theory has to be enlarged with respect to the analysis of the influence of environmental policy and institutional factors.

Table 1: Determinants of environmental innovation

Supply side	• Technological capabilities; • Appropriation problem and market characteristics
Demand side	• (Expected) market demand (demand pull hypothesis) • Social awareness of the need for clean production; environmental consciousness and preference for environmentally friendly products
Institutional and political influences	• Environmental policy (incentive based instruments or regulatory approaches) • Institutional structure: e. g. political opportunities of environmentally oriented groups, organization of information flow, existence of innovation networks

Technology push (supply side)

In the general innovation theory, firm’s technological capabilities are emphasized (see e.g. Baumol 2002, Rosenberg 1976). These capabilities comprise the physical and knowledge capital stock of a firm to develop new products and processes. To build up such capital stock inputs like R&D investment further education of the employees is necessary.

Highly developed innovation capacities of a firm may lead to further innovation success in the future. Baumol characterizes these path dependencies appropriately by the expression “innovation breeds innovation” (Baumol 2002:284). In other words, the available technological possibilities (accumulation of human capital, available knowledge) induce further innovations.

- Improvement of technological capabilities ("knowledge capital") by R&D or further education measures trigger innovations (*R&D, furthereducation*)[1]
- Path dependencies: "Innovation breeds innovation": Innovative firms in the past are more likely to innovate in the present (*innolag*)

An innovation only makes sense for the firm if the innovator is able to capture the returns of his innovation activities. In fact "… the creator of an asset will typically fail to appropriate all or perhaps most of the social returns it generates." (Jaffe et al. 2002:44). Therefore, the possibilities to minimize these so-called spill-overs are very important. These possibilities are dependent on technological characteristics (e.g. application of patents) and the market structure.
Monopolistic market structures may help to overcome the appropriation problem, especially for large firms because they " … must fear less imitation from competitors and gain more from scale economies associated with innovations" (Smolny 2003:449). On the other hand, large monopolistic firms have less incentives to innovate, whereas small firms in competitive markets are forced to "be better" than their competitors by developing new products. As a result, the effect of the firm's size on its innovation activities is undetermined from a theoretical perspective. It is important to note that market structures are not static. Competitors always try to destroy the monopolistic situation, and creative destruction can be seen as the driving force of endogenous technical change.

- The effects of market characteristics and the size of the firm are undetermined due to opposed forces (*scope, size, exports*)

Demand pull, business cycle

Especially in the diffusion phase of new (environmental) products the demand from consumers, public procurement, other firms and exports is relevant (Pavitt 1984). With regard to environmentally friendly products, the environmental consciousness of the consumers and firm is an important variable.
There is increasing literature on the relationship between the business cycle and innovative activities (see e. g. Flaig and Stadler 1994, Geroski and Walters 1995, Smolny 2003) but the empirical analyses do not show a uniform picture. Also from a theoretical point of view, the

[1] In brackets, the names of the respective variables of our econometric models in Section 4 are reported.

relationship remains ambiguous. On the one hand, an increasing demand in the past and high capacity utilization indicate growing markets in the future, but on the other hand Smolny (2003:453) argues that in periods of slack demand “Non-production activities such as the re-organization of production processes, R&D and training exhibit less opportunity costs in case of excess capacities.” This argument is not relevant for the effects of expected future demand on innovations, so we can expect that positive demand expectations will trigger present innovations.

- An increase in the expected future demand triggers (environmental) innovations but the effects of the capacity utilization and the economic situation in the past are ambiguous (*profitsituation, overtime, demand*)

Environmental Policy

Because of negative external effects characterizing most environmental problems, environmental innovations are at least less market-driven than other innovations, therefore making environmental policy one of the main drivers of environmental innovation. The famous *Porter-hypothesis* (Porter and van der Linde 1995) postulates that environmental regulation may lead to a win-win situation so that pollution is reduced and profits are increased. The Porter-hypothesis is largely based on evolutional innovation theory. Because of large uncertainties concerning the success of R&D, this theory (Nelson and Winter 1982) says that firms use rules of thumb and routines with respect to their innovation behaviour. Hence, innovation activities are not a result of an optimization process. Following Porter and van der Linde, this argument is specifically relevant for the case of environmental innovation. Firms do not detect the potential of environmental innovations because they are “ … still inexperienced in dealing creatively with environmental issues.” Environmentally and economically benign innovations are not realized because of incomplete information, organizational and coordination problems (Porter and van der Linde 1995:99). Firms are not able to recognize the cost saving potentials (e.g. energy or material savings) of environmental innovation. Therefore, environmental regulation may “force” firms to realize economically benign environmental innovation. Furthermore, the encouragement of “soft” environmental measures like environmental accounting systems or eco-audits may improve the information basis for environmental innovation.

A second component of the Porter-hypothesis states the assumption that environmental policy may induce early mover advantages for regulated firms, which may lead to higher profits in the future. Up to now, there has been no convincing empirical evidence for the Porter-hypothesis. Furthermore, the theoretical literature is very sceptic about its relevance. For instance, Schmutzler has shown that even in a framework with organizational inefficiencies environmental policy measures can only increase firm profits under very restrictive assumptions (Bonato and Schmutzler 2000).

- Environmental regulation and environmental management tools trigger environmental innovation (*regulation, organization, envmanagement*);
- Cost-savings are one of the main driving forces of environmental innovation, but environmental policy and especially the introduction of environmental management measures are needed to support firms in detecting cost saving potentials (*costsavings*, *regulation*, *organization*, *envmanagement*).

It is important to note that a relevant discussion about the effects of different environmental policy instruments is beyond the scope of this paper because our data bases used for the econometric analyses in Section 4 do not contain the necessary information. We refer to the extensive theoretical (e.g. Downing and White 1986, Fischer et. al. 2003, Montero 2003, Kemp 2000 etc.) and relatively poor empirical literature (e. g. Arimura et. al.2005, Frondel et. al. 2005).

3 Recent Empirical Analyses of Environmental Innovation

Empirical analyses on the driving forces of environmental innovation are still rare. This is mainly due to difficulties in obtaining adequate indicators for environmental innovation as well as relevant determinants like policy stringency. The following summarizes the different possibilities for measuring environmental innovation, which includes at least one example from the respective literature.

Brunnermeier and Cohen (2003) used the number of successful environmental patent applications granted to US manufacturing industries between 1983 and 1992. As an indicator for environmental policy stringency, they applied pollution abatement expenditures and government monitoring activities. The authors found that increases in abatement expenditures were correlated with increases of environmental innovation but the effects were only small. There was no effect in monitoring activities on environmental innovation.

A recent analysis of de Vries and Withagen (2005) also used environmentally related patents in Europe as environmental innovation indicators. They measured policy stringency according to three different indicators: Compliance with international agreements by individual signatories representing a more stringent domestic policy; an Index of Environmental Sensitivity Performance combining different pollutants, and furthermore, the authors modelled stringency as a latent variable: "Here the underlying idea is that high emission levels trigger strict environmental policy, which in turn provide an incentive for innovation." (de Vries and Withagen 2005:28). Only for the third stringency indicator did the authors find a strong positive relationship with environmental innovation.

There are several studies analyzing the introduction of new environment relevant products or processes based on surveys specifically carried out for these purposes.

Rennings et al. (2003) used survey data to analyze the influence of environmental management systems on environmentally related organizational, process and product innovations. Other than the positive influences of environmental management tools, the authors show that the existence of a specialized R&D department as an input variable triggers environmental innovation.

Rehfeld's et. al. paper (2004) detects a positive relationship between environmental organizational measures and environmental product innovations for German manufacturing. Furthermore, despite other factors and firm specific characteristics, waste disposal measures and product take-back systems are important drivers of environmental product innovations.

Survey results for the determinants in the introduction of environmental R&D and for cleaner technologies are available in a recent OECD project on Public Environmental Policy and the Private Firm covering seven OECD countries, (see Arimura et. al. 2005 and Frondel et. al. 2005). Econometric results show that a strict environmental policy measured by the perceived policy stringency of the questioned firm, environmental accounting systems and flexible environmental instruments stimulate environmental R&D. Environmental management tools and the possibility of cost savings are very important for the introduction of cleaner technologies.

In facing the dynamic character of innovation processes, an important limitation of the above-mentioned survey results is that they are restricted to one point in time. In the following sections, we try to overcome this problem by using panel data bases in Germany. Unfortunately, these panels have not been specifically established to analyze environmental innovation, so that interesting variables like different environmental instruments or the influence of pressure groups are not available. On the other hand, we are able to address the dynamic character of innovation processes by using panel information and lagged independent variables. In Germany, it is possible to identify environmental innovation in two reliable panel data sources, the establishment panel of the Institute for Employment Research (Section 4.1) and the Innovation Panel of the Centre for European Economic Research in Mannheim (Section 4.2).

4 Empirical Results from German Panel Data Sources

4.1 Employment Panel of the Institute for Employment Research

The employment panel of the Institute for Employment Research allows an analysis of the determinants of the introduction of environmental product innovations. The establishment panel was founded in 1993 to get a representative picture of German establishments who have at least one employee subject to social security. The establishment panel is characterized by very high response rates of more than 70%.

The environmental sector can be identified by a filter question of the wave 1999: “Does your firm offer goods or services related to the reduction of environmental impacts” (if yes, the firm belongs to the environmental sector). In 2001 and 2004, the questionnaires contained information about innovation activities making it possible to analyze the innovative behaviour of environmental firms. For our econometric analysis, a firm is defined as environmental innovative if it a) belongs to the environmental sector as defined above and b) has improved or developed a new product during the last two years before the respective survey. Following this definition, data from 753 firms belonging to the environmental sector is available. 56% of these firms (418) were environmentally innovative.

We were able to use panel estimation methods because the innovation question is available for two points of time (2001 and 2004). Unfortunately, a high number of the 2001 respondents do not appear in the 2004 investigation, therefore a fixed effects model is not feasible (see Verbeek 2004:375). We have used a random effects model, which assumes that the individual effects are uncorrelated with the regressors (Greene 2003:293). This way of proceeding seems to be appropriate because the sampled cross-sectional units of the IAB establishment panel are drawn from a large population.

As independent variables we use export intensity (*exports*), *size*, turnover expectations (*demand*), lagged economic performance (*profitsituation*), share of high qualified employees (*highqual*), *R&D* activities, *overtime* worked, existence of collective *wage agreements*, introduction of environmental management tools (*envmanagement*), *subsidies*, *age* of the firm, regional (*region*) and sector dummies. To avoid endogeneity problems, lagged values are used for several variables.

There are also some clear restrictions in our analysis since the establishment panel does not cover variables like political pressure, different environmental policy instruments or the influence of pressure groups that seem to be important for environmental innovation. Furthermore, the self-perception of some variables by the responding firm (e.g. turnover expectations) may be critical.

Table 2: Determinants of Environmental Product Innovations

Dependent variable: envinnovation: 1 Suppliers of environmental goods and services with product innovations, 0 Suppliers of environmental goods and services without product innovations			
Determinants		Sector Dummies	
Age	0.082 (0.60)	Sec3-6	0.46 (0.88)
Demand	0.30 (1.95)*	Sec7-12	0.73 (2.38)*
Envmanagement	0.63 (3.61)**	Sec13-18	1.33 (3.81)**
Exports	0.65 (2.61)**	Sec19-20	0.67 (2.47)*
Highqual	0.01 (3.81)**	Sec21-23	0.64 (2.30)*
Overtime	0.17 (1.20)	Sec24-31	0.85 (2.34)*
Profitsituation	0.02 (0.19)	Sec32	1.03 (3.37)**
Region	0.22 (1.46)	Sec33-41	0.98 (3.16)**
R&D	1.40 (6.61)**		
Size	0.00 (1.20)		
Subsidies	0.50 (3.08)**		
Wageagreement	0.04 (0.34)		
Random-effects probit regression. Number of observations: 967, number of groups: 681. Z-statistics are given in parentheses. Wald Chi^2 (20) = 100.84. Rho = 0.35**. The significant value of rho signifies that the panel level variance component matters in that a simple pooled model can not be applied. *, ** denote significance at the 5% and 1% level, respectively.			

The econometric results confirm our hypothesis (see Section 2) that the technological capabilities trigger environmental innovations. The coefficient of our indicator *R&D* is highly and positively significant. A high qualification (*highqual*) of employees, also interpretable as indicator of technological capabilities, promotes the introduction of environmental product innovations. The influence of the firm's *size* is not significant - a result that we would have expected from the theory. Unfortunately, the data does not allow testing for the effects of market characteristics such as the number of competitors, but as a proxy we may interpret the positive influence of the export share of the firm. High export (*exports*) shares may signify high (international) competition so that the respective firms are forced to develop new products compared to only nationally active firms. This result corresponds with literature on the determinants of general innovations. For instance, Smolny (2003:460) has found: "Note the very strong effect of export activities on product innovations. One interpretation is that firms acting on international markets have more incentives to engage in quality competition."

As theoretically outlined, the expected *demand* also matters for the realization of environmental product innovations. The respective coefficient is significant and positive. Furthermore, our hypothesis that the influence of the former and the present economic situation is ambiguous can also be confirmed in that the respective proxies *overtime* reflecting the capacity utilization and the three years lagged *profit situation* are not significant.

Another important result is that environmental management tools (*envmanagement*) are important for the introduction of environmental product innovation confirming the analyses of other survey results in the literature (see e. g. Rennings et. al. 2003; Rehfeld et. al. 2004 or Frondel et. al. 2005). Obviously, environmentally active firms are also more likely to develop more new environmentally related products. A further argument is that environmental management measures provide information for new product opportunities.

Environmental policy also matters. Unfortunately, the data basis only allows controlling for the influence of *subsidies*. There is a highly significant positive influence of the respective variable.

Furthermore, significant differences between sectors are observable - indeed not a surprising result because, for instance, sectors like machinery equipment are more likely to develop new environmental products in comparison to the textile sector. There is no significant difference between Eastern and Western Germany.

Table 3: Description and descriptive Statistics of the Variables

Name of variable	Description	Mean	Std.Dev.
Envinnovation	1 Supplier of environmental goods and services and has improved or developed a new product during the last two years 0 Supplier of environmental goods and services but has not improved or developed a new product during the last two years	0.42	0.49
Age	Foundation of the firm (1 before 1990, 0 after 1990)	0.44	0.50
Demand	1 Expecting an increasing turnover in the next year 0 Expecting a decreasing or stagnating turnover in the next year	0.25	0.43
Envmanagement	1 Introduction of environmental management tools during the last two years 0 No introduction of environmental management tools	0.15	0.35
Exports	1 Export quota greater than 20% 0 Export quota less or equal than 20%	0.13	0.33
Highqual	Share of high qualified employees with respect to all employees (in %)	24.5	27.5
Overtime	Overtime worked (1 yes, 0 no)	0.74	0.44
Profitsituation	1 (Very) good profit situation three years ago 0 Insufficient or satisfactory profit situation three years ago	0.34	0.47
Region	1 West Germany 0 East Germany	0.42	0.49
R&D	1 R&D activities, 0 No R&D activities	0.19	0.39
Size	Number of employees 2001 or 2004	258	1610
Subsidies	1 Financial assistance for investment 0 No financial assistance	0.18	0.38
Wageagreement	1 Existence of a collective wage agreement 0 No collective wage agreement	0.58	0.49
Sector dummies	1 yes, 0 no for all sector dummies		
Sec1-2	Agriculture, forestry, mining, energy and water supply	0.09	0.28
Sec3-6	Food products and beverages, textiles, wood, paper, printing	0.02	0.14
Sec7-12	Chemical Industry, rubber and plastic products, basic metals and fabricated metals, non-metallic mineral products, recycling	0.13	0.33
Sec13-18	Machinery, motor vehicles, other transport equipment, electrical machinery and apparatus, precision and optical instruments, furniture, musical instruments and other products	0.10	0.30
Sec19-20	Construction sector	0.21	0.41
Sec21-23	Trade with motor vehicles, wholesale and retail trade	0.19	0.39
Sec24-31	Transport and communication, banking sector, assurances, data processing, research and development, consulting, estate management	0.05	0.22
Sec32	Other services especially for enterprises	0.11	0.32
Sec33-41	Other services	0.11	0.31

4.2Mannheim Innovation Panel

The Mannheim Innovation Panel (MIP), which was introduced in 1993, analyzes the determinants and the effects of innovation activities in the manufacturing and service sector in Germany. The survey is not specifically designed to explore environmental innovation, but the panel wave of 2001 contains the question of whether innovation activities of the respective firm led to significant improvements of environment or health conditions. This question allows an analysis of the determinants on the (perceived) output of environmental innovation activities. In fact, this definition is relatively broad because it also includes health conditions.
Due to the panel character of the MIP, the inclusion of lagged independent variables such as economic performance in the past is possible. Unfortunately, the panel mortality of the MIP is high, therefore the integration of lagged variables causes a significant reduction in the number of cases. Different versions of the models are presented (with and without lagged variables). Furthermore, the “environmental question” is only available for 2001, so panel estimation methods are not applicable.

The panel wave of 2001 contains data for 4846 firms in the manufacturing and service sector. The response rate was about 20% (20.8% for the manufacturing, 19.7% for the service sector) which is in line with comparable non-mandatory surveys. Our econometric analyses of the MIP data address the following questions:

- Do environmental innovations have specific determinants with respect to other innovations?
- What triggers environmental, and other innovations, with respect to the no-innovation alternative?

In the first step, we try to detect specific determinants of environmental innovations versus other “non-environmental innovators”, analyzing a sub-sample of all innovating enterprises. “Environmental innovators” have realized innovations with relevant environmental or health effects. The other innovations are characterized by only low, or no environmental and health effects. For our econometric analysis we use a binary probit model with the dependent variable *envinnovationMIP* including the following outcomes:

1 Environmental innovators: realization of innovations with relevant environmental or health effects

0 Other innovators: realization of innovations with low or no environmental and health effects

Table 4: Determinants of Environmental Innovation with respect to other Innovations

Determinants		Sector Dummies	
AgeMIP	-0.065 (-0.90)	Sec1MIP	0.11 (0.63)
Cooperation	0.04 (1.32)	Sec2MIP	0.16 (1.82)$^{+}$
Costsavings	0.38 (7.09)**	Sec3MIP	-0.04 (-0.41)
DemandMIP	-0.01 (-0.46)	Sec4MIP	0.14 (1.67)$^{+}$
ExportsMIP	0.001 (1.88)$^{+}$	Sec5MIP	0.19 (2.95)**
FurtherEducation	-0.04 (-0.94)	Sec6MIP	-0.03 (-0.31)
HighqualMIP	-0.08 (-2.48)**	Sec7MIP	0.09 (1.34)
Organization	0.69 (2.59)**	Sec8MIP	0.04 (0.60)
RegionMIP	0.03 (0.83)	Sec9MIP	0.05 (0.74)
Regulation	0.40 (8.96)**	Sec10MIP	-0.10 (-1.51)
R&DMIP	0.09 (2.78)**	Sec11MIP	0.08 (0.83)
Scope	-0.01 (-0.16)	Sec12MIP	-0.11 (-1.21)
SizeMIP	0.00 (0.18)	Sec13MIP	0.31 (2.76)**
SubsidiesMIP	0.07 (2.05)*	Sec14MIP	0.31 (2.78)**
		Sec15MIP	0.09 (0.69)
		Sec16MIP	0.05 (0.89)
		Sec17MIP	0.06 (0.66)
		Sec18MIP	-0.18 (-2.49)**
		Sec19MIP	-0.03 (-0.48)
Probit regression. Number of observations: 1389, Chi^2 (33) = 291.70. Pseudo R^2 = 0.173. Z-statistics are given in parentheses; $^{+}$, *, ** denote significance at the 10%, 5%, and 1% level, respectively. Marginal effects are reported instead of coefficients.			

The econometric results show (see table 4) that *R&D* activities are more important for the realization of environmental innovations compared to other innovations. This may be explained by the fact that the introduction of cleaner technologies, which often requires a change of the whole production process, needs high resource inputs. In line with other results in the literature, *cost savings* and compliance with regulatory measures (*regulation*) are significant determinants for environmental innovations but they are not important for other innovations (see also Frondel et. al. 2004). Not surprisingly, there are significant sectoral differences, for instance, the chemical industry (*sec5MIP*) as an environmentally intensive industry realizes more innovations with environmental effects.

Interestingly, one of the main assumptions of the Porter hypothesis (see Section 3) seems to be empirically relevant: The introduction of new or relevant changes of organizational structures (*organization*) is especially important for environmental innovations.

Due to the negative external effects character of environmental problems, *subsidies* are significantly more important for environmental innovations.

In the second step, we estimated a binary probit model with lagged variables for the economic performance and innovative activities in the past, but there were no significant differences between our two types of innovation with respect to these variables. Due to the loss of many cases after including the lagged variables the respective model is not reported.

Furthermore, we analyze the firms´ choice between innovations with environmentally relevant effects, and other innovations versus the no-innovation alternative by applying a multinomial logit model. We try to explore common and different factors of the two innovation decisions with respect to the no-innovation alternative. Our unordered variable *innovation* contains the following categories:

1 Environmental innovators (realization of innovations with relevant environmental or health effects)

2 Other innovators

3 Non-innovators

Table 5: Multinomial Logit Model of (Environmental) Innovation

	Environmental Innovations	Other Innovations		Environ-mental Innovations	Other Innovations
Determinants			*Sectors*		
AgeMIP	0.70 (-0.89)	1.12 (0.41)	Sec5MIP	3.13 (3.81)**	0.97 (-0.14)
DemandMIP	2.21 (5.36)**	2.10 (6.25)**	Sec6MIP	1.16 (0.29)	0.90 (-0.29)
ExportsMIP	1.02 (5.04)**	1.01 (3.56)**	Sec7MIP	1.43 (1.16)	0.83 (-0.81)
FurtherEducation	0.33 (-5.10)**	0.47 (-5.58)**	Sec8MIP	2.16 (2.42)*	1.46 (1.51)
HighqualMIP	1.18 (0.92)	1.59 (3.37)**	Sec9MIP	4.84 (3.85)**	2.79 (2.90)**
Organization	2.91 (7.93)**	1.90 (6.20)**	Sec10MIP	2.21 (1.71)$^{+}$	2.74 (2.87)**
RegionMIP	1.14 (0.93)	1.01 (0.05)	Sec11MIP	2.55 (1.98)*	1.09 (0.19)
Scope	1.86 (3.65)**	1.66 (4.18)**	Sec12MIP	1.18 (0.29)	1.43 (0.92)
SizeMIP	1.00 (2.76)**	1.00 (2.75)**	Sec13MIP	1.75 (1.48)	0.39 (-2.64)**
			Sec14MIP	2.10 (1.74)	0.57 (-1.49)
Sectors			Sec15MIP	0.44 (-1.71)$^{+}$	0.25 (-3.92)**
Sec1MIP	0.90 (-0.15)	0.45 (-1.80)$^{+}$	Sec16MIP	1.03 (0.09)	0.81 (-1.09)
Sec2MIP	1.45 (1.01)	0.65 (-1.49)	Sec17MIP	0.50 (-1.86)	0.34 (-4.31)**
Sec3MIP	0.76 (-0.56)	0.81 (-0.64)	Sec18MIP	0.74 (-0.48)	3.00 (3.26)**
Sec4MIP	1.87 (1.67)$^{+}$	0.98 (-0.06)	Sec19MIP	1.10 (0.30)	1.08 (0.40)

Multinomial Logit Regression. Number of observations: 2435. Chi^2 (56) = 786.41. Pseudo R^2 = 0.157. The base outcome is “no innovation”. Z-statistics are given in parentheses; $^{+}$, * and ** denote significance at the 10%, 5% and 1% level, respectively. Exponentiated coefficients are reported. These values represent the relative-risk ratio of a one-unit change in the corresponding variable, where the term “relative risk” describes the risk of the outcome j relative to the base outcome (see also STATA Reference K-Q 2005:211).

An important assumption of multinomial logit models is that outcome categories have the property of independence of irrelevant alternatives (IIA). The results of Hausman/McFadden tests have shown that there is no systematic change in the coefficients if we exclude one of the alternatives.

Firms expecting higher employment levels (*demandMIP*) are more likely to innovate, which may be interpreted as a confirmation of the demand pull hypothesis.[2] There is no relevant difference between environmental and other innovators with respect to this variable. Because of higher competition (see also Section 3) nationwide or internationally active firms are more likely to innovate, the respective variable *scope* is highly significant. Improving the technological capacities is also relevant for both types of innovations indicated by the positive influence of *further education* measures. Furthermore, the size of the firm and the export share are positively correlated with both types of innovative activities.

Compared to the binary probit model our multinomial logit model does not enable us to detect all the differences in the determinants between environmental and other innovations. This is because several variables like cost savings and regulations data are exclusively available for innovative firms. Nevertheless, the results show that strategic and organizational measures significantly trigger both types of innovations but they are quantitatively more relevant for environmental innovations. Not surprisingly, there are sector differences, the dummy variable for the chemical industry (*sec5MIP*), for instance, is only significant for environmental innovators.

To test for the relevance of the economic situation in the past and to test the hypothesis of the path dependency of (environmental) innovations, we also estimated a multinomial logit model including lagged variables. In addition to our previous model the results show that the economic performance (*profitsituation*) in the past is not important, whereas path dependencies (*innolag*) are significant for both types of innovators. To be innovative in the past increases the probability for present or future innovations.

[2] Unfortunately, there is no variable for turnover expectations in the questionnaire so that we have to use employment expectations as a proxy.

Table 6: Multinomial Logit Model of (Environmental) Innovation (including lagged variables)

	Environ-mental Innovations	Other Innovations		Environ-mental Innovations	Other Innovations
Determinants			*Sectors*		
DemandMIP	1.39 (1.50)	1.62 (2.75)**	Sec5MIP	5.72 (4.18)**	1.14 (0.39)
FurtherEducation	0.28 (-3.81)**	0.54 (-3.17)**	Sec6MIP	2.36 (1.35)	1.05 (0.11)
HighqualMIP	0.99 (-0.04)	1.21 (0.98)	Sec7MIP	1.72 (1.25)	0.81 (-0.68)
Innolag	7.99 (9.65)**	4.43 (10.33)**	Sec8MIP	3.17 (2.80)**	1.11 (0.34)
Organization	2.53 (5.07)**	1.61 (3.38)**	Sec9MIP	5.62 (3.21)**	2.62 (2.15)*
ProfitsituationMIP	1.00 (0.69)	1.00 (0.32)	Sec10MIP	3.39 (2.11)*	1.82 (1.35)
RegionMIP	0.82 (-1.01)	0.94 (-0.44)	Sec11MIP	4.89 (2.60)**	1.36 (0.59)
Scope	1.60 (2.07)*	1.52 (2.61)**	Sec12MIP	1.86 (0.85)	1.41 (0.65)
SizeMIP	1.00 (2.93)**	1.00 (2.49)**	Sec13MIP	3.96 (2.86)**	0.25 (-2.60)**
			Sec14MIP	3.96 (2.39)*	0.94 (-13)
Sectors			Sec15MIP	0.81 (-0.33)	0.33 (-2.56)**
Sec2MIP	1.53 (0.77)	0.64 (-1.16)	Sec16MIP	1.79 (1.42)	0.70 (-1.29)
Sec3MIP	1.53 (0.69)	1.13 (0.30)	Sec17MIP	1.01 (0.02)	0.49 (-2.26)*
Sec4MIP	2.82 (1.95)*	0.92 (-0.23)	Sec18MIP	1.95 (0.85)	2.57 (1.91)+
			Sec19MIP	0.90 (-0.20)	0.97 (-0.09)

Multinomial Logit Regression. Number of observations: 1398. Chi^2 (54) = 579.66. Pseudo R^2 = 0.201. The base outcome is “no innovation”. Z-statistics are given in parentheses; $^{+}$, * and ** denote significance at the 10%, 5% and 1% level, respectively. Exponentiated coefficients are reported. These values represent the relative-risk ratio of a one-unit change in the corresponding variable, where the term “relative risk” describes the risk of the outcome j relative to the base outcome (see also STATA Reference K-Q 2005:211).

An important assumption of multinomial logit models is that outcome categories have the property of independence of irrelevant alternatives (IIA). The results of Hausman/McFadden tests have shown that there is no systematic change in the coefficients if we exclude one of the alternatives.

Table 7: Description and descriptive Statistics of the Variables

Name of variable	Description	Mean	Std.Dev.
EnvinnovationMIP	1 Environmental innovators: realization of innovations with relevant environmental or health effects 0 Other innovators	0.31	0.46
Innovation	1 Environmental innovators: realization of innovations with relevant environmental or health effects 2 Other innovators: realization of innovations with low or no environmental and health effects 3 Non-Innovators	-	-
AgeMIP	Foundation of the firm (1 before 1998, 0 after 1998-2000)	0.04	0.19
Cooperation	Participation in innovation cooperation (1 yes, 0 no)	0.30	0.46
Costsavings	1 High reduction of material and energy costs per unit 0 Moderate, low or no reduction of material and energy costs per unit	0.09	0.28
DemandMIP	1 Expecting an increasing employment in the next year 0 Expecting a decreasing or stagnating employment in the next year	0.29	0.46
ExportsMIP	1 Export quota greater than 20% 0 Export quota less or equal 20%	12.66	21.85
FurtherEducation	Investment in further education of employees (1 yes, 0 no)	0.19	0.39
HighqualMIP	1 Share of employees with university degree greater that 20% 0 Share of employees with university degree less or equal than 20%	0.29	0.45
Innolag	Innovator in the preceding panel wave (1 yes, 0 no)	0.58	0.49
Organization	Introduction of new organizational structures (1 yes, 0 no)	0.51	0.50
Profitsituation	Development of turnover from 1997 to 1998 (in %)	9.92	60.23
Region	1 East Germany 0 West Germany	0.36	0.48
Regulation	1 Fulfilment of regulations and standards as highly important motive of the innovation 0 Fulfilment of regulations and standards as moderate, low or no important motive of the innovation	0.12	0.33
R&DMIP	1 R&D activities 1998-2000, 0 No R&D activities 1998-2000	0.69	0.46
Scope	1 Main market: over-regional (more than a radius of 50 kilometres) or international 0 Main market: local/regional (less than a radius of 50 kilometres)	0.61	0.49
SizeMIP	Number of employees 2001	898	11938
SubsidiesMIP	1 Financial assistance for investment 0 No financial assistance	0.31	0.46

Table 7 (continued)			
Sector dummies	1 yes, 0 no for all sector dummies		
Sec1MIP	Mining, quarrying of stones	0.01	0.11
Sec2MIP	Food products and beverages, tobacco	0.03	0.18
Sec3MIP	Textiles, leather	0.02	0.15
Sec4MIP	Processing of wood, paper, printing	0.03	0.18
Sec5MIP	Chemical Industry, rubber and plastic products	0.06	0.24
Sec6MIP	Glass, ceramics	0.02	0.14
Sec7MIP	Basic metals and fabricated metals	0.06	0.24
Sec8MIP	Machinery	0.07	0.25
Sec9MIP	Electrical machinery and apparatus	0.04	0.19
Sec10MIP	Precision and optical instruments	0.03	0.16
Sec11MIP	Motor vehicles, other transport equipment	0.02	0.13
Sec12MIP	Furniture	0.01	0.12
Sec13MIP	Recycling, waste and waste water removal	0.03	0.16
Sec14MIP	Energy and water supply	0.02	0.15
Sec15MIP	Construction sector	0.03	0.18
Sec16MIP	Wholesale and retail trade	0.13	0.33
Sec17MIP	Transport and communication, banking sector, assurances, renting of cars and other products	0.09	0.28
Sec18MIP	Data processing	0.04	0.18
Sec19MIP	Research and development, consulting	0.11	0.32
Sec20MIP	Other services	0.15	0.36

5 Summary

In most cases, empirical firm-level analyses of environmental innovation were based on survey data for one point in time. These surveys, especially designed for the analysis of environmental innovations, are useful because they allow for the inclusion of many explanatory variables such as different policy instruments or the influence of stakeholders and pressure groups. On the other hand, it is not possible to address the dynamic character of the environmental innovation process. This paper uses two German panel data bases, the establishment panel of the Institute for Employment Research (IAB) and the Mannheim Innovation Panel (MIP) of the Centre for European Economic Research (ZEW), to explore the determinants of environmental innovations. These data bases were not specifically collected to analyze environmental issues, but they contain questions that allow the identification of environmental innovations.

We use discrete choice models for each of the data bases to analyze hypotheses derived from the theoretical (environmental) innovation literature. Concerning the establishment panel of the IAB, panel estimation methods were applicable because the questions about environmental innovations were available for two points in time (2001 and 2004). This data basis allows analyzing environmental product innovations.

The “environmental question” of the MIP - panel focused on the perceived environmental effects of the innovation activities of a firm. Unfortunately, the question is only available for 2001, but lagged independent variables could be used.

The econometric estimations show that the improvement of the technological capabilities (“knowledge capital”) by R&D or further education measures triggers environmental innovations – this result is confirmed by both data bases and both methods used to measure environmental innovation.

The hypothesis that “Innovation breeds innovation” is confirmed by the analysis of the MIP data. General and environmental innovative firms in the past are also more likely to innovate in the present. The demand pull hypothesis is confirmed in both models. An increase in the expected future demand triggers (environmental) innovations. On the other hand, the effects of capacity utilization and economic situation in the past are not significant.

Environmental regulation, environmental management tools and general organizational changes and improvements trigger environmental innovation, a result that has also been postulated by the famous Porter-hypothesis. Environmental management tools help especially to detect cost-savings (specifically material and energy savings). Following our econometric results, cost-savings are an important driving force of environmental innovation.

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