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Working Paper

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Publication date:

2008

Permanent link:

<https://doi.org/10.3929/ethz-a-005778569>

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Originally published in:

CIS working paper 36(2008)

*The Effects of Customer Benefit and Regulation on
Environmental Product Innovation – Empirical
Evidence from Appliance Manufacturers in Germany*

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Abstract

Environmental product (EP) innovations and their determinants have received increasing attention from researchers during the past years. So far, empirical studies have shown inconsistent results, especially regarding the impact of regulation. In this paper, I seek to advance the understanding of EP-innovation by introducing and testing a novel research framework. First, a novel unit of analysis, the environmental issue level, is applied. EP-innovation is not studied in broad terms but specifically for four environmental issues that are relevant to the electrical and electronic appliances industry: energy efficiency, toxic substances, material efficiency, and electromagnetic fields. Second, the customer benefit, a concept from the green marketing literature, is included as an explanatory variable for EP-innovation for the first time. The argument is that green products which besides their public benefits have private environmental benefits for the customer (e.g., energy savings) will generate stronger consumer demand and can thus constitute the firm's motivation to implement those innovations in the first place. Third, EP-innovation is observed more comprehensively, measuring its extent and level of novelty. I apply this research framework to study EP-innovations of German manufacturers of electrical and electronic appliances. My results support the issue level as unit of analysis. The impact of customer benefit and regulation on EP-innovation is analyzed with logit regression and the results clearly show that both customer benefit and regulation play a key role for EP-innovation. They not only foster the implementation of EP-innovations but also their broad application and their level of novelty. Customer benefit is more stimulating to overcome the initial obstacle of implementing an EP-innovation than stringent regulation. Customer benefit is also more stimulating for EP-innovations that are novel for the market – so-called real innovations. In contrast, stringent regulation has a larger impact on the broad application of EP-innovations.

Keywords

environmental innovation; customer benefit; environmental regulation; environmental management; green marketing; electronics

I am grateful to the Swiss National Science Foundation for funding this study (grant 100012-112029). Additionally I would like to thank Thomas Bernauer for his helpful comments and the 92 participating companies for their response to my survey that made this research possible.

Introduction

The electronics and electrical appliances (EEA) industry is globally one of the most dynamic industries with regard to innovation (Smith, Keith, 2005, p. 157) and growth rate (EEIG, 2004). The environmental impact of this industry has been a public topic since the early 1980s (Smith, Ted et al., 2006) and while production-related impacts, such as emissions and toxic spills, were the main concern then, the environmental burden caused by the products along the product life cycle are the focus of today's public and regulatory concerns.

The findings by the Gartner research company (2007) that information and communication technology “accounts for two percent of global CO₂ emissions, equivalent to the amount produced by the aviation industry” brought the increasing energy consumption of these appliances to the public attention. Even though most devices have become more energy efficient over the past years, the overall energy consumption is still growing due to the rapid spread of electronics in almost every sphere of life (EEIG, 2004) and the increasing trend towards ubiquitous connectivity (OECD, 2006, pp. 245-282). Additionally, there are environmental issues related to the products' disposal phase. E-waste accounts already for 8% of municipal waste and is expected to be the fastest growing waste category (Widmer et al., 2005). Also, these products contain hazardous substances like heavy metals and flame-retardants. These substances are very problematic, as a large share of e-waste is further processed under poor environmental standards in developing countries, thus generating toxic emissions (Puckett and Smith, 2002, Greenpeace, 2005).

Considering these environmental impacts of EEA, it is crucial to better understand how environmental innovations in this area can be fostered. Academia and regulators pay increasing attention to environmental innovations for their so-called double dividend: reducing environmental impacts and simultaneously benefiting the industry (Jaffe et al., 2002, EC, 2004). While the potential of environmental innovations to reduce the ecological footprint of products is undisputed, the drivers of these innovations are not. Research on environmental innovation has focused on three types of explanatory variables: regulation, market and firm-internal conditions (cf. Bernauer et al., 2007). Empirical results on the influence of some individual factors – most notably regulation – have remained inconclusive, especially regarding environmental *product* innovations. This paper seeks to advance our understanding in this area by proposing a novel research framework:

First, empirical data is observed regarding specific environmental issues. The research designs used in extant work measure environmental innovation in general, either at the industry or firm level, but do not account for variation of innovation and explanatory variables over different environmental issues. Yet in general regulations do not target the overall environmental performance of products but only specific environmental issues (e.g., energy consumption). Likewise, environmental innovations improve only one, at most a few, environmental attributes of products. Therefore the firm as the principal unit of analysis may be too general, as regulation and environmental innovation vary also at the level of environmental issues. Hence for this study I observed my main variables regarding the following four environmental issues per firm: energy efficiency, toxic substances, material efficiency, and electromagnetic fields. This shifts the unit of analysis from the firm level to the environmental issue level.

Second, the role of customer benefit is explicitly included. The marketing literature emphasizes customer benefits from environmental innovations (e.g., reduced energy costs) as a key factor for green market demand. Although empirical research on environmental product innovation has considered market pull factors in general, the concept of direct customer benefits has not been included in empirical studies so far. In this paper, I fill this gap and analyze the

effect of customer benefits on environmental product innovation.

Finally, environmental product innovation is observed using more comprehensive measures. So far, it has commonly been measured on a binary yes/no scale. In this paper, I also utilize the extent and novelty of innovations. Thus the impact of environmental regulation and customer benefits can be analyzed for more dimensions of environmental product innovation.

This paper is organized as follows: first, I provide basic definitions and discuss the conceptual framework. There I derive the hypotheses that stringent regulation and customer benefit have a stimulating effect on environmental product innovation. The next section describes the data set. I surveyed 92 German manufacturers of EEA regarding the four aforementioned environmental issues. With the following descriptive results I demonstrate that all main variables have substantial variation over these environmental issues. This supports my claim for the environmental issue level as unit of analysis for environmental innovation studies. Subsequently I present the statistical analyses. The logit models clearly show that regulatory stringency and customer benefit have a positive effect on the different measures of environmental product innovation. After discussing the results, I conclude with policy recommendations in the final section.

Conceptual Framework

In this paper, environmental innovations are defined as all innovations that have a beneficial effect on the natural environment regardless of whether this was the main objective of the innovation. They can be distinguished as process, product, and organizational innovations (OECD, 1997). This paper focuses on environmental product innovation. The emergence of life cycle analysis has made it clear that for many products the major environmental impact stems from their use (e.g., fuel consumption and CO₂ emissions of cars) and disposal (e.g., heavy metals in batteries) rather than their production (Berkhout and Smith, 1999). Accordingly, environmental product innovations, hereafter called EP-innovation, may reduce the impacts along a product's total life cycle for different environmental issues, such as reduction of toxics and materials in products, improved power consumption and emission output in use phase, as well as extended use phase or recycling schemes for obsolete products.

The literature on the determinants of innovation is vast. However, most of this literature focuses on single determinants of innovation, and only very small parts of it focus on environmental (product) innovation. Environmental innovations are different from other innovations as besides producing the spillover effect typical for R&D efforts (cf. Jaffe, 1986) they also produce positive externalities by improving environmental quality. Rennings (2000, p. 325) has called this characteristic the “double externality problem” of environmental innovation. As a consequence, environmental innovations are under provided calling for a “regulatory push / pull effect” (ibid.). Based on this double externality problem, current research rests on the assumption that regulation, market and firm-internal factors determine corporate behavior in respect to environmental innovation (cf. Bernauer et al., 2007).

Regulation

Researchers of business strategy and public policy have analyzed the relationship between regulation and environmental innovation in numerous studies. While qualitative case studies (e.g., Bonifant et al., 1995, Porter and van der Linde, 1995a, b, Shrivastava, 1995) are based on rather unsystematic analysis of anecdotal evidence, more systematic econometric studies often use indicators that are too simple. For instance, Jaffe and Palmer (1997) measure environmental innovation at the industry level by number of patents and R&D investment and ob-

tain very different results for these two indicators. More recent studies shift the unit of analysis to the individual firm level and distinguish between environmental process and product innovation.

The effects of regulation on EP-innovation remain disputed. For example, the results in Hemmelskamp (1999) indicate a negative influence of regulation on EP-innovation, whereas Cleff and Rennings (1999) find a positive effect, but solely for market-based regulations. In contrast, Rehfeld et al. (2007) could demonstrate positive impacts of regulation on EP-innovation. However, these studies may be drawing an inappropriate conclusion as they do not measure the actual regulatory environment but only observe whether legal (over-)compliance is an innovation goal for the firm. Another approach at measuring regulation is to rely on firms' perception of regulatory stringency. Using this approach, a recent OECD study finds that the stringency of environmental regulation is the single most important factor that drives firms' environmental activities and technological innovations (Johnstone et al., 2007, Frondel et al., 2008). However this study did not differentiate between environmental process and product innovation. Two recent studies that analyze the effect of regulatory stringency on EP-innovation in Switzerland and Germany show contradictory results: while regulatory stringency has a positive effect on EP-innovation in the chemical and pharmaceutical industry (Seijas-Nogareda, 2007), it has no effect in the food and beverages industry (Engels, 2008). These conflicting findings may be caused by industry characteristics. Another reason could be that in this studies regulatory stringency has not enough variation to lead to statistically significant effects as environmental product policies in Germany and Switzerland are very similar.

Customer Benefit

Technology push and market pull factors are relevant drivers for technological innovations in general (Pavitt, 1984) but also for environmental innovations (Rennings, 2000). In an empirical study on the differences of environmental process and product innovations, Cleff and Rennings (1999) find that market considerations are especially important for environmental product innovations. Firms may use environmental improvements to differentiate their products from others and thus gain a competitive advantage (Reinhardt, 1998). However, many consumers are reluctant to pay premium prices or trade off other product qualities solely for a product's green attributes (Peattie, 2001)¹. Additionally, consumers' claims of prioritizing green attributes have mostly not matched their actual purchasing behavior (Wong et al., 1996, Kuckartz, 1998, Prakash, 2002). The eco-marketing literature suggests that green products which besides their public benefits also have private (environmental) benefits for the customer will generate stronger consumer demand (Meffert and Kirchgeorg, 1998, Ottman, 1998, Reinhardt, 1998, Belz, 2001, Belz and Bilharz, 2005). Such customer benefits can have different sources, e.g. cost / energy savings through more efficient appliances, improved product quality and durability, better repair, upgrade, and disposal possibilities, as well as reduced health impacts.

These customer benefits help firms to overcome the second externality of environmental innovations: by shifting some portion of the environmental benefit from the public to the customers firms can deliver an added value. Thus they are able to increase the demand for their environmentally improved products and can thereby monetize on their environmental investments. Hemmelskamp and Brockmann (1997) and Reinhardt (1998) provide anecdotal evidence for environmental product improvements that increased or created customer demand due to private (environmental) benefits for the consumer. Therefore customer benefits can constitute the firm's motivation to implement those innovations in the first place. Consequently,

¹ For a review of the concept of "green consumers" see Pedersen and Neergaard (2006).

firms are expected to focus their environmental innovation activities more towards product improvements and environmental issues that have a potential for customer benefit. Econometric studies on environmental innovations have not taken the effects of customer benefits into account so far, although the concept is well established in the eco-marketing literature.

Green Capabilities

The resource-based view of the firm (cf. Wernerfelt, 1984, Barney, 1991) holds that firm characteristics such as strategy, structure, and core capabilities affect firms' innovation activities (Fagerberg et al., 2005). Based on this, Hart (1995) develops a concept of green capabilities, that is a firm's knowledge of environmental issues relevant to its business and procedures implemented to act and react on these issues. Russo and Fouts (1997) and Sharma and Vredenburg (1998) further elaborate and empirically corroborate this concept. Regarding environmental innovation, many studies look into organizational capabilities, particularly environmental management systems (EMS). The assumption is that (certified) EMS such as ISO 14001 facilitate environmental innovations directly by introducing environmental goals and management structures as well as programs to achieve them (Coglianese and Nash, 2001, Johnstone, 2001) and indirectly by inducing organizational learning and providing critical environmental information (Melnik et al., 2003). Gonzalez-Benito and Gonzalez-Benito (2006) point out that the popularity and visibility of EMS certification offers potential for opportunistic (mis-) use to reduce stakeholder pressure without actually improving any environmentally relevant activities. Empirically, a positive impact of EMS on environmental product innovation activity was found in recent studies by Rehfeld et al. (2007) and Wagner (2007).

Control Variables

Baylis et al. (1998) argue that larger firms have better opportunities and abilities to reduce environmental impacts due to their higher amount of financial and human resources. Additionally, Greening and Gray (1994) contend that larger firms may be subject to greater public scrutiny. Several empirical studies show that firm size has a positive effect on firms' environmental activities in general (King and Lenox, 2001, Melnik et al., 2003) and on EP-innovation in particular (Cleff and Rennings, 1999, Hitchens et al., 2000, Rehfeld et al., 2007). In contrast, Wagner (2007) as well as Seijas-Nogareda (2007) and Engels (2008) do not support this influence of firm size on EP-innovation.

R&D expenditure is a common proxy for and closely related to a firm's innovation activity (Acs and Audretsch, 1988). Although R&D does not automatically lead to innovations, R&D is still the most widely used strategy aiming at innovation. Rehfeld et al. (2007) find empirical evidence that R&D activities also have a positive influence on EP-innovation.

Research Design and Data

The empirical focus of this paper is on the electronics and electrical appliances (EEA) industry in Germany. The German EEA industry is a good case for the analysis of EP-innovation as Germany recently enacted public policies that regulate several environmental attributes of these appliances. Additionally, Germany is one of the largest exporters of information and communication technology in the EU (OECD, 2006, p. 91) and thus provides a large enough sample of manufacturers for an empirical study.

As mentioned in the introduction, I apply a novel unit of analysis for this study: the environmental issue. Instead of surveying firms regarding EP-innovation, regulation and customer benefit in general, I observe these variables individually for several environmental issues per

firm². This deeper level of analysis helps to overcome some of the limitations of earlier studies. Most importantly, it accounts for the fact that key explanatory variables – regulation and customer benefit – are not constant factors within a firm but do vary over different environmental issues. It is obvious that firms do not face the same regulatory stringency for each environmental issue. The same holds true for customer benefit. For example, EP-innovations in the field of energy-efficiency and those regarding toxic substances most likely have different potentials for customer benefit. Therefore, in order to analyze how these factors are related with EP-innovation we need to observe and analyze them at the environmental issue level. Additionally, this provides further variation on the regulatory variable within an industry-specific study.

I focus on the following four environmental issues in this study: energy efficiency, toxic substances, material efficiency, and electromagnetic fields. Most importantly, these issues account for the major environmental impacts of EEA products³. Furthermore, they are regulated by public environmental policies with (presumably) differing stringency: based on the EU directive RoHS⁴, the German Electrical and Electronic Equipment Act (BGBI, 2005) has banned several toxic substances in EEA for sale in Germany since July 2006. The same act holds producers of EEA responsible for taking back and recycling obsolete products originally sold by them in Germany, based on EU directive WEEE⁵. That is, the issues toxic substances and material efficiency are regulated with recent and presumably very stringent regulations. In contrast, the German ordinance on electromagnetic fields (BGBI, 1996) has not been amended or tightened since 2002. And most programs regarding energy efficiency of EEA are only voluntary⁶. Therefore regulations for these two issues are presumably less stringent than for the other two issues. As will be shown in the descriptive results, firms do rate regulations regarding energy efficiency to be less stringent than regulations regarding the other issues.

To obtain further variation on regulatory stringency, three different sectors within the EEA industry have been selected for the sample: information and communication technology (IT); household appliances including lamps and lighting fixtures (HA); and medical appliances (ME). The HA sector is the only one of these for which the German Energy Consumption Labelling Act (BGBI, 1997) established a mandatory energy label in 1998, thus increasing regulatory variation regarding the issue energy efficiency. The ME sector provides further variation for the issue toxic substances as these appliances are currently exempt from the restriction of hazardous substances that is in force for HA and ICT appliances.

For the data collection a survey was carried out using an online-questionnaire⁷. A random sample of EEA firms was drawn from the databases Creditreform (2006) and Hoppenstedt (2006), stratified for sector⁸ and firm size. In total, 360 companies were contacted by phone to

² There are empirical studies on environmental innovation that have focused on a specific environmental issue e.g., Hitchens et al. (2000), but none that has utilized environmental issues as unit of analysis for a large-N study and observed data for several environmental issues.

³ Cf. Behrendt and Kuom (1998), Berkhout and Hertin (2001), Kuehr and Williams (2003), and WHO (2008).

⁴ RoHS (restriction of the use of certain hazardous substances), see EU (2003a).

⁵ WEEE (waste electrical and electronic equipment), see EU (2003b).

⁶ The most prominent example is the EU Energy Star, see www.eu-energystar.org.

⁷ The survey questions for all variables used in this study are listed in the appendix.

⁸ The sector allocation was done using NACE, the EU classification system of economic activities. The following NACE codes have been selected: 2971, 315, and 323 for household appliances; 30 and 322 for information and communication technology; 33101

identify the most appropriate respondent in the company (typically the general manager or a director from R&D or environmental affairs) to fill in the questionnaire. Following the tailored-design method for surveys (Dillman, 2000) each respondent was contacted several times and by different means (phone, mail, e-mail) to achieve a high response rate. After the initial phone calls, 75 companies were found to be ineligible for the study⁹. From the remaining 285 eligible companies 92 filled in the online survey resulting in a response rate of 32%. Table 1 shows the amount of respondents and response rates broken down per sector and firm size.

Table 1: Number of respondents and response rate by sector and firm size.

	Household appliances (HA)	Information & communication technology (IT)	Medical appliances (ME)	Total
20-49 employees	4 (14%)	7 (29%)	11 (44%)	22 (29%)
50-250 employees	12 (31%)	9 (21%)	15 (39%)	36 (30%)
>250 employees	10 (34%)	11 (39%)	13 (42%)	34 (39%)
Total	26 (27%)	27 (28%)	39 (41%)	92 (32%)

Descriptive Results

Environmental Product Innovation

The 92 participating companies were about their EP (environmental product) innovation activities in the period of 2004 to 2006 regarding each of the four environmental issues. One company clearly answered the key questions in the questionnaire incorrectly, resulting in this company's removal from the data set. Therefore this data set consists of 364 cases (4 issues per company) on EP-innovation at the environmental issue level.

As mentioned earlier, I surveyed different measures of EP-innovation. The most basic measure is whether firms have implemented any EP-innovations at all regarding the respective environmental issue. Based on the OECD Oslo Manual innovation has been defined very broadly as “changes which involve a significant degree of novelty for the firm” OECD (1997, p. 8). Therefore this measure encompasses novelties to the market, or real innovations, and novelties to the firm, sometimes called diffusion (Smith, Keith, 2005). As can be seen in table 2, in 78% of the cases an EP-innovation has been implemented. Broken down by sector, IT (86%) clearly exceeds the other two sectors (74% and 75%, respectively).

Looking at the issue level, almost all companies have implemented EP-innovations regarding toxic substances (93%). For each sector it is the issue with the most EP-innovations, ranging from 85% (HA) to 97% (ME). The second issue is electromagnetic fields for which 77% have implemented EP-innovations. For this issue, considerably fewer HA companies (60%) have EP-innovations than ME (80%) and IT (88%) ones. In contrast, EP-innovations regarding ma-

and 33102 for medical appliances.

⁹ These are either only sales and distribution subsidiaries or manufacturing facilities that have no influence on the actual product development process.

material efficiency have been implemented evenly over the sectors by around 73% of companies. Energy efficiency is the issue for which the least companies (68%) have implemented EP-innovations. This relatively low rate is mainly caused by the ME sector where only 46% of the companies have been innovative in this area, compared to 81% for HA and 85% for IT.

Table 2: Number and share of firms with environmental product innovations (EPI_ANY) by sector and environmental issue (overall 2% of the cases have missing data for this variable).				
<i>“Has your company implemented any environmental improvements¹⁰ in your products in the past 3 years?”</i>	Household appliances (HA)	Information & communication technology (IT)	Medical appliances (ME)	Total
Energy efficiency (EFF)	21 (81%)	23 (85%)	17 (46%)	61 (68%)
Toxic substances (TOX)	22 (85%)	26 (96%)	37 (97%)	85 (93%)
Material efficiency (MAT)	19 (73%)	19 (73%)	27 (73%)	65 (73%)
Electromagnetic fields (EMF)	15 (60%)	22 (88%)	28 (80%)	65 (77%)
Total	77 (75%)	90 (86%)	109 (74%)	276 (78%)

A more specific measure of EP-innovation activity is the extent of innovation, defined as the proportion of products for which EP-innovations have been implemented with regard to the respective issue (see table 3). Overall, in around one quarter of the cases (26%) EP-innovations have been implemented very broadly for 76-100% of the product range. The frequencies in this category range from 15% for the issue of energy efficiency (EFF) to 36% for toxic substances (TOX). At the other end of the scale, that is an EP-innovation extent of *less than 5%*, the reverse applies: EFF has the highest rate (22%) and TOX the lowest (9%). Accordingly, the median category for EFF is an extent of 5-25%, while the median for TOX is 51-75%. For the issues of material efficiency (MAT) and electromagnetic fields (EMF) 26-50% is the median category.

¹⁰ The questionnaire was tested with a pilot study. A conclusion of this pilot study was that I had to exchange the term “innovation” with the term “improvement” as most respondents in the pilot study wrongly considered innovation to be restricted to novelties to the market and did not consider novelties to the firm for their responses.

Table 3: Extent of Environmental Product Innovations (EPI_EXT) by environmental issue (overall 2% of the cases have missing data for this variable).

“For what percentage of your products have you implemented at least one improvement in the last 3 years?”	<5%	5-25%	26-50%	51-75%	76-100%	Total
Energy efficiency (EFF)	22%	* 30%	25%	8%	15%	100%
Toxic substances (TOX)	9%	26%	15%	* 15%	36%	100%
Material efficiency (MAT)	16%	20%	* 19%	17%	28%	100%
Electromagnetic fields (EMF)	14%	35%	* 20%	8%	23%	100%
Total	14%	28%	* 19%	12%	26%	100%

The asterisks indicate the median category.

The third measure of EP-innovations is the degree of novelty, distinguishing between real innovations that are novel to the market and diffusion of innovations that are only novel to the firm. Respondents were asked whether their EP-innovations are *mainly market novelties*, *some market novelties*, or *no market novelties*, i.e. only novelties at firm level (see table 4). In almost half of all cases (48%), firms have implemented EP-innovations that are *no market novelties*. Around one fifth of the cases (21%) were *mainly market novelties*, and the remaining 31% have implement *some market novelties*, meaning their EP-innovations are split up in market novelties and firm novelties. Looking at the issue level, EFF and EMF have the middle category *some market novelties* as median while TOX and MAT tend more towards the lowest category *no market novelties*.

Table 4: Novelty of environmental product innovations (EPI_NOV) by environmental issue (overall 8% of the cases have missing data for this variable).

“Are these product improvements market novelties?”	No Market Novelties	Some Market Novelties	Mainly Market Novelties	Total
Energy efficiency (EFF)	36%	* 38%	25%	100%
Toxic substances (TOX)	* 50%	* 29%	21%	100%
Material efficiency (MAT)	* 58%	25%	17%	100%
Electromagnetic fields (EMF)	47%	* 33%	20%	100%
Total	48%	* 31%	21%	100%

The asterisks indicate the median category.

In summary, the distribution of each measure for EP-innovation differs over the environmental issues. For example, for TOX EP-innovations are more likely and have a larger extent than for the other issues. And regarding novelty, EP-innovations for MAT are clearly less often market novelties than for the other issues. This shows that the environmental issue level provides a deeper understanding of EP-innovation and thus supports our argument for this unit of analysis.

Regulatory Stringency

Analogous to innovation, firms have been surveyed on regulatory stringency for all four environmental issues. Regulatory stringency has been defined as how demanding it was for firms to meet the respective regulations in the last 3 years. Respondents replied using a 5-point ordinal scale ranging from *very easy* to *very difficult*. As shown in table 5, the maximum score *very difficult* has only rarely been selected (2%). Each of the ratings *very easy* and *moderate* has been given in around one third of the cases (32%), with *easy* getting another fifth of the answers (20%) and *difficult* the remaining 14%. However, there are clear differences between the issues. For EFF three quarters of the respondents reported regulations to be *very easy* to meet (74%). A rating that was given by less than one fourth of the companies for the other issues. For these issues, the middle category *moderate* was most frequently selected, making it the median category as well.

Table 5: Stringency of regulation (REG_STRING) by environmental issue (overall 3% of the cases have missing data for this variable).

<i>"In the past 3 years, how easy / difficult was it for your company to meet regulations in Germany?"</i>	Very Easy	Easy	Moderate	Difficult	Very Difficult	Total
Energy efficiency (EFF)	* 74%	9%	16%	1%	0%	100%
Toxic substances (TOX)	21%	22%	* 28%	24%	6%	100%
Material efficiency (MAT)	16%	29%	* 38%	17%	0%	100%
Electromagnetic fields (EMF)	14%	19%	* 47%	16%	4%	100%
Total	32%	* 20%	32%	14%	2%	100%

The asterisks indicate the median category.

Customer Benefit

Like innovation and regulatory factors, the potential for customer benefit has been measured at the environmental issue level. The 4-point ordinal scale ranges from *no benefit* to *large benefit*. Looking only at the issues, companies rated customer benefit most frequently *moderate* for the issues EFF and EMF, making it the median category for these issues (see table 6). For TOX and MAT, customer benefit has been rated lower with *little benefit* being the median and most frequent answer category.

Table 6: Customer benefit (CUST_BEN) by environmental issue and sector (overall 1% of the cases have missing data for this variable).

“How do you rate the direct benefit to your customers from product improvements?”	No Benefit	Little Benefit	Moderate Benefit	Large Benefit	Total
Energy Efficiency (EFF)	11%	29%	* 35%	25%	100%
HA sector	8%	19%	* 46%	27%	100%
IT sector	11%	26%	* 30%	33%	100%
ME sector	13%	* 37%	* 32%	18%	100%
Toxic Substances (TOX)	18%	* 43%	26%	13%	100%
HA sector	31%	* 38%	15%	15%	100%
IT sector	15%	* 48%	30%	7%	100%
ME sector	11%	* 42%	32%	16%	100%
Material Efficiency (MAT)	19%	* 37%	29%	15%	100%
HA sector	31%	* 42%	15%	12%	100%
IT sector	19%	* 44%	22%	15%	100%
ME sector	11%	29%	* 42%	18%	100%
Electromagnetic Fields (EMF)	18%	25%	* 39%	18%	100%
HA sector	28%	* 36%	20%	16%	100%
IT sector	8%	16%	* 60%	16%	100%
ME sector	18%	24%	* 37%	21%	100%

The asterisks indicate the median category.

Depending on the sector, companies gave different ratings for customer benefit from better energy efficiency: while *moderate* is the median category for HA and IT companies, ME companies consider the EFF issue less beneficial for their customers with the median lying between *little benefit* and *moderate benefit*. The TOX issue is less diverse among the sectors, with *little benefit* being the median category for all. Yet, around 30% of companies from the IT and ME sector rate customer benefit to be *moderate*, whereas the same share of HA firms sees *no benefit* at all.

For MAT there is again a difference between HA and IT on one side with *little benefit* being the median and ME on the other side where *moderate benefit* is the median category. Regarding EMF it is the HA sector that differs from the others. While the median IT and ME company attributes moderate benefit to this issue, the median HA company sees only *little benefit* for its customers.

Green Capabilities

In contrast to the major study variables, firms' green capabilities have been measured at firm

level. Firms may allocate resources and develop specific knowledge for certain environmental issues, however the underlying green capabilities are the same. Therefore these factors were surveyed at firm level. Green capabilities have been measured with 5 indicators (see table 7). Overall, the most prevalent measures are the *use of products' environmental attributes in marketing* (45%) and *voluntary environmental targets for products* (42%). Few companies have *systematic environmental analyses of products* (25%) and *environmental trainings for product developers* (21%) in place. The least frequent measure is *certified environmental management system*, which has only been implemented by 18% of respondents. Broken down by sectors, ME manufacturers clearly have the lowest rates for each indicator. While environmental trainings and environmental targets are most common in the IT sector, the other indicators are most prevalent with HA manufacturers.

Table 7: Green capabilities of firms by sector.

<i>Does your company...</i>	<i>... use the env. attributes of your products in marketing?</i>	<i>... have set up voluntary env. targets for products?</i>	<i>... conduct systematic env. analyses of your products?</i>	<i>... train its product developer in env. issues?</i>	<i>... have a certified env. management system (e.g. ISO 14'001)?</i>
HA sector	54%	46%	31%	23%	23%
IT sector	52%	48%	26%	26%	19%
ME sector	34%	34%	21%	16%	13%
Total	45%	42%	25%	21%	18%

Conclusion of Descriptive Results

The question of whether the environmental issue level provides additional information for the main variables of theoretical interest deserves an affirmative answer. The descriptive results clearly show that EP-innovation, regulatory stringency, and customer benefit have substantial variation over the environmental issues. This supports my proposed unit of analysis and provides evidence for the claim that environmental innovation should be studied at the environmental issue level.

Statistical Analyses

Models and Variables

In this section, I use econometric approaches to analyze the specific effects of regulatory stringency and customer benefits on environmental product innovations separated from other variables' influence. Specifically, I apply binary and ordered logit regression models¹¹. As seen in the descriptive results, the data set has missing data for some variables as most survey data sets do. By default, missing data in logit regression is handled with listwise deletion. This not only reduces the number of observations, but can also lead to biased estimates (Allison, 2001, p. 6). Therefore, I have imputed missing values using the multiple imputation method¹².

¹¹ Probit models lead to generally identical results as logit models, only the coefficients differ by a factor of 1.6 to 1.8 (Agresti, 2002, p. 246).

¹² I created 10 data sets with the multiple imputation using the ice package (Royston, 2005) with Stata 9.2. The Stata do-file performing the multiple imputation is available on request

However, for 9 of the 364 observations listwise deletion had to be applied nevertheless, as both the dependent and the main independent variables (i.e., EP-innovation, regulation and customer benefits) had missing values. Thus 355 observations are included in the logit regression analysis.

First, I apply a binary logit model. The binary outcome variable is EPI_ANY, measuring whether or not environmental product innovations were implemented for the respective environmental issue in the past 3 years. Next, I consider an ordered logit model for the extent of EP-innovation, again based on the past 3 years. Obviously, only firms that implemented EP-innovations in the first place (i.e., EPI_ANY is yes) were asked about the innovation extent. For those observations with no EP-innovation (i.e., EPI_ANY is no) the ordinal outcome variable EPI_EXT has been recoded to 0. Accordingly, the scale of EPI_EXT consists of the disjoint and ordinal categories 0%, 1-5%, 6-25%, 26-50%, 51-75%, and 76-100%. Due to this recoding the analysis is not restricted to innovative cases only but includes non-innovative cases as well. A further ordered logit model is applied for the novelty of EP-innovations. Again, firms were not asked about the novelty of EP-innovations if they did not implement any EP-innovations in the first place. Therefore the outcome variable EPI_NOV has been recoded in the exact same manner as EPI_RATE. The resulting categories are *no novelties*, *no market novelties*, *some market novelties*, and *mostly market novelties*.

In addition to the main explanatory variables portrayed in the descriptive results section, the following variables are included in the logit models: Firms' green capabilities have been summed up for the variable GREEN_CAP which ranges from 0 for firms with no capabilities to 5 for firms that have implemented all measures (see table 7). EMPLOYEE measures the number of employees (in thousands) the firms had in 2006. Concerning the general R&D activities of companies, the variable R&D_EMPL is included which is based on the ratio of employees in R&D to employees in total. Finally, I include dummy variables for the sector (SEC_ME and SEC_IT with HA being the base category) and environmental issue (I_EFF, I_TOX, I_MAT with EMF as base category).

Note that the control variables are at the firm level and not at the issue level like the explanatory and outcome variables. That is, the control variables do not vary over the environmental issues within a firm (e.g., EMPLOYEE). To adjust for this intragroup correlation, the logit models are estimated using the “cluster” option of Stata for cluster-sampled data (StataCorp, 2005, p. 354).

Binary Model for Environmental Product Innovation

In the following, I use a binary logit model to explain companies' environmental product innovation. The dependent variable, EPI_ANY, is measured as a binary variable for which respondents could state whether or not their company implemented EP-innovations. Table 8 reports the parameter estimates with level of significance, standard error, and z-value. Additionally, the discrete changes in the predicted probabilities are shown based on the independent variables' change from minimum to maximum value.

Table 8: Parameter Estimates and Discrete Changes for Binary Logit Model of EPI_ANY.

	Binary logit model				Discrete change
	Parameter Estimate	Level of Significance	Robust Std. Error	z-value	min- > max
REG_STRING	0.707	***	0.196	3.615	0.56
CUST_BEN	1.051	***	0.190	5.536	0.63
EMPLOYEE	-0.023		0.040	-0.581	-0.25
R&D_EMPL	0.017		0.019	0.900	0.34
GREEN_CAP	0.609	***	0.185	3.290	0.56
SEC_ME	0.105		0.452	0.232	0.03
SEC_IT	0.831		0.571	1.456	0.19
I_EFF	0.119		0.456	0.261	0.03
I_TOX	2.180	***	0.542	4.018	0.39
I_MAT	-0.021		0.381	-0.054	-0.01
_cons	-4.249	***	0.948	-4.481	

The estimates are based on 355 observations at the environmental issue level. Wald chi2 for 10 coefficients ranges from 63.52 to 64.42 in the regression models of the 10 imputed data sets. Log pseudolikelihood ranges from -128.5 to -127.9.
 * (**, ***) means that the null hypothesis that the appropriate parameter is zero can be rejected at the 10% (5%, 1%) level of significance.

This model clearly shows that the stringency of regulation (REG_STRING) has a highly significantly positive effect on the implementation of EP-innovations. Thus more stringent environmental regulation does increase the probability that a company implements EP-innovations. Customer benefit (CUST_BEN), the other variable of major theoretical interest in this paper, also has a highly significant positive effect on EP-innovation. The more potential for customer benefits a company attributes to an environmental issue, the more likely it is that it has implemented EP-innovations. Two more variables in the model display a highly significant influence on the likelihood of EP-innovation: the more green capabilities (GREEN_CAP) a company has, the more likely it is to have implemented EP-innovations. Finally, companies are significantly more likely to have implemented EP-innovations regarding the issue of toxic substances (I_TOX) than regarding any of the other issues¹³. Compared to the reference issue electromagnetic fields, EP-innovations are more likely for the environmental issues energy efficiency (I_EFF) and less likely for material efficiency (I_MAT), yet these influences are non-significant¹⁴.

Number of employees (EMPLOYEE) is non-significant with a negative influence on EP-innovation, thus smaller companies are more likely to have introduced EP-innovation than larger companies. R&D activities (R&D_EMPL) have a positive, though also non-significant, effect on EP-innovation. The sector is non-significant as well although manufacturers of medical appliances (SEC_ME) and information & communication technology (SEC_IT) are more

¹³ A Wald test was used to compare the effects of I_TOX with I_EFF (p=0.001) and I_MAT (p<0.001).

¹⁴ The Wald test comparing I_EFF with I_MAT reports p=0.745.

likely to implement EP-innovations compared to those of household appliances. The effects of SEC_ME and SEC_IT do not differ significantly either ($p=0.1357$).

To compare the effect sizes of the variables, the discrete changes are reported in table 9 as well. These show the difference in the predicted values as one explanatory variable changes while the others are held constant. CUST_BEN has the largest effect size: a change from its minimum value to its maximum value raises the predicted probability of EP-innovation by 0.63. Next come REG_STRING and GREEN_CAP with probability increases of 0.56 for both. R&D activities and the issue of toxic substances (compared to base category EMF) also raise the predicted probability by more than 0.3, while firm size decreases it by 0.25.

Ordinal Logit Model for Extent of EP-Innovation

In order to explain the extent of EP-innovation, an ordered logit model is applied. The outcome to be explained, EPI_EXT, is measured as a 6-point categorical variable. Companies have been asked for what percentage of their product range at least one EP-innovation has been implemented in the past 3 years. Answer categories are 0%, 1-5%, 6-25%, 26-50%, 51-75%, and 76-100%. The parameter estimates together with level of significance, standard error, and z-value are reported in table 9.

	Parameter Estimate	Level of Significance	Robust Std. Error	z-value
REG_STRING	0.631	***	0.127	4.978
CUST_BEN	0.623	***	0.142	4.376
EMPLOYEE	0.079	***	0.028	2.836
R&D_EMPL	0.001		0.008	0.188
GREEN_CAP	0.282	***	0.078	3.620
SEC_ME	0.027		0.319	0.083
SEC_IT	0.561		0.354	1.586
I_EFF	0.209		0.306	0.683
I_TOX	1.385	***	0.249	5.571
I_MAT	0.300		0.283	1.057
cut1_cons	2.618	***	0.629	4.165
cut2_cons	3.421	***	0.644	5.314
cut3_cons	4.650	***	0.691	6.730
cut4_cons	5.500	***	0.743	7.405
cut5_cons	6.140	***	0.772	7.953

The estimates are based on 355 observations at the environmental issue level. Wald chi2 for 10 coefficients ranges from 118.99 to 128.11 in the regression models of the 10 imputed data sets. Log pseudolikelihood ranges from -541.1 to -537.0.
 * (**, ***) means that the null hypothesis that the appropriate parameter is zero can be rejected at the 10% (5%, 1%) level of significance.

As in the binary model, this model clearly shows a highly significant positive influence of

REG_STRING on the extent of EP-innovations: the more stringent environmental regulation is, the more likely is a broad implementation of EP-innovations. And again, CUST_BEN also has a highly significant positive effect on EPI_EXT. Thus, companies that reported large potential benefits for their customers are more likely to implement EP-innovations to a large extent. Besides these variables of major theoretical interest, 3 more variables show a strong influence on the extent of EP-innovation: as for EPI_ANY, green capabilities and the issue of toxic substances have a highly significant positive effect on EPI_EXT. Companies with more green capabilities are more likely to have implemented EP-innovations broadly, and EP-innovations with regard to TOX are more likely to have a large extent than the ones regarding the other issues¹⁵. In contrast to the binary model, firm size (EMPLOYEE) has a positive effect on EP_EXT, which is highly significant as well. Thus, larger companies are more likely to implement EP-innovations on a broad basis.

Companies in the IT sector are more likely to have introduced EP-innovations broadly than companies in the ME sector, which in turn are more likely to do so than companies in the HA sector. However these effects are not significant besides the weakly significance for the effects of SEC_IT and SEC_ME (p=0.0935). R&D activities are also non-significant with a parameter close to zero. The effects of the issue dummies for EFF and MAT are non-significant¹⁶ with EP-innovations regarding MAT being the most likely to have a large extent and the ones regarding EMF being the least likely to do so.

Based on the ordered logit model for EP-innovation extent table 10 shows some predicted probabilities for crucial values. Regulatory stringency and customer benefit are the only variables to change in the table, green capabilities and employees (both in general and for R&D) are set to the median, sector is set to HA and issue is set to EMF. For example, a median company in the HA sector that faces very lax regulations regarding the EMF issue and attributes this issue no potential for customer benefits has the predicted probability of 0.74 of having an EP-innovation extent of 0%, that is not having implemented an EP-innovation. Further, it has a predicted probability of 0.12 of having an EP-innovation extent of 1-5%, and of less than 0.10 for any of the other categories.

Regulatory Stringency	Customer benefit	Pr 0%	Pr 1-5%	Pr 6-25%	Pr 26-50%	Pr 51-75%	Pr 76-100%
1 (Min)	1 (Min)	0.74	0.12	0.09	0.02	0.01	0.01
1 (Min)	4 (Max)	0.31	0.19	0.27	0.12	0.05	0.06
5 (Max)	1 (Min)	0.19	0.15	0.30	0.17	0.08	0.11

Calculated for EMF issue in the HA sector. The remaining variables have been set to their median: GREEN_CAP to 1, EMPLOYEE to 0.12, R&D_EMPL to 11.11.

However, if everything stays the same, only this time the company attributes the EMF issue a large potential for customer benefits, the predicted probability of not having implemented an EP-innovation reduces to 0.31, and the probabilities of all other categories increase with the extent of 6-25% having the second largest probability (0.27). If this company faces very strict

¹⁵ The Wald test reports p<0.001 for I_EFF and p=0.001 for I_MAT.

¹⁶ p=0.7805 for I_EFF compared to I_MAT.

regulations and does not attribute a customer benefit, the predicted probabilities of no EP-innovation and 1-5% extent further decline while the 5-25% extent has the largest probability with 0.30.

Comparing the maximum scenarios for regulatory stringency and customer benefit reveals that regulatory stringency has a stronger effect on the extent of EP-innovation than customer benefit. Maximum stringency results in the extent of 6-25% being the most likely outcome whereas maximum customer benefit does not change the most likely outcome: it remains at 0%.

Ordinal Logit Model for EP-Innovations' Degree of Novelty

Another ordered model is applied to explain the degree of novelty of EP-innovation. The outcome EPI_NOV is measured as a 4-point categorical variable for which companies could state how novel their EP-innovations have been on average in the past 3 years. Answer categories are *no novelties*, *no market novelties*, *some market novelties*, and *mainly market novelties*. Table 11 shows the parameter estimates, level of significance, standard error, and z-values for this model.

Table 11: Parameter estimates in the ordered logit model of EP-Innovations' Degree of Novelty (EPI_NOV).				
	Parameter Estimate	Level of Significance	Robust Std. Error	z-value
REG_STRING	0.210	*	0.118	1.775
CUST_BEN	0.615	***	0.132	4.659
EMPLOYEE	0.060	*	0.032	1.873
R&D_EMPL	-0.001		0.011	-0.069
GREEN_CAP	0.221	**	0.089	2.492
SEC_ME	0.075		0.344	0.219
SEC_IT	0.621		0.427	1.454
I_EFF	0.011		0.319	0.035
I_TOX	0.826	***	0.248	3.337
I_MAT	-0.203		0.261	-0.778
cut1_cons	1.383	*	0.706	1.958
cut2_cons	3.393	***	0.767	4.425
cut3_cons	4.733	***	0.843	5.617
The estimates are based on 355 observations at the environmental issue level. Wald chi2 for 10 coefficients ranges from 68.76 to 73.91 in the regression models of the 10 imputed data sets. Log pseudolikelihood ranges from -433.6 to -426.4. * (**, ***) means that the null hypothesis that the appropriate parameter is zero can be rejected at the 10% (5%, 1%) level of significance.				

In contrast to the previous two models, the effect of regulatory stringency is only weakly significant in this model. Companies that face more stringent environmental regulation are more likely to implement EP-innovations that are novel to the market. Customer benefit again has a highly significant effect: large potential for customer benefits increases the probability of EP-

innovations that are market novelties. Green capabilities also have a strong influence, with companies having more green capabilities being significantly more likely to introduce market novelties. A still significant influence displays the variable EMPLOYEE. The larger a company is, the more likely are EP-innovations that are market novelties.

R&D activities again have a non-significant coefficient close to zero. Regarding the industry sector, companies from IT have the highest probability of introducing market novelties while the ones manufacturing HA have the lowest probability of doing so. Besides the comparison of ME and IT ($p=0.0982$), these sector effects are non-significant. Like in the other two models, the only environmental issue that has a highly significant effect is TOX: EP-innovations regarding this issue are more likely to be market novelties than the ones regarding the other issues¹⁷. The probability for market novelties increases as follows for the other issues: MAT has the lowest probability, followed by EMF, with EFF having the highest probability; however these effects are non-significant¹⁸.

Likewise to the model for extent of EP-innovation, some predicted probabilities for the degree of novelty have been calculated for HA companies and the EMF issue, keeping the control variables at their median value (see table 12). Starting with the minimum values for regulatory stringency and customer benefit, the predicted probabilities for a median firm are 0.58 for no novelties at all, 0.33 for no market novelties, and below 0.10 for the remaining categories¹⁹. If customer benefit changes from the minimum to the maximum value, the probability of no novelties at all declines to 0.18 and the other ones increase to 0.44 for no market novelties, to 0.24 for some market novelties, and to 0.14 for mainly market novelties. In the reverse situation – maximum regulatory stringency and minimum customer benefit – the company also has a probability of 0.44 of no market novelties; however, the probabilities of some market novelties (0.13) and mainly market novelties (0.05) raise less strong than in the minimum stringency and maximum customer benefit scenario.

Regulatory Stringency	Customer benefit	Pr No Novelties at All	Pr No Market Novelties	Pr Some Market Novelties	Pr Mainly Market Novelties
1 (Min)	1 (Min)	0.58	0.33	0.06	0.02
1 (Min)	4 (Max)	0.18	0.44	0.24	0.14
5 (Max)	1 (Min)	0.38	0.44	0.13	0.05

Calculated for EMF issue in the HA sector. The remaining variables have been set to their median : GREEN_CAP to 1, EMPLOYEE to 0.12, R&D_EMPL to 11.11.

¹⁷ The p-values are 0.0057 for I_EFF and <0.001 for I_MAT.
¹⁸ The Wald test result is $p=0.4939$ for I_EFF compared to I_MAT.
¹⁹ The “no novelties at all” category of EPI_NOV is identical to the “0%” category of EPI_EXT: the company has not implemented an EP-innovation. At first sight it might be disturbing that the predicted probabilities for these two categories are not the same in the two models (EPI_EXT: 0.74, EPI_NOV: 0.58). However, both predicted probabilities fall into the confidence interval for the respective other probability (EPI_EXT: [0.57; 0.91], EPI_NOV: [0.33; 0.84]).

So in contrast to the EPI_EXT model, regarding novelty of EP-innovation it is customer benefit that has the larger effect than regulatory stringency. While no market novelty is the most likely outcome (0.44) in both maximum scenarios, maximum customer benefit results in higher probabilities for the outcomes some market novelties and mainly market novelties than maximum regulatory stringency.

Discussion

The aim of this paper is to analyze the influence of customer benefit and regulation on environmental product innovation and to utilize a novel unit of analysis, the environmental issue level, for this analysis. The statistical analyses clearly show that customer benefit plays a key role for environmental product innovations. Firms that attribute a large potential for customer benefit to an environmental issue are significantly more likely to implement EP-innovations for this issue. Furthermore, they implement their EP-innovations for more products and their EP-innovations are more often market novelties. In short, customer benefit fosters the implementation of EP-innovations, their broad application and their level of novelty.

However, as shown in the descriptive statistics section, customer benefit is not constant within an environmental issue and / or industry sector. Therefore, not every firm in a sector attributes the same potential for customer benefit to a given environmental issue. This raises the question of what influences firms in identifying potential customer benefit of environmental issues. Is it their specific market or the kind of customers they serve (consumers, industry, or public)? Or does it rather depend on firm-internal factors like customer orientation or environmental strategy whether customer benefits are recognized by firms? Further research on these questions is necessary and customer benefit, which has an important impact on EP-innovation, should be more comprehensively analyzed in further empirical studies.

For environmental regulation, the second variable of major theoretical interest in this paper, the results are a little less clear-cut. The analyses do demonstrate that regulation has a positive impact on the different measures of EP-innovation. While firms that face more stringent regulation are significantly more likely to implement EP-innovations and to implement them at a large extent, the stimulating effect of regulation on the novelty of EP-innovation is only weakly significant. Thus, more stringent regulation does lead to EP-innovations and their broad application. But it does not necessarily lead to EP-innovations that are novel to the market.

Whether customer benefit or regulatory stringency has the larger effect on EP-innovation depends on the specific measure that is looked at. A large potential for customer benefit is more stimulating to overcome the initial obstacle of implementing an EP-innovation than stringent regulation. Customer benefit is also more stimulating for EP-innovations that are novel for the market, so-called real innovations. In contrast, stringent regulation has a larger impact on the broad application of EP-innovations. In other words, while customer benefit motivates firms more strongly to come up with real innovations, regulation leads to larger diffusion of EP-innovations.

Another result from the statistical analyses is that green capabilities have a significant positive effect on all measures of EP-innovation. The resources and knowledge that builds up by implementing these green capabilities not only enable firms to implement more EP-innovations but also support the development of EP-innovations that are market novelties.

A further firm-internal factor that significantly influences EP-innovation is firm size. Though larger firms are non-significant less likely to implement an EP-innovation for a specific environmental issue, once they overcome the initial obstacle they implement EP-innovations on a

significantly wider basis than smaller firms. Economies of scale might be the underlying effect for this broader application of EP-innovation by larger firms. Better financial and human resources could be the explanation for the weakly significant, positive effect of firm size on the implementation of market novelties.

Contrary to the findings of Rehfeld et al. (2007), my results do not support the impact of firms' general innovation activity on EP-innovation. The coefficients for R&D_EMPL are close to zero in all models and none of them is significant. The different results could stem from the differing operationalization of R&D activities. In this paper, the share of employees in R&D has been used while Rehfeld et al. used a dummy measuring whether there were R&D activities or not (*ibid.*, p. 96).

For this study, EP-innovation and its hypothesized determinants have not been observed in general but for specific environmental issues. The argument is that EP-innovation as well as regulatory stringency and potential for customer benefit are not constant for firms but do vary over the different environmental issues. Therefore, these variables also have to be measured at the environmental issue level in order to analyze how they are related.

The descriptive results have clearly demonstrated that this reasoning is correct: all measures of EP-innovation as well as regulatory stringency and customer benefit vary over the different environmental issues. The utilization of this novel unit of analysis was essential to distinguish between strict regulation for issue A (or large customer benefit for issue B) and EP-innovation that might have been regarding yet another environmental issue C. Thus, the environmental issue level facilitates tracing back variation in one of the EP-innovation measures to variation in one of the variables of interest. Therefore, studies on the determinants of environmental innovation should not look at environmental innovation in general but consider specific environmental issues for their analysis.

Policy Recommendations

Based on these results, the following policy recommendations can be derived: Stringent environmental regulation does stimulate manufacturers to environmentally improve their products. This is especially true for the diffusion of improvements that have already been invented by others. However, stringent regulation alone might be insufficient to stimulate the development of real innovations.

Firms do concentrate their environmental innovation activities on areas with large potential for customer benefit. In order to leverage these customer benefits, industry should be supported in identifying and communicating how environmental improvements of products might be directly useful for consumers.

Particularly small and medium firms should be supported in their environmental innovation activities. They lack the financial and human resources to develop market novelties and to implement environmental innovations on a broad product base.

Acknowledgment

I am grateful to the Swiss National Science Foundation for funding this study (grant 100012-112029). Additionally, I would like to thank the 92 companies for their response to my survey that made this research possible.

Appendix

Underlying questions for the variables:

- EPI_ANY (environmental product innovation): “Has your company implemented any environmental improvements in your products in the past 3 years (In the area of energy efficiency; toxic substances; material efficiency; electromagnetic fields)?”
- EPI_RATE (implementation rate of environmental product innovation): “For what percentage of your products have you implemented at least one improvement in the last 3 years (In the area of energy efficiency; toxic substances; material efficiency; electromagnetic fields)?”
- EPI_NOV (novelty of environmental product innovation): “Are these product improvements market novelties (In the area of energy efficiency; toxic substances; material efficiency; electromagnetic fields)?”
- REG_STRING (regulatory stringency): “In the past 3 years, how easy / difficult was it for your company to meet regulations in Germany (In the area of energy efficiency; toxic substances; material efficiency; electromagnetic fields)?”
- CUST_BEN (Customer benefit): “How do you rate the direct benefit to your customers from product improvements (In the area of energy efficiency; toxic substances; material efficiency; electromagnetic fields)?”
- GREEN_CAP (Green Capabilities):
 - “Does your company have a certified env. management system (e.g. ISO 14'001)?”
 - “Does your company train its product developer in env. issues?”
 - “Does your company conduct systematic env. analyses of your products?”
 - “Has your company set up voluntary env. targets for products?”
 - “Does your company use the env. attributes of your products in marketing?”
- EMPLOYEE: “How many employees (full-time equivalent) did your company have in 2006?”
- R&D_EMPL (Employees in R&D) is based on EMPLOYEE and the the question: “How many employees (full-time equivalent) did your company have in research and development (R&D) in 2006?”

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