DISS. ETH NO. 18057

DETERMINANTS OF ENVIRONMENTAL PRODUCT INNOVATION

A Comparative Study on Manufacturers of Electrical and Electronic Appliances in Germany and California

A dissertation submitted to

ETH ZURICH

for the degree of

Doctor of Sciences

presented by

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2008

Acknowledgements

The writing of a PhD thesis is not the work of only one person, but the result of cooperation of many. Therefore, I would like to thank everyone who in one way or another contributed to this thesis. First of all, I would like to thank the members of my committee, namely Thomas Bernauer, Volker Hoffmann, and Marion Tobler. They not only provided academic support and arranged the necessary conditions for good research but also gave me a lot of freedom to develop my own ideas and make my own plans. I also want to thank the Swiss National Science Foundation for the funding of these ideas and plans (grant 100012-112029), which is very much appreciated.

Further, I would like to thank Robert van Buskirk for hosting me at the Lawrence Berkeley National Laboratory. This stay at the “Berkeley Lab” facilitated the surveying of Californian companies very much. Furthermore, I am deeply indebted to the companies that participated in my survey. Without their support, this study would not have been possible.

I also want to thank all my colleagues at the institute for the good company, especially Marcus Dapp for sharing the office with me through all the ups and downs of writing a dissertation, Stéphanie Engels and Jazmin Seijas for the discussions and collaboration, Anna Kalbhenn, Gabriele Ruoff and Lena Schaffer for support in statistics, and Claudia Jenny for proofreading.

Special thanks go to Emily Sadigh for establishing the contact to the Berkeley Lab and providing many stimulating experiences in the Bay Area. Further appreciation goes to Cindy Furukawa and Chuck Smith for making us feel at home in Berkeley.

My warmest thanks go to my friends and family, most of all my parents Edeltraud Erika and Karl-August Kammerer. My deepest gratitude goes to my fiancée Andrea Schünke for her love, support and encouragement throughout this entire journey.

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SUMMARY

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 dissertation, I contribute to the understanding of corporate EP-innovation by introducing a novel research framework and testing it in empirical studies on the electrical and electronic appliances industry.

- First, I apply a novel unit of analysis, the environmental issue level. EP-innovation is not studied in broad terms but specifically for four environmental issues that are relevant to these appliances: energy efficiency, toxic substances, material efficiency, and electromagnetic fields. The firm as principal unit of analysis may be too general as determinants (e.g., regulation) might vary at the firm level across different environmental issues.

- Second, customer benefit, a concept from the green marketing literature, is included as an explanatory variable for EP-innovation. 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 may thus motivate the firms to implement those innovations in the first place. The link between potential for customer benefit and EP-innovation has not been tested in systematic empirical analyses so far.

- Third, EP-innovation is observed more comprehensively. In addition to the binary measurement whether EP-innovations have been implemented, I measure the extent of the firms' product range for which they implemented the innovations. Furthermore, I observe the degree of novelty, that is I distinguish between innovations that are novel to the market and innovations that are only novel to the firm.

I apply this research framework to study EP-innovations of Californian and 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.

The potential for customer benefit not only stimulates firms to implement environmental product innovations and to apply them to a large share of their products, it also motivates firms to go beyond the diffusion of already-known improvements and to develop environmental product innovations that are novel to the market.

The stringency of regulation also promotes the broad implementation of EP-innovations. However an effect on market novelties could only be shown for German manufacturers and had statistically weak significance. While customer benefit is more stimulating for EP-innovations that are novel for the market, stringent regulation has a larger impact on the broad application of EP-innovations that are already known to the market.

With regard to the actual EP-innovation activity, this study revealed some interesting differences between California and Germany. Again, there is a distinction between the extent and the novelty of EP-innovation. On the one hand, a Californian firm is more likely to implement EP-innovations than a German firm is; and it also implements these innovations on a broader range. On the other hand, firms in Germany generally develop and implement more EP-innovations that are novel to the market.

ZUSAMMENFASSUNG

Ökologische Produktinnovationen (ÖP-Innovationen) und ihre Determinanten wurden in den letzten Jahren zunehmend Gegenstand der Forschung. Empirische Studien haben bisher jedoch widersprüchliche Ergebnisse geliefert, vor allem in Bezug auf den Einfluss von Regulierung. In dieser Dissertation erweitere ich unser Verständnis von ÖP-Innovationen indem ich ein neues Research-Design entwickle und es zur Untersuchung von Herstellern von elektrischer und elektronischer Geräte anwende.

- Zum Einen verwende ich eine neue Untersuchungseinheit. Ich untersuche ÖP-Innovationen nicht allgemein auf Firmenebene, sondern spezifisch für vier Umweltthemen, welche für diese Geräte relevant sind: Energie-Effizienz, Toxische Substanzen, Material-Effizienz und elektromagnetische Felder. Dadurch behebe ich die Problematik, dass manche Erklärungsfaktoren (z.B. Regulierung) nicht statisch sind auf Ebene der Firma, sondern innerhalb der gleichen Firma für die verschiedenen Umweltthemen variieren.

- Des Weiteren beziehe ich ein Konzept aus der Öko-Marketing Literatur, den direkten Kundennutzen, als erklärende Variable für ÖP-Innovationen ein. Es wird behauptet, dass jene Öko-Produkte eine höhere Kundennachfrage erzielen, bei welchen die ökologische Verbesserung nicht nur der Gesellschaft nutzt sondern auch dem Kunden (z.B. durch geringeren Energieverbrauch in der Nutzung). Und dass sich Firmen deshalb vermehrt auf solche ÖP-Innovationen konzentrieren, welche das Potenzial für diesen Kundennutzen haben. Dieser Zusammenhang zwischen dem Potenzial für Kundennutzen und ÖP-Innovationen wurde bisher noch nicht in systematischen, empirischen Studien untersucht.

- Schliesslich erhebe ich ÖP-Innovationen umfassender als bisherige Studien. Zusätzlich zum binären Mass ob Firmen ÖP-Innovationen implementiert haben oder nicht, erhebe ich das Ausmass und den Neuheitsgrad der ÖP- Innovationen. D.h. ich untersuche für welchen Anteil der Produktpalette ÖP-Innovationen implementiert wurden und ob es sich dabei um Firmen- oder Marktneuheiten handelt.

Dieses Research Design wende ich an, um ÖP-Innovationen bei Herstellern von Elektro- und Elektronikgeräten in Kalifornien und Deutschland zu untersuchen. Die Entscheidung für die Untersuchungseinheit Umweltthema wird von meinen Ergebnissen bestätigt. Die statistische Analyse für die Auswirkung von Kundennutzen und Regulierung auf ÖP-Innovationen wird mit Logit Regressionen durchgeführt. Die Resultate zeigen klar, dass Kundennutzen und Regulierung einen wichtigen Einfluss auf ÖP-Innovationen haben.

Die Aussicht auf Kundennutzen stimuliert die Firmen nicht nur zu ökologischen Produktinnovationen und einem grossen Ausmass bei der Implementierung dieser ÖP-Innovationen. Sie motiviert Firmen ausserdem über die Diffusion von bereits bekannten Verbesserungen hinaus ökologische Marktneuheiten zu entwickeln.

Auch die Stringenz der Regulierung fördert die breite Umsetzung von ÖP-Innovationen. Einen Einfluss auf die Einführung von Marktneuheiten konnte jedoch nur für Hersteller aus Deutschland nachgewiesen werden und nur mit geringer statistischer Signifikanz. Während das Potenzial für Kundennutzen stärker die Einführung von Marktneuheiten fördert, hat stringente Regulierung eine grössere Wirkung hinsichtlich dem Ausmass der Umsetzung von ÖP-Innovationen, welche bereits bekannt sind auf dem Markt.

Diese Untersuchung zeigt einige interessante Unterschiede zwischen Kalifornien und Deutschland bezüglich der tatsächlichen ÖP-Innovationsaktivität auf. Auch hier gibt es einen Unterschied bezüglich dem Ausmass und der Neuheit von ÖP-Innovationen. Einerseits implementieren mehr kalifornische Firmen ÖP-Innovationen als es die deutschen Firmen tun. Ausserdem werden die Innovationen in Kalifornien auf einen grösseren Teil der Produktpalette angewendet. Andererseits entwickeln und implementieren deutsche Firmen mehr ökologische Marktneuheiten im Vergleich zu den kalifornischen Herstellern.

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Chapter 1

Introduction

1 Motivation & Research Design

> *"Over the long haul, perhaps the most important single criterion on which to judge environmental policies is the extent to which they spur new technology toward the efficient conservation of environmental quality."*
>
> *Kneese and Schultze (1975:82)*

Since Kneese and Schulze made their statement more than 30 years ago, the question of what drives environmental innovation in industry and what role regulation plays in this regard has become ever more relevant. Although progress has been made for some environmental issues (e.g., the protection of the ozone layer), the overall consumption of natural resources and degradation of the environment in the developed countries continued to grow. Moreover, fast growing developing economies such as the BRIC countries (Brazil, Russia, India, and China) also rapidly increase both, their use of natural resources and their emission of pollutants (cf. OECD 2008).

Ten years ago, Porter and van der Linde (1995a, b) popularized the win-win proposition, stating that environmental regulation could induce innovation by making industry aware of and willing to exploit otherwise missed opportunities. This, they claimed, would result in environmental benefits *and* increased competitiveness. The Porter hypothesis has spurred a substantial amount of research on the influence of environmental regulation on innovation, but the results have so far remained inconclusive, especially with regard to environmental product innovations.

In this dissertation, I focus on environmental product innovations and examine when and why firms implement them. These innovations encompass all technical improvements which lessen environmental impacts caused by products during their life cycle, e.g., reduction of toxics and materials in products, improved power consumption and emission output in use phase, and recycling schemes for obsolete products. While environmental innovation in general and environmental process innovation in particular have been studied by researchers for a number of years, environmental product innovations have been analyzed in systematic empirical studies only in recent years. Through this dissertation, I advance the research on determinants of environmental product innovation with the following three contributions.

(1) A novel unit of analysis:

The research designs used in extant work analyze environmental innovation activities at the firm level. However, the firm as principal unit of analysis may be too general as determinants (e.g., regulation) might vary at the firm level across different environmental issues. For example, the regulatory environment a firm is facing regarding the energy consumption of its products might be very different compared to the one for the recycling of its products. Likewise, environmental innovations improve only one, at most a few, environmental attributes of products. Hence, an analysis purely at the firm level may not be able to directly trace back variation in the dependent variable to variation in one of the explanatory variables. Consequently, I use the environmental issue level as unit of analysis. That means I study firms' environmental innovation activities simultaneously for several environmental issues. This allows me to better analyze the causal mechanisms.

(2) A new explanatory factor:

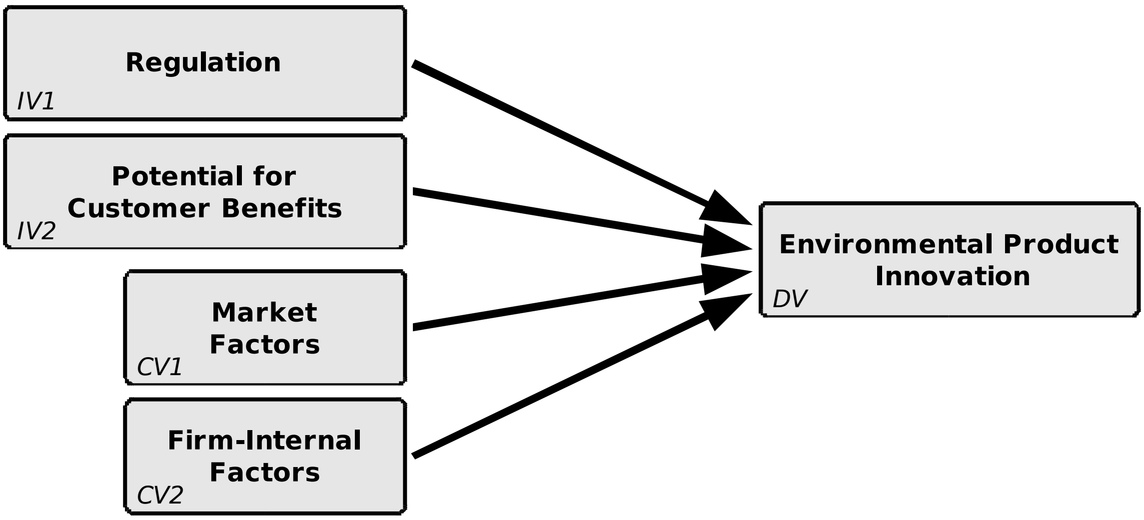
Besides the impact of regulation, I also examine the direct customer benefit which can accrue from these environmental innovations. In the green marketing literature, it is a common proposition that in order to be commercially successful, green products need to deliver a private benefit for customers in addition to the public benefit of improved environmental quality. The argument is that these anticipated customer benefits can constitute a firm's motivation to develop and implement those environmental product innovations in the first place. Consequently, firms are expected to focus their environmental innovation activities more towards product improvements and environmental issues that have a potential for customer benefit. While there are case studies that support this link between customer benefit and environmental product innovation, it has not been tested in systematic empirical analyses so far.

(3) More comprehensive operationalization:

In most studies, environmental innovation is measured using a binary yes/no scale or in terms of patents or R&D expenditure. However, R&D expenditure does not necessarily lead to innovation, many patents do not lead to innovations either, and some innovations are not patented. In addition to the binary measurement, I measure the extent of the firms' product range for which they implemented the innovations. Furthermore, I observe the degree of novelty, that is I distinguish between innovations that are novel to the market and innovations that are only novel to the firm. Thus, the impact of regulation and customer benefit can be analyzed for more dimensions of environmental product innovation.

In addition to the main explanatory variables environmental regulation and customer benefit, the analytical framework also includes market and firm-internal factors as control variables, as illustrated in figure 1.

Figure 1: Analytical Framework with independent variables (IV), control variables (CV), and the dependent variable (DV)



The empirical focus is on the electrical and electronic appliances (EEA) industry in California and Germany. This industry is globally one of the most dynamic industries with regard to innovation (Smith, 2005, p. 157) and growth rate (EEIG 2004). Electrical and electronic appliances affect the physical environment throughout their life cycle and have a growing ecological footprint due to their increasing spread to almost every sphere of modern life. The main environmental burden is caused by a) the high raw material input for the manufacturing of the appliances, b) the hazardous substances that are in the products and often generate toxic emissions as a large share of old appliances is disposed under poor environmental standards, and c) the energy consumption of the appliances (Puckett and Smith, 2002; Kuehr and Williams, 2003; Hilty, 2008). Hence, I use the following environmental issues for the study: energy efficiency, toxic substances, and material efficiency. Additionally, I use the issue of electromagnetic-fields and their potential health impact. Although currently no scientific basis exists for this health impact, the issue causes concerns and the World Health Organization recommends adopting the precautionary principle (WHO, 2000, 2005).

Recently enacted regulations in the European Union regarding toxic substances (EU, 2003a) and the recycling (EU, 2003b) of EEA predestine these countries for research on the effects of environmental regulation. By exceeding non-EU countries' regulations both in stringency and scope, these EU regulations offer the possibility to analyze regulatory effects in a cross-national study. California and Germany are a good choice for this study because both are home to a large population of electrical and electronic appliances manufacturers (Eurostat, 2004; US-Census-Bureau, 2004a, b, c). Thus, they allow for relatively large sample sizes and increase the practical relevance of the findings. Further, Germany and California are comparable with regard to the advancement of environmental policy in general, as both states are the regional leader for this policy field (for details see Vogel, 1995). Given that US states have wide-ranging authority in environmental regulation, we can treat California like a country in a federal political system, with Germany being the equivalent in the EU.

2 Structure and Main Findings

The first study, which I co-authored with Thomas Bernauer, Stéphanie Engels, and Jazmin Seijas, has been published in a special edition of the Politische Vierteljahresschrift (Bernauer et al., 2007) and reprinted in Ghose (2008). In this article, the existing literature on the determinants of environmental innovation is reviewed. Based on this review, an analytical framework for further research is developed and its application in empirical research is discussed. Specifically, it is argued that systematic empirical analyses of the effects of environmental regulation on environmental innovation have to be done alongside market and firm-internal conditions. The analytical framework in figure 1 is based on this proposition. Additionally, it is proposed that the application of the analytical framework at the “innovation field” level within firms can provide further insights into the effects of regulation and customer benefit on environmental innovation. I use this unit of analysis for my empirical studies in chapter 3 and chapter 4, however call it the “environmental issue level” as in the previous section.

This theoretical article has been written as part of a research project and led to two more empirical studies: Jazmin Seijas analyzed the determinants of environmental innovation in the German and Swiss chemical industry (2007), and Stéphanie Engels did the same for the food and beverages industry in these countries (2008).

The second and the third study report the results of the empirical analysis for the EEA sector. To collect the data for this analysis, I conducted two online-surveys, one for German firms from summer to winter 2006, and one for Californian firms from spring to autumn 2007. The questionnaires are provided in full length in the appendix. As (unfortunately) usual in surveys, not every firm completed all questions. Therefore, I could not include data from all questions in the analysis. For the logit analysis, I imputed missing data for the most interesting variables using the multiple imputation approach proposed by Allison (2001). Compared to listwise deletion that is normally applied in regression analyses, multiple imputation does not reduce the number of observations and does not lead to biased estimates.

The second study is accepted for publication in the Journal for Ecological Economics (Kammerer, 2009). In this study, the effects of customer benefit and regulation on environmental product innovation (EP-innovation) are analyzed using the data from German EEA manufacturers. Altogether, 355 observations are included in the logit analyses for the three measures of EP-innovation.

The statistical analyses clearly show that customer benefit plays a key role for EP-innovations. The potential for customer benefit not only stimulates firms to implement environmental product innovations and to apply them to a large share of their products, it also motivates firms to go beyond the diffusion of already-known improvements and to develop environmental product innovations that are novel to the market.

For environmental regulation the results are a little less clear-cut. 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.

In the third study, the data from Californian EEA manufacturers is analyzed and compared to the results from the German sample. Overall, the statistical analysis of the Californian sample corroborates the findings from the study on German EEA manufacturers. The main difference is that regulation showed a weakly significant effect on the novelty of EP-innovation in the German sample which could not be corroborated by the Californian sample.

With regard to the actual EP-innovation activity, this study revealed some interesting differences between California and Germany. Again, there is a distinction between the extent and the novelty of EP-innovation. On the one hand, Californian firms are more likely to implement EP-innovations than German firms are; and they also implement these innovations on a broader range. On the other hand, firms in Germany generally develop and implement more EP-innovations that are novel to the market.

3 Policy Recommendations

Based on the empirical studies in this dissertation, the following policy recommendations can be derived: first and foremost, regulators should use their power to implement stringent environmental regulations more bravely. The results clearly show that stringent environmental regulation does stimulate manufacturers to environmentally improve their products. This is especially true for the diffusion of improvements that already exist in the market place. And it is especially important for issues for which firms cannot derive a direct customer benefit from the improved environmental attribute. 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. Thus, a further fruitful area for regulators is the creation of a market conditions that transform the environmental quality of products into a direct benefit for customer. This could mean taxes on resources and emissions but also differentiated rights of use in dependence of products' environmental performance. The environmental zones in German cities are an example for the latter: more and more cities limit access to the city center for cars that have high pollution profiles.

Additionally, regulators should support firms in identifying and leveraging areas in which environmental improvements will generate direct customer benefits. To this end, the development of green capabilities in firms should be promoted through direct incentives but also through resources and knowledge transfer. Particularly small and medium firms lack the financial and human resources to develop these capabilities by themselves. Of course, the impact of all these measures will further grow if supported by awareness raising activities that inform customers on their potential benefits from products with higher environmental quality.

4 Limitations and Further Research

This dissertation has some limitations that are mostly related with the mode of data collection. In contrast to the previous two dissertations on environmental innovation, which were written at the Center for International Studies at ETH Zurich (Seijas 2007, Engels 2008), I decided to collect my data using an online-questionnaire instead of face-to-face interviews. The online-questionnaire has several advantages, with larger sample size and better geographical outreach being the most important ones. However, there are also some drawbacks associated with this method.

First of all, the response rate is typically lower in questionnaire-based studies (postal or online) than in studies that apply face-to-face interviews. While the response rate in the German study is considerably high with 32%, the Californian study has a low response rate with only 11%. This might be an indication of self selection however, no systematic non-response has been found. Moreover, the results do not differ considerably for Germany and California.

A second issue is the reliability of the answers given by the firm representatives. This is a challenge in every social survey, especially with online-questionnaires. Although a benchmark-report was offered to every respondent in order to minimize their incentive for strategically biased answers, there might be some biased answers in my data. Closely related is the issue that much data was provided on the basis of respondents' perception. Again, there is the possibility that managers who consider environmental regulation to be a burden in general overestimate the stringency of some regulations. And other managers that consider their firm to be ahead of the current regulation might underestimate the actual burden of some regulation for their firm. This is definitively an issue that further research could improve upon by taking third party data into consideration as well, e.g. with expert panels.

A further issue is the concept of customer benefit. The results show that 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 studies, for example with case studies.

Last but not least, my dissertation has a regional as well as sectoral focus. The results are based on the electrical and electronic appliances industry in California and Germany. To elaborate whether the findings can be generalized to other industries and economies, further empirical studies will have to be conducted.

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Chapter 2

Explaining Green Innovation

Ten Years after Porter's Win-Win Proposition: How to Study the Effects of Regulation on Corporate Environmental Innovation?

co-authored with Thomas Bernauer, Stéphanie Engels, and Jazmin Seijas

published in K. Jacob, F. Biermann, P.-O. Busch, P.H. Feindt (editors),
PVS Sonderheft 39 - Politik und Umwelt (2007).
VS Verlag für Sozialwissenschaften, Wiesbaden, Germany, pp. 323-341.

ABSTRACT

While consumption and degradation of natural resources and the environment continue to grow worldwide, worries about declining competitiveness of European industry vis-à-vis US and Asian competitors persist. Against this background, the question of *what drives environmental innovation in industry and what role regulation plays in this regard* has become ever more relevant. Ten years ago, Porter and van der Linde popularized the win-win proposition, stating that environmental regulation could induce innovation by making industry aware of and willing to exploit otherwise missed opportunities. This, they claimed, would result in environmental benefits *and* increased competitiveness. The Porter hypothesis has spurred a substantial amount of research on the influence of environmental regulation on innovation, but the results have so far remained inconclusive. We discuss the key problems in extant research and outline a comprehensive analytical framework for studying the effects of environmental regulation on innovation alongside firm-internal conditions and external market forces. This framework also takes into account varying opportunities for direct customer benefits across areas of environmental innovation. Very few political scientists have, thus far, ventured into this research area. Those who have, have focused on the sectoral, national or systemic (international) level. To complement this research we propose to improve the micro-foundations of our understanding of environmental innovation by applying the framework outlined in this paper at the firm and innovation field level within and across firms, industries, and countries.

1 Introduction

"Financial performance and environmental performance can go hand in hand. Eco-efficiency is the key to sustainability, in both economic and ecological terms. The key to eco-efficiency is innovation and productivity improvement."

Alex Krauer, Chairman and CEO, Ciba-Geigy, Switzerland, cited in Milmo (1995, p. 22)

Krauer's statement is one of countless examples of the "Porter spirit", which has emerged in the last 10-15 years in advanced industrialized countries. It reflects the belief that so called win-win opportunities could benefit industry and the environment alike. The best known heralds of such win-win opportunities are Porter and van der Linde who argued that "…properly designed environmental standards can trigger innovation that may partially or more than offset the costs of complying with them" (Porter and van der Linde, 1995a, p. 98). Environmental regulation could, they claimed, induce innovation by making industry aware of and willing to exploit otherwise missed opportunities.

The "Porter hypothesis" has spurred substantial amounts of research on the influence of environmental regulation on innovation. While adherents of the Porter hypothesis have sought to demonstrate the empirical relevance of the win-win claim, neoclassical economists have argued that such win-win opportunities are exceptions. They have pointed to significant compliance costs of industry, competitive disadvantages of domestic firms in international markets, and opportunity costs of forced environmental activities (e.g., Jaffe et al., 1995, Palmer et al., 1995). Recent research has sought to bridge the boundaries between "traditional" economists and "revisionists" by combining assumptions from neoclassical and evolutionary economics, and by testing propositions in large-N quantitative studies (e.g., Johnstone et al., 2007)[1]. But so far, the results have remained inconclusive.

The question of *what drives environmental innovation in industry and what role environmental regulation can or should play in this regard* has become ever more policy-relevant in recent years. On the one hand, worldwide consumption and degradation of natural resources and the environment has continued to grow and environmental innovations are considered an important option for mitigation or avoidance of environmental degradation. On the other hand, worries about declining competitiveness of European industry vis-à-vis American and Asian competitors persist and policy makers

1 This publication reports preliminary results from an OECD study that covers more than 4000 facilities in seven OECD countries.

are seeking to reduce the regulatory burden on industry. We address this debate by developing *an empirically useful analytical framework* for studying the drivers (regulatory and other) of environmental innovation.

We argue that identifying key determinants of “green” innovation requires analysis of the effects of environmental regulation alongside market and firm-internal conditions. Presently, research on innovation, including “green” innovation, is scattered across different academic disciplines; each piece of research tends to focus on a narrow range of determinants and particular levels of analysis. Industrial organization specialists concentrate on market structure, while strategic management specialists focus primarily on firm-internal variables. Those studying the impact of environmental regulation on green innovation (most often economists, but also some political scientists) tend to sideline non-regulatory influences. We use previous work by authors such as Hemmelskamp (1999), Kemp (1997), and Klemmer et al. (1999) as a starting point. Our contribution focuses on identifying gaps, deficiencies, and unresolved issues in extant studies and developing a framework for further research.

We locate the principal weaknesses in existing research primarily in problematic definitions / operationalizations of the dependent variable (i.e., innovation), level of analysis problems (i.e., sector / industry, firm, facility, regulated activity), and poorly understood causal effects of explanatory variables on each other and on innovation. We argue that changing the focus from the sector / industry level to the firm and innovation field level – the levels at which environmental innovations in fact take place - can improve our understanding of causal mechanisms. Those few political scientists who have thus far worked on issues of environmental innovation have concentrated on cross-sector and cross-country comparisons(e.g., Jaenicke Martin et al., 2000, Jacobs et al., 2005). This research has offered very useful insights into macro-level trends in this field but needs to be combined with stronger insights into the underlying micro-level processes, notably, innovation-related decisions and behavior at the firm level. To this end, our paper builds primarily on the economic and business studies literature.

The paper is organized as follows. After clarifying some definitional issues, we review the existing literature and develop an analytical framework for further research. We end by discussing how this framework could be applied in empirical research.

2 Literature Review and Analytical Framework

We begin by clarifying some definitional issues before reviewing the existing literature. *Regulation* can be defined broadly "to include the full range of legal instruments by which governing institutions, at all levels of government, impose obligations or constraints on private sector behavior. Constitutions, parliamentary laws, subordinate legislation, decrees, orders, norms, licenses, plans, codes and even some forms of administrative guidance can all be considered as regulation" (OECD, 1997a, p. 9). Environmental regulation includes environment-related regulation that considers and impacts the environment (Kemp R., 1998, p. 14).

Environmental innovations encompass all innovations that have a beneficial effect on the environment regardless of whether this effect was the main objective of the innovation[2]. They include process, product, and organizational innovations (OECD, 1997b). We will focus primarily on explanations of product and process innovations.

- *Organizational innovations* do not reduce environmental impacts directly, but facilitate the implementation of technical (process and product) environmental innovations in companies (Murphy and Gouldson, 2000).
- *Process innovations* are defined as improvements in the production process resulting in reduced environmental impacts, e.g., closed loops for solvents, material recycling, or filters.
- The principal environmental impact of many products stems from their use (e.g., fuel consumption and CO_2 emissions of cars) and disposal (e.g., heavy metals in batteries) rather than their production. Accordingly, *product innovations* aim at reducing environmental impacts during a product's entire life cycle (from cradle to grave).

Environmental innovations are different from other innovations; besides producing the spillover effect typical of most R&D efforts they also produce positive externalities in and of themselves, i.e., they reduce external environmental costs of production or products. Rennings (2000, p. 325) has called this characteristic a "double externality effect".

The literature on the determinants of innovation is vast. Yet, most of this literature focuses on particular determinants of innovation, and only small parts of this literature focus on environmental innovation. Contemporary research on the relationship

2 The terms *eco-innovation* and *green innovation* are used synonymously for *environmental innovation*.

between environmental innovation and regulation is based on the assumption that technology push and market pull factors, firm internal conditions, and regulatory conditions drive the extent and form of environmental innovations. Kemp et al. (2000), for example, propose to focus on the incentives to innovate, meaning competitive pressure and market demand, the ability of firms to process and integrate knowledge, and the managerial capability to handle the innovation process within and across companies. This approach combines perspectives from evolutionary economics and environmental economics, as explained in Rennings (2000). It is used in recent "multi-dimensional" studies that take into account regulatory, market, and firm-internal conditions.

The following literature review, from which we derive a set of hypotheses, is structured along the following lines: (1) research concentrating on the impact of regulation on green innovation, (2) studies on market factors and how they influence green innovation, and (3) research focusing on impacts of firm-internal factors on green innovation.

2.1 Regulation

Environmental regulation is viewed in neoclassical economics as a means to force firms to internalize external costs they would otherwise impose on society. Environmental regulation is (or rather should be), therefore, implemented in cases of market failure. Though, in principle, its necessity under conditions of market failure is uncontested in environmental economics (Rennings, 2000), the policies to be chosen (instrument type) in particular cases and the stringency of regulation are very much subject to debate.

Traditionally, the neoclassical economic view has been that (strict) regulation has negative effects on productivity and competitiveness, as it leads to higher expenses by businesses and imposes constraints on industry behavior. Regulation can also increase uncertainty associated with future investments, so that they are postponed. Given that investment budgets are limited, enforced R&D for cleaner technology can have the effect of reduced R&D expenditure in other, more profitable areas, such as a firm's core business (Gray and Shadbegian, 1995).

In the 1990s, Porter and van der Linde popularized the claim that properly structured environmental regulation may not only benefit the environment – and hence society as a whole – but also the regulated industries by making firms realize otherwise neglected investment opportunities (1995b, a)[3]. Specifically, Porter and van der Linde argued that (strict) environmental regulation and associated compliance costs could

3 Ashford et al. (1985) and Ashford and Heaton (1983) had made this point already in the early- to mid-1980s.

force industry to innovate and thus increase resource efficiency and enhance productivity. They suggested that environmental regulation could also increase turnovers and profits by creating markets for environmentally improved products and technologies, and that compliance costs may be offset by the gains from these innovations, so-called innovation offsets.

Neoclassical economists have heavily criticized the “win-win” hypothesis. They have argued that regulation might motivate firms to develop eco-innovations, but that these efforts would produce opportunity costs offset only in exceptional cases (see e.g., Jaffe et al., 1995; Palmer et al., 1995). Some authors have refined Porter’s argument and have offered more nuanced theoretical explanations for the existence of previously overlooked win-win opportunities that could be stimulated by regulation (see e.g., Roediger-Schluga, 2004). Applying principal-agent theory, bounded rationality, and spillover effects, Gabel and Sinclair-Desgagné (1998), Bonato and Schmutzler (2000), Schmutzler (2001) and Mohr (2002) derive possible but rare conditions under which regulation can induce innovations that fully offset compliance costs.

This theoretical controversy has motivated empirical research on a considerable scale on the relationship between regulation and green innovation. So far, the empirical results have remained inconclusive. While qualitative case studies (e.g., Bonifant et al., 1995, Porter and van der Linde, 1995b, a, Shrivastava, 1995) are based on rather anecdotal evidence, more systematic econometric studies have failed to produce unequivocal results (e.g., Jaffe et al., 1995). Quantitative studies in particular often use (overly) simple indicators, e.g. measuring innovation by the number of patents and R&D investment (including also non-environmental R&D). Jaffe and Palmer (1997) for instance obtain different results for the aforementioned two innovation indicators. Brunnermeier and Cohen (2003) find that increases in pollution abatement expenditure influence green innovation (measured by the number of successful environmental patent applications granted to industry), but only marginally. Using a theoretical model, Bonato and Schmutzler (2000) derive strategic (spillover effects) and organizational (principal agent problem) factors explaining why environmental regulation could stimulate cost-reducing innovations that would not have been undertaken without regulation.

Another important area of research focuses on the influence of instrument choice, notably market-based incentives versus command-and-control instruments, on technological innovation[4]. Since market-based incentives provide more flexibility for economic actors, they are generally viewed as more efficient than command-and-control instru-

4 See Jaffe et al.(1995, 1997, 2002, 2004). See Jaffe et al. (2002, 2004) for a detailed review of studies on the effects of instrument choice on technological innovation.

ments. However, it remains unclear how and to what extent instrument choice actually affects innovation (Jaffe et al., 2004). In his comparison of instruments, Kemp (1997, p. 317) finds that "there is no single best policy instrument to stimulate clean technology, all instruments have a role to play, depending on the context in which they are to be used". Based on case studies, Klemmer et al. (1999) reach the same conclusion. A recent study by Frondel et al. (2007) shows that policy stringency is more important than policy instrument choice.[5]

Jaenicke et al. (2000) observe that a combination of different policy instruments works better and propose to take into account policy style, arguing that "[a] policy style is innovation friendly if it is based on dialogue and consensus, is calculable, reliable and has continuity, is decisive, proactive and ambitious, is open and flexible…" (Jaenicke et al., 2000, p. 135). How these variables could be made operational for purposes of large-N research remains open (Jacob et al., 2005).

Recent research has moved the unit of analysis from the industry level to the individual firm and facility level. It also distinguishes between process and product innovations. These studies survey firms' environmental behavior and the role played by several determinants of green innovation. They have produced plausible evidence for some firm-internal determinants of green innovation. However, effects of regulation have been observed only for environmental *process* innovation (Cleff and Rennings, 1999, Johnstone et al., 2007), but remain unclear for environmental *product* innovation. For example: a study by Hemmelskamp (1999) suggests a negative influence of regulation on environmental product innovation, whereas Rehfeld et al. (2007) as well as Johnstone et al. (2007) find positive effects and Cleff and Rennings (1999) find a positive effect solely for market-based regulation.

In other words, responding to the question of whether (strict) environmental regulation fosters or impedes environmental innovation appears to require a differentiation between process and product innovation. Most studies have failed to do so.

We submit that further research should pay particular attention to two aspects of (environmental) regulation that may have an influence on environmental innovation: *stringency* and (reliable) *predictability*. Regulation, measured in those terms, may have two types of effects on environmental innovation. On the one hand, it can push environmental innovations that have no sufficient market pull or technology push effects or were simply overlooked by a firm. By setting standards, regulations can force compan-

5 For a discussion of why it is so difficult to determine the influence of single policy instruments see Jaenicke (1997).

ies to adapt products or production processes. On the other hand, regulation can promote environmental (product) innovations by establishing market incentives that promise an increase in turnovers and profits (market pull effects).

The *stringency* of regulation can be measured in terms of how much change in a given firm regulation induces. Whether stringency has a weak or strong effect on innovation at the firm level depends in part on how well the firm can adapt to external pressure. The ability to adapt may vary with firm size and market structure, how research driven the firm is, etc. For example, firms may choose to abstain from research on and development of environmentally friendly products if costs are very high and potential markets do not look promising.

➔ H1: We hypothesize that the *stringency* of regulation influences environmental innovation. The direction and extent of this influence depends on market and firm-internal factors. Regulation is more likely to have a positive impact on process innovations than on product innovations.

Innovation processes usually involve substantial risks and uncertainties; the strategies concerned require a long planning horizon. Therefore, *predictability* – the degree to which future regulation and its properties can be foreseen – has a positive influence on innovation because it reduces risks and uncertainty. Predictability not only means that new regulations are announced early. Early signals of future regulation will only induce prospective action if regulators are considered to be reliable; reliability goes hand in hand with credibility (Jaenicke, 1997). This means that in assessing predictability we have to take into account at least the two dimensions: “early announcements” by a “reliable” actor.

➔ H2: We hypothesize that predictability of regulation supports environmental innovation.

2.2 Market Factors

Research in innovation economics has long centered on whether technological development (technology push) or demand factors (market pull) are more important drivers of technological innovation. Empirical research has shown both to be relevant (Pavitt, 1984). Technology push seems to be more important at the beginning of the product cycle, market opportunities seem to be more important at later stages (Mowery and Rosenberg, 1979, Freeman, 1994, Jaenicke et al., 2000). A peculiarity of environmental innovation, however, may be that market pull and technology push are comparatively weak, calling for a “regulatory push/pull effect” (Rennings, 2000:326).

Market pull includes aspects such as competitiveness (mostly considered by the industrial organization literature) and customer demand (be it the end consumer or corporate customers; mainly studied by strategic management research). Technology push includes aspects such as energy or materials efficiency and product quality.

The industrial organization literature focuses on market structure as a key determinant of innovation. Many of these studies are, in one way or another, derived from Schumpeter’s hypothesis (1942), postulating a positive influence of market concentration and firm size on innovation. Schumpeter argued that market concentration reduces market uncertainty and motivates firms to invest in R&D. Other authors argue the opposite, claiming that concentration leads to inertia and hinders innovation due to missing competitive pressure (Levin et al., 1985). Schumpeter (1939) states, furthermore, that the possibility of large firms to act in a monopolistic way increases their willingness to take risks.

Many authors have tested Schumpeter’s hypothesis, predominantly in regard to forms of innovation other than environmental. According to Acs and Audretsch (1987), large firms are more innovative in concentrated, capital-intensive markets; smaller firms have an advantage in markets that are more competitive. Their smaller size enables them to react faster to change, because of less bureaucracy, higher commitment of management, more exposure to competition, higher R&D efficiency, and niche strategies (Geschka, 1990, Rothwell and Dodgson, 1994). Levin et al. (1985) emphasize the importance of appropriate technological opportunities and reject the influence of market concentration on innovation. Baylis et al. (1998) and Clayton et al. (1999) argue that environmental activities go along with a higher amount of financial and human resources, which is why larger firms have better opportunities and abilities to reduce environmental impacts. Several empirical studies show that, by and large, firm size has a positive influence on environmental innovation (e.g., Cleff and Rennings, 1999; Rehfeld et al., 2007).

The strategic management and green marketing literature focuses on various market factors, but pays particular attention to market demand for green products (Meffert and Kirchgeorg, 1998, Belz, 2001). In this literature, environmental product innovations are seen as a differentiation tool for firms that helps maintain/increase market share. In the 1980s and early 1990s, green consumerism, i.e., consumers' consideration of environmental aspects in purchasing situations and their willingness to pay premiums for green products, was widely believed to emerge and gain momentum (Peattie, 2001). For example, Straughan and Roberts (1999) identify high income, high education level, liberal political orientation and, most importantly, perceived consumer effectiveness (PCE)[6] as positive determinants of environmental attitudes and behavior (see also Roberts, 1996, Roberts and Bacon, 1997). Yet, other studies show that consumers' claims to prioritize green attributes have mostly not matched their actual purchasing behavior (Wong et al., 1996, Kuckartz, 1998, Prakash, 2002).

Meffert and Kirchgeorg (1998) emphasize that (public) environmental benefits need to be combined with private consumer benefits for products to be successful in the market. Examples of such customer benefits include cost savings through energy efficient appliances, improved product quality and durability, beneficial health effects, and prestige enhancement (ibid). Products that have no customer benefits additional to their environmental benefits are not likely to be favored by the mass-market (Villiger et al., 2000). Provision of understandable and credible information on products' environmental attributes is noted as a further success factor for green products (Wong et al., 1996, Meffert and Kirchgeorg, 1998, Reinhardt, 1998). Such efforts can be facilitated by eco-labelling schemes (Hemmelskamp and Brockmann, 1997, Prakash, 2002).

Only few studies have looked at differences between demand for environmental product and process innovations, and between corporate customers and end consumers, in respect to purchasing behavior and, therefore, influence on strategic decisions. Cleff and Rennings (1999) find that, empirically, market considerations are more important for product, and environmental regulation more important for process innovations. While a firm’s visibility from a public perspective decreases with its distance from the end consumer, supply chain pressure – large firms demanding environmentally friendly behavior from their suppliers – can be an important driver (Gunningham et al., 1999). But the importance of such supply chain pressure has not been systematically analyzed and rests on anecdotal evidence, for instance from the automobile industry.

In summary, the industrial organization literature provides ambiguous evidence on the influence of market concentration on environmental innovation. The green marketing literature predicts market success primarily for environmentally improved *products* that have bundled customer benefits and / or provide credible information on their environmental quality. However, empirical studies focusing on these determinants of innovation are sparse. We submit that further research should focus particularly on *com-*

6 Consumers’ attitudes and responses to environmental issues are a function of their beliefs that they can positively influence the outcome of environmental problems. See Straughan and Roberts (1999).

petitiveness and *customer demand* as potential determinants of environmental innovation.

In *competitive markets* firms' principal differentiation tools are price and quality– innovations are important either to enhance efficiency (reduce costs) or to improve a product's quality. Radical innovations often imply high R&D efforts, long development time, and high risks. Large firms in concentrated markets are more likely to have the capacity for such efforts.

➔ H3: We hypothesize that the more competitive a market is the more environmental innovations will occur, particularly in large firms.

Customer demand can be a strong driver of firm behavior. The most promising environmental innovations, from the perspective of firms, are those that offer a *triple* benefit: for the environment, the customer, and the producer alike. Such innovations are more likely to be *product* innovations, because in this case the *potential benefits for the customer* are clearer and easier to market.[7] Products of this kind should offer *direct* customer benefits in addition to diffuse environmental improvement. Such direct benefits include for instance better quality, longevity, better repair, upgrade, and disposal possibilities, as well as reduced consumption costs (e.g., energy efficiency) or health impacts (depending on the industry analyzed).

Not every environmental improvement in a product holds the same potential for direct customer benefits. For instance, higher energy efficiency of products yields a clearer customer benefit than a reduction of materials – notably, if combined with higher energy prices (due to market developments or energy taxes). Also, immediate economic benefits such as higher product longevity or energy efficiency can be more attractive to customers than more hidden, long-term benefits such as a reduction in toxic substances. We denote the aspects of products that can be improved as *innovations fields*.

➔ H4: We hypothesize that firms are more likely to engage in environmental innovation the higher and more obvious the *potential customer benefits* in an environmental innovation field are.

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7 There are, of course, also non-monetary, say ideational or ideological benefits for certain customers from buying a "green" product without material benefits. But such products tend to occupy very small niche markets.

2.3 Firm-Internal Factors

The strategic management literature provides insights into firm-internal conditions and firm strategies. Theoretically, the consideration of firm-internal factors is often based on evolutionary theory and most notably the resource-based view of the firm (Nelson and Winter, 1982, Wernerfelt, 1984, Barney, 1991). The resource-based view of the firm holds that firm-internal characteristics, such as strategy, structure, and core capabilities, are important determinants of innovation (Fagerberg et al., 2005) and important to competitive advantage. Resources are classified into tangible (e.g., financial reserves), intangible (e.g., reputation), and personnel-based (e.g., culture, training) resources. The consideration and benefits of intangible properties are particularly emphasized. Organizational capabilities to "assemble, integrate, and manage" these bundles of capabilities / resources play an important role (Russo and Fouts, 1997, p. 537). Collis and Montgomery note, "[r]esources cannot be evaluated in isolation, because their value is determined in the interplay with market forces" (Collis and Montgomery, 1995, p: 120).

Building on the resource-based view, Hart (1995) links competitive advantage to a firm's relationship with the natural environment. The strategic implications focus on pollution prevention, product stewardship, and sustainable development. Pollution prevention can provide win-win opportunities through process innovations (resource-efficiency). Product stewardship can foster competitive advantage through product differentiation and prevention of potential regulation[8]. Russo and Fouts (1997) elaborate on this concept and postulate a positive link between firms' environmental and economic performance based on reputation benefits from environmental performance. Sharma and Vredenburg (1998) find empirical evidence that companies develop green organizational capabilities after having adopted a proactive environmental strategy.

As regards innovation, an important asset is the general commitment to innovation. Besides showing a high commitment, R&D units are considered tools for solving organizational problems. R&D expenditure is a common proxy for and closely related to a firm's innovation activity (Sanchez, 1997). Rehfeld et al. (2007) find that R&D activities tend to have a positive influence on environmental product innovation. But they find no effect for process innovation.

Building on the Porter hypothesis, a considerable body of literature classifies and analyzes corporate environmental strategies and their potential for gaining competitive

8 There are some indications that the *low hanging fruits* of direct cost savings through environmental innovations have mostly been found and realized already. See Hoffman (2000).

advantage.[9] Most typologies differentiate between two dimensions (Meffert and Kirchgeorg, 1998): first, the timing of corporate activities in relation to regulations or public concerns; such timing is often viewed in terms of proactiveness or reactiveness. Second, the scope of corporate environmental activities – usually defined as firm-internal (processes) or market-oriented (products) or both. Cleff and Rennings (1999) find significant effects on environmental *product* innovation only for the strategic goal of maintaining or increasing market share. In contrast, Rehfeld et al. (2007) find significant effects for the goal of complying with existing / anticipated legal requirements. As regards environmental *process* innovation, Cleff and Rennings (1999), but not Rehfeld et al. (2007), observe that legal compliance as an innovation goal has a significant effect on environmental innovation.

Some authors concentrate on organizational capabilities, particularly environmental management systems (EMS), and their influence on green innovation. The assumption is that (certified) EMS such as ISO 14'001 or its European version EMAS facilitate the introduction of environmental innovations directly by mandating companies to establish 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 (Melnyk et al., 2003). Thereby the "capacity to innovate" is enhanced (Bradford et al., 2000, p. 10). Empirically, a positive impact of EMS on green innovation activity is observed in a recent OECD study (Johnstone et al., 2007). Melnyk et al. (2003) examine the impacts of certified / non-certified EMS. They find that certified EMS are associated with stronger overall environmental performance of a firm. Dyllick and Hamschmidt (2000) observe that the influence of ISO 14'001 appears to be gradually shifting from process to product innovation. When voluntary self-regulations are employed as surrogate environmental regulations, a major concern is of course that they might be employed as fig leafs because there are no impartial control mechanisms. In a quantitative analysis of data from the US EPA's Toxic Release Inventory (TRI), King and Lenox (2000) find that particularly the larger, dirtier, and more visible firms participated in the voluntary Responsible Care program of the chemical industry. But as the authors note, it could also be that participating firms report their emissions more reliably, and therefore just appear to be dirtier.

In summary, several studies have examined the influence of firm internal factors on environmental innovation. EMS certification appears to have a positive effect on environmental innovation, but for environmental strategy / innovation goals, the results are in-

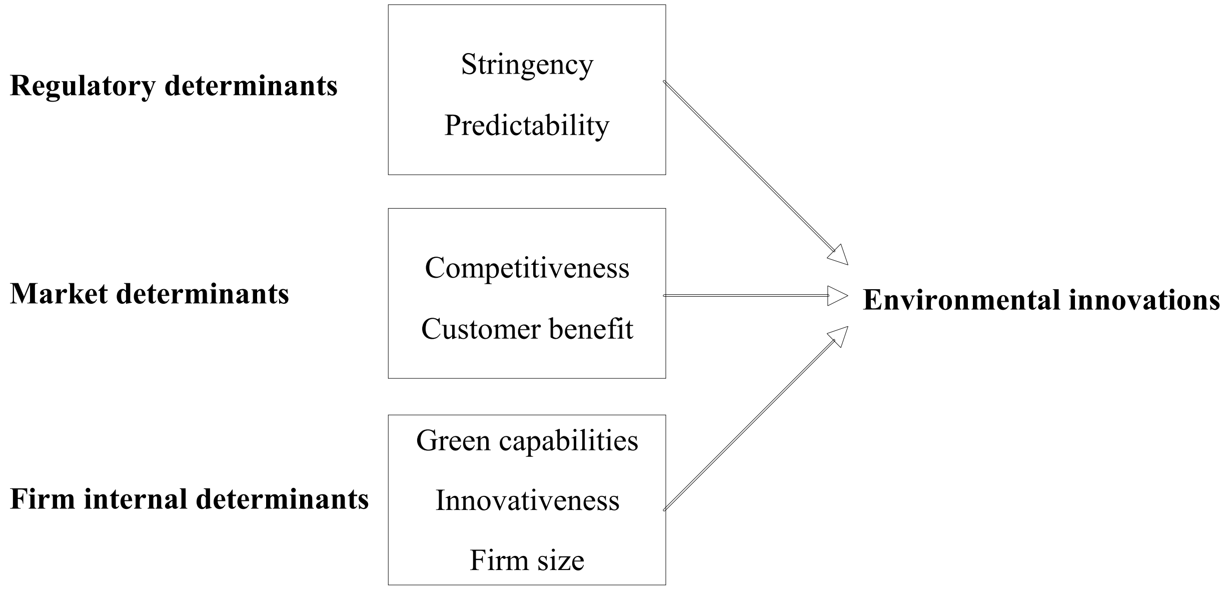
9 Examples include Rugman and Verbeke (1998) and Hoffman (2000).

conclusive. Further research should focus particularly on the effects of *green capabilities, R&D intensity*, and *firm size*.

Green capabilities comprise a firm's attitude towards and knowledge of environmental issues relevant to its business, and procedures for acting and reacting on these issues. These capabilities as well as related structures and activities facilitate the identification of potential environmental innovations. Moreover, when forced by regulation, the acquired knowledge and procedures facilitate the development and implementation of environmental innovations to meet those requirements. *Green corporate strategies* affect whether the search for environmental opportunities is part of the main scope and a leverage instrument for competitive advantage. The implementation and advancement of an *environmental management system* generates knowledge on the firm's environmental impacts as well as procedures to mitigate them.

➔ H5: We hypothesize that with growing maturity of a firm’s green capabilities more environmental innovations will take place.

Figure 1: Framework for studying the determinants of environmental innovations



General *innovativeness* increases the probability that firms will also be environmentally innovative. As shown in previous studies, the R&D activity of a firm may indicate its commitment to and experience with environmental innovation. Although R&D does not automatically lead to innovations, R&D is still the most widely used strategy aiming at innovation - its importance for a firm mirrors the importance of innovation in a firm's competitive setting.

➔ H6: Firms with a stronger commitment to innovation in general (R&D intensity) are more likely to engage in environmental innovation.

Larger firms tend to have more resources for R&D and environmental activities. They are also able to exploit economies of scale more easily and thus to acquire innovation benefits.

➔ H7: We expect firm size to have a positive influence on green innovation.

3 Empirical Application

Recent research focusing on the three types of determinants (regulation, market and firm-internal conditions) *simultaneously* has advanced our understanding of when and how these factors influence innovation activity and how they might interact. Yet, many if not most of the empirical results on the impacts of individual factors – most notably regulation – as well as on their interacting effects have remained inconclusive or controversial. This section discusses how the analytical framework sketched above could be applied in empirical research.

3.1 Dependent Variable

Most empirical studies on environmental innovation use questionable indicators for the dependent variable. Environmental innovation is usually measured in a binary fashion (yes/no), often at the facility level, or in terms of patents or R&D expenditure. R&D expenditure does not necessarily lead to innovation, many patents do not lead to innovations, and some innovations are not patented. Also, many industry sectors cannot and/or do not patent their innovations at all.

We submit that environmental innovation should be measured in more comprehensive ways. We suggest defining the outcome to be explained in terms of the *extent* and *type* of environmental innovation as well as *environmental performance improvement* for individual innovations.

Extent of innovation: The number of environmental innovations within each field of innovation provides a much better understanding of firms' innovation activities than the simple yes/no measurement of innovation.

Type of innovation (product or process innovation): As discussed above, this distinction is necessary to disentangle the effects of potential determinants.

Environmental performance improvement: It is important to measure the environmental relevance of innovations because the ultimate question is in fact to what extent green innovations really benefit the natural environment.

3.2 Explanatory Variables

Most empirical studies to date have not systematically considered how explanatory variables may impact differently on different types of environmental innovations (notably, product and process innovations) and how they interact. Most importantly, we submit that the relevance of regulation as a trigger of environmental innovation is likely to depend on how important market demand is. It will be crucial to understand under what conditions governments establish regulation to compensate for weak market pull, and with what effect on environmental innovation and environmental performance.

Analyses of market pull factors mostly focus on market structure and fail to consider differences between innovation types and *direct customer* benefits of environmental innovations (in addition to environmental improvements). As noted above, product innovations in particular can deliver additional customer benefits (e.g., reduced maintenance costs). These benefits can constitute the firm's motivation to implement those innovations in the first place. Producer benefits, in particular cost savings through process innovations, have been considered in some studies. But these benefits / cost savings have been observed only at the firm level, even though, depending on the environmental innovation field, different kinds of process innovations may have different potentials for cost savings (e.g., increased process efficiency versus reduction of toxic emissions).

3.3 Level of Analysis

In designing empirical studies for the hypotheses outlined above, we need to ascertain sufficient variation on key explanatory variables and the dependent variable (environmental innovation). In principle, such tests are possible at various levels of analysis.

Sector / industry level. At this level of analysis, the effects of changes in regulation on sector-wide environmental innovation activity can be studied over time (i.e., with panel-data). Regulation is usually designed for and applied to entire industries. It is not tailor-made for individual firms. Yet, generating comparable macro-level environmental and innovation data on industries or sectors without surveying individual firms is difficult. One option is to measure *environmental innovation* in terms of the relative improvement in environmental outcomes (e.g., emissions, concentrations of pollutants, energy and water and raw materials consumption, extent of recycling, number of organic products, EMS certification, etc.) along with economic developments of the sector and its regulation over time. Unfortunately, reliable environmental and innovation data is usually not available for many sectors and certainly not for long periods of time. Moreover, drawing inferences in respect to firm-level decision-making and behavior from sectoral or industry-level data is vulnerable to ecological fallacies.

Firm level. Collecting data on decision-making and behavior at the firm level – the level where environmental innovation in fact occurs – allows for more direct testing of the hypotheses outlined above. It also allows for the study of such phenomena at the level of individual environmental innovations within firms. Sufficient variation on regulatory variables, arguably the most problematic aspect in focusing on the firm level, can be obtained by running comparisons of firms across industries, sectors, countries, or time. Longitudinal studies are very difficult, however, because environmental and innovation data is usually available only for a few (recent) years. Comparisons across industries, sectors, or countries require control of a plethora of other explanatory variables – controlling systematically for such influences requires sample sizes that usually exceed the resources of academic researchers. However, sufficient variation in regulatory variables can be obtained even when comparing firms within a single sector and country: the solution here is not to focus on sectoral regulation per se (which tends to vary only over time), but to concentrate on individual firms' (perceived, or actually experienced) exposure to regulation (e.g., measured in terms of compliance costs).

Innovation fields. Yet another option is to focus on certain innovation fields, i.e. the various aspects of a product or process that can be improved. Regulations are usually targeted at such particular aspects or environmental media (e.g., water or air pollution). Examples include energy use, concentration of pollutants, and prohibition or limitation of certain toxic substances in products. Data for such research will have to be generated at the firm level. Additionally, this approach provides variation on the regulatory variable even within firms, that is, the influence of different regulatory conditions can be compared with constant values for the other explanatory variables. Cross-sector and cross-country comparisons are also possible within individual innovation fields.

Only very few political scientists have thus far ventured into research on environmental innovation. They have focused on cross-sector and cross-country comparisons (e.g., Jaenicke et al., 2000; Jacob et al., 2005). Recent quantitative studies by management experts and economists have surveyed innovations at the facility level (cf. Johnstone et al., 2007), whereas the development of product innovations usually happens at the firm level. Furthermore, the simple empirical definitions of environmental innovation at the facility level cannot provide direct insights into the causal linkages between regulation and innovation – notably, the design of these studies can usually not exclude the possibility that green innovation (if reported as yes/no) is in another field than those targeted by existing environmental regulation. That is, firms may report environmental innovations and state that they experience strict regulation, but the two phenomena may be causally unrelated.

We propose to account for variation in the relevance of particular determinants not only at the firm level, but also at a *deeper level within the firm*. Regulatory frameworks and non-environmental benefits vary at the level of environmental innovation fields within firms (e.g., energy-efficient products, resource-efficient production processes). Strengthening the micro-foundations of our understanding of environmental innovation by applying the analytical framework sketched above to the firm and innovation field level within and across firms, industries, and countries is important for complementing research on environmental innovation at the sector / industry and country level.

3.4 Sample Size

The research framework outlined in this paper can easily be applied in large-N, medium-N, and small-N (qualitative case study) research at the firm- and innovation field-level. In view of the advantages and shortcomings of each of the three approaches discussed below, we submit that a combination of all three approaches will be most fruitful.

The main advantage of large-N surveys, based on questionnaires administered via mail or telephone – with pure or stratified random samples of several hundred to several thousand firms – lies in the ability to use sophisticated statistical procedures for drawing broadly generalizable inferences. The main disadvantage, as evident from surveys in this field carried out to date, stems from response rates that are usually lower than 30% (sometimes no more than 10%). Since it is virtually impossible to control for selection bias with such low response rates, the results are quite vulnerable because the coefficients may be strongly biased. Moreover, large-N surveys are usually based on closed-end questions that do not generate very detailed data on the characteristics of environmental innovations, how they emerged in firms, and what their drivers were.

That is, they usually do not allow for more than (albeit rigorous) testing of rather simple and static hypotheses.

Medium-N surveys – usually with sample sizes of less than one hundred firms – can obtain much higher response rates. Moreover, they are usually carried out person-to-person. This allows for open questions and collection of much more detailed data, particularly on the dynamics of environmental innovation and their drivers. The downside is the smaller number of observations and, therefore, the need to rely on simpler statistical tools (usually descriptive statistics, contingency tables, simple OLS, logit or probit regression with few explanatory variables). Surprisingly in view of its potential for contributing important insights into environmental innovation processes, research based on medium-N surveys is, thus far, very rare, probably because it is very time-consuming and less attractive to academics intent on demonstrating their statistical skills.

Comparative small-N qualitative case studies, preferably based on most similar or most different case designs (Mitchell and Bernauer, 2004), are still rare in research on the determinants of environmental innovation. The business studies literature contains many case studies, but comparison across cases (firms) is usually not very systematic. The form of reasoning and empirical analysis in those studies often consists of arguing by example or deriving "lessons learned", rather than testing hypotheses. Carefully designed qualitative, comparative case studies can provide important insights into the processes that lead from firm-external stimuli (such as regulation or market forces) to environmental innovation. However, future research will have to engage in much more hypotheses-oriented case studies based on careful case selection as an instrument for controlling (or holding constant) variables that are of lesser theoretical interest.

4 Conclusion

What started with a simple claim has, ten years after Porter and van der Linde made the win-win proposition popular among business leaders, turned into a lively field of academic research. Economists and business studies scholars have carried out most of this research. Political scientists have only recently started to engage in this endeavor, focusing mainly on the effects of environmental regulation on innovation at the sector or national level.

Besides theoretical controversies – particularly among advocates of neoclassical, evolutionary, and ecological economics – empirical research on the effects of environmental regulation on innovation has thus far produced inconclusive and contested results.

At this state of theoretical and empirical knowledge, we are unable to say whether these inconclusive findings are due to incomplete or wrong model specifications, deficient empirical definitions of key concepts, or problematic data for key variables, or whether the win-win proposition as such is fundamentally flawed (in the sense that win-win outcomes are very rare, as neoclassical economists claim).

In this paper we have argued that the jury is still out, and that systematic empirical testing requires simultaneous analysis of the effects of regulation on environmental innovation alongside firm-internal and market conditions. We have also proposed that focusing on firms and innovation fields within and across firms, industries, and jurisdictions can provide important insights into the combined effects of regulation and producer and/or consumer benefits of particular environmental innovations. Such research will take us beyond the overly simplistic focus on whether or not environmental regulation promotes or hinders environmentally beneficial innovation. It forces us to look in more sophisticated ways at the conditions under which particular kinds of regulation are more or less conducive to particular kinds of environmental innovation.

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Chapter 3

The Effects of Customer Benefit and Regulation on Environmental Product Innovation in Germany

Empirical Evidence from Appliance Manufacturers

forthcoming in Ecological Economics,
doi:10.1016/j.ecolecon.2009.02.016

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.

1 Introduction

The electrical and electronic appliances (EEA) industry is globally one of the most dynamic industries with regard to innovation (Smith, 2005, p. 157) and growth rate (EEIG, 2004). The environmental impact of this industry has been a public topic since the early 1980s (Smith 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, econometric studies on environmental innovations have commonly applied 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.

2 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. While the Oslo Manual (OECD, 2005) distinguishes four different types of innovations, this paper focuses solely 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 CO_2 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).

2.1 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 obtain 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 these studies regulatory stringency does not have enough variation to lead to statistically significant effects as environmental product policies in Germany and Switzerland are very similar.

2.2 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,

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

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, 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.

2.3 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 (Melnyk 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 in general on environmental product innovation activity was found in recent studies by Rehfeld et al. (2007) and Wagner (2008) whereas Rennings et al. (2006) showed evidence for the stimulating effect of EMS induced learning processes.

2.4 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, Melnyk et al., 2003) and on EP-innovation in particular (Cleff and Rennings, 1999, Hitchens et al., 2000, Rehfeld et al., 2007). In contrast, Wagner (2008) 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.

3 Research Design and Data

The empirical focus of this paper is on the electrical and electronic 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 firm[2]. This deeper level of analysis helps to overcome some of the

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.

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 products[3]. Furthermore, they are regulated by public environmental policies with (presumably) differing stringency: based on the EU directive RoHS[4], the German Electrical and Electronic Equipment Act (BGBl, 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 WEEE[5]. 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 (BGBl, 1996) has not been amended or tightened since 2002. And most programs regarding energy efficiency of EEA are only voluntary[6]. 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 (BGBl, 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.

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.

For the data collection a survey was carried out using an online-questionnaire[7]. A random sample of EEA firms was drawn from the databases Creditreform (2006) and Hoppenstedt (2006), stratified for sector[8] and firm size. In total, 360 companies were contacted by phone to 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 study[9]. 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

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

4 Descriptive Results

4.1 Environmental Product Innovation

The 92 participating companies were asked 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 that involve a significant degree of novelty for the

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 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.

firm” OECD (2005, p. 17). Therefore this measure encompasses novelties to the market, or real innovations, and novelties to the firm, sometimes called diffusion (Smith, 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 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).

“Has your company implemented any environmental improvements in your products in the past 3 years?”	**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. Respondents could choose one of following answer categories: <5%, 5-25%, 26-50%, 51-75%, or 76-100%, (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.

Table 3: Extent of environmental product innovations (EPI_EXT) by environmental issue. 2% of the cases have missing data for EPI_EXT. (Asterisks indicate the median)

"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 third measure of EP-innovations is the degree of novelty. It distinguishes between so-called real innovations that are novel to the market and innovations that are only novel to the implementing firm. Respondents were asked whether their EP-innovations are *mainly market novelties*, *some market novelties*, or *no market novelties* (see table 4).

Table 4: Novelty of environmental product innovations (EPI_NOV) by environmental issue. 8% of the cases have missing data for EPI_NOV. (Asterisks indicate the median)

"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%**

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*.

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.

4.2 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. 3% of the cases have missing data for REG_STRING. (Asterisks indicate the median category)

"In the past 3 years, how easy / difficult was it for your company to meet regulations in Germany?"	**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%**

4.3 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. 1% of the cases have missing data for CUST_BEN. (Asterisks indicate the median category)

"How do you rate the direct benefit to your customers from product improve-ments?"	**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%

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. 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.

4.4 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%). The least frequent measure is *certified environmental management system*, which has only been implemented by 18%. 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 measures are most prevalent with HA manufacturers.

Table 7: Green capabilities of firms by sector

Does your company...	*... use the env. attributes of your products in marketing?*	*... have set up voluntary env. targets for products?*	*... conduct systematic env. analyses of your products?*	*... train its product developer in env. issues?*	*... have a certified env. management system (e.g. ISO 14'001)?*
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%**

4.5 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.

5 Statistical Analyses

5.1 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 models[10]. 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 method[11]. 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_EXT. The resulting categories are *no novelties*, *no market novelties*, *some market novelties*, and *mostly market novelties*.

10 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).

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

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 dependence between observations that stem from identical firms, I employ standard errors that are robust against clustering by firms.

5.2 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, robust standard error, and z-value.

This model clearly shows that the stringency of regulation (REG_STRING) has a highly significant 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 issues[12]. There are no significant effects for the remaining issue pairs[13].

12 A Wald test was used to compare the effects of I_TOX with I_EFF ($p=0.001$) and I_MAT ($p<0.001$).
13 The Wald test comparing I_EFF to I_MAT reports $p=0.745$.

Number of employees (EMPLOYEE) as well as R&D activities (R&D_EMPL) do not have a significant effect on EP-innovation. The effects of the sector are not significantly different either[14].

Table 8: Binary logit analysis for existence of EP-innovation (EPI_ANY)

	Parameter Estimate	Level of Significance	Robust Std. Error	z-value
REG_STRING	0.707	***	0.196	3.615
CUST_BEN	1.051	***	0.190	5.536
EMPLOYEE	-0.023		0.040	-0.581
R&D_EMPL	0.017		0.019	0.900
GREEN_CAP	0.609	***	0.185	3.290
SEC_ME	0.105		0.452	0.232
SEC_IT	0.831		0.571	1.456
I_EFF	0.119		0.456	0.261
I_TOX	2.180	***	0.542	4.018
I_MAT	-0.021		0.381	-0.054
_cons	-4.249	***	0.948	-4.481
aic	278.445			
bic	321.038			

The estimates are based on 355 observations at the environmental issue level. Robust standard errors are clustered by firm. * (**, ***) means that the null hypothesis that the appropriate parameter is zero can be rejected at the 10% (5%, 1%) level of significance.

I included the observations for all environmental issues in this analysis and thereby implicitly assumed that the effects on EP-innovation are the same for all environmental issues. In order to test whether this assumption holds true, I analyzed the same model using different sub-samples. As the sample size is too small for analyzing each environmental issue separately, I used the reversed setup: alternately excluding the observations for one of the environmental issues. These restrictions of the sample do hardly affect the coefficients' level of significance (see table A1 in the appendix for details). The sub-sample without observations for material efficiency is the only one with a change, there the dummy variable for the IT sector obtains a significant effect compared to the base sector HA. Furthermore, for each coefficient the confidence intervals coincide across all sub-samples. Therefore, the estimated coefficients are also robust against excluding observations for one of the environmental issues. So these analyses show that the existence of EP-innovation has the same determinants across the different environmental issues and that these determinants affects this variable in the same way.

14 The Wald test comparing SEC_ME to SEC_IT reports p=0.1357.

5.3 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 levels of significance, robust standard errors, and z-values are reported in table 9.

Table 9: Ordered logit analysis for extent of EP-innovation (EPI_EXT)

	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
aic	1108.835			
bic	1166.917			

The estimates are based on 355 observations at the environmental issue level. Robust standard errors are clustered by firm. * (**, ***) 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 issues[15]. There are no significant effects for the remaining issue pairs[16].

In contrast to the binary model, firm size (EMPLOYEE) has a highly significant, positive effect on EP_EXT. Thus, larger companies are more likely to implement EP-innovations on a broad basis. A weakly significant difference between the sectors IT and medical devices (p=0.0935) is the only effect that the choice of sector has, whereas R&D has no significant effect.

Again, I re-analyzed the model with sub-samples to test whether these effects are constant across the environmental issues (see table A2 in the appendix). Similar to the model for existence of EP-innovation, there is no substantial change in the significance levels besides a significant positive effect of the sector IT compared to the base sector HA in the sub-sample without material efficiency observations. Also, each coefficient has overlapping confidence intervals across the sub-samples. So the determinants of the extent of EP-innovation as well as their effects are the same across the different environmental issues.

5.4 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 10 shows parameter estimates, levels of significance, robust standard errors, and z-values for this model.

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.

15 The Wald test reports p<0.001 for I_TOX and I_EFF and p=0.001 for I_TOX and I_MAT.
16 The Wald test result is p=0.7805 for I_EFF compared to I_MAT.

R&D activities again have a non-significant coefficient. Regarding the industry sector, companies from IT have a higher probability of introducing market novelties than the ones manufacturing medical devices, although only weakly significant (p=0.0982). 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 issues[17].

Table 10: Ordered logit analysis for novelty of EP-innovation (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
aic	885.266			
bic	935.604			

The estimates are based on 355 observations at the environmental issue level. Robust standard errors are clustered by firm. * (**, ***) means that the null hypothesis that the appropriate parameter is zero can be rejected at the 10% (5%, 1%) level of significance.

As with the other models, the logit analysis of EPI_NOV has also been repeated with sub-samples excluding observations for each of the environmental issues (see table A3 in the appendix). These analyses show slight changes in the significance levels for regulatory stringency and firm size. However, the effects of both are only weakly significant in the unrestricted model. Again, the coefficients do not change across the sub-samples as the respective confidence intervals are coinciding with each other. Therefore, these analyses show evidence that my assumption of constant determinants and effects across environmental issues holds true for the novelty of EP-innovation as well.

17 The p-values are 0.0057 for I_TOX compared to I_EFF; <0.001 for I_TOX compared to I_MAT; and 0.4939 for I_EFF compared to I_MAT.

6 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.

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. Green capabilities have been defined very broadly in this study. Besides the purely capacity building measures EMS, environmental analyses and trainings, I also included voluntary environmental targets and the use of environmental attributes in marketing into the definition. The latter two are not directly related to environmental capacity building, instead they are proxies for the scope of the environmental management system. To test whether the results are robust for a more restrictive definition of green capabilities, I also ran the logit analyses without those two measures (see tables A1 to A3 in the annex). The influence on both, the existence and the extent of EP-innovation is robust, irrespective whether the broad or restrictive definition of green capabilities is applied. Yet the impact on novelty of innovation turns non-significant for the more restrictive definition of green capabilities.

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. This different result could stem from differing operationalizations. 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). Another explanation could be that the impact of R&D activities on EP-innovation is sector specific and not very relevant for the electrical and electronic appliances industry.

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.

Regarding the limitations of this study, the response rate has to be acknowledged. While it is larger than in most other surveys on firms' environmental activities[18], a response rate of 32% might still be an indication of self selection. However, no systematic non-response has been found besides the slightly higher responses of firms from the medical appliances sector. A second issue is the regional and sectoral focus of the study. The results in this paper are based on the electrical and electronic appliances industry in Germany. To elaborate whether the findings can be generalized to other industries and economies, further empirical studies will have to be conducted.

7 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.

18 E.g., response rates between 15% and 26% have been reported by Johnstone et al. (2007), Rehfeld et al. (2007), and Wagner (2008). However, Rennings et al. (2006) reached an exceptionally high response rate when surveying EMAS certified firms.

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9 Appendix

Underlying questions for the variables:

Environmental product improvements[19] are all technical changes that render a product more environmentally friendly. It does not matter, whether these changes are ecologically motivated or not.

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_EXT (extent of EP-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 EP-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 (FTE) did your company have in 2006?"

R&D_EMPL: "How many employees (FTE) did your company have in R&D in 2006?"

19 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 A1: robustness tests for logit analysis of existence of EP-innovation (EPI_ANY)

Parameter Estimate (95% CI) / Level of Sig.	**Normal Model**	**Sub-Sample 1** Without EFF Obs.	**Sub-Sample 2** Without TOX Obs.	**Sub-Sample 3** Without MAT Obs.	**Sub-Sample 4** Without EMF Obs.	**Alternative green_cap** Without voluntary goals and marketing measures
REG_ STRING	[0.32;1.09] ***	[0.33;1.22] ***	[0.27;1.12] ***	[0.35;1.22] ***	[0.13;0.96] **	[0.30;1.02] ***
CUST_ BEN	[0.68;1.42] ***	[0.52;1.43] ***	[0.68;1.41] ***	[0.65;1.64] ***	[0.61;1.43] ***	[0.71;1.45] ***
EMPLOYEE	[-0.10;0.05]	[-0.17;0.02]	[-0.10;0.07]	[-0.10;0.10]	[-0.11;0.12]	[-0.09;0.13]
R&D_ EMPL	[-0.02;0.05]	[-0.02;0.06]	[-0.02;0.05]	[-0.02;0.06]	[-0.03;0.07]	[-0.02;0.05]
GREEN_ CAP	[0.25;0.97] ***	[0.27;1.52] ***	[0.19;0.87] ***	[0.06;0.85] **	[0.30;1.06] ***	[0.13;1.18] **
SEC_ME	[-0.78;0.99]	[-0.36;1.96]	[-1.09;0.65]	[-0.69;1.13]	[-1.23;0.83]	[-0.96;0.85]
SEC_IT	[-0.29;1.95]	[-0.44;2.24]	[-0.41;1.76]	[0.02;2.51] **	[-0.75;1.88]	[-0.41;1.95]
I_EFF	[-0.77;1.01]		[-0.82;1.07]	[-0.77;1.01]		[-0.80;0.88]
I_TOX	[1.12;3.24] ***	[1.16;3.36] ***		[1.14;3.28] ***	[1.12;3.23] ***	[1.01;3.16] ***
I_MAT	[-0.77;0.73]	[-0.77;0.79]	[-0.76;0.71]		[-0.82;0.89]	[-0.77;0.67]
_cons	[-6.11;-2.39] ***	[-7.25;-2.49] ***	[-5.83;-2.02] ***	[-6.68;-2.51] ***	[-5.42;-2.06] ***	[-5.35;-1.99] ***
N	355	265	264	266	270	355

Table A2: robustness tests for ordered logit analysis of extent of EP-innovation (EPI_EXT)

Parameter Estimate (95% CI) / Level of Sig.	**Normal Model**	**Sub-Sample 1** Without EFF Obs.	**Sub-Sample 2** Without TOX Obs.	**Sub-Sample 3** Without MAT Obs.	**Sub-Sample 4** Without EMF Obs.	**Alternative green_cap** Without voluntary goals and marketing measures
REG_ STRING	[0.38;0.88] ***	[0.42;0.96] ***	[0.15;0.75] ***	[0.43;1.00] ***	[0.36;0.87] ***	[0.40;0.90] ***
CUST_ BEN	[0.34;0.90] ***	[0.13;0.77] ***	[0.52;1.09] ***	[0.38;1.04] ***	[0.27;0.85] ***	[0.37;0.92] ***
EMPLOYEE	[0.02;0.13] ***	[0.00;0.11] **	[0.01;0.12] **	[0.04;0.16] ***	[0.03;0.16] ***	[0.02;0.13] ***
R&D_ EMPL	[-0.01;0.02]	[-0.01;0.02]	[-0.02;0.02]	[-0.02;0.01]	[-0.01;0.02]	[-0.02;0.02]
GREEN_ CAP	[0.13;0.43] ***	[0.14;0.49] ***	[0.14;0.45] ***	[0.02;0.36] **	[0.15;0.49] ***	[0.21;0.68] ***
SEC_ME	[-0.60;0.65]	[-0.37;0.97]	[-0.60;0.75]	[-0.73;0.72]	[-0.85;0.44]	[-0.66;0.62]
SEC_IT	[-0.13;1.25]	[-0.22;1.38]	[-0.32;1.07]	[0.13;1.62] **	[-0.30;1.21]	[-0.14;1.29]
I_EFF	[-0.39;0.81]		[-0.67;0.58]	[-0.38;0.90]		[-0.38;0.82]
I_TOX	[0.90;1.87] ***	[0.84;1.80] ***		[0.98;2.06] ***	[0.65;1.79] ***	[0.91;1.88] ***
I_MAT	[-0.26;0.85]	[-0.27;0.83]	[-0.28;0.81]		[-0.57;0.75]	[-0.23;0.87]
_cons cut1	[1.39;3.85] ***	[1.23;3.89] ***	[1.29;3.89] ***	[1.33;4.32] ***	[1.21;3.20] ***	[1.28;3.77] ***
_cons cut2	[2.16;4.68] ***	[1.99;4.66] ***	[2.01;4.70] ***	[2.15;5.25] ***	[2.00;4.09] ***	[2.06;4.59] ***
_cons cut3	[3.30;6.00] ***	[3.14;6.02] ***	[3.02;5.91] ***	[3.47;6.80] ***	[3.12;5.32] ***	[3.19;5.92] ***
_cons cut4	[4.04;6.96] ***	[3.81;6.86] ***	[3.76;6.92] ***	[4.29;7.89] ***	[3.91;6.25] ***	[3.94;6.89] ***
_cons cut5	[4.63;7.65] ***	[4.36;7.59] ***	[4.34;7.53] ***	[4.86;8.56] ***	[4.61;7.02] ***	[4.53;7.60] ***
N	355	265	264	266	270	355

Table A3: robustness tests for ordered logit analysis of novelty of EP-innovation (EPI_NOV)

Parameter Estimate (95% CI) / Level of Sig.	**Normal Model**	**Sub-Sample 1** Without EFF Obs.	**Sub-Sample 2** Without TOX Obs.	**Sub-Sample 3** Without MAT Obs.	**Sub-Sample 4** Without EMF Obs.	**Alternative green_cap** Without voluntary goals and marketing measures
REG_ STRING	[-0.02;0.44] *	[-0.03;0.48] *	[-0.01;0.59] *	[-0.04;0.44]	[-0.09;0.39]	[-0.02;0.44] *
CUST_ BEN	[0.36;0.87] ***	[0.27;0.84] ***	[0.31;0.86] ***	[0.37;0.99] ***	[0.36;0.89] ***	[0.37;0.89] ***
EMPLOYEE	[-0.00;0.12] *	[-0.02;0.11]	[-0.01;0.12] *	[-0.00;0.13] *	[0.00;0.15] **	[0.01;0.15] **
R&D_ EMPL	[-0.02;0.02]	[-0.02;0.02]	[-0.02;0.02]	[-0.02;0.02]	[-0.02;0.03]	[-0.02;0.02]
GREEN_ CAP	[0.05;0.40] **	[0.04;0.45] **	[0.06;0.41] ***	[-0.02;0.36] *	[0.06;0.41] ***	[-0.10;0.47]
SEC_ME	[-0.60;0.75]	[-0.29;1.22]	[-0.86;0.54]	[-0.54;0.96]	[-0.85;0.50]	[-0.69;0.67]
SEC_IT	[-0.22;1.46]	[-0.16;1.62]	[-0.41;1.39]	[-0.04;1.69] *	[-0.41;1.38]	[-0.24;1.44]
I_EFF	[-0.61;0.64]		[-0.56;0.80]	[-0.62;0.61]		[-0.61;0.64]
I_TOX	[0.34;1.31] ***	[0.34;1.35] ***		[0.35;1.35] ***	[0.32;1.53] ***	[0.34;1.30] ***
I_MAT	[-0.72;0.31]	[-0.76;0.32]	[-0.67;0.31]		[-0.76;0.50]	[-0.71;0.32]
_cons cut1	[-0.00;2.77] *	[-0.17;2.88] *	[-0.01;3.05] *	[0.09;3.00] **	[-0.00;2.44] *	[-0.19;2.59] *
_cons cut2	[1.89;4.90] ***	[1.95;5.30] ***	[1.69;4.96] ***	[1.92;5.11] ***	[1.95;4.62] ***	[1.68;4.66] ***
_cons cut3	[3.08;6.38] ***	[3.13;6.76] ***	[2.84;6.44] ***	[3.16;6.65] ***	[3.15;6.11] ***	[2.86;6.13] ***
N	355	265	264	266	270	355

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Chapter 4

The Effects of Customer Benefit and Regulation on Environmental Product Innovation in California and Germany

Evidence from Appliance Manufacturers

ABSTRACT

In this article, I explain corporate environmental product innovations with their potential for customer benefit and the effect of environmental regulation. The empirical focus is on appliance manufacturers in California and Germany. The multiple regression results show that the influence of regulation and customer benefit is robust for different measures of environmental product innovation. The potential for customer benefit not only stimulates firms to implement environmental product innovations and to apply them to a large share of their products, it also motivates firms to go beyond the diffusion of already-known improvements and to develop environmental product innovations that are novel to the market. While stringent regulation also promotes the broad implementation of environmental product innovations, its effect on market novelties could not be corroborated. Further findings are that more Californian firms implement environmental product innovations and they also implement them on a broader range than German firms. In contrast, German firms implement more environmental product innovations that are novel to the market.

1 Introduction

The recent LOHAS (lifestyle of health and sustainability) movement in the industrialized countries draws on an old insight: to reach the goal of sustainable development it is essential to reduce the environmental burden of our production and consumption systems, as claimed by the United Nations Rio Declaration (UN, 1992). Environmental innovations play an important role in achieving this goal. While regulators have been promoting environmental *process* innovations to reduce pollution and waste in manufacturing processes for a long time, their attention to environmental *product* innovation to lessen environmental burdens along the whole life cycle of products is more recent. Examples for the latter are the promotion of an integrated product policy (IPP) by the European Commission (EC, 2001, 2003) and the extended producer responsibility (EPR) approach (e.g., OECD, 2001, 2004). Accordingly, research on the impact of regulation on environmental innovation primarily focuses on environmental *process* innovations (e.g., Lanjouw and Mody, 1996, Jaffe and Palmer, 1997, Brunnermeier and Cohen, 2003) or does not distinguish between *process* and *product* innovations (e.g., Johnstone et al., 2007b, Frondel et al., 2008). Only in recent years, have environmental *product* innovations and their determinants been analyzed in empirical studies (e.g., Rehfeld et al., 2007, Seijas-Nogareda, 2007, Wagner, 2008, Engels, 2008).

In this paper, I contribute to the research on determinants of environmental product innovations (hereafter EP-innovations). Besides the impact of regulation, I also examine a novel explanatory factor: the direct customer benefit which can accrue from these environmental innovations. In the green marketing literature, it is a common proposition that in order to be commercially successful, green products need to deliver a private benefit for customers in addition to the public benefit of improved environmental quality. Additionally, EP-innovation is measured more comprehensively than in similar studies to date. I do not only consider whether or not firms implemented EP-innovations but also the extent of the product range for which they were implemented as well as the level of novelty of the EPI.

The empirical focus is on manufacturers of electrical and electronic appliances (EEA) in California and Germany. These products have a rapidly growing ecological footprint due to their increasing spread to almost every sphere of modern life (EEIG, 2004). In a recent study on EP-innovations of the German EEA industry, Kammerer (2008) shows that both regulation and the potential for customer benefit stimulate firms' environmental innovation activities. The purpose of this paper is twofold. First, the impact of regulation and customer benefit on EP-innovation is analyzed using a data set from a survey on Californian firms. This analysis validates the findings of Kammerer (2008) and provides further evidence that customer benefit stimulates firms more strongly to come up with novel EP-innovations while more stringent regulation leads to a broader diffusion of EP-innovations already introduced to the market.

Second, EP-innovation and its determinants are compared for California and Germany. These two states are a good choice for a comparison because they are the largest producers of EEA in the US (US-Census-Bureau, 2004a, b, c) and in the European Union (Eurostat, 2004, p. 184-190) respectively. Thus, they allow for relatively large sample sizes and increase the practical relevance of the findings. Further, Germany and California are comparable with regard to the advancement of environmental policy in general, as both states are the regional leader for this policy field (for details see Vogel, 1995). And finally, the theory of varieties of capitalism provides an important difference between Germany and California. Hall and Soskice (2001) distinguish between two types of political economies: liberal market economies and coordinated market economies. They postulate that liberal market economies like the United States (and therefore California) are characterized by intense product competition. In contrast, coordinated market economies like Germany focus more on product differentiation and niche production. Through this difference in market strategies, the comparison of these two states provides a perfect research design for my study. The results of the comparison support the varieties of capitalism theory: while Californian firms are more likely to implement EP-innovations than German firms and also implement these innovations on a broader range, German firms develop and implement more EP-innovations that are novel to the market. These results also provide further support for my theory as they show that the influence of customer benefit and regulation on EP-innovations is robust with regard to the type of market economy.

In the following section, I will discuss the theoretical arguments and hypotheses to be tested. Section 3 provides the survey design and descriptive statistics of the data. The next section reports the results of the multiple regression analyses and is followed by the conclusion in the final section.

2 Theoretical Background and Hypotheses

In accordance with other studies on this topic (cf. Bernauer et al., 2007), I define environmental product innovation (EP-innovation) as technical innovations that reduce environmental impacts along a product's total life cycle, such as reduction of toxics and materials in products, improved power consumption and emission output in the use phase, or recycling schemes for obsolete products. I use three measures of EP-innovation: besides the binary measure of whether or not a firm has implemented EP-innovations in the last three years, I also examine to what extent these innovations have been implemented with regard to the firm's product range. The third measure is the novelty of the EP-innovations, that is whether they are novel to the market or already common to the market but novel to the implementing firm.

Regarding the determinants of environmental innovations, current research rests on the assumption that regulation, market and firm-internal factors influence corporate environmental innovation behavior (cf. Bernauer et al., 2007). The theoretical arguments and derived hypotheses are as follows.

2.1 Regulation

There are two theoretical strands in the literature for the relationship of regulation and environmental innovation. The “induced innovation” approach (Jaffe et al., 2003, p. 469) is based on neoclassical theory and the “double externality problem” (Rennings, 2000, p. 325) of environmental innovations: in addition to the spillover effect of creating knowledge that cannot be appropriated fully by the inventor (Jaffe, 1986), environmental innovations provide a further positive externality to the public by improving environmental quality. As a consequence of these market failures, firms under-invest in environmental R&D relative to the social optimum (Jaffe et al., 2003). Environmental regulation implicitly or explicitly changes the prices of environmental goods and thus induces innovation.

The second approach is based on evolutionary economics and views firms as “satisficing” rather than optimizing (Nelson and Winter, 1982). Following this approach, firms' R&D activities are path-dependent and rely on routines and rule of thumb. Thus, environmental regulation functions as an external shock, forcing firms to focus their attention on environmental issues. As firms are not optimizing, they might find previously missed inefficiencies or opportunities for competitive advantage through environmental improvements. The famous “win-win” proposition of Porter and van der Linde (1995a,b) is based on this reasoning.

Empirically, recent studies find that stringency of environmental regulation is the single most important factor that drives firms' environmental activities and technological innovations (Johnstone et al., 2007a, Frondel et al., 2008). However, these studies do not differentiate between environmental process and product innovation. My first hypothesis is:

> Hypothesis 1: Regulatory stringency has a stimulating effect on firms' activities regarding environmental product innovations.

Adapted to the three kinds of EP-innovation measures used in this study:

> More stringent regulation leads to ...
>
> H1a: ... more firms implementing EP-innovations.
>
> H1b: ... firms implementing more EP-innovations.
>
> H1c: ... firms implementing more novel EP-innovations.

2.2 Market Demand and Customer Benefit

Firms can utilize environmental product innovations to differentiate their products and thus gain a competitive advantage (Reinhardt, 1998, Banerjee et al., 2003). Based on the green marketing literature (Meffert and Kirchgeorg, 1998, Ottman, 1998, Reinhardt, 1998, Belz, 2001, Belz and Bilharz, 2005), market demand is stronger for green products that can offer a direct benefit to the customer in addition to the public benefit of reducing the environmental burden. Examples of such customer benefits are cost savings through energy-efficient appliances or reduced health impacts. Elkington (1994, p. 90) coined the term “triple win” for these products, as they “simultaneously benefit company, its customers, and the environment”.

Utilizing EP-innovations that provide products with such customer benefits thus increases the demand for these environmentally improved products. Therefore, anticipated customer benefits can constitute the firm's motivation to develop and implement those EP-innovations in the first place. Consequently, firms are expected to focus their environmental innovation activities more towards product improvements and environmental issues that have a potential for customer benefit.

Empirically, the effects of customer benefit on EP-innovation have not been tested systematically before Kammerer (2008). So my second hypothesis is:

> Hypothesis 2: The potential for customer benefit has a stimulating effect on firms' activities regarding environmental product innovations.

Adapted to the three kinds of EP-innovation measures used in this study:

Larger anticipated customer benefit leads to ...

H2a: ... more firms implementing EP-innovations.

H2b: ... firms implementing more EP-innovations.

H2c: ... firms implementing more novel EP-innovations.

2.3 Control variables

In the literature, several firm-internal factors have been proposed to influence firms' environmental innovation activity. It is argued that larger firms implement more environmental innovations due to economies of scale and their higher amount of financial and human resources (1998, Gonzalez-Benito and Gonzalez-Benito, 2006). 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. I will control for firm size and R&D expenditure in the analyses.

Another firm-internal control variable is firms' green capabilities. Based on the resource-based view of the firm (cf. Wernerfelt, 1984, Barney, 1991), Hart (1995) develops a concept of green capabilities. These comprise a firm's knowledge of environmental issues relevant to its business and procedures implemented to act and react on these issues.

3 Data Collection and Descriptive Statistics

The data for this study was collected in two surveys, one for Californian firms and one for Germany firms. To reduce any bias and to facilitate the comparison of the results, both surveys have been conducted using the same framework: first, it has the same empirical focus, namely the electrical and electronic appliances (EEA) industry. A random sample of EEA firms was drawn for each state, stratified for sub-sector and firm size. The selected sub-sectors are information and communication technology (IT); household appliances including lamps and lighting fixtures (HA); and medical appliances (ME)[1]. Second, in both surveys the level of analysis is the environmental issue level. That is, firms were surveyed on the main study variables (EP-innovation, regulat-

1 For the sampling, the business directory Manufacturers' News (http://www.manufacturersnews.com) was used with the following SIC codes: 363, 3641, 3648, 3651, 366 for HA; 357 for IT; and 384 for ME.

ory stringency, and customer benefit) regarding four environmental issues: energy efficiency, toxic substances, material efficiency, and electromagnetic fields. The actual survey was conducted consecutively using an online-questionnaire. The Germany survey was performed from summer to winter 2006, the one in California from spring to autumn 2007. The time frame for the surveyed EP-innovation activity is the three years before the surveying.

The number of respondents and response rates are shown in table 1. With a total response rate of 11% the participation is markedly lower in the California sample than in the Germany sample (32%)[2].

Table 1: Number of respondents (and response rate) by sub-sector and firm size

		10-49 employees	50-250 employees	>250 employees	Total
Household Appliances (HA)	**Cal**	9 (9%)	5 (14%)	1 (10%)	15 (10%)
	Ger	4 (14%)	12 (31%)	10 (34%)	26 (27%)
Information & Communication Techn. (IT)	**Cal**	7 (11%)	6 (7%)	11 (28%)	24 (12%)
	Ger	7 (29%)	9 (21%)	11 (39%)	27 (28%)
Medical Appliances (ME)	**Cal**	5 (13%)	3 (6%)	5 (12%)	13 (10%)
	Ger	11 (44%)	15 (39%)	13 (42%)	39 (41%)
Total	**Cal**	21 (11%)	14 (8%)	17 (18%)	52 (11%)
	Ger	22 (29%)	36 (30%)	34 (39%)	92 (32%)

Thus, the California data set consists of 208 cases from 52 firms, with four issues per firm and the Germany data set of 368 cases (92 firms x 4 issues). As is (unfortunately) common in surveys, not all questions in the questionnaire were answered by every firm. Compared to the Germany data set, the share of missings is higher in the California data set, with the EMF issue having the most missings in both data sets[3].

In the following, I provide descriptive statistics for the key variables regulatory stringency, customer benefit, and EP-innovation. Their distributions in the California and Germany sample are displayed and discussed for each environmental issue. Then, I compare the data from California and Germany using the median and Spearman's rank correlation, as all variables are ordinal scaled. Additionally, I analyze the bivariate rela-

2 The low response rate is at least partly due to Californian firms being more reluctant to reply to the survey invitation. In the Germany survey, around 20% of the contacted firms answered that they will not participate because of their firm not fulfilling the eligibility criteria. That is their products do not fit into the selected subsectors or the product development is not in their responsibility. These non-eligible firms have been removed from the list of non-respondents and therefore considerably increased the response rate calculated for Germany. Further, the OECD study on firms' environmental innovations exhibits similar differences with response rates of 18% in Germany and 12% in the US (Johnstone et al., 2007, p. 6).

3 Missings always raise the question of social desirability bias, e.g., that firms deliberately skipped a question instead of answering that they have not implemented any EP-innovations. As most records with missing data have missings for all main variables in the respective environmental issue, it is not possible to do a nonresponse analysis for these cases.

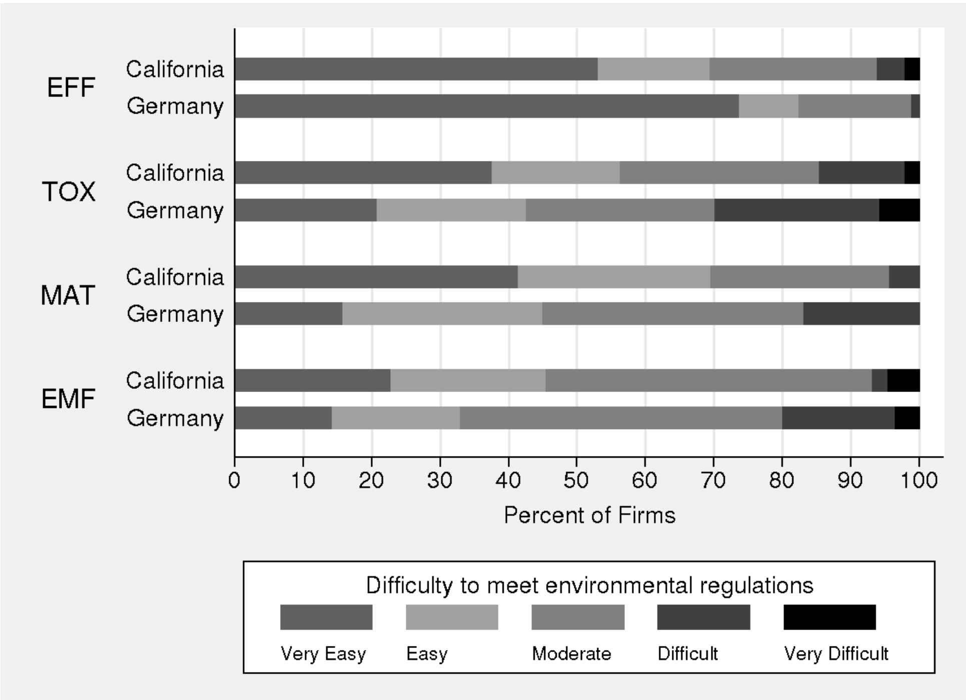
tionship of regulatory stringency and customer benefit with the EP-innovation variables. These analyses are first tests of my hypotheses.

3.1 Regulatory Stringency

For each environmental issue the regulatory stringency was surveyed. The participating firms were asked to rate the difficulty to meet regulations regarding the respective issue for the last three years (REG_STR). The five answer categories range from „very easy“ to „very difficult“[4]. Figure 1 shows the distribution of REG_STR for both samples, ordered by environmental issue.

Looking first at the California sample, we can see that regulations regarding energy efficiency (EFF) have the lowest median (“very easy”) while electromagnetic fields (EMF) has the highest one (“moderate”). The issues toxic substances (TOX) and material efficiency (MAT) have a median of “easy”. MAT is the only issue, for which no firm rated regulations with the maximum rank “very difficult”; for all other issues REG_STR is distributed over all ranks.

Fig. 1: Regulatory stringency in California and Germany by env. issue[5]



Corr: ρ(EFF)=0.209**; ρ(TOX)=-0.196**; ρ(MAT)=-0.299***; ρ(EMF)=-0.169*
(* p<0.1; ** p<0.05; *** p<0.01)

Spearman's rank correlation coefficients have been computed to compare the data from California and Germany at the environmental-issue level. A positive coefficient in-

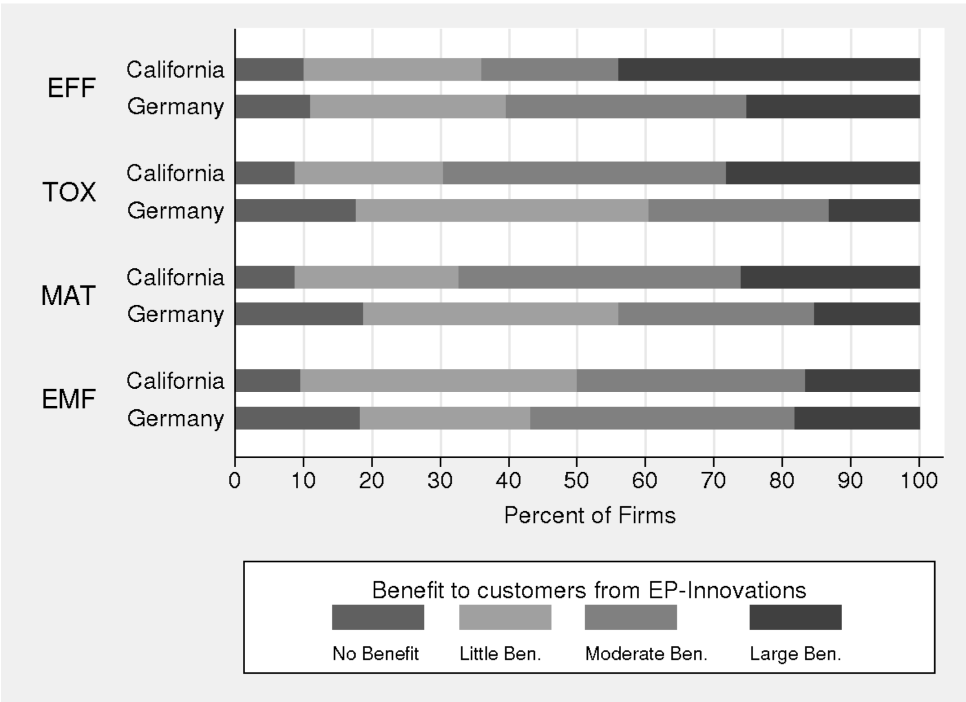
4 The survey questions for all variables used in this study are listed in the appendix.
5 See table A1 in the appendix for the data underlying this figure, including information on missing data.

dicates that regulatory stringency for the respective issue is higher in California and vice versa. All coefficients are significant and their signs show that in general, EFF regulations are more stringent in California, while the remaining issues are more stringently regulated in Germany.

3.2 Customer Benefit

The firms were asked to rate the potential for customer benefit for each of the four environmental issues using a 4-point ordinal scale from „no benefit“ to „large benefit“. The answers for this variable CUST_BEN are shown in figure 2.

Fig. 2: Customer benefit in California and Germany by env. issue[6]



Corr: ρ(EFF)=0.121; ρ(TOX)=0.275***; ρ(MAT)=0.220***; ρ(EMF)=-0.012
* p<0.1; ** p<0.05; *** p<0.01

Within the California sample, for all issues the median category of CUST_BEN is “moderate benefit”. Therefore, the potential for customer benefit does not vary widely across the environmental issues. However, the share of the rank “large benefit” varies considerably: more than 40% consider EFF to have large customer benefits whereas less than 30% gave this rating for the issues TOX and MAT and even less than 20% for EMF. As we can see in the correlation coefficients, CUST_BEN also does not vary significantly between California and Germany for the issues EFF and EMF. However, regarding TOX and MAT Californian firms in general reported a larger potential for customer benefit than German firms did.

6 See table A2 in the appendix for the data underlying this figure, including information on missing data.

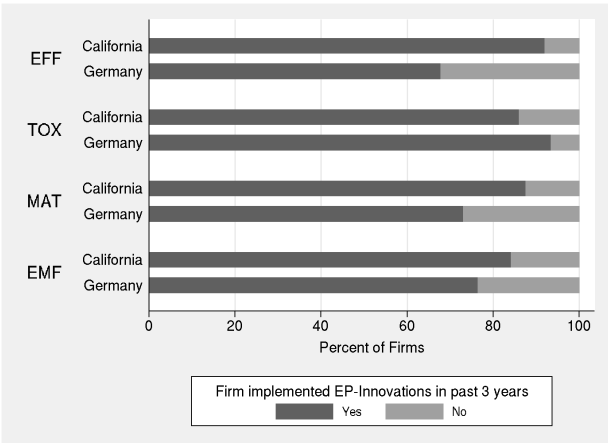
3.3 Existence of EP-Innovation

Environmental product innovation was surveyed using three measures. The most basic one is whether or not firms implemented EP-innovations for the respective environmental issue. Figure 3a shows the distribution of this binary variable EPI_ANY.

In California, for each environmental issue more than 80% of the respondents implemented EP-innovations. EFF is the issue for which most firms implemented EP-innovations (92%) whereas EMF has the lowest share (84%). Compared to Germany, EP-innovation is more frequent for the issues EFF, MAT, and EMF and less frequent for TOX in California. However, the correlation coefficients show that these differences of EPI_ANY between California and Germany are not statistically significant for TOX and EMF, and only weakly significant for MAT.

Figures 3a-c: Existence of EP-innovation (EPI_ANY) in California and Germany

3a: EPI_ANY by env. issue[7]



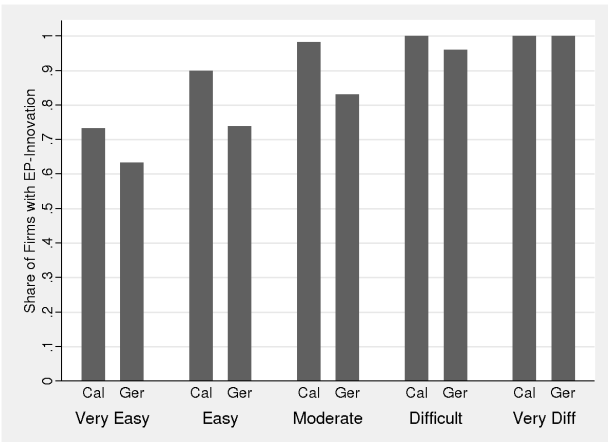
Spearman's rank correlation coefficients
(p<0.1; ** p<0.05; *** p<0.01)*

3a: Corr. EPI_ANY and being in the Cal. sample
ρ(EFF)=0.273 ***
ρ(TOX)=-0.123
ρ(MAT)=0.167 *
ρ(EMF)=0.089

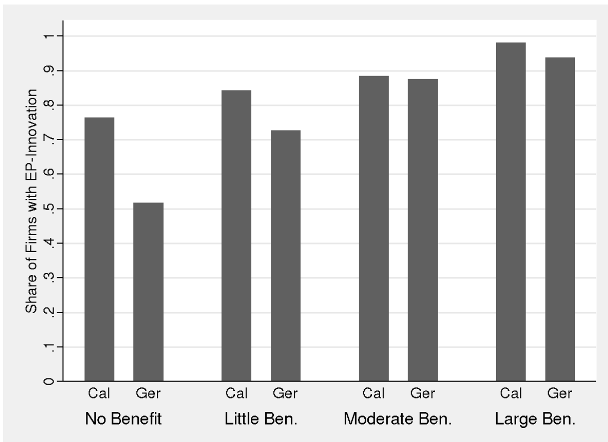
3b: Corr. EPI_ANY and REG_STR
ρ(Cal)=0.330 ***; ρ(Ger)=0.279 ***

3c: Corr. EPI_ANY and CUST_BEN
ρ(Cal)=0.212 ***; ρ(Ger)=0.325 ***

3b: Relationship of EPI_ANY and REG_STR



3c: Relationship of EPI_ANY and CUST_BEN



7 See table A3 in the appendix for the data underlying this figure, including information on missing data.

Figure 3b shows the relationship between firms' rating of regulatory stringency and whether they implemented EP-innovations. These pairs of REG_STR and EPI_ANY are at the environmental issue level but have been aggregated over all issues for the purpose of illustration. We can see that the more stringent the regulation is, the larger the share of firms that implemented EP-innovations, for both states. The evidence of highly significant correlation coefficients for these variables are a first support for hypothesis 1a that more stringent regulation leads to more firms implementing EP-innovations in California.

In an analogous way, figure 3c illustrates the relationship between firms' ratings of customer benefit and whether they implemented EP-innovations. As customer benefit grows, the likelihood of EP-innovation increases in both states. This evidence is supported by the highly significant correlation coefficients for these two variables. Thus, we also have first evidence for hypothesis 1b that customer benefit has a positive influence on EPI_ANY in California.

Interestingly, the cases with low regulatory stringency or customer benefit have a larger share of EP-innovation in California than in Germany, while the shares converge with increasing values of the respective variable.

3.4 Extent of EP-Innovation

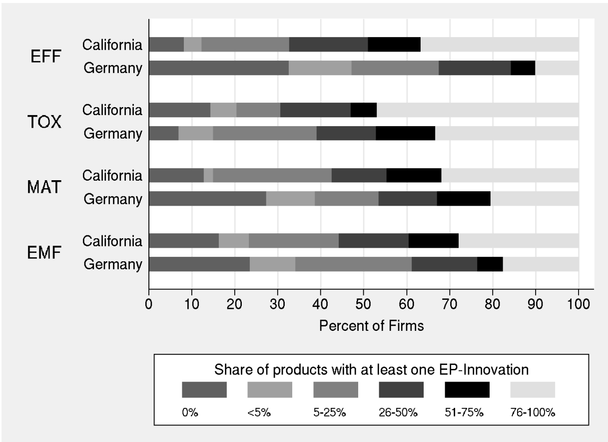
To obtain a more detailed measure of EP-innovation, firms were also asked to report the percentage of products for which they implemented EP-innovations. This extent of EP-innovation (EPI_EXT) had the following five answer categories: “<5%”, “5-25%”, “26-50%”, “51-75%, and “76-100%”. For companies that have not implemented any EP-innovations for the respective issue (i.e., EPI_ANY = 0) this variable has been coded to “0%”. Figure 4a shows the extent of EP-innovation for all issues in California and Germany.

Within the California sample, the maximum rank “76-100%” is the predominant answer for each issue; it even reaches a share of almost 50% for the issue TOX. For all issues, it is rare that EP-innovations were implemented only for a small range of products: less than 10% of the firms answered to have an extent of EP-innovation of “<5%”. Compared to the Germany sample, in general EPI_EXT is larger in California as can be seen in the larger medians for each issue. Additionally, the correlation coefficients have positive signs and are statistically significant except for TOX.

I ran a first test of EPI_EXT in California being influenced by regulatory stringency (hypothesis 2a) and customer benefit (hypothesis 2b). Figure 4b demonstrates that more stringent regulation corresponds with larger extent of EP-innovation in both states: the median category for EPI_EXT increases with larger REG_STR. This relationship is further supported by the significant and positive correlation coefficients (Cal: 0.353; Ger: 0.373). The same holds true for customer benefit in figure 4c, again supported by significant correlation coefficients (Cal: 0.313; Ger: 0.273).

Figures 4a-c: Extent of EP-innovation (EPI_EXT) in California and Germany

4a: EPI_EXT by env. issue[8]



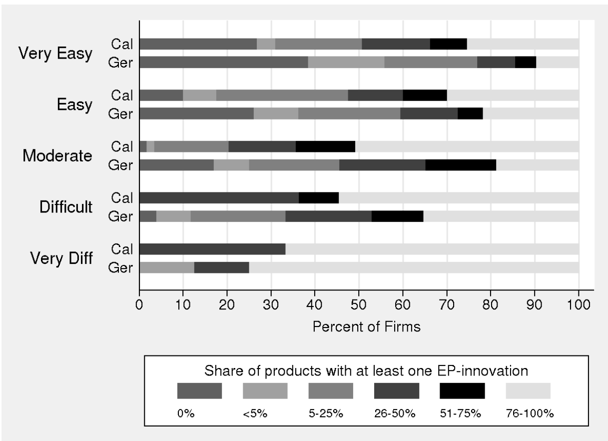
Spearman's rank correlation coefficients
($p<0.1$; ** $p<0.05$; *** $p<0.01$)*

4a: Corr. EPI_EXT and being in the Cal. sample
ρ(EFF)=0.407 ***
ρ(TOX)=0.072
ρ(MAT)=0.183 **
ρ(EMF)=0.163 *

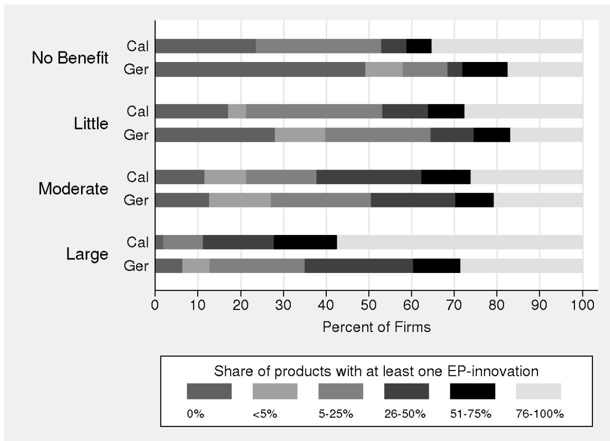
4b: Corr. EPI_EXT and REG_STR
ρ(Cal)= 0.353 ***; ρ(Ger)=0.373 ***

4c: Corr. EPI_EXT and CUST_BEN
ρ(Cal)=0.313 ***; ρ(Ger)=0.273 ***

4b: Relationship of EPI_EXT and REG_STR



4c: Relationship of EPI_EXT and CUST_BEN



3.5 Novelty of EP-Innovation

Another more detailed measure of EP-innovation is the novelty of innovation (EPI_NOV). Firms were asked to state what share of their EP-innovations could be considered market novelties. Answer categories are “no market novelties” “some market novelties” and “mainly market novelties” (see figure 5a). For firms that have not imple-

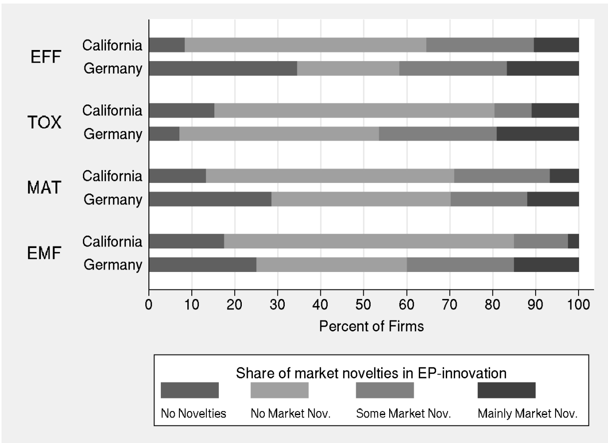
8 See table A4 in the appendix for the data underlying this figure, including information on missing data.

mented any EP-innovations for the respective issue (i.e., EPI_ANY = 0) I coded EPI_NOV to the minimum category "no novelties".

Looking first at the California sample, EPI_NOV does not show strong variation across the issues. "No market novelties" is the median answer category for every issue and also the predominant one. Only around 10% of the firms implemented "mainly market novelties", with EMF having the lowest share. While around 10% of the firms implemented "some market novelties" for the issues TOX and EMF, these shares increase to more than 20% for EFF and MAT respectively.

Figures 5a-c: Novelty of EP-innovation (EPI_NOV) in California and Germany

5a: EPI_NOV by env. issue[9]



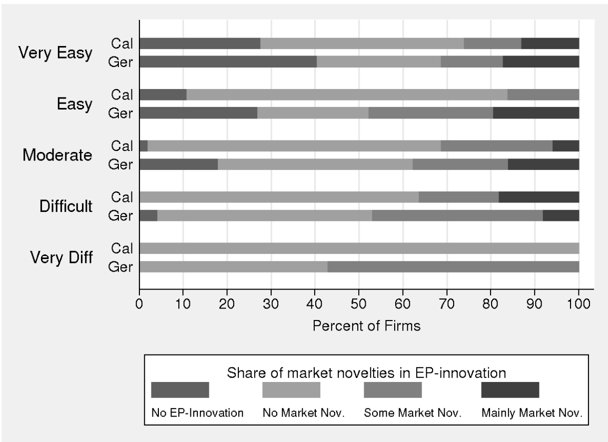
Spearman's rank correlation coefficients
(p<0.1; ** p<0.05; *** p<0.01)*

5a: Corr. EPI_NOV and being in the Cal. sample
ρ(EFF)=-0.084
ρ(TOX)=-0.253 ***
ρ(MAT)=0.076
ρ(EMF)=-0.135

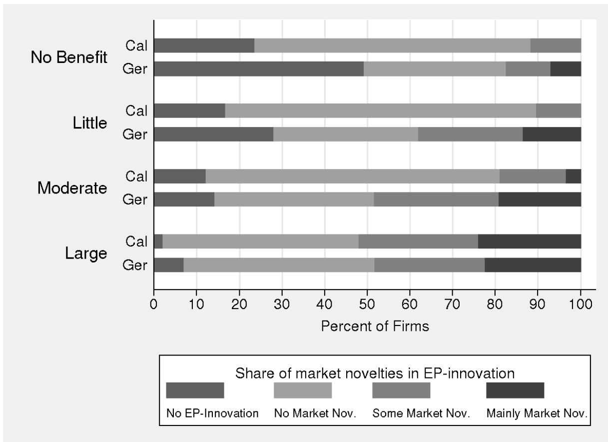
5b: Corr. EPI_NOV and REG_STR
ρ(Cal)=0.183 **; ρ(Ger)=0.167 ***

5c: Corr. EPI_NOV and CUST_BEN
ρ(Cal)=0.402 ***; ρ(Ger)=0.293 ***

5b: Relationship of EPI_NOV and REG_STR



5c: Relationship of EPI_NOV and CUST_BEN



Compared to the California sample, EPI_NOV is distributed more evenly in Germany, that is the minimum and maximum categories are more frequent. However, here too "no market novelties" is the median for every issue. The correlation coefficients indicate that TOX is the only issue for which EPI_NOV significantly differs between Califor-

9 See table A5 in the appendix for the data underlying this figure, including information on missing data.

nia and Germany: in general the novelty of EP-innovation regarding TOX is larger in Germany.

Figure 5b illustrates how REG_STR relates to EPI_NOV. Again, the median of EPI_NOV remains almost constant at “No Market Novelty” for all sub-groups with the exception of the sub-group “very difficult” in Germany, for which “some market novelties” is the median. Looking at the Germany data, we can see that the share of firms that implemented at least “some market novelties” is growing with increasing regulatory stringency (with a drop for the “moderate” sub-group). In the California sample, this share does also somewhat increase for REG_STR values from “very easy” to “difficult”, but decline to zero for the sub-group “very difficult”. The ambiguity of this relationship is also found in the relatively low correlation coefficients (Cal: 0.183; Ger: 0.167). In other words, hypothesis 1c stating that regulatory stringency stimulates the novelty of EP-innovation in California is only weakly supported by this bivariate analysis.

The relationship between EPI_NOV and CUST_BEN, displayed in figure 5c, is less ambiguous: the median remains constant at “no market novelties” (except for the sub-group “large benefit” in California), but the share of firms that implemented at least “some market novelties” clearly grows with increasing regulatory stringency. This dependency is also demonstrated by the correlation coefficients (Cal: 0.402; Ger: 0.293). Thus, we have some first evidence for hypothesis 2c, that customer benefit positively influences the novelty of EP-innovation in California.

3.6 Conclusions

The descriptive statistics show that the main independent variables exhibit considerable variation in the California sample. They vary within the environmental issues as well as across the issues. Compared to Germany, Californian firms generally rated regulations to be less stringent, with the exception of the issue EFF. Regarding customer benefit, Californian firms generally reported larger benefits for TOX and MAT, while there are no significant differences for the other two issues, EFF and EMF.

With regard to the three EP-innovation measures, the descriptive analysis shows two differences between California and Germany. On the one hand, with regard to whether firms implement EP-innovations (EPI_ANY) and if so to what extend (EPI_EXT), Californian firms are at least as innovative as their German counterparts. Californian firms are even more likely to implement EP-innovations for EFF and MAT. And, overall, they implement them to a larger extent for the issues EFF, MAT, and EMF. On the other hand, the overall novelty of EP-innovation in the California sample is not larger than in the Germany sample. For the issue TOX it is even lower in California.

Note that these comparisons cannot be used to test my hypotheses. As hypotheses H1 and H2 state relationships at the firm level and these comparisons are at the aggregated state level such an inference would be an ecological fallacy.

However, the bivariate correlation tests at the individual level (fig. 3b,c / 4b,c / 5b,c) provide first evidence for hypotheses H1 and H2: regulatory stringency and customer benefit have significant positive dependencies with each of the three measures of EP-innovation in the California sample. The respective correlation coefficients are summarized in table 2. We can see that most correlations for California have a coefficient of above 0.3, only for the relations of CUST_BEN and EPI_ANY as well as REG_STR and EPI_NOV the coefficients are around 0.2. While the correlation of REG_STR and EPI_NOV also has the lowest coefficient in the Germany sample, there the coefficient for CUST_BEN and EPI_ANY is one of the highest.

Table 2: Spearman's rank correlation coefficients of main variables at the issue level

		EPI_ANY		**EPI_EXT**		**EPI_NOV**	
		Coeff.	**N**	**Coeff.**	**N**	**Coeff.**	**N**
California	REG_STR	0.330 ***	184	0.353 ***	184	0.183 **	171
	CUST_BEN	0.212 ***	183	0.313 ***	179	0.402 ***	173
Germany	REG_STR	0.279 ***	349	0.373 ***	344	0.167 ***	328
	CUST_BEN	0.325 ***	355	0.273 ***	349	0.293 ***	332

* p<0.1; ** p<0.05; *** p<0.01

Of course, these bivariate examinations are not a thorough test of the hypotheses, as neither is the influence of the other key variable considered (customer benefit or regulatory stringency respectively) nor is the ceteris paribus condition fulfilled (e.g., firm size).

4 Multiple Analysis

In this section, I test the influence of regulatory stringency and customer benefit on the three EP-innovation measures using multiple regression analysis. Thus, these influences are analyzed simultaneously while also controlling for firm-internal factors, market factors, and environmental issue. For the binary outcome variable EPI_ANY, I apply logit regression, while ordered logits are used for the outcomes EPI_EXT and EPI_NOV[10].

10 All statistics have been calculated with the software package Stata 9.2.

As mentioned, some data records have missing data, especially the ones regarding the issue EMF. I have imputed these missing values separately for the California and the German data, using the multiple imputation method[11] (Allison, 2001). However, for 29 observations listwise deletion had to be applied nevertheless, as both the dependent and main independent variables (i.e., EP-innovation, regulation, and customer benefits) had missing values. Thus, the regressions are based on 192 observations at the issue level in the California sample and 355 observations in the Germany sample.

To test whether the regression results are robust and not biased by the relatively high number of missing data (and high number of multiple-imputed data) for the EMF issue in the California sample, all models were re-estimated without the EMF-specific data. Overall, the regression results are robust with regard to sign and magnitude of the estimated coefficients. Some estimates have a weaker statistical significance in the restricted sample because their sample size is 25% smaller[12]. I control for the following variables in the logit models:

Firm internal factors

- EMPLOYEE: size of the firm, measured as number of employees (in thousands)
- EMPL_R&D: general R&D activities of the firm, measured as the share of employees in R&D
- GREENCAP: green capabilities the firm developed, operationalized as the number of measures implemented from the following: certified environmental management system, voluntary environmental targets for products, systematic environmental analyses of products, use of environmental attributes in marketing, environmental trainings for product developers
- SCTR_REV: ratio of the firm's revenue in the surveyed sub-sector to total revenue (ranging from 1 for “0-20%” to 5 for “80-100%”)

Market factors

- COMP_PRE: competitive pressure, operationalized as number of direct competitors (measured as “0”, “1-5”, “6-10”, “11-15”, “16-20”, and “>20”)
- SEC_: dummy variables for the firm's sub-sector (_HA, _IT, and _ME)

Environmental issue

- I_: dummy variables for the environmental issue (_EFF, _TOX, _MAT, and _EMF)

11 The multiple imputation process has been performed with the ice package (Royston, 2005) in Stata. The Stata do-file is available from the author on request.
12 The results of these restricted models are provided in the appendix (tables A6-A8).

While the main study variables regulatory stringency, customer benefit, and the three measures of EP-innovation are at the environmental issue level, the control variables have been measured at the firm level. That is, the control variables do not vary across the environmental issues within a firm. To adjust for this intra-group correlation, I use standard errors that are robust against clustering by firms.

For each EP-innovation measure, the regression models for the California sample were reduced by dropping non-significant control variables. The models for the Germany sample were re-estimated with the same constrained specification to facilitate their comparison. I decided for this order of model specification because the California models are of main interest. The full models containing all predictor variables are provided in the appendix, as are the original, slightly differently specified, Germany models from the study of Kammerer (2008). The results of the reduced Germany models in this study and the ones from the previous study are robust with regard to sign and significance of effects.

4.1 Existence of EP-Innovation

The results of the logit regression for EPI_ANY are displayed in table 3. The second column shows coefficients as odds ratios, levels of significance, and robust standard errors for the California sample. The evidence clearly supports hypotheses H1a and H2a: both regulatory stringency (REG_STR) and customer benefit (CUST_BEN) have a statistically significant positive effect on whether firms implement EP-innovations. While the effect of regulatory stringency is highly significant, customer benefit only has a weakly significant effect (10% level of significance).

As to the control variables, most firm-internal factors have statistically significant effects on EPI_ANY as well. GREENCAP has a positive effect: the more green capability measures a firm has realized, the more likely are EP-innovations. Firm size (EMPLOYEE) has a negative effect[13], while R&D activity (EMPL_R&D) does not have a statistically significant effect[14]. SCTR_REV also has a positive effect: the more important the surveyed sub-sector is for a firm's total revenue, the more likely are EP-innovations.

13 The odds ratio is the factor by which a 1-unit increase of the predictor variable changes the odds of the outcome. In general, odds is the probability of the successful outcome divided by the probability of the unsuccessful outcome. For EPI_ANY the odds is the probability of having implemented EP-innovations divided by the probability of not having implemented EP-innovations. Therefore an odds ratio between 0 and 1 means that the predictor has a negative effect, while an odds ratio larger than 1 indicates a positive effect.

14 The reduced model has been tested using a Wald test for the dropped variables. The test statistics that the effects of R&D_EMPL, SEC_HA and SEC_IT are simultaneously equal to zero are chi2(3) = 3.73; Prob = 0.2926

Table 3: Logit analysis for existence of EP-innovation (EPI_ANY)

	California sample	Germany sample
REG_STR	7.345***	2.000***
	(3.889)	(0.381)
CUST_BEN	1.907*	2.870***
	(0.632)	(0.571)
GREENCAP	1.763**	1.774***
	(0.507)	(0.299)
EMPLOYEE	0.871***	0.985
	(0.034)	(0.046)
R&D_EMPL		
SCTR_REV	1.923***	1.150
	(0.437)	(0.193)
COMP_PRE	2.187**	0.967
	(0.865)	(0.159)
SEC_HA		
SEC_IT		
I_TOX	0.201**	7.321***
	(0.157)	(3.890)
I_MAT	0.470	0.848
	(0.390)	(0.363)
I_EMF	0.089**	0.853
	(0.087)	(0.388)
N	192	355
aic	97.2	282.0
bic	129.8	320.8

Reduced models with odds ratios for 1-unit increases of predictor variables; robust standard errors clustered by firms in parentheses; constants are not reported. * p≤0.1; ** p≤0.05; *** p≤0.01

Regarding market factors, the competitive pressure (COMP_PRE) a firm is exposed to – measured as number of competitors – has a significant positive effect on whether it implements EP-innovations. However, the sub-sector a firm operates in – household appliance (SEC_HA), information & communication technology (SEC_IT), or medical appliances (the base category) – does not have a significant effect.

As to environmental issues, there are some significant differences between them: firms are less likely to implement EP-innovations for the issues toxic substances (I_TOX) and electromagnetic fields (I_EMF) than for the base category energy efficiency. Additionally, EP-innovations are significantly more likely for the issue material efficiency (I_MAT) than for I_EMF. There are no statistically significant differences between the remaining issue pairs. The Wald test statistics for all issue pairs are reported in table A9 in the appendix.

In column 3 of table 3 the regression result for EPI_ANY with the same restricted predictor set for the Germany sample are shown. As in the previous study[15], REG_STR, CUST_BEN, GREENCAP, and I_TOX have statistically significant positive effects on EPI_ANY in the model for Germany. As to the effect of regulatory stringency on EPI_ANY, the results show that this effect is stronger in California than in Germany. A 1-unit raise of REG_STR increases the odds of EPI_ANY by a factor of 7.3 in the California model, but only by a factor of 2 in the Germany model. In contrast, the effect of customer benefit is smaller in the California model: a 1-unit increase of CUST_BEN changes the odds of EPI_ANY by a factor of 1.9 in the California model compared to a factor of 2.9 in the Germany model.

To visualize these differences, figures 6a-d show how these two variables increase the predicted probabilities of EPI_ANY for each model. The effects of regulatory stringency are illustrated in figure 6a for California and figure 6b for Germany. Each has four curves illustrating how REG_STR (the x-axes) affects the predicted probability of EPI_ANY (the y-axes) for a specific environmental issue. In order to facilitate the comparison of the two models, I estimated an additional curve for a synthetic issue. The effects of each surveyed issue account for 25% of the synthetic issue[16]. Besides customer benefit, the remaining variables are held constant at their median. CUST_BEN is held at its minimum to lower the predicted probabilities and thus make them easier to compare in the figures[17].

Looking at the synthetic issue, we can see that EP-innovations are more likely in California than in Germany, irrespective of regulatory stringency: for minimum REG_STR (and CUST_BEN) a median California firm already has a likelihood of around 60% to implement EP-innovations. A firm in Germany only has a likelihood of around 30% to do so under the same conditions. Additionally, in California the increase of REG_STR has a larger effect on EPI_ANY: increasing REG_STR from “very easy” to “moderate” raises the likelihood of EPI_ANY to 99%. In contrast, the likelihood of EPI_ANY in Ger-

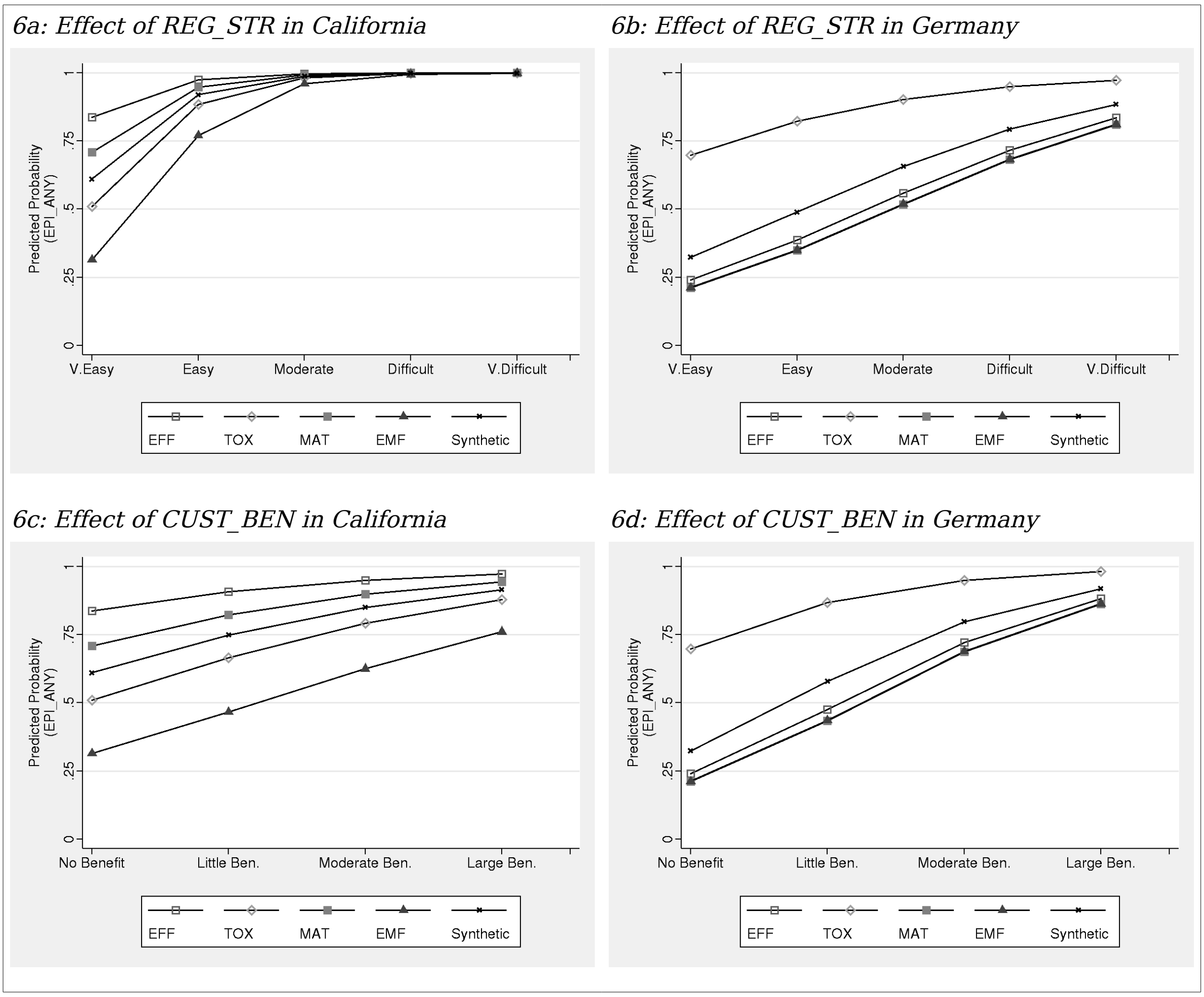
15 The regression results for EPI_ANY with specification from Kammerer (2008) are reported in table A6 in the appendix.

16 These predictions have been estimated by holding the issue dummies I_TOX, I_MAT, and I_EMF constant at 0.25.

17 Figures A1a-d in the appendix display the predicted probabilities of EPI_ANY with all variables (including CUST_BEN) held constant at their median. They show the same characteristics regarding effect size as figures 6a-d.

many rises only to 66%. Interestingly, for all environmental issues the likelihood of EPI_ANY is larger in California except for TOX. For this issue, the median firm in Germany is more likely to implement EP-innovations than the one in California, as long as regulatory stringency is at its lowest rank. For all other environmental issues, the median firm in California is more likely to implement EP-innovations than the one in Germany, regardless of regulatory stringency.

Figures 6a-d: Predicted probabilities of EP-innovation (EPI_ANY)[18]



Figures 6c,d show the effects of customer benefit on EPI_ANY in California (6c) and Germany (6d) when REG_STR is held constant at its minimum. Obviously, the probability of EPI_ANY with minimum customer benefit is larger in California than in Germany as these are the same conditions as in figures 6a-b: REG_STR and CUST_BEN are at their minimum and the other variables are at their median. However, with increasing customer benefit the probability of EPI_ANY rises steeper in Germany. For the maxim-

18 Predicted probabilities for medians of GREENCAP (1), EMPLOYEE (0.12; in thds.), SEC_REV ("81-100%"), COMP_PRE ("6-10"); and for minima of CUST_BEN (fig. 6a,b) and REG_STR (fig. 6c,d), respectively.

um customer benefit it even catches up with the probability in California: in both states, the median firm has a likelihood of 92% to implement EP-innovations.

4.2 Extent of EP-Innovation

Table 4 reports the results for the ordered logit regression of EPI_EXT. The extent of EP-innovation measures the share of products for which EP-innovations have been implemented.

Table 4: Ordered logit analysis for extent of EP-innovation (EPI_EXT)

	California sample	Germany sample
REG_STR	1.793***	1.804***
	(0.355)	(0.222)
CUST_BEN	1.606**	1.854***
	(0.330)	(0.271)
GREENCAP		
EMPLOYEE		
R&D_EMPL		
SCTR_REV	1.396**	1.036
	(0.199)	(0.130)
COMP_PRE	1.343*	1.129
	(0.232)	(0.149)
SEC_HA		
SEC_IT		
I_TOX	0.924	2.889***
	(0.340)	(0.694)
I_MAT	0.676	1.136
	(0.182)	(0.323)
I_EMF	0.469**	0.818
	(0.174)	(0.230)
N	192	355
aic	592.5	1152.1
bic	631.6	1198.6

Reduced models with odds ratios for 1-unit increases of predictor variables; robust standard errors clustered by firms in parentheses; thresholds are not reported. * p≤0.1; ** p≤0.05; *** p≤0.01

As for the California results in the second column, regulatory stringency and customer benefit have a highly significant positive effect on the extent of EP-innovation. This supports hypotheses H1b and H2b: the more stringent regulation is and the larger customer benefit, the larger is the extent to which firms implement EP-innovations. Regarding the control variables, SCTR_REV is the only firm-internal factor that has a statistically significant effect: the extent of EP-innovation is larger when a firm's revenue in the surveyed sub-sector exhibits a larger share of its total revenue. However, neither green capabilities nor firm size or R&D activities have a significant effect on EPI_EXT[19].

The positive impact of competitive pressure on EPI_EXT is only weakly significant, while the sub-sector itself does not play a role. As for environmental issues, firms implement EP-innovation to a lesser extent for EMF than for EFF or TOX (see table A9). There are no statistically significant differences between the remaining issue pairs.

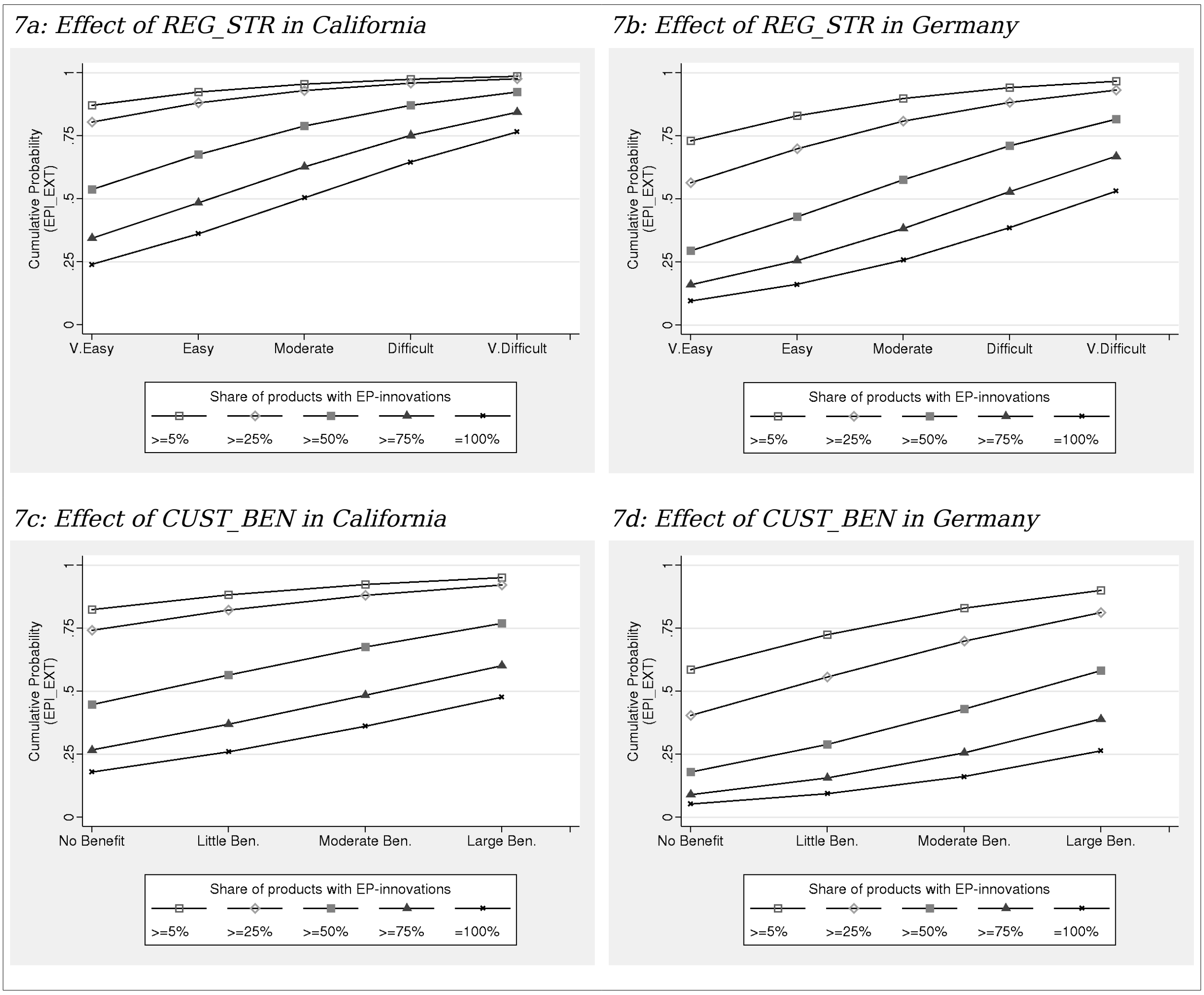
To compare the California data with the Germany data, the regression model for the Germany data – in the third column – has the same predicator variables as the reduced California model. As in the model of my previous study, in the Germany model REG_STR, CUST_BEN, and I_TOX have highly significant positive effects on EPI_EXT[20]. Comparing the regression results for California and Germany, we can see that the effect of REG_STR is about the same in both models, whereas the effect of CUST_BEN is stronger in Germany than in California. Note that regulation has a larger maximal effect than customer benefit in both models. The odds ratios reported are computed for a 1-unit increase of the predictor variables. As REG_STR has a range of 5 units compared to 4 units for CUST_BEN, the odds ratios for a minimum to maximum change are considerably larger for regulation[21] than for customer benefit[22].

To visualize these effect sizes, figures 7a-d show cumulative probabilities of EPI_EXT. These probabilities have been estimated for the median firm, varying only regulatory stringency (fig. 7a,b) and customer benefit (fig. 7c,d), respectively. Looking at the upper figures we can see that a median firm in California (fig. 7a) implements EP-innovations to a larger extent than its German counterpart does (fig. 7b), irrespective of the regulatory stringency. For example, with minimum regulatory stringency the cumulative probability of an EP-innovation extent of “>=50%” is already 0.54 in California, and increases via 0.79 (medium regulatory stringency) to 0.92 for maximum regulatory stringency; the same outcome in Germany only has a cumulative probability of 0.29

19 The Wald test statistics for EMPLOYEE, R&D_EMPL, GREENCAP, SEC_HA, and SEC_IT to simultaneously have a coefficient of zero are chi2(5) = 4.36; Prob = 0.4991
20 The test results for EPI_EXT from the previous study are reported in table A7 in the appendix.
21 Cal: $OR(REG\_STR)_{min->max} = (1.793)^5 = 18.5$; Ger: $OR(REG\_STR)_{min->max} = (1.804)^5 = 19.1$
22 Cal: $OR(CUST\_BEN)_{min->max} = (1.606)^4 = 6.7$; Ger: $OR(CUST\_BEN)_{min->max} = (1.854)^4 = 11.8$

(minimum REG_STR) that rises via 0.58 to 0.82 (maximum REG_STR). The slopes are very similar for California and Germany.

Figures 7a-d: Predicted probabilities of EP-innovation extent (EPI_EXT)[23]



Even if customer benefit varies, a median firm in California (fig. 7c) has a larger extent of EP-innovation compared to a median German firm (fig. 7d). Here the slopes differ, however, with the California one being less steep. For example, the probability of the outcome “=100%” rises from 0.18 to 0.48 in California with increasing customer benefit. For Germany, the cumulative outcome “>=50%” starts with the same probability of 0.18, yet rises up to 0.58 for maximum customer benefit.

23 Variables are held at their median (REG_STR: “easy”; CUST_BEN: “moderate”; SEC_REV: “81-100%”; COMP_PRE: “6-10”), issue dummies are held at 0.25 (synthetic issue). Cumulative probabilities for specific issues are provided in figures A2-A3 in the appendix.

4.3 Novelty of EP-Innovation

The third EP-innovation variable is EPI_NOV, measuring the novelty of innovation, that is if EP-innovations are only novel for the firm or also (partly) novel to the market. It has four ordered categories, ranging from "No Novelties" to "Mainly Market Novelties". Table 5 reports the ordered logit results of EPI_NOV for the California (second column) and Germany (third column) samples.

Table 5: Ordered logit analysis for novelty of EP-innovation (EPI_NOV)

	California sample	**Germany sample**
REG_STR	1.347	1.224*
	(0.268)	(0.142)
CUST_BEN	2.038***	1.866***
	(0.442)	(0.246)
GREENCAP	1.458**	1.354***
	(0.225)	(0.112)
EMPLOYEE		
R&D_EMPL		
SCTR_REV		
COMP_PRE	1.931***	1.036
	(0.360)	(0.119)
SEC_HA	0.271**	0.857
	(0.173)	(0.296)
SEC_IT	1.124	1.657
	(0.568)	(0.539)
I_TOX	0.462**	2.290***
	(0.155)	(0.664)
I_MAT	0.594	0.817
	(0.241)	(0.253)
I_EMF	0.300***	0.989
	(0.116)	(0.313)
N	192	355
aic	351.9	889.1
bic	391.0	935.5

Reduced models with odds ratios for 1-unit increases of predictor variables; robust standard errors clustered by firms in parentheses; thresholds are not reported. * p≤0.1; ** p≤0.05; *** p≤0.01

First discussing the California model, it can be seen that regulatory stringency does not have a significant effect on the novelty of EP-innovation. Thus, my hypothesis 1c is rejected by the California data set. Customer benefit however has a highly significant positive effect on the novelty of EP-innovation supporting hypothesis 2c. As for firm-internal factors, green capabilities is the only factor to have a significant effect on EPI_NOV[24]: the more green capabilities a firm has the more likely it is to implement EP-innovations that are market novelties. Regarding market factors, EPI_NOV is the only EP-innovation measure for which there are significant differences between the sub-sectors: manufacturers of household appliances (SEC_HA) are less likely to implement market novelties than IT or medical appliances manufacturers[25]. Additionally, competitive pressure has a positive influence on EPI_NOV. There are also differences between the environmental issues. Similar to the results for EPI_ANY, firms implement more novel EP-innovations for energy efficiency than for toxic substances (I_TOX) and electromagnetic fields (I_EMF). There are no significant differences between the remaining issue pairs (see table A9).

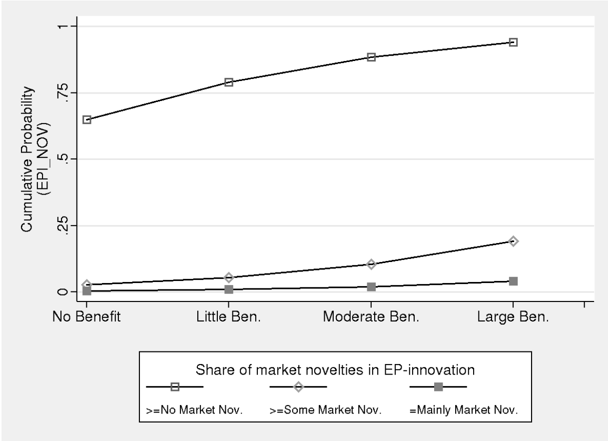
Contrary to the California model, regulatory stringency has a positive effect on EPI_NOV in the Germany model, yet with weak significance only. Further, CUST_BEN, GREENCAP, and I_TOX have positive effects on EPI_NOV. Interestingly, there are no differences between the sub-sectors regarding novelty of EP-innovation in the Germany model.

Figures 8a-f illustrate the effect of CUST_BEN on EPI_NOV in California (left column) and Germany (right column). In figure 8a, we can see that the median firm in California is very unlikely to implement at least “some market novelties”. Even for a “large” customer benefit, the probability only reaches 19%. In Germany (fig. 8b), the odds for market novelties are higher. Here a median firm already has a probability of 53% to implement at least “some market novelties”. In figures 8c-f, these conditions are retained but firms' green capabilities are raised. Still, the probability of at least “some market novelties” does not surpass the 50% line in California, unless CUST_BEN and GREENCAP are at its maximum (fig. 8e). In Germany, the probability of at least “some market novelties” passes over 50% for firms with a GREENCAP score of 3 and “moderate” customer benefit (fig. 8d); or for firms with a GREENCAP score of 5 if they recognize at least a “little” customer benefit (fig. 8f). For those firms, even the outcome “mainly market novelties” surpasses the 50% line if they recognize a “large” customer benefit.

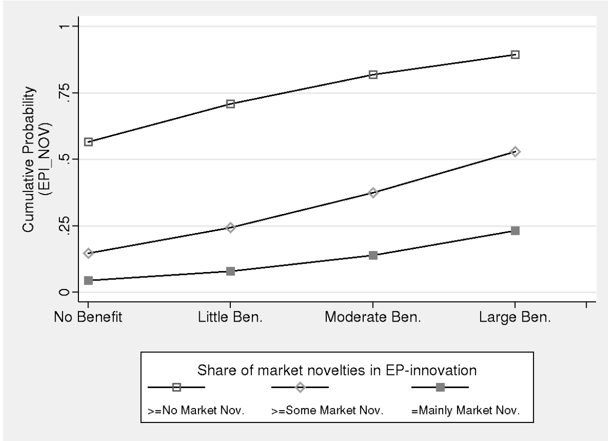
24 The Wald test statistics for EMPLOYEE, R&D_EMPL, and SEC_REV to simultaneously have a coefficient of zero are chi2(3) = 1.36; Prob > chi2 = 0.7149
25 Wald test statistics for SEC_HA = SEC_IT: chi2(1) = 6.98; Prob = 0.0082

Figures 8a-f: Effects of customer benefit on EP-innovation novelty (EPI_NOV)[26]

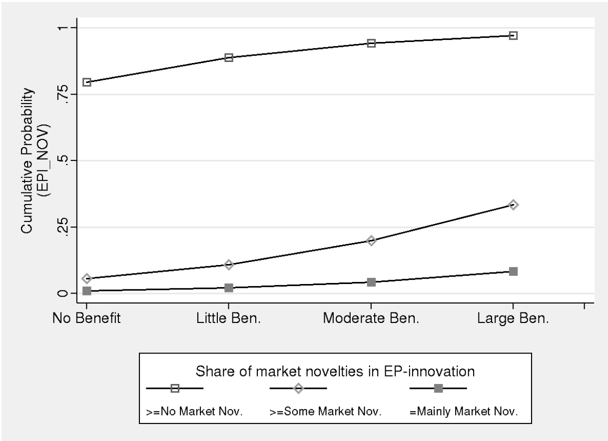
8a: Effects for GREENCAP=1 in California



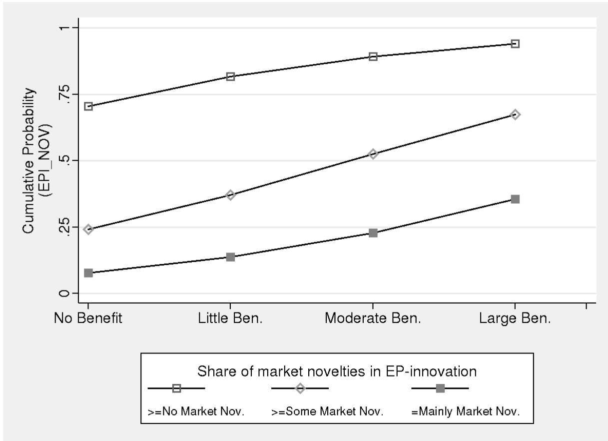
8b: Effects for GREENCAP=1 in Germany



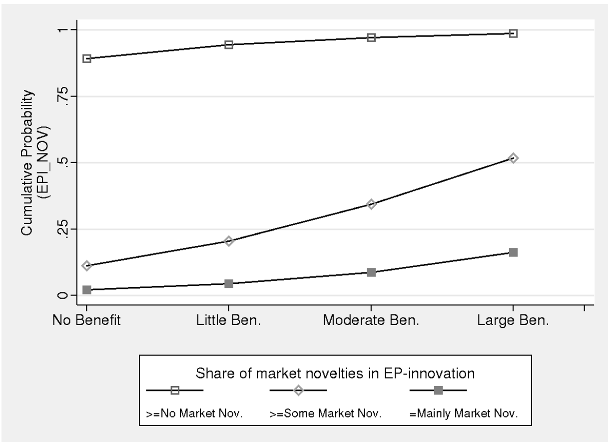
8c: Effects for GREENCAP=3 in California



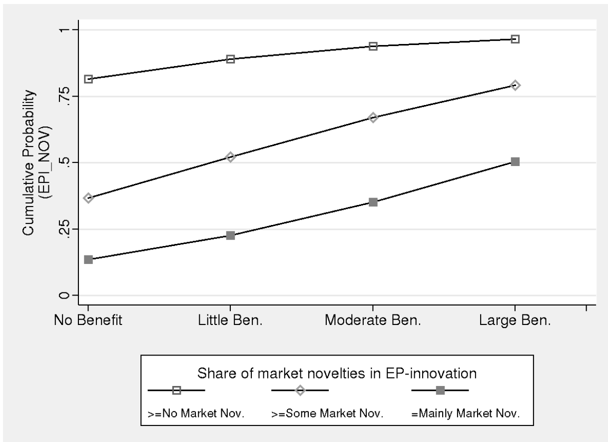
8d: Effects for GREENCAP=3 in Germany



8e: Effects for GREENCAP=5 in California



8f: Effects for GREENCAP=5 in Germany



26 Predicted probabilities for median REG_STR ("easy") and COMP_PRE ("6-10"); issue dummies are held at 0.25 (synthetic issue) and sector dummies at 0.333 (synthetic sub-sector).

5 Conclusion

In this paper, I have examined influence of regulation and customer benefit on environmental product innovation in California. The empirical testing was done on a unique data set: 52 Californian manufacturers of electrical and electronic appliances have been surveyed on their environmental product innovations regarding four environmental issues (energy efficiency, toxic substances, material efficiency, and electromagnetic fields). Additionally, I compared this data with a similar data set on German manufacturers.

The most important empirical finding is that, overall, the stimulating effect of regulation and customer benefit has been corroborated. More specifically, the importance of customer benefit for firms' environmental innovation activities is supported for all EP-innovation measures. The potential for customer benefit not only stimulates firms to implement EP-innovations and to apply them to a large share of their products, it also motivates firms to go beyond the diffusion of already-known improvements and to develop and implement environmental product innovations that are novel to the market.

The influence of regulation – the other variable of main interest in this study – is less extensive. It has been shown that more stringent regulation leads to both more firms implementing EP-innovations and firms implementing EP-innovations more broadly. However, a relationship between regulation and EP-innovations which are novel to the market could not be corroborated. This leads me to the conclusion that regulation plays only a minor role – if at all – for the development and implementation of market novelties. Nevertheless, for the diffusion of EP-innovations, regulation is more important than customer benefit, that is, it has a larger effect size. This can be summarized as customer benefit stimulates firms more strongly to come up with novel EP-innovations while more stringent regulation leads to a broader diffusion of EP-innovations that have already been introduced to the market.

With regard to the actual EP-innovation activity, this study revealed some interesting differences between California and Germany. Again, there is a distinction between the extent and the novelty of EP-innovation. On the one hand, a Californian firm is more likely to implement EP-innovations than a German firm is; and it also implements these innovations on a broader range. On the other hand, firms in Germany generally develop and implement more EP-innovations that are novel to the market.

This can be explained by the varieties of capitalism theory. Following this approach, liberal market economies like California are characterized by intense product competition. In such a competitive market, firms need to quickly adopt new (environmental) attributes that competitors have introduced to their products. This interpretation is further supported by the fact that competitive pressure, which has no effect in Germany, has a positive effect on all EP-innovation measures in California. In contrast, coordinated market economies like Germany focus more on product differentiation and niche production. Therefore, those firms have the capacity to develop novel solutions to environmental challenges and they also have a market strategy that embraces novel (environmental) product attributes.

While it has not been the intention of this paper to test the varieties of capitalism framework, the fact that my hypotheses are confirmed in a liberal market economy as well as in a coordinated market economy – and even adapt themselves to the specific market characteristics – provides strong support for my hypotheses. Therefore, although the hypotheses have only been tested for these two states, I am confident that they also apply to other states, be they liberal or coordinated market economies.

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7 Appendix

Variables and their underlying questions in the online-questionnaire:

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_EXT (extent 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 California (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)?”

GREENCAP (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 its products?”

“Has your company set up voluntary env. targets for products?”

“Does your company use the env. attributes of its products in marketing?”

EMPLOYEE (firm size): “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 question: "How many employees (full-time equivalent) did your company have in research and development (R&D) in 2006?"

SCTR_REV (sector specific revenue): "What percentage of total revenue did your company achieve in the past 3 years with household appliances (information & communication technology / medical appliances) products?"

COMP_PRE: (competitive pressure): "How many direct competitors do you have in the household appliances (information & communication technology / medical appliances) industry?"

Table A1: Regulatory stringency in the two samples (California and Germany)

		Very Easy	Easy	Moderate	Difficult	Very Difficult	No Answer	Total
EFF	**Ger**	67	8	15	1	0	0	91
	(%)	73.6	8.8	16.5	1.1	0.0	0.0	100
	Cal	26	8	12	2	1	3	52
	(%)	50.0	15.4	23.1	3.9	1.9	5.8	100
TOX	**Ger**	18	19	24	21	5	4	91
	(%)	19.8	20.9	26.4	23.1	5.5	4.4	100
	Cal	18	9	14	6	1	4	48
	(%)	34.6	17.3	26.9	11.5	1.9	7.7	100
MAT	**Ger**	14	26	34	15	0	2	91
	(%)	15.4	28.6	37.4	16.5	0	2.2	100
	Cal	19	13	12	2	0	6	52
	(%)	36.5	25.0	23.1	3.9	0	11.5	100
EMF	**Ger**	12	16	40	14	3	6	85
	(%)	13.2	17.6	44.0	15.4	3.3	6.6	100
	Cal	10	10	21	1	2	8	44
	(%)	19.2	19.2	40.4	1.9	3.9	15.4	100

Table A2: Customer benefit in the two samples (California and Germany)

		No Benefit	Little Benefit	Moderate Benefit	Large Benefit	No Answer	TOTAL
EFF	**Ger**	10	26	32	23	0	91
	(%)	11.0	28.6	35.2	25.3	0	100
	Cal	5	13	10	22	2	52
	(%)	9.6	25.00	19.2	42.3	3.9	100
TOX	**Ger**	16	39	24	12	0	91
	(%)	17.6	42.9	26.4	13.2	0	100
	Cal	4	10	19	13	6	52
	(%)	7.7	19.2	36.5	25.0	11.5	100
MAT	**Ger**	17	34	26	14	0	91
	(%)	18.7	37.4	28.6	15.4	0	100
	Cal	4	11	19	12	6	52
	(%)	7.7	21.2	36.5	23.1	11.5	100
EMF	**Ger**	16	22	34	16	3	91
	(%)	17.6	24.2	37.4	17.6	3.3	100
	Cal	4	17	14	7	10	52
	(%)	7.7	32.7	26.9	13.5	19.2	100

Table A3: EPI_ANY in the two samples (California and Germany)

		No	Yes	No Answer	TOTAL
EFF	**Ger**	29	61	1	91
	(%)	31.9	67.0	1.1	100
	Cal	4	46	2	52
	(%)	7.7	88.5	3.9	100
TOX	**Ger**	6	85	0	91
	(%)	6.6	93.4	0	100
	Cal	7	43	2	52
	(%)	13.5	82.7	3.9	100
MAT	**Ger**	24	65	2	91
	(%)	26.4	71.4	2.2	100
	Cal	6	42	4	52
	(%)	11.5	80.8	7.7	100
EMF	**Ger**	20	65	6	91
	(%)	22.0	71.4	6.6	100
	Cal	7	37	8	52
	(%)	13.5	71.2	15.4	100

Table A4: EPI_EXT in the two samples (California and Germany)

		0%	<5%	5-25%	26-50%	51-75%	76-100%	No Answer	TOTAL
EFF	**Ger**	29	13	18	15	5	9	2	91
	(%)	31.9	14.3	19.8	16.5	5.5	9.9	2.2	100
	Cal	4	2	10	9	6	18	3	52
	(%)	7.7	3.9	19.2	17.3	11.5	34.6	5.8	100
TOX	**Ger**	6	7	21	12	12	29	4	91
	(%)	6.6	7.7	23.1	13.2	13.2	31.9	4.4	100
	Cal	7	3	5	8	3	23	3	52
	(%)	13.5	5.8	9.6	15.4	5.8	44.2	5.8	100
MAT	**Ger**	24	10	13	12	11	18	3	91
	(%)	26.4	11.0	14.3	13.2	12.1	19.8	3.3	100
	Cal	6	1	13	6	6	15	5	52
	(%)	11.5	1.9	25.0	11.5	11.5	28.9	9.6	100
EMF	**Ger**	20	9	23	13	5	15	6	91
	(%)	22.0	9.9	25.3	14.3	5.5	16.5	6.6	100
	Cal	7	3	9	7	5	12	9	52
	(%)	13.5	5.8	17.3	13.5	9.6	23.1	17.3	100

Table A5: EPI_NOV in the two samples (California and Germany)

		No Novelties	No Market Novelties	Some Market Novelties	Mainly Market Novelties	No Answer	TOTAL
EFF	**Ger**	29	20	21	14	7	91
	(%)	31.9	22.0	23.1	15.4	7.7	100
	Cal	4	27	12	5	4	52
	(%)	7.7	51.9	23.1	9.6	7.7	100
TOX	**Ger**	6	39	23	16	7	91
	(%)	6.6	42.9	25.3	17.6	7.7	100
	Cal	7	30	4	5	6	52
	(%)	13.5	57.7	7.7	9.6	11.5	100
MAT	**Ger**	24	35	15	10	7	91
	(%)	26.4	38.5	16.5	11.0	7.7	100
	Cal	6	26	10	3	7	52
	(%)	11.5	50.0	19.2	5.8	13.5	100
EMF	**Ger**	20	28	20	12	11	91
	(%)	22.0	30.8	22.0	13.2	12.1	100
	Cal	7	27	5	1	12	52
	(%)	13.5	51.9	9.6	1.9	23.1	100

Table A6: Full and reduced logit models for EPI_ANY

	California sample			Germany sample		
	full model	**reduced model**	**reduced (no EMF cases)**	**full model**	**reduced model**	**Kammerer 2008 model**
REG_STR	6.851***	7.345***	13.189**	2.049***	2.000***	2.028***
	(3.284)	(3.889)	(16.611)	(0.412)	(0.381)	(0.397)
CUST_BEN	2.156**	1.907*	1.852	2.841***	2.870***	2.859***
	(0.811)	(0.632)	(0.741)	(0.550)	(0.571)	(0.543)
GREENCAP	2.095**	1.763**	1.805	1.838***	1.774***	1.838***
	(0.700)	(0.507)	(0.657)	(0.339)	(0.299)	(0.340)
EMPLOYEE	0.781	0.871***	0.840***	0.982	0.985	0.977
	(0.170)	(0.034)	(0.054)	(0.040)	(0.046)	(0.039)
R&D_EMPL	0.319			5.008		5.418
	(1.167)			(9.748)		(10.167)
SCTR_REV	1.930**	1.923***	1.817**	1.090	1.150	
	(0.556)	(0.437)	(0.448)	(0.180)	(0.193)	
COMP_PRE	2.818**	2.187**	2.819	0.967	0.967	
	(1.259)	(0.865)	(1.881)	(0.169)	(0.159)	
SEC_HA	0.164*			0.939		0.901
	(0.156)			(0.420)		(0.407)
SEC_IT	0.540			2.060		2.068
	(0.537)			(1.008)		(1.007)
I_TOX	0.192**	0.201**	0.174*	7.904***	7.321***	7.853***
	(0.161)	(0.157)	(0.155)	(4.175)	(3.890)	(4.185)
I_MAT	0.503	0.470	0.450	0.855	0.848	0.870
	(0.448)	(0.390)	(0.402)	(0.364)	(0.363)	(0.373)
I_EMF	0.078***	0.089**		0.888	0.853	0.888
	(0.074)	(0.087)		(0.405)	(0.388)	(0.405)
_cons	0.001**	0.001***	0.000**	0.014***	0.017***	0.018***
N	192	192	148	355	355	355
aic	98.4	97.3	69.1	281.8	282.0	278.4
bic	140.8	129.8	96.1	332.2	320.8	321.0

Table A7: Full and reduced ordered logit models for EPI_EXT

	California sample			Germany sample		
	full model	**reduced model**	**reduced (no EMF cases)**	**full model**	**reduced model**	**Kammerer 2008 model**
REG_STR	1.766***	1.793***	1.835***	1.851***	1.804***	1.879***
	(0.368)	(0.355)	(0.395)	(0.244)	(0.222)	(0.238)
CUST_BEN	1.565**	1.606**	1.499*	1.832***	1.854***	1.864***
	(0.331)	(0.330)	(0.334)	(0.262)	(0.271)	(0.265)
GREENCAP	1.253			1.335***		1.325***
	(0.213)			(0.102)		(0.103)
EMPLOYEE	0.965			1.091***		1.082***
	(0.081)			(0.030)		(0.030)
R&D_EMPL	1.147			1.167		1.160
	(1.538)			(0.923)		(0.917)
SCTR_REV	1.331**	1.396**	1.347**	1.162	1.036	
	(0.176)	(0.199)	(0.192)	(0.117)	(0.130)	
COMP_PRE	1.392**	1.343*	1.474**	1.065	1.129	
	(0.220)	(0.232)	(0.286)	(0.125)	(0.149)	
SEC_HA	0.514			0.948		0.974
	(0.340)			(0.305)		(0.311)
SEC_IT	0.867			1.620		1.706*
	(0.542)			(0.512)		(0.544)
I_TOX	0.924	0.924	0.906	3.273***	2.889***	3.242***
	(0.353)	(0.340)	(0.340)	(0.861)	(0.694)	(0.857)
I_MAT	0.708	0.676	0.667	1.110	1.136	1.095
	(0.204)	(0.182)	(0.183)	(0.365)	(0.323)	(0.355)
I_EMF	0.478**	0.469**		0.834	0.818	0.811
	(0.179)	(0.174)		(0.256)	(0.230)	(0.248)
cut1	9.988*	10.345*	10.708*	23.470***	9.323***	10.826***
cut2	16.736**	16.861**	16.600**	52.545***	19.527***	24.164***
cut3	61.286***	60.010***	60.507***	181.237***	60.446***	82.599***
cut4	138.708***	133.185***	134.809***	426.303***	132.013***	193.372***
cut5	234.783***	221.113***	219.764***	811.022***	235.240***	366.473***
N	192	192	148	355	355	355
aic	592.7	592.5	452.4	1108.8	1152.1	1108.8
bic	648.0	631.6	485.3	1174.6	1198.6	1166.9

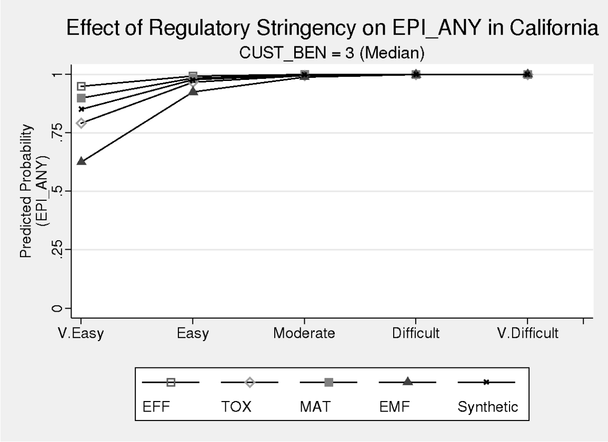
Table A8: Full and reduced ordered logit models for EPI_NOV

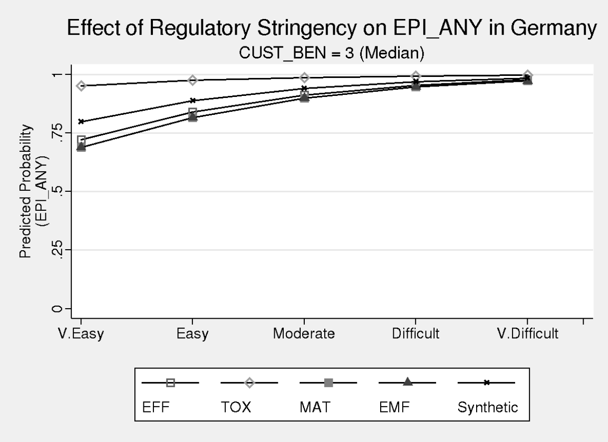
	California sample			Germany sample		
	full model	**reduced model**	**reduced (no EMF cases)**	**full model**	**reduced model**	**Kammerer 2008 model**
REG_STR	1.282	1.347	1.389	1.231*	1.224*	1.234*
	(0.248)	(0.268)	(0.319)	(0.143)	(0.142)	(0.146)
CUST_BEN	2.051***	2.038***	1.884***	1.835***	1.866***	1.849***
	(0.458)	(0.442)	(0.417)	(0.246)	(0.246)	(0.244)
GREENCAP	1.388*	1.458**	1.484**	1.254**	1.354***	1.247**
	(0.258)	(0.225)	(0.241)	(0.114)	(0.112)	(0.111)
EMPLOYEE	0.990			1.065*		1.062*
	(0.088)			(0.036)		(0.034)
R&D_EMPL	2.379			0.928		0.928
	(2.518)			(0.998)		(1.005)
SCTR_REV	1.107			1.077		
	(0.184)			(0.136)		
COMP_PRE	1.999***	1.931***	2.103***	1.018	1.036	
	(0.393)	(0.360)	(0.461)	(0.118)	(0.119)	
SEC_HA	0.320	0.271**	0.350	0.909	0.857	0.927
	(0.231)	(0.173)	(0.237)	(0.326)	(0.296)	(0.319)
SEC_IT	1.163	1.124	1.493	1.675	1.657	1.726*
	(0.570)	(0.568)	(0.764)	(0.551)	(0.539)	(0.570)
I_TOX	0.474**	0.462**	0.456**	2.262***	2.290***	2.259***
	(0.161)	(0.155)	(0.151)	(0.664)	(0.664)	(0.666)
I_MAT	0.601	0.594	0.603	0.805	0.817	0.807
	(0.245)	(0.241)	(0.244)	(0.253)	(0.253)	(0.253)
I_EMF	0.313***	0.300***		0.992	0.989	0.989
	(0.124)	(0.116)		(0.316)	(0.313)	(0.315)
cut1	13.868**	7.596**	10.737***	5.189**	4.227**	3.655**
cut2	932.026***	498.603***	730.115***	38.963***	31.856***	27.277***
cut3	5210.561***	2739.003***	4029.391***	149.093***	118.657***	104.186***
N	192	192	148	355	355	355
aic	355.7	351.9	278.0	888.4	889.1	885.3
bic	404.5	391.0	310.9	946.5	935.5	935.6

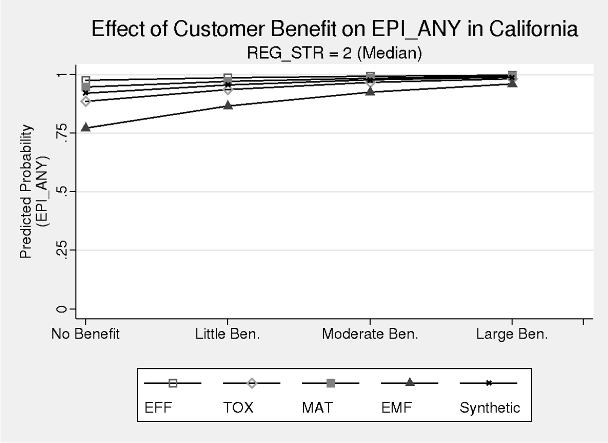
Table A9: Wald test statistics (chi2) and probabilities (prob) of null hypothesis for environmental issue pairs to simultaneously have an effect equal to zero in the logit models

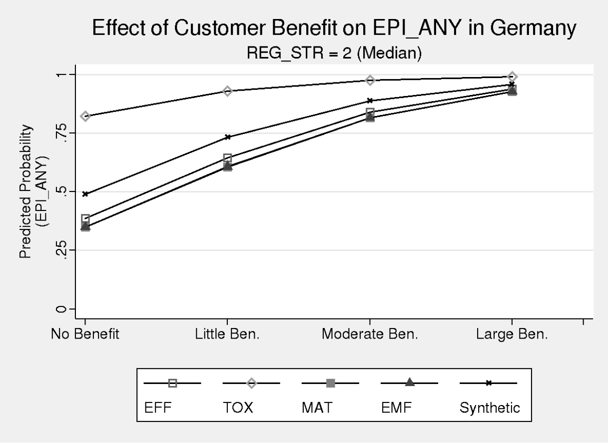
		I_TOX : I_MAT		**I_TOX : I_EMF**		**I_MAT : I_EMF**	
		chi2	**prob**	**chi2**	**prob**	**chi2**	**prob**
California	EPI_ANY	1.28	0.2578	0.92	0.3377	2.76	0.0968
	EPI_EXT	1.17	0.2792	4.09	0.0432	1.34	0.2469
	EPI_NOV	0.36	0.5463	1.39	0.2389	2.41	0.1208
Germany	EPI_ANY	22.52	< 0.0001	16.52	< 0.0001	0.00	0.9880
	EPI_EXT	12.54	0.0004	30.47	< 0.0001	1.56	0.2116
	EPI_NOV	23.91	< 0.0001	11.72	0.0006	0.54	0.4625

Figures A1a-d: Predicted probabilities of EPI_ANY

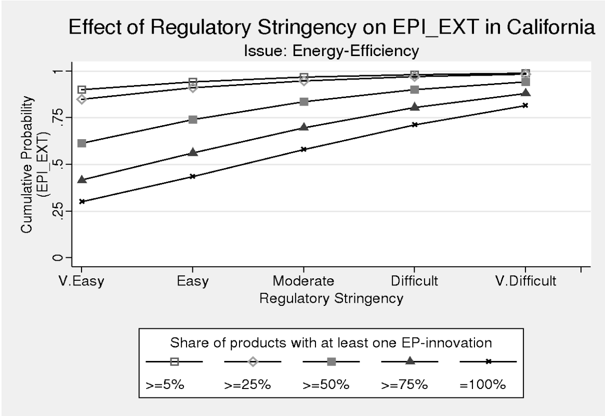


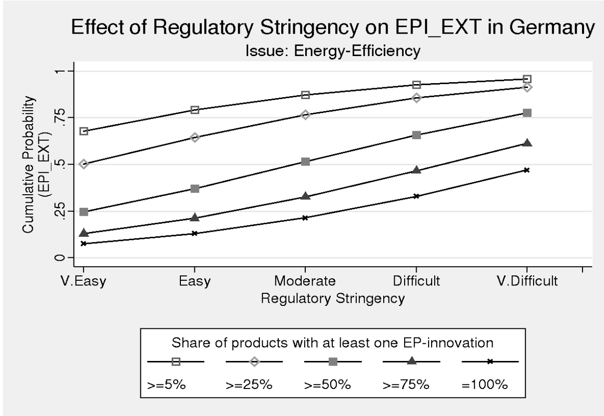


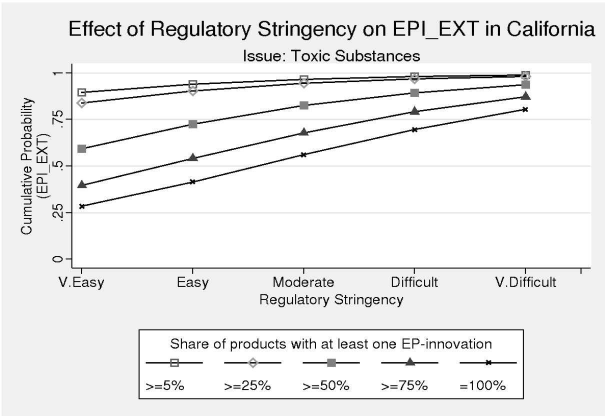


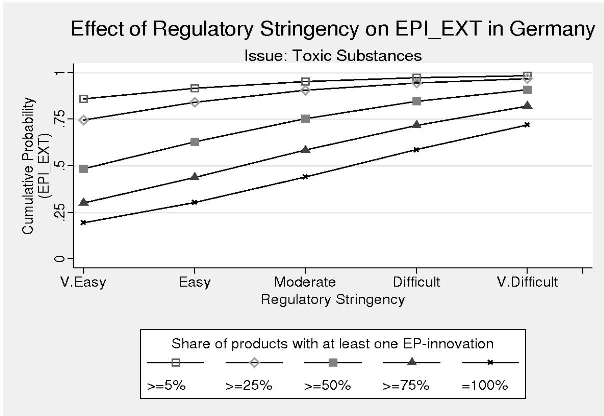


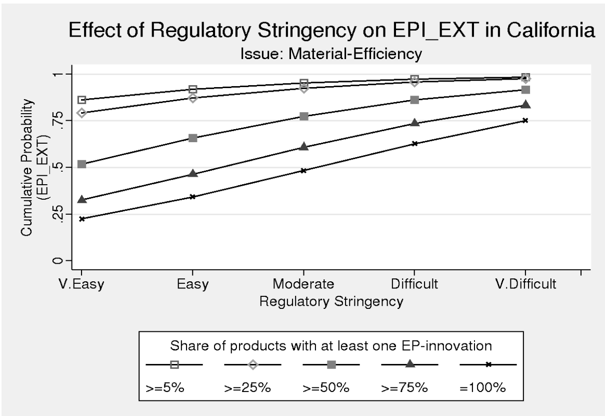
Figures A2a-h: Effect of Regulatory Stringency on Predicted probabilities of EPI_EXT

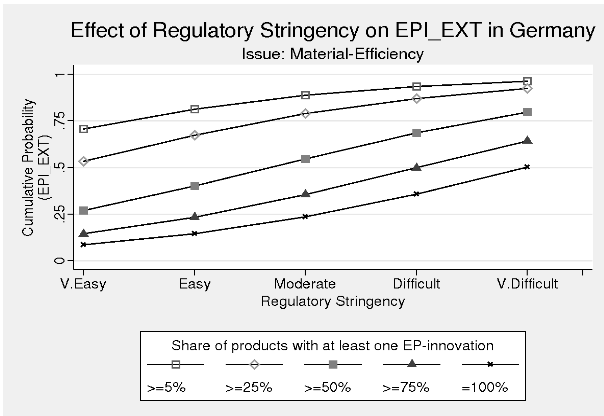


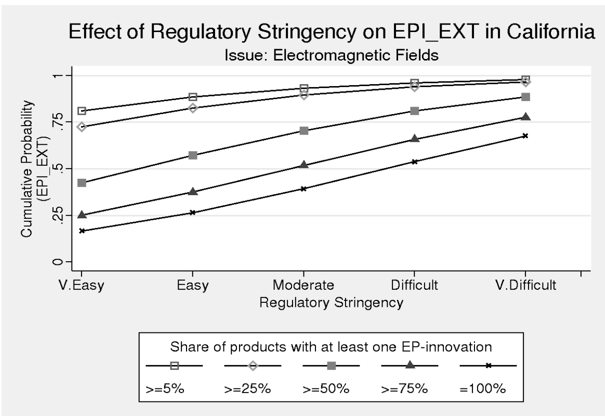


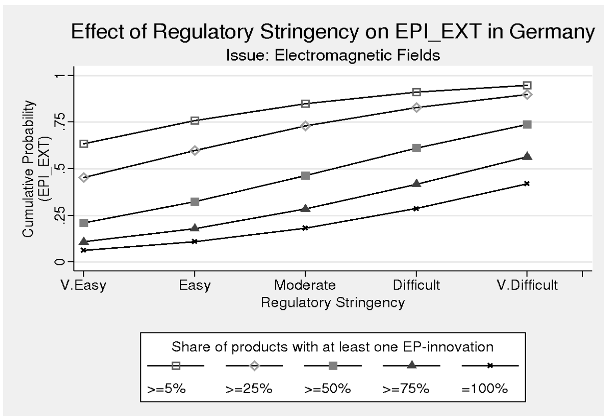




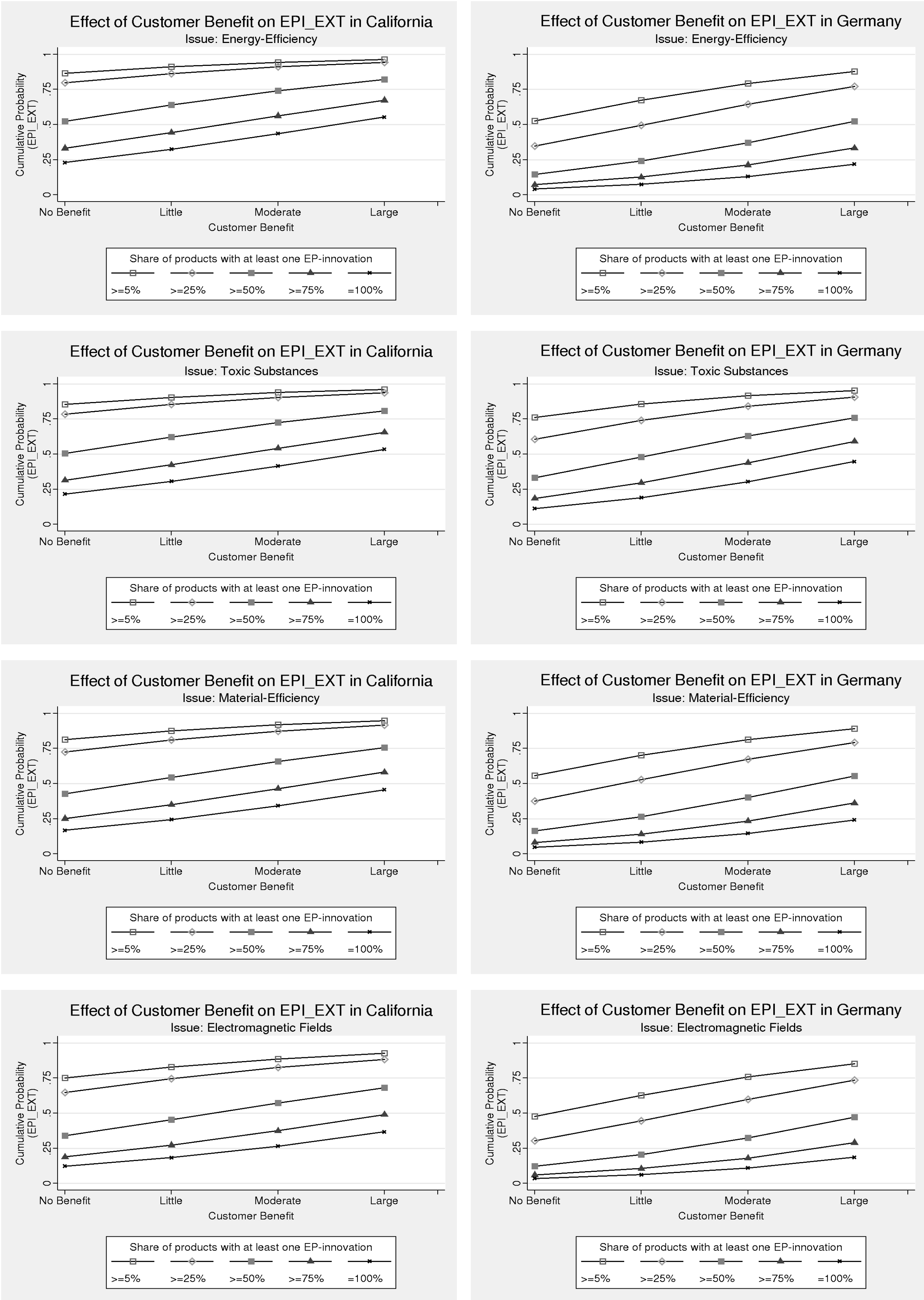








Figures A3a-h: Effect of Customer Benefit on Predicted probabilities of EPI_EXT



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APPENDIX A: QUESTIONNAIRE OF SURVEY IN CALIFORNIA

ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Environmental Improvements in Electrical and Electronic Appliances

Welcome to our survey!
We would like to thank you and your company for participating in our study.
ETH Zurich in collaboration with the **Lawrence Berkeley National Laboratory** is conducting this government-funded survey to study the drivers of environmental improvements in electrical and electronic appliances.

Instructions

Filling out this online-questionnaire is very straightforward. Just follow the instructions below.

Scope

This questionnaire is for the **Information & Communication Technology** division of the company **Sample Company**. The following definition of Information & Communication Technology applies to the entire questionnaire:

electronic devices / components for the processing / transmission of information

If your company is part of a multinational corporation, the questions only refer to those products **which are developed in California**.

Answering questions

The questionnaire consists of 6 sections. It takes about 30 minutes to answer all the questions. If there are any questions you cannot answer (either because you do not know the answer or the question is not applicable to your company) please enter n.a. (no answer) or skip the question altogether.

Personalization

Your name: __________

Your function in the company: __________

Your e-mail address: __________

☐ Please send us the company-specific benchmark report free of charge.

Section 1: General company characteristics

This section is intended to help us obtain a general picture of your company regarding ownership structure, size and R&D activities.

1: Company structure

	Yes	No	n.a.
Does your company belong to a business / corporate group?	○	○	○
If yes, are you a subsidiary / branch?	○	○	○

2: Employees

How many employees (full-time equivalent) did your company have in 2006?

3: R&D Manpower

How many employees (full-time equivalent) did your company have in research and development (R&D) in 2006?

4: R&D Investments

What percentage of total revenue did your company spend on research and development (R&D) in the past 3 years?

5: Earning potential

	Significantly Worse	Worse	Average	Better	Significantly Better	n.a.
In comparison to the industry, how do you rate your company's earning potential?	○	○	○	○	○	○

Section 2: Regulatory Environment

In this section you will be asked about environmental regulation for Information & Communication Technology products. The questions are limited to 4 areas: **Energy Efficiency, Toxic Substances in Products, Material Efficiency and Electromagnetic Fields (EMF)**.

1: Regulations in the area of Energy Efficiency

This area comprises products' energy consumption during use / standby.

What percentage of your Information & Communication Technology products (based on total revenue) are affected by ...	0-25%	26-50%	51-75%	76-100%	n.a.
... the DOE Appliances and Commercial Equipment Standards Program? For details click here (www1.eere.energy.gov/buildings/appliance_standards)	○	○	○	○	○
... California's 2006 Appliance Efficiency Regulations? For details click here. (www.energy.ca.gov/appliances/2006regulations)	○	○	○	○	○
... the DOE Appliance Labeling Rule (EnergyGuide Label)? For details click here. (www.ftc.gov/bcp/conline/edcams/eande/contentframe_appliance_guide.html)	○	○	○	○	○

2: Further Regulations

Are there other federal or state regulations (laws, taxes, standards...) that apply to your Information & Communication Technology in the area of **Energy Efficiency**? If yes, please note.

3: Regulations in the area of Toxic Substances

This area comprises:
the number / total amount of toxic substances in the products
and the recycling / disposal of toxic material after the products' service life (e-waste).

What percentage of your Information & Communication Technology products (based on total revenue) are affected by ...	0-25%	26-50%	51-75%	76-100%	n.a.
... the California RoHS Law? For details click here (www.dtsc.ca.gov/HazardousWaste/RoHS.cfm)	○	○	○	○	○
... the California Proposition 65? For details click here (www.oehha.ca.gov/prop65/law/P65Regs.html)	○	○	○	○	○

4: Further Regulation

Are there other federal or state regulations (laws, taxes, standards...) that apply to your Information & Communication Technology in the area of **Toxic Substances**? If yes, please note.

5: Regulations in the area of Material Efficiency

This area comprises:
the number / amount of materials used in the products,
the re-use of material after the products' service life (recycling),
and the re-use of components after the products' service life (modularity).

What percentage of your Information & Communication Technology products (based on total revenue) are affected by ...	**0-25%**	**26-50%**	**51-75%**	**76-100%**	**n.a.**
... the California Electronic Waste Recycling Act? For details click here (www.dtsc.ca.gov/HazardousWaste/EWaste/#How_do_I_Know_if_my_E-Waste_is_Covered_by_the_Electronic_Waste_Recycling_Act?)	○	○	○	○	○
... the California Cell Phone Recycling Act? For details click here (www.dtsc.ca.gov/HazardousWaste/EWaste/upload/HWMP_FS_AB2901.pdf)	○	○	○	○	○

6: Further Regulation

Are there other federal or state regulations (laws, taxes, standards...) that apply to your Information & Communication Technology in the area of **Material Efficiency**? If yes, please note.

7: Regulations in the area of Electromagnetic Fields

This area comprises the strength of products' electromagnetic fields.

What percentage of your Information & Communication Technology products (based on total revenue) are affected by ...	**0-25%**	**26-50%**	**51-75%**	**76-100%**	**n.a.**
... the FDA Radiation Control Law? For details click here (www.fda.gov/cdrh/radhealth/lawsregstandards.html)	○	○	○	○	○
... the FCC Policy on Human Exposure to Radiofrequency Electromagnetic Fields? For details click here (www.fcc.gov/oet/rfsafety/)	○	○	○	○	○

8: Further Regulation

Are there other federal or state regulations (laws, taxes, standards...) that apply to your Information & Communication Technology in the area of **Electromagnetic Fields**? If yes, please note.

9: Most Important Products

Is your most commercially important Information & Communication Technology product subject to these regulations?

	Yes	No	n.a.
DOE Appliances and Commercial Equipment Standards	○	○	○
California's 2006 Appliance Efficiency Regulations	○	○	○
DOE Appliance Labeling Rule (EnergyGuide Label)	○	○	○
California RoHS Law	○	○	○
California Proposition 65	○	○	○
California Electronic Waste Recycling Act	○	○	○
California Cell Phone Recycling Act	○	○	○
FDA Radiation Control Law	○	○	○
FCC Policy on Human Exposure to Radiofrequency Electromagnetic Fields	○	○	○

10: Regulatory Stringency

In the past 3 years, how easy / difficult was it for your company to meet (federal or state) regulations in California for Information & Communication Technology?

In the area of ...	Very Easy	Easy	Moderate	Difficult	Very Difficult	n.a.
... Energy Efficiency	○	○	○	○	○	○
... Toxic Substances	○	○	○	○	○	○
... Material Efficiency	○	○	○	○	○	○
... Electromagnetic Fields	○	○	○	○	○	○

11: Regulatory Outlook

In your opinion, how will the regulatory environment for Information & Communication Technology change in California in the next 5 years?

In the area of ...	Much Less Stringent	Less Stringent	Remain As Is	More Stringent	Much More Stringent	n.a.
... Energy Efficiency	○	○	○	○	○	○
... Toxic Substances	○	○	○	○	○	○
... Material Efficiency	○	○	○	○	○	○
... Electromagnetic Fields	○	○	○	○	○	○

12: Regulatory Certainty

How easy / difficult is it to estimate the future development of regulations for Information & Communication Technology in California?

In the area of ...	Very Easy	Easy	Moderate	Difficult	Very Difficult	n.a.
... Energy Efficiency	○	○	○	○	○	○
... Toxic Substances	○	○	○	○	○	○
... Material Efficiency	○	○	○	○	○	○
... Electromagnetic Fields	○	○	○	○	○	○

Section 3: Environmental Product Improvements

This section concerns environmental product improvements. Please read the questions and annotations carefully. These are the most important questions for our study.

1: Environmental Product Improvements

Environmental product improvements are all technical changes that render a product more environmentally friendly. It does not matter, whether these changes are

- ecologically motivated or not
- based on your own developments or on your suppliers'.

Has your company implemented any environmental improvements in your Information & Communication Technology products in the past 3 years?	Yes	No	n.a.
In the area of Energy Efficiency (reduced energy consumption by products during use / standby)	○	○	○
In the area of Toxic Substances (reduced number / amount of toxic substances in products and improved disposal of these substances after service life)	○	○	○
In the area of Material Efficiency (reduced number / amount of materials in products and better re-use of materials and components after service life)	○	○	○
In the area of Electromagnetic Fields (reduced strength of products' electromagnetic fields)	○	○	○

2: Extent of Environmental Product Improvements

For what percentage of your Information & Communication Technology products have you implemented at least one improvement in the last 3 years?

In the area of ...	<5%	5-25%	26-50%	51-75%	76-100%	n.a.
... Energy Efficiency	○	○	○	○	○	○
... Toxic Substances	○	○	○	○	○	○
... Material Efficiency	○	○	○	○	○	○
... Electromagnetic Fields	○	○	○	○	○	○

3: Are these product improvements market novelties?

In the area of ...	Mainly Market Novelties	Some Market Novelties	No Market Novelties	n.a.
... Energy Efficiency	○	○	○	○
... Toxic Substances	○	○	○	○
... Material Efficiency	○	○	○	○
... Electromagnetic Fields	○	○	○	○

4: Origin of KnowHow

Are these product improvements based on in-house developments or externally acquired developments?

In the area of ...	Mainly In-House Developments	Both Equally	Mainly External Developments	n.a.
... Energy Efficiency	○	○	○	○
... Toxic Substances	○	○	○	○
... Material Efficiency	○	○	○	○
... Electromagnetic Fields	○	○	○	○

5: Reasons for product improvements in the area of Energy Efficiency

How important were the following reasons for the implementation of product improvements in the area of Energy Efficiency?

	Not Important	Somewhat Important	Important	Very Important	n.a.
Lowering of manufacturing costs	○	○	○	○	○
Product differentiation	○	○	○	○	○
Legal compliance (National)	○	○	○	○	○
Legal compliance (Overseas)	○	○	○	○	○
Avoiding further regulations	○	○	○	○	○
Improving the company's image	○	○	○	○	○
Satisfying customer demands	○	○	○	○	○

6: Reasons for product improvements in the area of Toxic Substances

How important were the following reasons for the implementation of product improvements in the area of Toxic Substances?

	Not Important	Somewhat Important	Important	Very Important	n.a.
Lowering of manufacturing costs	○	○	○	○	○
Product differentiation	○	○	○	○	○
Legal compliance (National)	○	○	○	○	○
Legal compliance (Overseas)	○	○	○	○	○
Avoiding further regulations	○	○	○	○	○
Improving the company's image	○	○	○	○	○
Satisfying customer demands	○	○	○	○	○

7: Reasons for product improvements in the area of Material Efficiency

How important were the following reasons for the implementation of product improvements in the area of Material Efficiency?

	Not Important	Somewhat Important	Important	Very Important	n.a.
Lowering of manufacturing costs	○	○	○	○	○
Product differentiation	○	○	○	○	○
Legal compliance (National)	○	○	○	○	○
Legal compliance (Overseas)	○	○	○	○	○
Avoiding further regulations	○	○	○	○	○
Improving the company's image	○	○	○	○	○
Satisfying customer demands	○	○	○	○	○

8: Reasons for product improvements in the area of EMF

How important were the following reasons for the implementation of product improvements in the area of Electromagnetic Fields?

	Not Important	Somewhat Important	Important	Very Important	n.a.
Lowering of manufacturing costs	○	○	○	○	○
Product differentiation	○	○	○	○	○
Legal compliance (National)	○	○	○	○	○
Legal compliance (Overseas)	○	○	○	○	○
Avoiding further regulations	○	○	○	○	○
Improving the company's image	○	○	○	○	○
Satisfying customer demands	○	○	○	○	○

9: Past Eco-Performance of Products

Compared to the competition, how would you rate the eco-performance of your Information & Communication Technology products **3 years ago**?

In the area of ...	Significantly Worse	Worse	Average	Better	Significantly Better	n.a.
... Energy Efficiency	○	○	○	○	○	○
... Toxic Substances	○	○	○	○	○	○
... Material Efficiency	○	○	○	○	○	○
... Electromagnetic Fields	○	○	○	○	○	○

10: Present Eco-Performance of Products

Compared to the competition, how would you rate the eco-performance of your Information & Communication Technology products **today**?

In the area of ...	Significantly Worse	Worse	Average	Better	Significantly Better	n.a.
... Energy Efficiency	○	○	○	○	○	○
... Toxic Substances	○	○	○	○	○	○
... Material Efficiency	○	○	○	○	○	○
... Electromagnetic Fields	○	○	○	○	○	○

11: Amount of Environmental Product Improvements

How many product improvements have been implemented in your most popular Information & Communication Technology product / product line in the last 3 years? (If over the last 3 years the same thing has been improved upon, e.g. a more efficient adapter each year, then each single improvement is counted.)

In the area of Energy Efficiency:	
In the area of Toxic Substances:	
In the area of Material Efficiency:	
In the area of Electromagnetic Fields:	

Section 4: Direct Customer Benefit

In this section the questions are about direct customer benefit. Environmental product improvements do not just improve the eco-performance of products but can also provide direct benefits to the customer.

1: Direct benefit to customers from product improvements in the area of Energy Efficiency

Potential benefits:

- lower electricity costs
- less heat build-up
- extended battery life for portable devices

How do you rate the direct benefit to your Information & Communication Technology customers from product improvements in the area of ...	**No Benefit**	**Little Benefit**	**Moderate Benefit**	**Large Benefit**	**n.a.**
... Energy Efficiency?	○	○	○	○	○

2: Direct benefit to customers from product improvements in the area of Toxic Substances

Potential benefits:

- lower health risks
- easier waste disposal

How do you rate the direct benefit to your Information & Communication Technology customers from product improvements in the area of ...	**No Benefit**	**Little Benefit**	**Moderate Benefit**	**Large Benefit**	**n.a.**
... Toxic Substances?	○	○	○	○	○

3: Direct benefit to customers from product improvements in the area of Material Efficiency

Potential benefits:

- smaller appliances
- improved repair and upgrade possibilities (modular design)
- easier disposal in the case of a recycling program

How do you rate the direct benefit to your Information & Communication Technology customers from product improvements in the area of ...	**No Benefit**	**Little Benefit**	**Moderate Benefit**	**Large Benefit**	**n.a.**
... Material Efficiency?	○	○	○	○	○

4: Direct benefit to customers from product improvements in the area of Electromagnetic Fields

Potential benefits:

- lower potential of health risks
- less electromagnetic interference with other electronic devices

How do you rate the direct benefit to your Information & Communication Technology customers from product improvements in the area of ...	**No Benefit**	**Little Benefit**	**Moderate Benefit**	**Large Benefit**	**n.a.**
... Electromagnetic Fields?	○	○	○	○	○

5: Importance of Customer Benefits

Do these customer benefits play an important part in the development and implementation of product improvements in your company?

In the area of ...	**Not Important**	**Somewhat Important**	**Important**	**Very Important**	**n.a.**
... Energy Efficiency	○	○	○	○	○
... Toxic Substances	○	○	○	○	○
... Material Efficiency	○	○	○	○	○
... Electromagnetic Fields	○	○	○	○	○

Section 5: Environmental Management

This section contains questions related to the environmental activities of your company.

1: Environmental Management

	Yes	No	n.a.
Has your company set up voluntary environmental targets?	○	○	○
If yes, do the voluntary environmental targets also concern your products?	○	○	○
Does your company conduct systematic environmental analyses of its products?	○	○	○
Does your company have environmental checklists for product development?	○	○	○
Does your company train its product developer in environmental issues?	○	○	○
Does your company use the environmental attributes of its products in marketing?	○	○	○

2: Manpower for Environmental Affairs

How many employees (full-time equivalent) did your company have for environmental affairs in 2006?

[ ]

3: Environmental Management System

	Yes	No	n.a.
Does your company have a certified environmental management system (e.g. ISO 14'001)?	○	○	○

If yes

A) according to which standard was it certified?

☐ISO 14'001

☐EMAS

Other: [ ]

B) in what year has it been certified for the first time?

[ ]

Section 6: Market Place

This last section concerns the market place. All questions refer only to your market segments in the Information & Communication Technology industry.

1: Importance of Information & Communication Technology for your company

	0-20%	21-40%	41-60%	61-80%	81-100%	n.a.
What percentage of total revenue did your company achieve in the past 3 years with Information & Communication Technology products?	○	○	○	○	○	○

2: Revenue of Information & Communication Technology

What percentage of the Information & Communication Technology revenue did your company achieve in the past 3 years in ...	0-20%	21-40%	41-60%	61-80%	81-100%	n.a.
... California?	○	○	○	○	○	○
... other US states?	○	○	○	○	○	○

3: Position in Supply Chain

What percentage of the Information & Communication Technology revenue did your company achieve in the past 3 years with ...	0-20%	21-40%	41-60%	61-80%	81-100%	n.a.
... industry / intermediate goods?	○	○	○	○	○	○
... final goods for private consumers?	○	○	○	○	○	○
... final goods for corporate / public customers?	○	○	○	○	○	○

4: Competitive Strategy

	<5%	5-20%	21-40%	41-60%	61-80%	81-100%	n.a.
For what percentage of your Information & Communication Technology range is cost leadership more important than product differentiation?	○	○	○	○	○	○	○

5: Product Life Cycle

How long is the average product life cycle of your Information & Communication Technology products (in years)?

[ ]

6: New Information & Communication Technology Products

	<5%	5-20%	21-40%	41-60%	61-80%	81-100%	n.a.
How many new Information & Communication Technology products does your company launch on average every year (as a percentage of total Information & Communication Technology range)?	○	○	○	○	○	○	○

7: Direct Competitors

	0	1-5	6-10	11-15	16-20	>20	n.a.
How many direct competitors do you have in the Information & Communication Technology industry?	○	○	○	○	○	○	○

8: Environmentally Friendly Products

	Very Low	Low	Moderate	Large	Very Large	n.a.
How large is the customer demand for Information & Communication Technology that clearly exceed the legally required environmental standards?	○	○	○	○	○	○
How large is the supply of Information & Communication Technology products that clearly exceed the legally required environmental standards?	○	○	○	○	○	○

End of Questionnaire

Finally, you have the opportunity to state your expertise in the specific subjects and comment on the questionnaire.

Please let us know how you rate your personal expertise in relation to the questions raised:	Very Low	Low	Moderate	High	Very High	n.a.
Section 2: Regulatory Environment	○	○	○	○	○	○
Section 3: Environmental Product Improvements	○	○	○	○	○	○
Section 5: Environmental Activities	○	○	○	○	○	○
Section 6: Market Place	○	○	○	○	○	○

Would you like to comment on the questionnaire?

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APPENDIX B: QUESTIONNAIRE OF SURVEY IN GERMANY

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Ökologische Verbesserungen von elektrischen & elektronischen Geräten

Willkommen zu unserer Studie

Wir möchten uns herzlich bei Ihnen und Ihrer Firma für die Teilnahme bedanken! Mit Ihren Antworten helfen Sie uns zu untersuchen, welchen Einfluss Umweltgesetze auf die Produktentwicklung von elektrischen & elektronischen Geräten haben.

Anleitung

Hier noch einige wichtige Instruktionen:

Beantwortung der Fragen

Der Fragebogen besteht insgesamt aus 6 Teilen. Die vollständige Beantwortung benötigt im Durchschnitt nicht länger als 30-40 Minuten. Sollten Sie auf eine der Fragen keine Antwort geben können (weil Sie es nicht wissen, oder die Frage für Ihr Unternehmen nicht passt) so wählen Sie bitte k.A. (keine Antwort) aus bzw. lassen Sie das Antwortfeld frei.

Personalisierung

Dieser Fragebogen ist angepasst für die **Informations- und Kommunikationstechnologie** Sparte des Unternehmens Musterfirma. Für den gesamten Fragebogen gilt die folgende Definition der Informations- und Kommunikationstechnologie Sparte:

Elektr. Komponenten und Geräte zur Informationsverarbeitung und -übertragung

Falls Ihre Firma zu einem internationalen Konzern gehört, berücksichtigen Sie im Fragebogen bitte nur jene Produkte, welche ihre Firma **in Deutschland entwickelt**.

Ihr Name und Vorname: ____________

Ihre Funktion im Unternehmen: ____________

☐ Wir möchten die Ergebnisse der Studie (inkl. firmenspezifischem Benchmark-Report) kostenlos zugestellt bekommen.

Teil 1: Generelle Angaben zu Ihrem Unternehmen

Zu Beginn befragen wir Sie zu einigen generellen Charakteristika Ihres Unternehmens.

1: Angaben zur Unternehmensstruktur

	Ja	Nein	k.A.
Gehört Ihr Unternehmen einer Unternehmensgruppe an?	○	○	○
Wenn ja, als Tochtergesellschaft?	○	○	○

2: Firmengrösse

Wie viele Beschäftigte (Vollzeitäquivalent) hatte Ihr Unternehmen 2005?

3: F&E Mitarbeiter

Wie viele Beschäftigte (Vollzeitäquivalent) hatte Ihr Unternehmen 2005 im Bereich Forschung und Entwicklung (F&E)?

4: F&E Investitionen

Welchen Anteil des Umsatzes (in Prozent) gab Ihr Unternehmen in den letzten 3 Jahren durchschnittlich für Forschung und Entwicklung (F&E) aus?

5: Bedeutung der Informations- und Kommunikationstechnologie Sparte für Ihr Unternehmen

	0-20%	21-40%	41-60%	61-80%	81-100%	k.A.
Welchen Anteil Ihres Gesamtumsatzes erzielte Ihr Unternehmen in den letzten 3 Jahren mit der Informations- und Kommunikationstechnologie Sparte?	○	○	○	○	○	○

6: Umsatz von Informations- und Kommunikationstechnologie

Welchen Anteil Ihres Informations- und Kommunikationstechnologie-Umsatzes erzielte Ihr Unternehmen in den letzten 3 Jahren in ...	**0-20%**	**21-40%**	**41-60%**	**61-80%**	**81-100%**	**k.A.**
... Deutschland?	○	○	○	○	○	○
... den anderen EU-Ländern (inkl. Schweiz)?	○	○	○	○	○	○

7: Position in der Lieferkette

Welchen Anteil Ihres Informations- und Kommunikationstechnologie-Umsatzes erzielte Ihr Unternehmen in den letzten 3 Jahren mit ...	**0-20%**	**21-40%**	**41-60%**	**61-80%**	**81-100%**	**k.A.**
... Zwischenprodukten?	○	○	○	○	○	○
... Endprodukten für Privatkunden?	○	○	○	○	○	○
... Endprodukten für Industrie & Wirtschaft?	○	○	○	○	○	○

8: Angaben zur Ertragskraft

	Deutlich Schlechter	**Schlechter**	**Im Durchschnitt**	**Besser**	**Deutlich Besser**	**k.A.**
Wie bewerten Sie die Ertragskraft Ihres Unternehmens im Branchenvergleich?	○	○	○	○	○	○

Teil 2: Marktumfeld

Im 2. Teil kommen Fragen zum Marktumfeld. Diese Fragen beziehen sich alle nur auf Ihre Marktsegmente in der Informations- und Kommunikationstechnologie-Branche.

1: Wettbewerbsstrategien

	<5%	**5-20%**	**21-40%**	**41-60%**	**61-80%**	**81-100%**	**k.A.**
Bei wieviel Prozent Ihrer Informations- und Kommunikationstechnologie Produkte ist Kostenführerschaft wichtiger als Produktdifferenzierung?	○	○	○	○	○	○	○

2: Produktlebenszyklus

Wie viele Jahre beträgt der durchschnittliche Produktlebenszyklus Ihrer Informations- und Kommunikationstechnologie Produkte?

3: Neue Informations- und Kommunikationstechnologie Produkte

	<5%	5-20%	21-40%	41-60%	61-80%	81-100%	k.A.
Wie viele neue Informations- und Kommunikationstechnologie Produkte bringt Ihr Unternehmen pro Jahr durchschnittlich auf den Markt (als Prozentsatz vom gesamten IKT Sortiment)?	○	○	○	○	○	○	○

4: Angaben zu den direkten Konkurrenten

	0	1-5	6-10	11-15	16-20	>20	k.A.
Wie gross ist die Anzahl Ihrer direkten Konkurrenten in der Informations- und Kommunikationstechnologie-Branche?	○	○	○	○	○	○	○

5: Umweltfreundliche Produkte

	Sehr Gering	Gering	Mittel	Gross	Sehr Gross	k.A.
Wie gross ist in der Informations- und Kommunikationstechnologie-Branche die Nachfrage nach Produkten, welche die gesetzlich geforderten Umweltstandards deutlich übertreffen?	○	○	○	○	○	○
Wie gross ist in der Informations- und Kommunikationstechnologie-Branche das Angebot an Produkten, welche die gesetzlich geforderten Umweltstandards deutlich übertreffen?	○	○	○	○	○	○

Teil 3: Regulatorisches Umfeld

In diesem Teil kommen Fragen zum regulatorischen Umfeld für Informations- und Kommunikationstechnologie Produkte. Die Fragen beschränken sich auf die vier Bereiche: **Energie-Effizienz, Toxische Substanzen in Produkten, Material-Recycling und elektromagnetische Felder**.

1: Regulierungen im Bereich Energie-Effizienz

Hierzu zählen alle Regulierungen, die den Energieverbrauch von Produkten während der Nutzung / im Ruhezustand (Standby) betreffen.

	0-25%	26-50%	51-75%	76-100%	k.A.
Welcher Anteil Ihrer Informations- und Kommunikationstechnologie-Produkte (bezüglich Umsatz) ist von der Verordnung zur Energieverbrauchskennzeichnung (EU Energie-Label) betroffen? Für mehr Informationen klicken sie hier: (www.eu-label.de/)	○	○	○	○	○

2: Weitere Umweltregulierungen

Gibt es weitere Umweltregulierungen (Gesetze, Verordnungen, Steuern...) in Deutschland für Ihre Informations- und Kommunikationstechnologie Produkte im Bereich **Energie-Effizienz**?

3: Regulierungen im Bereich Toxische Substanzen

Hierzu zählen alle Regulierungen, welche:

- die Anzahl toxischer Substanzen / Gesamtmenge an toxischem Material in den Produkten betreffen
- oder die sichere Verwertung und Entsorgung der toxischen Substanzen nach der Nutzungsphase der Produkte (Elektroschrott) betreffen.

	0-25%	26-50%	51-75%	76-100%	k.A.
Welcher Anteil Ihrer Informations- und Kommunikationstechnologie-Produkte (bezüglich Umsatz) ist vom Stoffverbot (RoHS) im Elektro- & Elektronikgerätegesetz betroffen? Für mehr Informationen klicken sie hier: (www.elektrogesetz.de/elektrog.shtml#05)	○	○	○	○	○

4: Weitere Umweltregulierungen

Gibt es weitere Umweltregulierungen (Gesetze, Verordnungen, Steuern...) in Deutschland für Ihre Informations- und Kommunikationstechnologie Produkte im Bereich **Toxische Substanzen**?

5: Regulierungen im Bereich Material-Recycling

Hierzu zählen alle Regulierungen, welche:

- die Anzahl / Gesamtmenge eingesetzter Materialien in den Produkten betreffen,
- die Rückgewinnung von Materialien (Recycling) nach der Nutzungsphase der Produkte betreffen,
- oder die Wieder- / Weiterverwertung von Bauteilen (Modularität) nach der Nutzungsphase betreffen.

	0-25%	26-50%	51-75%	76-100%	k.A.
Welcher Anteil Ihrer Informations- und Kommunikationstechnologie-Produkte (bezüglich Umsatz) ist von den Material-Recycling Bestimmungen (WEEE / Elektroschrott) im Elektro- & Elektronikgerätegesetz betroffen? Für mehr Informationen klicken sie hier: (www.elektrogesetz.de/elektrog.shtml#04)	○	○	○	○	○

6: Weitere Umweltregulierungen

Gibt es weitere Umweltregulierungen (Gesetze, Verordnungen, Steuern...) in Deutschland für Ihre Informations- und Kommunikationstechnologie Produkte im Bereich **Material-Recycling**?

7: Regulierungen im Bereich Elektromagnetische Felder (EMF)

Hierzu zählen alle Regulierungen, welche die elektromagnetische Feldstärke von Produkten betreffen.

	0-25%	26-50%	51-75%	76-100%	k.A.
Welcher Anteil Ihrer Informations- und Kommunikationstechnologie-Produkte (bezüglich Umsatz) ist vom Gesetz über Funkanlagen und Telekommunikationsendeinrichtungen (FTEG) betroffen? Für mehr Informationen klicken sie hier: (www.bundesnetzagentur.de/media/archive/741.pdf)	○	○	○	○	○

8: Weitere Umweltregulierungen

Gibt es weitere Umweltregulierungen (Gesetze, Verordnungen, Steuern...) in Deutschland für Ihre Informations- und Kommunikationstechnologie Produkte im Bereich **Elektromagnetische Felder**?

9: Umsatzstärkstes Produkt / Produktlinie

Ist Ihr umsatzstärkstes Informations- und Kommunikationstechnologie Produkt / Produktlinie von den jeweiligen Regulierungen betroffen?

	Ja	Nein	k.A.
Verordnung zur Energieverbrauchskennzeichnung (EU Energie-Label)	○	○	○
Stoffverbot (RoHS) im Elektro- & Elektronikgerätegesetz	○	○	○
DOE Appliance Labeling Rule (EnergyGuide Label) Material-Recycling Bestimmungen (WEEE / Elektroschrott) im Elektro- & Elektronikgerätegesetz	○	○	○
Verordnung über elektromagnetische Felder (FTEG)	○	○	○

10: Stringenz der Umweltregulierungen

Wie leicht bzw. schwer war es für Ihr Unternehmen in den letzten 3 Jahren, die gesetzlich geforderten Umweltstandards in Deutschland für Ihre Informations- und Kommunikationstechnologie Produkte zu erfüllen?

Im Bereich ...	Sehr Leicht	Leicht	Mittel	Schwer	Sehr Schwer	k.A.
... Energie-Effizienz	○	○	○	○	○	○
... Toxische Substanzen	○	○	○	○	○	○
... Material-Recycling	○	○	○	○	○	○
... Elektromagnetische Felder	○	○	○	○	○	○

11: Regulatorische Entwicklung

Wie wird sich das regulatorische Umfeld in Deutschland für Informations- und Kommunikationstechnologie Produkte Ihrer Meinung nach in den nächsten 5 Jahren entwickeln?

Im Bereich ...	Wird Viel Lockerer	Wird Lockerer	Bleibt So	Wird Strenger	Wird Viel Strenger	k.A.
... Energie-Effizienz	○	○	○	○	○	○
... Toxische Substanzen	○	○	○	○	○	○
... Material-Recycling	○	○	○	○	○	○
... Elektromagnetische Felder	○	○	○	○	○	○

12: Regulatorische Unsicherheit

Wie gut lässt sich abschätzen, wie sich das regulatorische Umfeld in Deutschland für Ihre Informations- und Kommunikationstechnologie Produkte zukünftig entwickelt?

Im Bereich ...	Sehr Leicht	Leicht	Mittel	Schwer	Sehr Schwer	k.A.
... Energie-Effizienz	○	○	○	○	○	○
... Toxische Substanzen	○	○	○	○	○	○
... Material-Recycling	○	○	○	○	○	○
... Elektromagnetische Felder	○	○	○	○	○	○

Teil 4: Ökologische Produktverbesserungen

Im 4. Teil kommen Fragen zu ökologischen Produktverbesserungen. Dieser Teil enthält die komplexesten und zugleich wichtigsten Fragen für unsere Untersuchung. Bitte lesen Sie die Fragen und Erläuterungen aufmerksam durch.

1: Ökologische Produktverbesserungen

Als ökologische Produktverbesserungen werden alle technischen Änderungen / Weiterentwicklungen bezeichnet, welche Produkte umweltfreundlicher machen. Es spielt jedoch keine Rolle,

- ob diese Änderungen ökologisch motiviert sind oder nicht,
- ob diese Änderungen von Ihnen selber entwickelt oder eingekauft wurden.

Hat Ihr Unternehmen in den letzten 3 Jahren ökologische Produktverbesserungen bei Informations- und Kommunikationstechnologie Produkten implementiert?	Ja	Nein	k.A.
Im Bereich Energie-Effizienz? (reduzierter Energieverbrauch der Produkte bei Nutzung / Standby)	○	○	○
Im Bereich Toxische Inhaltsstoffe? (verringerte Anzahl / Gesamtmenge an toxischen Substanzen in Produkten; bessere Entsorgung dieser Substanzen nach der Nutzungsphase)	○	○	○
Im Bereich Material-Recycling? (verringerte Anzahl / Gesamtmenge an Materialien in Produkten; bessere Rückgewinnung von Materialien nach der Nutzungsphase; bessere Wieder- / Weiterverwertung von Bauteilen nach der Nutzungsphase)	○	○	○
Im Bereich Elektromagnetische Felder? (verringerte elektromagnetische Feldstärken der Produkte)	○	○	○

2: Ausmass der ökologische Produktverbesserung

Für welchen Anteil Ihrer Informations- und Kommunikationstechnologie Produkte wurde in den letzten 3 Jahren wenigstens eine ökologische Produktverbesserung implementiert?

Im Bereich ...	<5%	5-25%	26-50%	51-75%	76-100%	k.A.
... Energie-Effizienz	○	○	○	○	○	○
... Toxische Substanzen	○	○	○	○	○	○
... Material-Recycling	○	○	○	○	○	○
... Elektromagnetische Felder	○	○	○	○	○	○

3: Neuheit der ökologischen Produktverbesserungen

Handelt es sich bei den ökologischen Produktverbesserungen um Marktneuheiten?

Im Bereich ...	Vor allem Marktneuheiten	Einige Marktneuheiten	Keine Marktneuheiten	k.A.
... Energie-Effizienz	○	○	○	○
... Toxische Substanzen	○	○	○	○
... Material-Recycling	○	○	○	○
... Elektromagn. Felder	○	○	○	○

4: Herkunft des KnowHows

Basieren die ökologischen Produktverbesserungen auf eigenen Entwicklungen oder externen / eingekauften Entwicklungen?

Im Bereich ...	Vor allem eigene Entwicklungen	Beides etwa gleich	Vor allem externe Entwicklungen	k.A.
... Energie-Effizienz	○	○	○	○
... Toxische Substanzen	○	○	○	○
... Material-Recycling	○	○	○	○
... Elektromagn. Felder	○	○	○	○

5: Gründe für die ökologischen Produktverbesserungen im Bereich Energie-Effizienz

Wie wichtig waren die folgenden Gründe für die Implementierung der ökologischen Produktverbesserungen im Bereich Energie-Effizienz?

	Nicht Wichtig	Teilweise Wichtig	Wichtig	Sehr Wichtig	k.A.
Produktionskosten senken	○	○	○	○	○
Produktdifferenzierung	○	○	○	○	○
Rechtliche Rahmenbedingungen erfüllen	○	○	○	○	○
Strengere Regulierung vermeiden	○	○	○	○	○
Image verbessern	○	○	○	○	○
Kundenwünsche erfüllen	○	○	○	○	○

6: Gründe für die ökologischen Produktverbesserungen im Bereich Toxische Substanzen

Wie wichtig waren die folgenden Gründe für die Implementierung der ökologischen Produktverbesserungen im Bereich Toxische Substanzen?

	Nicht Wichtig	Teilweise Wichtig	Wichtig	Sehr Wichtig	k.A.
Produktionskosten senken	○	○	○	○	○
Produktdifferenzierung	○	○	○	○	○
Rechtliche Rahmenbedingungen erfüllen	○	○	○	○	○
Strengere Regulierung vermeiden	○	○	○	○	○
Image verbessern	○	○	○	○	○
Kundenwünsche erfüllen	○	○	○	○	○

7: Gründe für die ökologischen Produktverbesserungen im Bereich Material-Recycling

Wie wichtig waren die folgenden Gründe für die Implementierung der ökologischen Produktverbesserungen im Bereich Material-Recycling?

	Nicht Wichtig	Teilweise Wichtig	Wichtig	Sehr Wichtig	k.A.
Produktionskosten senken	○	○	○	○	○
Produktdifferenzierung	○	○	○	○	○
Rechtliche Rahmenbedingungen erfüllen	○	○	○	○	○
Strengere Regulierung vermeiden	○	○	○	○	○
Image verbessern	○	○	○	○	○
Kundenwünsche erfüllen	○	○	○	○	○

8: Gründe für die ökologischen Produktverbesserungen im Bereich Elektromagnetische Felder

Wie wichtig waren die folgenden Gründe für die Implementierung der ökologischen Produktverbesserungen im Bereich Elektromagnetische Felder?

	Nicht Wichtig	Teilweise Wichtig	Wichtig	Sehr Wichtig	k.A.
Produktionskosten senken	○	○	○	○	○
Produktdifferenzierung	○	○	○	○	○
Rechtliche Rahmenbedingungen erfüllen	○	○	○	○	○
Strengere Regulierung vermeiden	○	○	○	○	○
Image verbessern	○	○	○	○	○
Kundenwünsche erfüllen	○	○	○	○	○

9: Umwelt-Performance vor 3 Jahren

Wie bewerten Sie die Umwelt-Performance, die Ihre Informations- und Kommunikationstechnologie Produkte **vor 3 Jahren** im Branchenvergleich hatten?

Im Bereich ...	Deutlich Schlechter	Schlechter	Im Durchschnitt	Besser	Deutlich Besser	k.A.
... Energie-Effizienz	○	○	○	○	○	○
... Toxische Substanzen	○	○	○	○	○	○
... Material-Recycling	○	○	○	○	○	○
... Elektromagn. Felder	○	○	○	○	○	○

10: Umwelt-Performance heute

Wie bewerten Sie die Umwelt-Performance, die Ihre Informations- und Kommunikationstechnologie Produkte **heute** im Branchenvergleich haben?

Im Bereich ...	Deutlich Schlechter	Schlechter	Im Durchschnitt	Besser	Deutlich Besser	k.A.
... Energie-Effizienz	○	○	○	○	○	○
... Toxische Substanzen	○	○	○	○	○	○
... Material-Recycling	○	○	○	○	○	○
... Elektromagn. Felder	○	○	○	○	○	○

11: Anzahl ökologischer Produktverbesserungen

Wie viele ökologische Produktverbesserungen wurden in den letzten 3 Jahren bei Ihrem umsatzstärksten Informations- und Kommunikationstechnologie Produkt / Produktlinie implementiert?

Im Bereich Energie-Effizienz:	
Im Bereich Toxische Substanzen:	
Im Bereich Material-Recycling:	
Im Bereich Elektromagnetische Felder:	

Teil 5: Direkter Kundennutzen

Im vorletzten Teil kommen Fragen zum direkten Kundennutzen. Einige ökologische Produktverbesserungen verbessern nicht nur die Umweltfreundlichkeit der Produkte, sondern bringen auch den Kunden einen direkten Nutzen.

1: Direkter Nutzen für Kunden aus ökologischen Produktverbesserungen im Bereich Energie-Effizienz

Im Bereich Energie-Effizienz können Produktverbesserungen u.a. folgende Kundennutzen bringen:

- geringere Stromkosten
- geringere Wärmeentwicklung durch das Gerät
- längere Nutzungszeiten bei mobilen Geräten

Als wie gross erachten Sie den direkten Nutzen für Ihre IKT Kunden aus ökologischen Produkt-verbesserungen im Bereich ...	**Kein Nutzen**	**Geringer Nutzen**	**Mittlerer Nutzen**	**Grosser Nutzen**	**k.A.**
... Energie-Effizienz?	○	○	○	○	○

2: Direkter Nutzen für Kunden aus ökologischen Produktverbesserungen im Bereich Toxische Substanzen

Im Bereich Toxische Substanzen können Produktverbesserungen u.a. folgende Kundennutzen bringen:

- verringertes Gesundheitsrisiko
- einfachere Entsorgung

Als wie gross erachten Sie den direkten Nutzen für Ihre IKT Kunden aus ökologischen Produkt-verbesserungen im Bereich ...	**Kein Nutzen**	**Geringer Nutzen**	**Mittlerer Nutzen**	**Grosser Nutzen**	**k.A.**
... Toxische Substanzen?	○	○	○	○	○

3: Direkter Nutzen für Kunden aus ökologischen Produktverbesserungen im Bereich Material-Recycling

Im Bereich Material-Recycling können Produktverbesserungen u.a. folgende Kundennutzen bringen:

- kleinere Geräte
- bessere Reparatur- und Upgrademöglichkeiten bei modularer Bauweise
- einfachere Entsorgung bei Rücknahmeprogrammen

Als wie gross erachten Sie den direkten Nutzen für Ihre IKT Kunden aus ökologischen Produkt-verbesserungen im Bereich ...	**Kein Nutzen**	**Geringer Nutzen**	**Mittlerer Nutzen**	**Grosser Nutzen**	**k.A.**
... Material-Recycling?	○	○	○	○	○

4: Direkter Nutzen für Kunden aus ökologischen Produktverbesserungen im Bereich Elektromagnetische Felder

Im Bereich Elektromagnetische Felder können Produktverbesserungen u.a.folgende Kundennutzen bringen:

- verringertes Gesundheitsrisiko
- geringere Störanfälligkeit für andere elektronische Geräte

Als wie gross erachten Sie den direkten Nutzen für Ihre IKT Kunden aus ökologischen Produkt-verbesserungen im Bereich ...	**Kein Nutzen**	**Geringer Nutzen**	**Mittlerer Nutzen**	**Grosser Nutzen**	**k.A.**
... Elektromagnetische Felder?	○	○	○	○	○

5: Relevanz dieser Kundennutzen

Spielen diese Kundennutzen in Ihrem Unternehmen eine wichtige Rolle für die Entwicklung und Einführung von ökologischen Produktverbesserungen?

Im Bereich ...	**Nicht Wichtig**	**Teilweise Wichtig**	**Wichtig**	**Sehr Wichtig**	**k.A.**
... Energie-Effizienz	○	○	○	○	○
... Toxische Substanzen	○	○	○	○	○
... Material-Recycling	○	○	○	○	○
... Elektromagnetische Felder	○	○	○	○	○

Teil 6: Angaben zum Umweltmanagement

Im letzten Teil kommen noch Fragen zum Umweltmanagement in Ihrem Unternehmen.

1: Angaben zum Umweltmanagement

	Ja	**Nein**	**k.A.**
Hat sich Ihr Unternehmen zu freiwilligen Umweltzielen verpflichtet?	○	○	○
Falls ja, gibt es auch freiwillige Umweltziele für Ihre Produkte?	○	○	○
Führt Ihr Unternehmen systematische Umweltanalysen von Ihren Produkten durch?	○	○	○
Gibt es in Ihrem Unternehmen ökologische Checklisten für die Produktentwicklung?	○	○	○
Führt Ihr Unternehmen ökologische Schulungen für Ihre Produktentwickler durch?	○	○	○
Verwendet Ihr Unternehmen ökologische Produkteigenschaften im Marketing?	○	○	○

2: Mitarbeiter im Bereich Umweltmanagement

Wie viele Beschäftigte (Vollzeitäquivalent) hatte Ihr Unternehmen 2005 im Bereich Umweltmanagement?

[ ]

3: Umweltmanagement-System

	Ja	Nein	k.A.
Hat Ihr Unternehmen ein zertifiziertes Umweltmanagement-System (z.B. ISO 14'001 oder EMAS)?	○	○	○

Falls ja,

A) Nach welchen Standards wurde Ihr Umweltmanagement-System zertifiziert?

☐ISO 14'001
☐EMAS
Anderer: [ ]

B) In welchem Jahr wurde es das erste Mal zertifiziert?

[ ]

Teil 7: Ende des Fragebogens

Sie können jetzt noch Ihre Kompetenz für bestimmte Themenbereiche angeben sowie einen Kommentar zum gesamten Fragebogen abgeben.

Please let us know how you rate your personal expertise in relation to the questions raised	Sehr Gering	Gering	Mittel	Gross	Sehr Gross	k.A.
Teil 2: Marktumfeld	○	○	○	○	○	○
Teil 3: Regulatorisches Umfeld	○	○	○	○	○	○
Teil 4: Ökologische Produktverbesserungen	○	○	○	○	○	○
Teil 6: Umweltmanagement	○	○	○	○	○	○

Möchten Sie noch einen Kommentar zum Fragebogen abgeben?

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Oct. 1997 – Apr. 2003	**Diploma** in Environmental Sciences ETH Zurich
Oct. 1995 – Jul. 1997	**Pre-Diploma** in Computer Science University Freiburg (Germany)
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Professional Experience

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Jul. 2005 – Feb. 2008	**Delegate to the Environmental Committee** ETH Zurich (part-time)
Sep.2004 – Sep. 2008	**Research Associate** ETH Zurich (part-time)
Aug. 2003 – Jul. 2004	**Project Leader** ETHsustainability – ETH Competence Center, Zurich