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The Influence of the EU Environmental Management and Auditing Scheme on Environmental Innovations and Competitiveness in Germany: An Analysis on the Basis of Case Studies and a Large-Scale Survey

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Non-technical summary

This paper investigates the effects of the EU Environmental Management and Auditing Scheme (EMAS) on environmental innovations and competitiveness in German facilities. It comprises twelve in-depth case studies and telephone interviews with 1277 EMAS-validated facilities.

The surveys show a positive influence of EMAS on environmental process and product innovations as well as on environmental organisational innovations. In addition, environmental reports contribute to the diffusion of environmental innovations. The study shows as well that the scope of these innovations depends on the maturity of EMAS (measured as age of EMAS, two revalidations of EMAS, beforehand experience concerning the organisation of environmental protection, ISO 14001 validation). A decisive factor of success regarding the implementation of environmental innovations is the organisational scope of EMAS in a given facility. EMAS-participants position themselves towards competitors with quality of products rather than low prices. An influence of the strategic importance of EMAS on the facilities' market success was not established. Facilities who have achieved significant learning processes by EMAS are particularly successful in economic terms.

An important advice to be given to facilities on basis of this study is to improve their competitiveness by a better linkage between environmental management and innovation management. The organisational implementation of environmental and innovation management as well as the practical introduction of new and changed environmental processes and products is relevant in this regard. The organisational scope of EMAS in the facility is an important factor of success in inducing environmental innovations within the facility. The R&D department plays a central role in this matter and it should participate in further development of EMAS in order to achieve improved linkage between product-related and strategic issues.

The results also hold policy advice. Public subsidies are justified if an activity offers positive external effects, i.e. benefits unredeemed via market prices. This is often true for innovation processes, with basic research being a well-known example. In the case of environmental innovations, there is an additional "external" benefit to society, which is an improved quality of the environment. The ability of certified environmental management systems to foster environmental innovations is a finding of our study and the protection of public goods and of benefits to society should be taken into account with regard to aid policies. Public procurement is an important aid instrument in this context. EMAS-participants demand privileges regarding public procurement processes to be awarded for their participation in the auditing scheme.

Yet another question is what management standard should be supported and whether EMAS should be privileged in this regard. Concerning the question of environmental innovation effects it has become clear that EMAS can make a difference. Unlike the ISO 14001 standard, EMAS requires external communication via an environmental report. Our study shows that the environmental reports of other facilities are being used for gathering ideas for a facility's own environmental innovations. Two conclusions can be drawn from this issue as policy advice. On the one hand, from an innovation perspective it seems justified to discriminate between the two standards with regard to political support. On the other hand, if this is not desired or possible, it seems advisable to link equal treatment of ISO 14001 to the voluntary publication of an environmental report.

The Influence of the EU Environmental Management and Auditing Scheme on Environmental Innovations and Competitiveness in Germany: An Analysis on the Basis of Case Studies and a Large-Scale Survey

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March 2003

Summary

This paper investigates the effects of the EU Environmental Management and Auditing Scheme (EMAS) on environmental innovations and competitiveness in German facilities. It comprises twelve in-depth case studies and telephone interviews with 1277 EMAS-validated facilities. The surveys show a positive influence of EMAS on environmental organisational, process and product innovations. Moreover, the environmental report supports the diffusion of environmental innovations. The econometric analysis with binary probit models shows a significant positive impact of the maturity of environmental management systems on environmental innovations. Another determinant of environmental innovations is the strong participation of specific departments in further development of EMAS, especially of the R&D department. An effect of strategic importance of EMAS on market success could not be confirmed. Facilities with high learning processes by environmental management systems however have a significantly better performance concerning turnover and exports.

Keywords: Environmental management systems, environmental innovation, technological progress, cleaner production.

1 Introduction

An important aim of environmental modernisation is the implementation of policies which connect environmental management to improved competitiveness. Some of the most important instruments in this respect are standards for environmental management systems (EMS) such as the EU Environmental Management and Auditing Scheme (EMAS). Implementations of EMS's are intended to promote process innovations towards improved environmental quality in combination with decreased costs (e.g. energy, water, waste, materials) as well as product innovations in the field of eco-efficient products and services. While the general cost-benefit relation of EMS complying with EMAS have been the subject of a number of studies, the influence of EMS and EMAS on environmental innovations and competitiveness has not been studied systematically until now (see ANKELE et al. 2002). The study of BRADFORD et al. (2000) is an exception, but while it does indeed deal with the influence of EMAS on innovation, it confines itself methodologically to case studies and does not offer further analysis of a representative sample of EMAS-participants.

This paper follows a more far-reaching approach. As a first step, we develop hypotheses on the basis of a literature review (e.g. BMU/UBA 2000, DYLLICK/HAMSCHMIDT 2000, for a survey see ANKELE et al. 2002) in section 2. Based on the literature study, the hypotheses have been pre-tested in the context of twelve in-depth case studies on German EMAS-validated facilities. Moreover, a large-scale telephone survey with German EMAS-participants has been conducted to allow representative conclusions. These methodological approaches are presented in section 3. In section 4, the results of the surveys and especially the results of the econometric analysis with binary probit models based on the data of the large-scale survey are discussed. Section 5 draws some conclusions and offers directions for further research.

2 Hypotheses

2.1 Key definitions: Innovations and environmental innovations

Regarding the general definition of innovations, the study follows the guidelines on empirical innovation research laid out in the Oslo-manual which defines innovations in general as technological or organisational changes (OECD/EUROSTAT 1997). Most of all, product and process innovations are being distinguished. Process innovations lead to decreased inputs, at a constant level of output. Product innovations enable improved or new goods. As of late, the OECD-definition, apart from technical innovations, includes organisational innovations and new services.

With an instrument aiming at environmental improvements such as EMAS, the focus is on innovations contributing to improvements of the environment. Following KLEMMER (1999), we define environmental innovations as techno-economic, institutional and social changes leading to an improved quality of the environment. With respect to environmental technical innovations, integrated and end-of-pipe environmental protection can be distinguished (see RENNINGS 2000).

In the literature currently available, environmental organisational innovations are rarely addressed. BRADFORD et al. (2000, p. 8) evade the consequent narrowing of scope via a comprehensive and at the same time target-oriented definition, which we will use as our working definition: "Environmental organisational innovations are managerial and organisational changes

aimed at identifying environmental problems associated with existing products and processes and creating structures, programmes and competencies to address these problems".

The application of a facility-oriented innovation concept means that a number of environmental innovations are an immanent result of the EMAS-requirements (e.g. a clarification of responsibilities at the organisational level or, with respect to processes, the requirement to apply the best technology available under the given economic constraints). These "standard environmental innovations" are to be distinguished from changes evolving from the facility-specific design and subsequent development of the system. We will call the latter "advanced environmental innovations".

2.2 Hypotheses

2.2.1 Hypothesis 1: EMAS has a largely indirect influence and increases the environmental innovation potential of the facility

Especially organisational changes are being induced by EMAS, such as environmental project or innovation teams or employee suggestion schemes. These can support learning processes and contribute to capacity building (see BRADFORD et al. 2000). Additional environmental innovations, especially process and product innovations of a technical nature, are often a result of preceding organisational innovations. This hypothesis is being tested by asking the EMAS-participants to name, in the first step, all implemented environmental innovations (organisational, process, product-related, see Table 1). The list of innovation types has been derived from the case-study results. In addition, we have asked the person responsible for EMAS, if the environmental innovations from his/her point of view were substantially influenced by the EMS.

Table 1: Environmental innovations implemented by EMAS-participants

Environmental organisational innovations
• Internal: Environmental indicators, environmental employee suggestion scheme, environmental team, environmental employee objectives plan
• External: Supplier surveys, R&D co-operations
Environmental process innovations
• Production process: Process-integrated, end-of-pipe, process recycling
• Preceding and succeeding stages: Procurement, energy production, distribution
Environmental product-related innovations
• Technical: Improved or new products
• Product planning: Environmental R&D criteria, environmental product performance specifications, explicit consideration of environmental aspects in product development, participation of the environmental manager in product development

2.2.2 Hypothesis 2: The scope of the implemented EMS increases over time (phase model)

This hypothesis can be specified by a phase model of the temporal development of EMAS-based EMS's (see KOTTMANN et al. 1999), which proposes that in phase one the formal elements of the EMS are being installed, followed by an analysis and re-organisation of the technical and organisational processes in phase two and the broadening of the facility-related EMS towards co-

operations in phase three. The distinction between phases one and two is more of an analytical nature because the formal elements are always being introduced for the purpose of developing and implementing managerial actions. Yet the beginning of the introduction process is marked by the elaboration of competencies, responsibilities and structures. The transition from phase one to phase two usually takes place in the first validation cycle.

In order to test the phase model, the variable maturity of EMAS needs to be determined and a way of measuring scope has to be developed. The tested hypothesis would be that more mature EMAS-participants show increased scope (i.e. implement advanced environmental innovations) compared to EMAS-participants in an earlier phase. For this purpose, we made a comprehensive survey of environmental organisational innovations in the context of the case studies where we distinguished innovations in organisational structures and procedures, implemented environmental instruments and innovations concerning more than one facility.

Table 2: Indicators for high scope concerning environmental innovations and maturity of EMAS

High scope concerning environmental organisational innovations (OR-integration)
• Environmental employee suggestion scheme
• Environmental employee objectives plan
• R&D co-operations
High scope concerning environmental organisational innovations (AND-integration)
• Environmental employee suggestion scheme
• Environmental employee objectives plan
• R&D co-operations
High scope concerning environmental innovations in product planning (OR-integration)
• Environmental R&D-criteria
• Environmental product performance specifications
• Participation of the environmental manager in product development
High scope concerning environmental process innovations (AND-integration)
• Process-integrated
• At least one environmental innovation on a preceding or succeeding stage
High scope concerning environmental technical product-related innovations
• Improved or new products
Maturity of EMAS
• Age of EMAS
• Two re-validations of EMAS
• Beforehand experience concerning the organisation of environmental protection
• ISO 14001 validation

On this basis we have developed high scope indicators for the large-scale survey data which are listed in Table 2 and allow a differentiation between standard and advanced environmental inno-

vations. A facility is awarded a high scope if it has undertaken the advanced environmental innovations given in the table. For example, a facility shows a high scope in the field of environmental organisational innovations if it has implemented at least one of the measures: Environmental employee suggestion scheme, environmental employee objectives plan or R&D co-operations (see Table 2, "High scope concerning environmental organisational innovations", OR-integration).

2.2.3 Hypothesis 3: Contextual factors inside and outside the facility have an influence on the scope of environmental innovations induced by EMAS

The effects of EMAS depend on external factors such as industry structure and customer demands and on internal factors such as beforehand experience concerning the organisation of environmental protection, the firm's strategies and ability with respect to organisational learning as well as firm size (see KOLK 2000). Based on the data of the large-scale survey, the hypothesis is econometrically tested using binary probit models. In this way it can for example be tested whether one of the mentioned variables increases the probability of the introduction of advanced environmental innovations.

The hypothesis is part of a two-level impact model which is illustrated in Table 3 with a list of variables. At level one, we analyse internal and external factors influencing high scope concerning the implementation of environmental organisational and technical innovations. At level two, the impact of environmental innovations on a set of indicators of competitiveness (number of employees, turnover, exports) is examined (Hypothesis 7).

2.2.4 Hypothesis 4: Additional supporting contextual factors inside and outside the facility are required to induce the facilities to deal with environmental consequences of their products and to assume responsibility for the life cycle of their products

Existing evaluation studies on EMS show that a number of positive examples of facilities improving the environmental performance of their products in the context of their environmental management do exist. Yet a majority of the facilities limit their environmental management to dealing with production processes and facility organisation (see JÜRGENS et al. 1997, DYLLICK and HAMSCHMIDT 1999). On the basis of this experience, the COUNCIL OF THE EUROPEAN UNION (2000) in its revision of EMAS explicitly requires the inclusion of product planning and in advance assessment of environmental consequences of new products in the context of environmental policy and programme as well as eco-management audit.

As a first step, the hypothesis is tested by relating the number of facilities which report EMS to have substantially influenced environmental technical product-related innovations to the number of facilities who did not undertake changes relevant to their products. Apart from such environmental product-integrated innovations, we asked for environmental innovations in product planning (see list of advanced innovations in Table 2). This way we can answer the question whether, from the facility's point of view, EMS made a substantial contribution towards environmental organisational and technical product-related innovations.

Table 3: Dependent and explanatory variables for environmental innovations and competitiveness (binary probit models)

Dependent variables for environmental innovations

Implementation of specific advanced environmental innovations

- Organisational innovations
- Process innovations
- Product innovations

Dependent variables for competitiveness

- Increase of the facility's competitiveness, measured via performance indicators (number of employees, turnover, exports)

Explanatory variables for environmental innovations and competitiveness

- Maturity of EMS (age of EMAS, two re-validations of EMAS, beforehand experience concerning the organisation of environmental protection, ISO 14001 validation)
- Strategic importance of EMAS
- Learning processes by EMS
- Organisational scope of EMAS (strong participation of general mangement, executives, all employees, R&D department, production, marketing, administration and distribution in further development of EMAS)
- Environmental innovations (partially in earlier phases)
- Environmental innovation targets (environmental improvement, image, compliance with regulations, anticipation of future regulations, cost reduction, market shares)
- Importance of factors for competitiveness (price, quality, customer satisfaction, innovation, environmental issues)
- Additional facility-specific variables:
  Age of facility
  Supplier to environmental protection market
  Share of turnover with industrial customers
  Facility size (number of employees)
  Employee qualification (share of employees with university degree)
  Share of turnover
  Share of exports
  Legal independence
- Industry
- Domestic region (Land)

2.2.5 Hypothesis 5: Environmental reporting as required by EMAS supports the diffusion of environmental innovations

This may take place either because of induced increased openness of the facilities, which facilitates co-operation among facilities, or via the diffusion of information on innovative solutions. Following CLAUSEN et al. (1997), facilities sometimes use other facility's environmental reports for comparisons. In order to check this finding, we included a question on use of other facility's environmental reports into the large-scale survey (possible answers: no use, use for own environmental report, use for environmental organisational, process or product-related innovations). The hypothesis will be tested via the answers to this question.

2.2.6 Hypothesis 6: The environmental innovation effect of EMAS is substantially improved if a link between (operational) environmental management and strategic management is established

EMS increase the commitment to environmental protection at the operational level. DYLLICK and HAMSCHMIDT (2000) perceive EMS to be under-developed at the strategic level, which they fear to lead to a loss of importance unless it is developed into a strategic management instrument. If environmental management and strategic management are linked, EMS may be developed towards co-operation and product planning. The strategic importance of EMAS has already been included as a factor of influence into the binary probit models with respect to Hypothesis 3 (see Table 3). Within the framework of these econometric approaches it can be examined whether a strategic layout of the EMS has an influence on the implementation of advanced environmental innovations.

2.2.7 Hypothesis 7: A strategic layout of EMAS/EMS strengthens the facility's competitiveness

Innovative firms are often competitive firms, either because of cost-reducing process innovations or product innovations improving their market position (in this context, organisational changes can facilitate product and process innovations). It can be deduced from Hypothesis 6 that the effect of EMAS/EMS on competitiveness depends on a strategic linkage of the environmental management to the facility as a whole.

In order to test this hypothesis, we apply again binary probit models based on the data of the large-scale survey. Thus, the sample has to be divided into groups of facilities with good and bad competitiveness. As variables to explain the competitiveness we choose the implementation of environmental innovations as well as those variables which have been examined as determinants of environmental innovations (see Table 3). This approach seems appropriate because of the lack of theoretically better specified models, so that variables that may potentially explain competitiveness should better not be excluded.

As the literature holds no consensus on indicators of competitiveness, a multitude of indicators were examined. It should however be noted that the manager responsible for EMAS as the interviewee is a person who can often report only on a general level on the facility's economic success indicators (number of employees, turnover, exports). Specific knowledge on other indicators of competitiveness from the fields of production management (productivity indicators) or marketing research (e.g. indicators of customer satisfaction) usually fall into the competencies of general management.

3 Methodological approach

3.1 Case studies

As a pre-test for the hypotheses as well as for exploring relevant determinants, twelve case studies with German facilities (from Baden-Württemberg) which covered the most important economic sectors were completed by IÖW in spring and summer 2001. For these case-studies, environmental reports were analysed and semi-structured face-to-face interviews with facility representatives were conducted. The survey focus (environmental innovations, maturity of EMAS, strategic importance of EMAS, learning processes by EMS, organisational scope of EMAS, competitiveness) falls into the competencies of EMAS manager, general management and R&D department. As a consequence, these three groups were chosen as interviewees and the questionnaire items were divided up. In this process, some items were allocated to more than one group to depict different perspectives and to narrow the margin of error. In order to examine maturation, facilities who had been validated to EMAS for several years were chosen.

3.2 Large-scale telephone survey

To examine the presented hypotheses, a sample of the population of facilities as a whole, including EMAS-participants as well as other facilities, would be considered ideal. If all facilities would have been interviewed with regard to the performance indicators of interest as well as facility-specific variables, (given sufficient sample size) the data collected would allow for statistical tests on facility data as well as econometric analysis. However, while a register of firms is available (but could not be used for our purposes since an EMAS questionnaire has to address the facility level), the relevant register of facilities is not available.

For this reason, only EMAS-participants have been interviewed. As a consequence, a comparative analysis of EMAS-participants and other facilities is not possible and remains for future studies to undertake. As a matter of fact, a census of all manufacturing facilities participating in EMAS has been carried out. The case study results contributed to the large-scale survey, especially with regard to questionnaire design and the specification of the model for the explanation of internal and external determinants of environmental innovation and competitiveness. In this way it was possible to describe EMAS-induced environmental innovation processes in a qualitative manner and subsequently to draw conclusions which can be generalised from the large-scale survey.

The large-scale telephone survey was conducted at ZEW between February 2002 and early June 2002. It was the intention that all German manufacturing facilities (NACE-Codes 15, 17-41) EMAS-validated in 2001 were interviewed. The facility addresses were drawn from the chamber of industry and commerce' online-database (DIHK 2001), comprising 2270 entries. The facilities have been notified in advance by mail of the forthcoming survey. The respective facility EMAS manager or environmental manager was the target of the telephone survey. They were chosen because our case studies had shown that they were most competent with regard to our set of questions compared to other relevant persons (R&D manager, general manager). In addition, our in-depth interviews had shown no systematic differences between these groups with regard to their evaluation of the effects of EMAS on environmental innovation and competitiveness.

As shown in Table 4, of the 2270 German manufactoring facilities, 372 (=16.4%) could not be reached, 621 (=27.4%) refused to participate in the survey and 1277 (=56.3%) participated in the survey. The shares among all facilities reached are as follows: 67.3% were interviewed, 32.7% refused to participate. The responses show no bias concerning industries or domestic regions, i.e.

the completed interviews are representative of the EMAS-participants with regard to these attributes.

Table 4: Response rates of the large-scale telephone survey

	Number of facilities	Share of all notified facilities	Share of all facilities reached
Participations	1277	56.3%	67.3%
Refusals	621	27.4%	32.7%
Facilities reached	1898	83.6%	100.0%
Facilities not reached	372	16.4%	
Notified facilities (population)	2270	100.0%	

4 Results

4.1 Hypothesis 1: EMAS has a largely indirect influence and increases the environmental innovation potential of the facility

The surveys showed that EMAS indirectly as well as directly has an influence on environmental innovation. The large-scale survey showed an especially strong influence on environmental organisational innovations, but EMS also show a considerable influence on environmental process and product innovations. Much proof of the indirect effects was obtained in the case studies, where the facilities described causal chains and follow-up innovations. In addition, the case studies showed an increase of the environmental innovation potential of the facilities.

Table 5 shows the answers of the large-scale survey and distinguishes the following categories:

- Environmental organisational, process and product-related innovations.
- Introduction of an environmental innovation on a general basis, introduction of this innovation between 1999 and 2001, substantial contribution by EMS.

The introduction on a general basis has been addressed with regard to all organisational innovations (including product planning). They differ from technical innovations in being regularly implemented in a singular fashion, with few changes made afterwards. With technical initiatives it is to be presumed that these are only to be deemed innovative if changes to processes or products have been made in the preceding three years.

Environmental organisational innovations

The majority of the 1277 EMAS-validated facilities in our sample reportedly implemented internal environmental organisational innovations. Most frequent were environmental indicators (68.9%), followed by environmental employee objectives plans (64.6%), environmental teams (50.6%) and environmental employee suggestion schemes (49.6%). 81.1% of the innovators agreed that EMS contributed substantially to the introduction of environmental indicators. 82.7% of the innovators also perceived a considerable contribution of EMS to the introduction of environmental employee objective plans. The rate of positive answers was a bit lower with regard to the introduction of environmental teams (76.6%) and environmental employee suggestion schemes (60.1%). Approximately half of all internal environmental organisational innovations were introduced between 1999 and 2001.

Table 5: Environmental innovations implemented by the interviewed EMAS-validated facilities

		a) Environmental innovation implemented						b) Innovation implemented between 1999 and 2001 [partially if a) = yes]						c) Substantial contribution by EMS [if a) or b) = yes]					
		Yes		No		Don't know		Yes		No		Don't know		Yes		No		Don't know	
Environmental organisational innovations																			
	Internal																		
	Environmental indicators	*880*	68.9%	*391*	30.6%	*6*	0.5%	*438*	49.8%	*438*	49.8%	*4*	0.5%	*714*	81.1%	*163*	18.5%	*3*	0.3%
	Environmental employee suggestion scheme	*634*	49.6%	*634*	49.6%	*9*	0.7%	*277*	43.7%	*355*	56.0%	*2*	0.3%	*381*	60.1%	*249*	39.3%	*4*	0.6%
	Environmental team	*646*	50.6%	*628*	49.2%	*3*	0.2%	*282*	43.7%	*364*	56.3%	*0*	0.0%	*495*	76.6%	*148*	22.9%	*3*	0.5%
	Environmental employee objectives plan	*825*	64.6%	*439*	34.4%	*13*	1.0%	*437*	53.0%	*384*	46.5%	*4*	0.5%	*682*	82.7%	*139*	16.8%	*4*	0.5%
	External																		
	Supplier surveys	*994*	77.8%	*274*	21.5%	*9*	0.7%	*595*	59.9%	*395*	39.7%	*4*	0.4%	*854*	85.9%	*137*	13.8%	*3*	0.3%
	R&D co-operations	*352*	27.6%	*896*	70.2%	*29*	2.3%	*142*	40.3%	*206*	58.5%	*4*	1.1%	*172*	48.9%	*177*	50.3%	*3*	0.9%
Environmental process innovations																			
	Production process																		
	Process-integrated							*1044*	81.8%	*219*	17.1%	*14*	1.1%	*640*	61.3%	*396*	37.9%	*8*	0.8%
	End-of-pipe							*693*	54.3%	*567*	44.4%	*17*	1.3%	*431*	62.2%	*258*	37.2%	*4*	0.6%
	Process recycling							*479*	37.5%	*783*	61.3%	*15*	1.2%	*300*	62.6%	*175*	36.5%	*4*	0.8%
	Preceding and succeeding stages																		
	Procurement							*727*	56.9%	*517*	40.5%	*33*	2.6%	*536*	73.7%	*189*	26.0%	*2*	0.3%
	Energy production							*324*	25.4%	*942*	73.8%	*11*	0.9%	*180*	55.6%	*144*	44.4%	*0*	0.0%
	Distribution							*501*	39.2%	*744*	58.3%	*32*	2.5%	*288*	57.5%	*211*	42.1%	*2*	0.4%
Environmental product-related innovations																			
	Technical																		
	Improved or new products							*561*	43.9%	*685*	53.6%	*31*	2.4%	*277*	49.4%	*281*	50.1%	*3*	0.5%
	Product planning																		
	Environmental R&D-criteria	*408*	31.9%	*731*	57.2%	*138*	10.8%	*170*	41.7%	*236*	57.8%	*2*	0.5%	*254*	62.3%	*150*	36.8%	*4*	1.0%
	Environmental product performance specifications	*577*	45.2%	*542*	42.4%	*158*	12.4%	*253*	43.8%	*319*	55.3%	*5*	0.9%	*413*	71.6%	*160*	27.7%	*4*	0.7%
	Explicit consideration of environmental aspects in product development	*535*	41.9%	*584*	45.7%	*158*	12.4%	*249*	46.5%	*284*	53.1%	*2*	0.4%	*401*	75.0%	*134*	25.0%	*0*	0.0%
	Participation of the environmental manager in product development	*612*	47.9%	*512*	40.1%	*153*	12.0%	*238*	38.9%	*372*	60.8%	*2*	0.3%	*406*	66.3%	*203*	33.2%	*3*	0.5%

With regard to external environmental organisational innovations, 77.8% of all interviewed facilities introduced supplier surveys which most of the time (85.9%) were substantially contributed by EMS. More often than not (59.9%), these innovations had been introduced in the last three years. Yet only 27.6% of the interviewed facilities reported implementations of R&D co-operations. Furthermore, the substantial contribution by EMS is much smaller (48.9%) here than with regard to any other environmental organisational innovation.

Environmental process innovations between 1999 and 2001

Concerning the production process, 81.8% of the 1277 EMAS-validated interviewed facilities reportedly implemented process-integrated innovations. 54.3% have implemented end of pipe innovations concerning the production process while only 37.5% reported process recycling as an innovation they had implemented. In all three categories of environmental innovations concerning the production process between 1999 and 2001, a little more than 60% of the innovating facilities assign a substantial contribution by EMS.

With regard to procurement, 56.9% of the interviewed facilities introduced environmental innovations which most facilities (73.7%) perceive to have been substantially influenced by EMS. Environmental innovations in energy production were reported much less frequently. Only 25.4% of the facilities introduced changes in this regard between 1999 and 2001. In the majority of these cases (55.6%), EMS had a substantial influence on the initiative. Environmental innovations in distribution were reported by 39.2%, which most of the time (57.5%) were substantially influenced by EMS.

Environmental product-related innovations

43.9% of the 1277 interviewed EMAS-validated facilities introduced environmentally improved or new products between 1999 and 2001, which in 49.4% of the cases were substantially influenced by EMS. This percentage is higher than expected. The most frequent environmental innovations in product planning were the participation of the environmental manager in product development (47.9%), followed by environmental product performance specifications (45.2%), the explicit consideration of environmental aspects in product development (41.9%) and, finally, environmental R&D-criteria (31.9%). The share of substantial contribution by EMS is much higher with regard to innovations in product planning than concerning technical product-related innovations. 75.0% of the innovating facilities perceive a substantial influence of EMS on the explicit consideration of environmental aspects in product development. Concerning environmental product performance specifications and participation of the environmental manager in product development, the respective figures are 71.6% and 66.3%. Environmental R&D criteria were for 62.3% of the innovating respondents substantially influenced by EMS.

4.2 Hypothesis 2: The scope of the implemented EMS increases over time (phase model)

This hypothesis was further specified on the basis of the case studies. They have shown that increased scope can be deduced from a development from a narrow location focus to a value chain focus (with regard to environmental organisational as well as environmental process innovations). As a matter of fact, more mature facilities (whereas the maturation process may have started prior to EMAS) show more external environmental organisational innovations (supplier audits, participation in working groups, regional environmental protection activities) and do not limit process innovation to more traditional issues in facility-related environmental protection (production, recycling, disposal) but also address, for example, energy production. With regard to environmental process innovations, a development from add-on to integrated solutions was observed. In addition, the case studies showed that facilities without beforehand experience con-

cerning the organisation of environmental protection had a clear tendency to induce more innovations through EMAS. Facilities which had implemented an EMS prior to EMAS had already implemented the potential environmental innovations in part.

On the basis of the case studies, factors identified to be of importance were included into the large-scale survey (see Table 3 on the variables used). For the econometric analysis on determinants of environmental innovations, binary probit models were used. Note that the summarised findings in Table 6 (and also in Table 8) are the results of various probit model estimations.

Different model specifications refer to the different inclusion of several explanatory variables. These estimations have been performed to avoid potential multi-collinearity problems. For example, such problems can arise if all variables of the maturity of EMAS would simultaneously be included as explanatory factors.

The analysis showed that beforehand experience concerning the organisation of environmental protection often holds high explanatory power for high scope concerning environmental organisational innovations (see Table 6). Therefore, pioneering facilities who have begun early to develop an EMS independent of EMAS are obviously environmentally innovative facilities. Age of EMAS as well as two re-validations of EMAS also have partially a positive influence on high scope concerning environmental organisational innovations. Thus, there seems to be a tendency for a certain degree of maturity of EMAS to have a positive influence on the level of environmental organisational innovation activity which supports notions of a phase model.

Comparing the econometric results of the determinants of high scope concerning environmental process and technical product-related innovations, a difference with regard to the phase model can be observed. While maturity of EMS is an important determinant of process innovations, there is no apparent relationship between maturity of EMS and product-integrated innovation. This may be due to the fact that indirect environmental effects and consequently a product-oriented focus has only recently been increased with the revision of EMAS and will only be given more attention in the future. Another reason suggested by the case-studies are different positions in the value-chain and related scope for innovation (see section 4.6 below). More mature EMAS-participants have no lead regarding environmental technical product-related innovations, in contrast to environmental process innovations where EMAS has required an integrated approach all along.

Table 6: Results of binary probit models for the explanation of environmental innovations

Dependent variable: High scope concerning environmental organisational innovations (OR-integration)	
++	Strong participation of R&D department in further development of EMAS, Strong participation of production in further development of EMAS, Image as environmental innovation target
- -	Legal independence
+	Two re-validations of EMAS, ISO 14001 validation, Environmental improvement as environmental innovation target
Dependent variable: High scope concerning environmental organisational innovations (AND-integration)	
++	Age of EMAS, Strong participation of R&D department in further development of EMAS, Strong participation of production in further development of EMAS, Facility size
+	Beforehand experience concerning the organisation of environmental protection, Anticipation of future regulations as environmental innovation target, Share of turnover with industrial customers
-	Price as important competitiveness factor
Dependent variable: High scope concerning environmental innovations in product planning (OR-integration)	
++	Beforehand experience concerning the organisation of environmental protection, Strong participation of R&D department in further development of EMAS, Legal independence, Supplier to environmental protection market, Employee qualification, Share of exports
- -	Strong participation of administration in further development of EMAS
-	Environmental issues as important competitiveness factor
Dependent variable: High scope concerning environmental process innovations (AND-integration)	
++	Two re-validations of EMAS, Beforehand experience concerning the organisation of environmental protection, Strategic importance of EMAS, Strong participation of general management in further development of EMAS, Strong participation of R&D department in further development of EMAS, Strong participation of distribution in further development of EMAS, Environmental improvement as environmental innovation target, Compliance with regulations as environmental innovation target, Facility size
+	Explicit consideration of environmental aspects in product development, Legal independence
-	Strong participation of executives in further development of EMAS, Employee suggestion scheme, Innovation as important competitiveness factor
Dependent variable: High scope concerning environmental technical product-related innovations	
++	Learning processes by EMS, Image as environmental innovation target, Market shares as environmental innovation target, Price as important competitiveness factor, Supplier to environmental protection market
- -	Share of turnover with industrial customers
+	Innovation as important competitiveness factor
-	Environmental indicators, Employee qualification

Note:

++ (**- -**) mean that the explanatory variable always has a positive (negative) effect on the dependent variable at the 5% level of significance.

+ (**-**) mean that the explanatory variable always has a positive (negative) effect on the dependent variable at the 10% level of significance.

4.3 Hypothesis 3: Contextual factors inside and outside the facility have an influence on the scope of environmental innovations induced by EMAS

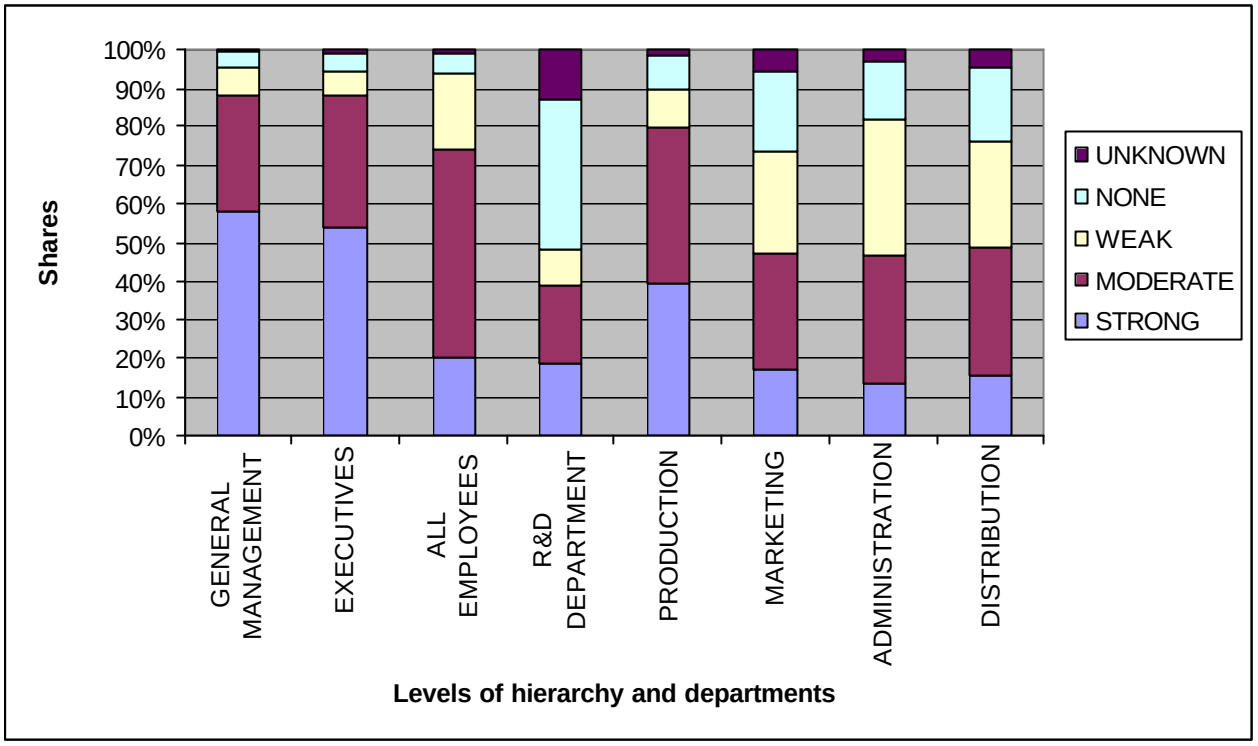
As a first step, the in-depth case studies examined factors inside and outside the facility influencing the overall scope concerning environmental innovations. An important determinant identified was, among others, the organisational scope of EMAS in a given facility. In the large-scale survey, these factors were taken into account via variables for the participation of different departments and levels of hierarchy in further development of EMAS. Figure 1 shows to what extent EMAS permeates the various departments and levels of hierarchy of the facility.

For the most part, the 1277 EMAS-validated interviewed facilities perceive a strong involvement of executives in further development of EMAS. Over 50% stated that general management and other executives were strongly involved groups while less than 12% credited these groups with weak or no participation. The participation of all employees is much less pronounced. Only 20.0% of the facilities claimed that their workforce was strongly involved in further development of EMAS, 54.0% reported it as being moderate.

With regard to various departments, participation is comparatively weak. Production is reported to be strongly involved by 39.2% of the respondents and moderately involved by 40.0%. With these figures, production is the most involved department whereas R&D department, marketing, administration and distribution are far behind. Especially R&D department is mentioned to be strongly involved in further development of EMAS by only 18.4% and moderately involved by 20.5% of the facilities.

Our econometric analysis showed that a strong participation of R&D department in particular plays a decisive role for high scope concerning environmental innovations (see Table 6). The influence of the respective variable on the scope indicator for environmental organisational innovations is highly significant - irrespective of the applied scope indicator. The positive effect of a strong participation of production in further development of EMAS is not significant applying the third scope indicator. Regarding the determinants of advanced environmental technical innovations, it is quite remarkable that the environmental innovation target "compliance with regulations" has a positive influence on the implementation of process innovations whereas image and market share targets have a rather positive influence on product innovations. "Price" and "innovation" (less significant) as important factors of competitiveness show a tendency to have a positive influence on the implementation of technical product-related innovations. Facilities who supply to environmental protection markets, who have a relatively small share of employees with university degrees or who supply to consumers rather than industrial buyers – other facility characteristics being similar – show a greater probability to implement environmental product-integrated innovations. A large number of employees and legal independence have a positive influence on the implementation of environmental process innovations.

Figure 1: Participation of different levels of hierarchy and departments in further development of EMAS



4.4 Hypothesis 4: Additional supporting contextual factors inside and outside the facility are required to induce the facilities to deal with environmental consequences of their products and to assume responsibility for the life cycle of their products

On the basis of the case studies, a number of factors promoting the introduction of environmental product-integrated innovations in the context of EMAS were identified. These factors include an important role of product ecology with respect to competitiveness, and participation of the R&D department in further development of environmental management. Additionally, it is positive if a certain importance of the environmental department for product innovations is being assumed. Finally, it is important that the facilities have possibilities to create product innovations, and are not completely bound by customer requirements. Facilities fulfilling these preconditions were found to have achieved environmental product-integrated innovations which they placed in the context of EMAS. In addition, in nearly all facilities, EMAS-induced innovations in product planning were observed.

The positive impression regarding the influence of EMAS on environmental product innovation gained from the case studies was confirmed by the large-scale survey. Between 31.9% (environmental R&D criteria) and 47.9% (participation of the environmental manager in product development) of the 1277 EMAS-validated interviewed facilities reported the implementation of these innovations. Depending on the environmental product-related innovation, the share of facilities attributing the innovation to a substantial extent to EMS ranges between 49.4% (technical product-related innovation) and 75.0% (explicit consideration of environmental aspects in product development). As a consequence, environmental product-integrated innovations substantially influenced by EMAS can not be seen as singular cases. Thus, we are able to draw an overall more positive conclusion than earlier studies on EMAS (see e.g. JÜRGENS et al. 1997, DYL-

LICK and HAMSCHMIDT 1999). This can be seen as an indication of a process of maturation and further development of EMS in the facilities.

4.5 Hypothesis 5: Environmental reporting as required by EMAS supports the diffusion of environmental innovations

This hypothesis suggests that the diffusion of environmental innovations is fostered by environmental reporting as required by EMAS. In order to test this hypothesis, the EMAS managers were asked if and for what purposes they use other facilities' environmental reports. Table 7 shows the results of the large-scale survey. 71.4% of all interviewed facilities use other facilities' environmental reports for the preparation of their own reports. At least a substantial share of the respondents use them to gather ideas for environmental innovations. 38.7% of the respondents state that they gather ideas for organisational innovations in environmental reports, for 34.6% this is true with regard to process innovations and for 20.2% with regard to product-related innovations. 21.5% of the facilities do not use other facilities' environmental reports at all. On the whole, it can be concluded that, from the facilities' point of view, environmental reports are very useful for the diffusion of environmental innovations. This result is true for all industry sectors and size groups.

Table 7: Use of other facilities' environmental reports

Use for:	**Number of facilities**	**Share of all interviewed facilities**
Own environmental report	912	71.4%
Environmental organisational innovations	495	38.7%
Environmental process innovations	442	34.6%
Environmental product-related innovations	259	20.2%
No use	275	21.5%

4.6 Hypothesis 6: The environmental innovation effect of EMAS is substantially improved if a link between (operational) environmental management and strategic management is established

The large-scale survey obtained the result that 50.0% of the 1277 EMAS-validated interviewed facilities attribute a strategic importance of EMAS while for 47.5% it has only an operative relevance. A relationship between strategic importance of EMAS and environmental innovations can only partially be observed. Following the respective econometric analysis, the corresponding variable has a positive influence on the implementation of process innovations (see Table 6). As we only attribute a high scope concerning environmental process innovations including at least one preceding or succeeding stage of the value chain, this can be interpreted as a high importance of a strategic orientation for not location-bound initiatives. Changes to product planning processes (see Hypothesis 4) are a reliable indicator for a strategic layout of the EMS. The re-

sults suggest that the strategic deficit is not as important as DYLLICK and HAMSCHMIDT (2000) feared it would be.

4.7 Hypothesis 7: A strategic layout of EMAS/EMS strengthens the facility's competitiveness

With respect to the assessment of factors of competitiveness, the large-scale survey shows that EMAS-participants take quality of products to be more important than low prices for their market position. As Table 8 shows, a significantly positive influence of a strategic importance of EMAS on market success was not established according to the econometric analysis. Positive influences on the increase of turnover and exports can be shown if the facility achieved significant learning processes by EMS.

Table 8: Results of binary probit models for the explanation of competitiveness

Dependent variable: Increase of number of employees	
++	High scope concerning environmental process innovation, Legal independence, Share of turnover, Employee qualification
- -	Cost reduction as environmental innovation target, Age of facility
-	Price as important competitiveness factor
Dependent variable: Increase of turnover	
++	High scope concerning environmental process innovation, Learning processes by EMS, Legal independence, Facility size, Share of exports
- -	Environmental team (before 1999), Price as important competitiveness factor, Age of facility
Dependent variable: Increase of exports	
++	Participation of the environmental manager in product development (before 1999), Learning processes by EMS, Facility size
- -	Environmental improvement as environmental innovation target, Environmental issues as important competitiveness factor
-	Age of facility

Note:

++ (**- -**) mean that the explanatory variable always has a positive (negative) effect on the dependent variable at the 5% level of significance.

+ (**-**) mean that the explanatory variable always has a positive (negative) effect on the dependent variable at the 10% level of significance.

The econometric analysis also suggests that environmental organisational innovations have little direct influence on market success. A weak relationship can be established only with respect to a few innovations. Especially changes to product planning have a positive influence on the increase of exports. In contrast, the influence of environmental technical innovations on market success is stronger. Facilities with advanced environmental process innovations (i.e. with high scope concerning environmental process innovation) develop significantly better with respect to the increase of number of employees and turnover. Yet this positive relationship does not hold for exports.

Price as important competitiveness factor has a negative influence on the market success of EMAS-participants. This relationship does not hold for the increase of exports of products because of apparent price competition in international markets. A negative impact of cost reduction as environmental innovation target on the increase of number of employees can be explained by

rationalisation effects incurred pursuing this target. There is a negative influence on the increase of exports if environmental improvement is a environmental innovation target and if environmental issues are an important competitiveness factor. It can be interpreted that facilities with a strong environmental commitment are less oriented on international markets and exports. Other factors showing a positive influence on the competitiveness of EMAS-participants are low facility age, large number of employees, large share of employees with university degree, legal independence and a large share of exports and turnover.

5 Conclusions and directions for further research

It can be summarised that EMAS does have a positive influence on environmental process and product innovations as well as on environmental organisational innovations. In addition, environmental reports contribute to the diffusion of environmental innovations. The study shows as well that the scope of these innovations depends on the maturity of EMAS (measured as age of EMAS, two re-validations of EMAS, beforehand experience concerning the organisation of environmental protection, ISO 14001 validation). A decisive factor of success regarding the implementation of environmental innovations is the organisational scope of EMAS in a given facility. EMAS-participants position themselves towards competitors with quality of products rather than low prices. An influence of the strategic importance of EMAS on the facilities' market success was not established. Facilities who have achieved significant learning processes by EMAS are particularly successful in economic terms.

An important advice to be given to facilities on basis of this study is to improve their competitiveness by a better linkage between environmental management and innovation management. The organisational implementation of environmental and innovation management as well as the practical introduction of new and changed environmental processes and products is relevant in this regard. The organisational scope of EMAS in the facility is an important factor of success in inducing environmental innovations within the facility. The R&D department plays a central role in this matter and it should participate in further development of EMAS in order to achieve improved linkage between product-related and strategic issues.

The results also hold policy advice. Public subsidies are justified if an activity offers positive external effects, i.e. benefits unredeemed via market prices. This is often true for innovation processes, with basic research being a well-known example. In the case of environmental innovations, there is an additional "external" benefit to society, which is an improved quality of the environment. The ability of certified environmental management systems to foster environmental innovations is a finding of our study and the protection of public goods and of benefits to society should be taken into account with regard to aid policies. Public procurement is an important aid instrument in this context. EMAS-participants demand privileges regarding public procurement processes to be awarded for their participation in the auditing scheme.

Yet another question is what management standard should be supported and whether EMAS should be privileged in this regard. Concerning the question of environmental innovation effects it has become clear that EMAS can make a difference. Unlike the ISO 14001 standard, EMAS requires external communication via an environmental report. Our study shows that the environmental reports of other facilities are being used for gathering ideas for a facility's own environmental innovations. Two conclusions can be drawn from this issue as policy advice. On the one hand, from an innovation perspective it seems justified to discriminate between the two standards with regard to political support. On the other hand, if this is not desired or possible, it seems advisable to link equal treatment of ISO 14001 to the voluntary publication of an environmental report.

From our point of view, the methodological combination of case studies and large-scale survey has proven to be beneficial. Qualitative insights on the hypotheses and on environmental innovation processes at the level of the facility were gained from the case studies and contributed to the large-scale survey. The large-scale survey especially delivered the possibility to draw conclusions which can be generalised while the insights gained from the case studies again facilitated the interpretation of the econometric results.

The applied methodology can also be improved upon in a number of ways. As this study has focussed on EMAS-participants, for a future study samples of the universe of facilities would be desirable, which would allow for comparisons between EMAS-participants and other facilities. Comparative studies between countries as well as specialised studies on the service sector (this study was limited to the manufacturing sector) would also be useful. There is also a need for further research applying a comparable methodology to determinants of product-related environmental protection (e.g. Integrated Product Policy – IPP) whereas this study rather focussed on location-related environmental protection. As an analysis of determinants of environmental innovations on the basis of binary discrete choice models has only limited explanatory value (since in the basic alternative, facilities could be grouped which are rather environmentally innovative) additional and further-reaching econometric analyses on the basis of multinomial discrete choice models should be established. It is also to be taken into account, that environmentally innovative facilities could have a more than average propensity to introduce EMS such as EMAS. This conclusion can be drawn from the fact that beforehand experience concerning the organisation of environmental protection often has a positive influence on environmental innovations. This leads to the question of causality, i.e. environmental innovations may also have an influence on the certification and layout of EMAS. If causality in both directions is to be accepted, alternative models become necessary, e.g. models with lagged explanatory variables or simultaneous systems of equations.

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