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Environmental innovation and employment dynamics in different technology fields – an analysis based on the German Community Innovation Survey 2009

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ABSTRACT

The employment effects of environmental technologies are in the focus of politicians but studies analyzing these effects for different environmental innovation fields are rare. We use the 2009 wave of the Community Innovation Survey (CIS) allowing for such an analysis at the firm level. Our econometric analysis shows that innovative firms in general are characterized by a significantly more dynamic employment development. Especially the introduction of cleaner technologies as process innovations leads to a higher employment within the firm. The theoretical background of this finding is that cost savings induced by this type of process innovation improve the competitiveness of firms. This has positive effects on demand and thus also increases employment. Especially material and energy savings are positively correlated to employment because they help to increase the profitability and competitiveness of the firm. On the other side, air and water process innovations that are still dominated by end-of-pipe technologies have a negative impact on employment.

1. Introduction

In a controversial political debate, environmental technologies are often regarded as a job creator or – due to increasing production costs – as a job killer. The relevant literature, however, has shown so far that the effects are quite small (Horbach, 2010; Rennings and Zwick, 2002; Pfeiffer and Rennings, 2001). While the knowledge of employment effects in general has improved due to this empirical evidence, the heterogeneity of environmental technologies regarding employment is still largely unknown.

The paper tries to fill at least partially this gap by using the new Community Innovation Survey of 2009 which allows differentiating between different types of environmental technology areas such as process and product innovation and further distinguishing between e.g. material and energy savings, air emissions or recycling.

Due to the data basis, our analysis is restricted to the employment behavior of firms but it seems to be highly interesting to analyze the adjustment processes triggered by eco-innovations. It is therefore not the aim to find out if eco-innovations are advantageous for the employment of the whole economy on a macroeconomic level but we are interested in the employment adaption behavior of firms.

Besides a descriptive analysis, we use econometric methods to analyze the relationship between eco-innovation and employment. Within a firm, the planning and realization of an eco-innovation often requires a simultaneous decision on employment adjustment. The simultaneous nature of the decision on increasing or decreasing employment requires the application of adequate econometric methods such as the use of an endogenous switching model (see Section 4).

The paper is organized as follows: Section 2 analyzes the employment effects of eco-innovation from a theoretical perspective and gives an overview of the main empirical results in the literature. In Section 3, descriptive results from our data basis of the CIS 2009 are presented linked to the macroeconomic background of the respective time period. Our econometric results for the relationship between eco-innovation and employment are discussed in Section 4. A summary (Section 5) finalizes the paper.

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2. Employment effects of eco-innovative process and product innovations for different technological areas – theory and empirical perspective

The relationship between (eco-) innovation and employment within a firm strongly depends on the nature of innovation, especially between process and product innovation (see Pfeiffer and Rennings, 2001 and Table 1). Concerning process innovations, a further distinction between end-of-pipe and cleaner technologies is important.

Process innovations are often suspected to induce negative employment effects (see e.g. Edquist et al., 2001; Harrison et al., 2008). This may be the case if process innovations lead to a higher labor productivity within the firm accompanied by a given output. The case of environmentally oriented process innovations requires a more detailed argumentation making the difference between end-of-pipe and cleaner technologies.

Cleaner production technologies are integrated into the production process often leading to less pollution or material or energy savings (Frondel et al., 2007). These cost-savings may lead to an increase in total factor productivity (including labor, capital and energy) of the firm. It depends on the specific case if the cost-saving process innovations also affect the share of labor of the corresponding production process. A higher efficiency of capital induced by cleaner technologies may lead to a substitution of labor by capital because labor becomes relatively less valuable to the firm accompanied by lower wages. On the other side, these lower wages may help to reduce the negative employment effects. Cleaner technologies may also be realized by organizational innovations and/or the improvement of human capital. Then, the cost-saving effects may be achieved by taking on more specialized and high qualified employees who are able to reorganize production processes in a more resource-efficient way.

All in all, depending from the specific cleaner production technology, a higher, constant or lower labor share may result. In any case, an increase in total factor productivity caused by cleaner technologies strengthens the competitiveness of firms and thus may lead to positive employment effects by lower prices and a higher demand (see also Edquist et al., 2001) that is also in line with the famous Porter hypothesis (Porter and van der Linde, 1995). In case of a lower labor share resulting from the introduction of the cleaner technology the higher demand may compensate the employment loss, in case of a higher labor share the competitiveness effect enforces the employment gain.

On the other hand, we have to discuss the case of end-of-pipe oriented process innovations, e.g. the introduction of an additional filter system added to the production process. The construction, the installation and the maintenance of the filter system may require additional staff and thus lead to positive direct employment effects. The indirect effect, however, may be negative since end-of-pipe technologies lead to higher costs connected with a lower competitiveness and a decline of output and employment.

All in all, the effects of environmental process innovations on employment remain an empirical question.

The employment effects of environmental product innovations also remain theoretically unclear. On the one hand, product innovations may induce new demand for the firm if they create completely new markets or if they substitute products of competitors. In this case, the effect for employment at the firm level is positive. On the macroeconomic level, the effect is not determined and depends inter alia on the labor intensity of the substituted products. Negative employment effects of product innovations may also arise because the introduction of the new product may cause a monopolistic position leading to a reduction of output (Hall et al., 2006).

From an empirical point of view, there are many papers analyzing the general link between innovation and employment but relatively few analyses for the specificities of eco-innovations.

Econometric studies on general innovation and employment rely on different methodologies. There are cross-sectional studies such as Entorf and Pohlmeier (1990) that cannot address the dynamic character of the relationship between innovation and employment. Most analyses use growth rates between two different points in time (e.g. RWI, 2005; Peters, 2005; Harrison et al., 2008). Other authors use panel data over a longer period of time and apply corresponding (dynamic) panel data models to analyze the data (e.g. van Reenen, 1997; Smolny, 1998, 2002; Smolny and Schneeweis, 1999; Rottmann and Ruschinsky, 1998; Piva and Vivarelli, 2005; Lachenmaier and Rottmann, 2007, 2011).

Most of these studies in Germany, focusing on general innovations, found positive effects of product innovations on labor demand (see e.g. RWI, 2005; Peters, 2005; Smolny, 1998, 2002; Piva and Vivarelli, 2005; Zimmermann, 2009). Similar results were detected for the UK (van Reenen, 1997) and for France (Greenan and Guellec, 2000) and in a comparative study for France, Great Britain, Germany and Spain based on harmonised data of the Community Innovation Panel (CIS) (Harrison et al., 2008).

In a recent analysis, Bogliacino and Pianta (2010) use a sectoral database including CIS data from 1994 to 2004 for eight European countries. Interestingly, they find different roles of innovation, wages and demand for employment across different types of industries. Further studies on the European level have been undertaken by Antonucci and Pianta (2002) and Pianta (2000).

Analyses on the employment effects of environmental innovations are still rare due to data problems. In general, these studies also detect positive effects of eco-innovations on employment (Bijman and Nijkamp, 1988; Pfeiffer and Rennings, 2001; Rennings and Zwick, 2002; Harabi, 2000; Rennings, 2003). Rennings and Zwick (2002) find a small positive employment effect at the firm level. The positive effects relate to both product and service innovations. The other determinants of employment development in this study, including more than 1500 firms from five European countries, the market share as an innovation goal, innovation size and the strictness of environmental regulation, are significant for employment changes. Confirming our theoretical considerations, Pfeiffer and Rennings (2001) show that cleaner production is more likely to increase employment compared to end-of-pipe technologies. This result is confirmed by Rennings et al. (2004) where the econometric results show that product and service eco-innovations have a positive effect on the probability of an employment increase, whereas end-of-pipe measures lead to a decline.

Table 1
Employment effects of eco-innovation at the firm level.

Process innovation	Product innovation
End-of-pipe *Positive*: The introduction of end-of-pipe measures may require additional staff *Negative*: Higher costs because of implementation of end-of-pipe technologies (e.g. new air emission filters)	*Positive*: Higher demand for the firm's new products *Negative*: Substitution of more conventional, less environmentally friendly products *Negative*: Product innovation may cause a monopolistic position of the firm leading to less output
Cleaner Technologies *Positive*: Cost-savings (e.g. material and energy savings) may lead to a higher competitiveness and a higher demand *Negative*: The introduction of cleaner technologies may lead to labor saving effects	

Mazzanti and Zoboli (2009) analyze the relationship between environmental efficiency and labor productivity. In most cases, their econometric analyses confirm a positive correlation between these two variables.

In a recent paper, Horbach (2010) confirms a positive influence of eco-product innovations on employment. The positive effects of eco-innovation seem to be larger compared to other non-environmental innovation fields.

Especially the employment effects in specific technology fields such as recycling, energy and resource efficiency are only rarely analyzed. Fortunately, our database of the Community Innovation Survey (CIS) 2009 allows such a technology-specific analysis (Section 4).

Our empirical analysis based on the CIS is limited to the firm-level. Macroeconomic effects may be captured by adequate models such as Computable General Equilibrium (CGE) models but not on a firm data basis. However, since the size and direction of effects is unclear, survey data can explain the adaptation behavior of firms' employment demand with respect to eco-innovation.

3. Data, descriptive results and the macroeconomic background

3.1. Data

Our study rests on a unique firm data set collected in the context of the Community Innovation Surveys (CIS) of the European Commission. Conducted for the CIS in 2009, a separate module on environmental innovations was introduced. An environmental innovation has been defined as "a new or significantly improved product (good or service), process, organisational method or marketing method that creates environmental benefits compared to alternatives. The environmental benefits can be the primary objective of the innovation or the result of other innovation objectives. The environmental benefits of an innovation can occur during the production of a good or service, or during the after sales use of a good or service by the end user."(Horbach et al., 2012:114)[1] What follows is a list of environmental benefits that an environmental innovation could have produced either with the firm or from the after sales use of a product by the user for which surveyed firms should state whether this benefit has occurred or not.

The German CIS further developed this question in two respects. Firstly, firms reporting a certain environmental benefit were asked to assess whether this benefit was of high, medium or low importance in terms of reducing environmental impacts. Secondly, the list of potential environmental benefits has been enlarged to better distinguish different areas of environmental externalities and associated policies.

The German CIS of 2009 covers 7061 firms in mining and quarrying, manufacturing, energy and water supply, and a large number of service sectors. The response rate was 26% both for manufacturing and services which is in line with comparable non-mandatory surveys. In order to control for a likely response bias between innovating and non-innovating firms, a non-response survey was performed, covering a stratified random sample of more than 4800 non-responding firms. This survey was conducted by telephone and revealed that the share of innovators among non-responding firms did not differ significantly from that of responding firms.

Furthermore, we also use data stemming from a telephone survey that the Centre for European Economic Research (ZEW) conducted in addition to the German CIS 2009. A subsample of 3778 firms of the German CIS 2009 was considered, the response rate was 78% so that the answers of 2952 firms are available. The firms were considered for the additional telephone survey if they

- answered to the CIS questionnaire;
- had introduced an innovation from 2006 to 2008 with at least low environmental impacts in one or several environmental fields.

The telephone survey was carried out to get further insights in the nature of the eco-innovation activities of the questioned firms. For our analysis, the question on the employment effects of the most important eco-innovation of the firm was important (see Table 3).

3.2. Descriptive results

Our descriptive results show a dynamic development of employment in nearly all environmental technology fields. Especially firms with environmental process innovations are characterized by a much higher employment dynamic compared to all other innovative firms (see Table 2) confirming the results of Horbach (2010) based on the establishment panel of the Institute for Employment Research in Nuremberg. Following our descriptive results, the differences between the different environmental innovation fields do not seem to be significantly high. Firms that did not realize an innovation during 2006–2008 only show a small increase of employment (1.3%).

Finding an adequate answer to the question if the introduction of a new eco-process or product increases employment requires an econometric analysis allowing to control for further variables such as size of the firm, market structure or demand (see Section 4).

An aspect that we may have to bear in mind when interpreting our results lies in the specific time period of the CIS 2009 data that only

Table 2
Employment development by different environmental technology areas from 2006 to 2008.

Environmental impact areas	Employment development from 2006 to 2008 in %	Number of firms[a]
Introduction of innovations with environmental benefits within the firm 2006 to 2008		
Reduced material use per unit of output	7.3	1107
Reduced energy use per unit of output	7.9	1245
Reduced CO_2 emissions	7.7	1044
Reduced emissions of other air pollution	8.9	706
Reduced water pollution	7.9	698
Reduced soil pollution	8.2	414
Reduced noise pollution	9.2	679
Replacement of hazardous substances	7.9	707
Recycled waste, water or materials	8.8	1133
Introduction of innovations with environmental benefits from using a firm's products 2006 to 2008		
Reduced energy use	6.0	1240
Reduced air, water, soil or noise emissions	8.8	893
Improved recycling of products after use	8.0	700
Other innovators (no eco-innovation)	3,0	2054
All innovative firms	7.1	4158
Firms without innovations	1.3	2597
All firms	6.7	6755

[a] All firms with high or medium environmental impacts in the respective area are included. The growth rates are weighted by the size of the firms.
Source: German CIS 2009.

[1] This definition is based on a recent EU funded research project called "Measuring Eco-Innovation" (MEI). For a further discussion see Horbach et al. (2012).

allow analyzing the employment development from 2006 to 2008. From a macroeconomic background, in Germany, the time period from 2003 to 2008 was characterized by an increase of employment of approximately 4% accompanied by a clear increase of productivity measured by the real GDP per employee of 5.1% (Statistisches Bundesamt, 2011). Obviously, the German firms succeeded in improving their competitiveness by increasing their productivity e.g. by process innovations or by better trained or motivated employees. The higher competitiveness then led to a high demand and allowed the firms to take on more employees. This process was supported by a sharp decline of real wages of approximately 4% from 2003 to 2008 – a development that has only been rarely observed in the post-world war history of Germany (Brenke, 2009).

Next, we will present results of the telephone survey since they allow analyzing the employment effects of the most important eco-innovation of the questioned firm. In fact, only 1.8% of the firms report a lower employment due to the main eco-innovation, 13.3% report a higher employment, whereas for 85% of the questioned firms employment remains unchanged. Thus, the earlier finding of Rennings and Zwick (2002) of a small positive employment effect seems to be confirmed. Table 3 shows some examples for innovations with negative and positive employment effects. Especially energy saving measures seem to be accompanied by positive employment effects.

Table 3
Examples for the employment effects of the “most important eco-innovation” of the firm.

Decrease of employment from 2006 to 2008
- Introduction of electronic records
- Completely new paint equipment
- Introduction of solar technology
Increase of employment from 2006 to 2008
- Energy saving measures (e.g. energy efficient engines)
- Reduction of solvents in paints
- Introduction of heat pumps
- Introduction of a new sewage-works

Source: Additional telephone survey of CIS 2009 firms.

4. Econometric analysis

4.1. Overall effects of (eco-) innovation on employment: an endogenous switching model

The descriptive analysis in Section 3 shows a dynamic employment development for most of the environmental technology areas. Compared to other innovators, and especially non-innovators, the employment dynamics of eco-innovations seem to be over-proportionally high.

But in fact, a descriptive analysis is not suitable to explain causal relationships between innovation and employment. Furthermore, the analysis of this relationship is not trivial because, on the one hand, the decision of a firm to realize an innovation may cause the need of an adaptation of employment (e.g. employees to develop and realize the innovation) whereas, on the other hand, innovation may trigger employment because of a higher demand due to a higher competitiveness of the firm. An adequate econometric analysis has to cope with this endogeneity problem. To address the simultaneity problem of employment development and the decision to innovate or not, we apply the so-called endogenous switching regression model (Maddala, 1983; Lokshin and Sajaia, 2004).[2] The model can be described as follows:

Selection equation that describes the determinants of the decision of a firm to innovate (regime 1) or not (regime 0):

$$\begin{aligned} \text{Inno}_i &= 1 \quad \text{if} \quad \gamma Z_i + u_i > 0 \quad (\text{Innovators}) \\ \text{Inno}_i &= 0 \quad \text{if} \quad \gamma Z_i + u_i \leq 0 \quad (\text{Non}-\text{Innovators}) \end{aligned}$$

Continuous equations:

$$\begin{aligned} \text{Regime 1}: \quad \text{Empdynamic}_{1i} &= \beta_1 X_{1i} + \varepsilon_{1i} \quad \text{if Inno}_i = 1 \\ \text{Regime 0}: \quad \text{Empdynamic}_{0i} &= \beta_0 X_{0i} + \varepsilon_{0i} \quad \text{if Inno}_i = 0 \end{aligned}$$

The error term u_i is assumed to be correlated with the error terms of the continuous equations, ε_{1i} and ε_{0i}.

[2] This model has already been used in a similar context exploring the relationship between the introduction of environmental management systems and environmental performance (Johnstone et al., 2007).

The dependent variables *empdynamic*$_{ji}$ ($j = 0, 1$) in the continuous equations denote the growth rate of employment from 2006 to 2008 for the two regimes of the selection equation. The dependent variable of the selection equation (*inno*) gets the value 1 for innovators (product, process or organizational innovators) and 0 otherwise. The endogenous switching model allows integrating different sets of independent variables for the two regimes. This is an important feature because it is possible to include variables such as the type of innovation for innovative firms where there is obviously no variation for non-innovative firms concerning this variable.

Our correlated variables (X_i and Z_i) can be described as follows (for an exact definition of the variables see the Appendix):

Perform denotes the growth rate of turnover from 2006 to 2008 as a proxy for product demand. *Envprocess* and *envproduct* are dummy variables signifying whether a firm is specialized in environmental process or product innovations, respectively. *Rad* gets the value 1 if the firm realized internal or external research activities during 2006 and 2008. *Highqual* represents the share of employees with a university degree in a firm and can be interpreted as an indicator for the technological capability of a firm.

The investment intensity (*invintens*) is measured by the gross investment 2008 per employee. The dummy variable *international* captures the geographical orientation of a firm, getting the value 1 if the firm exports goods and/or services to foreign countries.

To capture the influence of the competitive situation on the firms' decision to innovate, we include the dummy variables *competition1–4*. *Competition1* describes the situation if the market position of the firm is highly threatened by new competitors, *competition2* indicates the length of the product life cycle, *competition3* gets the value 1 if the firm' products are easily replaceable by those of the competitors and *competition4* captures the competition pressure from foreign competitors.

Furthermore, control variables such as *size* (number of employees in 2008), *age* (age of the firm measured in years) *region* (dummy for East and West Germany) and sector dummies are included.

As expected from the literature, the results of our endogenous switching model (Table 4) show that innovative firms are characterized by a significantly more dynamic employment development compared to non-innovative firms. This can be verified by the positive and significant correlation coefficient $\text{rho}_1 = 0.8$ denoting a positive correlation between ε_{1i} and u_i. An innovative firm shows a better employment development compared to a randomly chosen firm from the whole sample.

A very important result for evaluating the employment effects of eco-innovation is that environmental process innovations seem especially promoting employment confirmed by the significant coefficient of the variable *envprocess*. This result confirms our theoretical considerations in Section 2: Environmental process innovations induce cost savings (e.g. material and energy savings) then leading to a higher competitiveness (lower prices) and a higher demand.

Table 4
Eco-Innovation and Employment: An Endogenous Switching Model.

Dependent variable:
Empdynamic$_{ji}$ (continuous equations): Growth rate of employment from 2006 to 2008 for the two regimes
Inno (selection equation): 1 Innovators, 0 Non-innovators

Variables	*Empdynamic* of innovators	*Empdynamic* of non-innovators	Selection equation
Age	−0.06 (−2.18)*	−0.07 (−2.50)**	−0.00 (−1.88)$^{+}$
Competition1	–	–	−0.02 (−0.58)
Competition2	–	–	0.25 (5.15)**
Competition3	–	–	0.04 (1.21)
Competition4	–	–	0.09 (2.16)*
Envprocess	6.44 (1.76)$^{+}$	–	–
Envproduct	−0.92 (−0.36)	–	–
Highqual	0.25 (4.95)**	−0.07 (−1.39)	0.01 (6.23)**
International	17.6 (7.24)**	1.32 (0.51)	0.51 (11.3)**
Invintens	0.00 (0.32)	−0.00 (−1.93)*	–
Perform	0.10 (36.27)**	0.36 (18.5)**	–
Rad	2.59 (1.30)	–	–
Region	–	–	−0.06 (−1.68)$^{+}$
Size	0.00 (0.64)	0.00 (0.32)	0.00 (4.91)**
Sec1	−14.3 (−1.61)	−15.0 (−2.32)*	−0.14 (−0.93)
Sec2	−0.68 (−0.12)	−7.53 (−1.41)	0.19 (1.76)$^{+}$
Sec3	−5.90 (−0.84)	−17.2 (−2.53)**	−0.02 (−0.16)
Sec4	−7.56 (−1.45)	−12.8 (−2.87)**	−0.06 (−0.63)
Sec5	0.32 (0.05)	−7.61 (−0.86)	0.61 (4.22)**
Sec6	−9.96 (−1.48)	−7.11 (−1.18)	−0.13 (−1.03)
Sec7	−3.74 (−0.52)	−13.0 (−1.85)$^{+}$	0.09 (0.68)
Sec8	2.30 (0.46)	−12.2 (−2.61)**	0.13 (1.36)
Sec9	18.8 (3.73)**	−10.8 (−1.73)$^{+}$	0.45 (4.43)**
Sec10	5.56 (1.02)	−6.2 (−0.93)	0.30 (2.65)**
Sec11	6.74 (1.22)	−8.01 (−1.09)	0.44 (3.62)**
Sec12	6.51 (1.03)	−9.14 (−1.20)	0.24 (1.84)$^{+}$
Sec13	−4.76 (−0.63)	−15.3 (−1.84)$^{+}$	0.11 (0.71)
Sec14	−6.10 (−0.52)	−8.25 (−0.91)	−0.10 (−0.50)
Sec15	−23.2 (−3.07)**	−1.30 (−0.27)	−0.43 (−3.61)**
Sec16	−36.9 (−3.09)**	−12.7 (−2.26)*	−0.81 (−4.77)**
Sec17	−16.3 (−2.54)**	−9.52 (−2.21)*	−0.50 (−4.80)**
Sec18	−4.93 (−0.92)	−11.2 (−2.85)**	−0.29 (−3.24)**
Sec19	−4.68 (−0.76)	−9.67 (−1.91)$^{+}$	0.05 (0.47)
Sec20	−3.19 (−0.72)	−8.45 (−2.11)*	0.8 (1.00)

Endogenous switching model. Number of observations: 4535. Z-statistics are given in parentheses. Wald Chi^2 (26) = 400. $^{+}$, *, ** denote significance at the 10%, 5% and 1% level, respectively. Rho$_0$ = 0.037, rho$_1$ = 0.81**. Constants are not reported. LR test of independent equations: Chi^2 = 131**.

Contrary to that result, environmental product innovations do not seem to trigger employment over-proportionally compared to other innovations.

Customer demand (*perform*), using the turnover development as a proxy variable, is positively correlated to the employment development for both innovators and non-innovators. More internationally oriented firms are more forced to be innovative showed by the significantly positive sign of the coefficient of *international* in the selection equation. A higher degree of internationalization is also connected with a higher employment dynamics of the innovative firms. This is also true for the significance of a highly qualified staff. A high qualification (*highqual*) level triggers the innovativeness of a firm within the selection equation and the employment dynamics of innovative firms.

Younger firms (*age*) seem to be more innovative connected with a more dynamic employment development for both innovative and non-innovative firms.

Our results for further control variables of the selection equation show that larger firms are more likely to innovate (*size)*. This is also true for West German compared to East German firms (*region*). The competition conditions also matter for the innovativeness of a firm. A short length of the product life seems to require more innovation activities (*competition2*). This is also the case for a high competition pressure from foreign competitors (*competition4*).

4.2. Employment effects of different environmental innovation fields

In Section 4.1, the employment effects of eco-innovations compared to other innovations and to firms without innovative activities were analyzed. In the following, we try to go more into detail by analyzing the employment effects of different eco-innovation fields. Since the overall effects of eco-innovations on the growth rate of employment within the questioned firms are relatively low, we restrict our analysis to the question if a certain type of eco-innovation is correlated to a positive employment development or not. Therefore, we use a dummy variable getting the value 1 if a firm realized a positive employment development from 2006 to 2008 and zero otherwise. Furthermore, we restrict our sample of firms to those having realized an eco-innovation (see also Table 5).

Due to the binary character of our dependent variable *empdynamicbin*, we use a binary probit model: The firm has to decide whether to increase employment (*empdynamicbin* = 1), or to reduce or keep employment constant (empdynamicbin = 0). Following our theoretical considerations in Section 2, we believe that different factors such as the introduction of different eco-innovations, the demand for eco-innovative products or control variables such as the size of the firm summarized by a vector **x** influence this decision. Therefore, we need an estimation of the probability Prob ($empdynamicbin = 1|\mathbf{x}) = F(\mathbf{x}, \beta)$. The probit model assumes the normal distribution: Prob ($empdynamicbin = 1|\mathbf{x}) = \Phi(\mathbf{x}'\beta)$.

The parameters β reflect the impact of changes in **x** on the probability (Greene, 2008: 772). We calculate marginal effects that

Table 5
Employment effects of different environmental innovation fields.

Dependent variable: *Empdynamicbin*
1 Increasing employment from 2006 to 2008
0 Constant or decreasing employment from 2006 to 2008
Correlates

Types of eco-innovation		*Sector dummies*	
Airwater	−0.06 (−1.84)$^{+}$	Sec1	−0.18 (−2.63)**
Materialenergy	0.05 (1.97)*	Sec2	−0.07 (−1.54)
Soilnoise	0.06 (1.60)	Sec3	−0.28 (−4.96)**
Dangrecyc	0.03 (1.02)	Sec4	−0.13 (−3.03)**
Envproduct	0.01 (0.48)	Sec5	−0.15 (−2.91)**
Determinants of eco-innovation		Sec6	−0.15 (−2.95)**
		Sec7	−0.12 (−2.10)*
		Sec8	0.02 (0.51)
		Sec9	0.07 (1.58)
		Sec10	−0.07 (−1.61)
Present regulations	0.03 (1.26)	Sec11	−0.07 (−1.53)
Future regulations	−0.03 (−1.48)	Sec12	−0.04 (−0.79)
EnvSubsidies	0.02 (0.57)	Sec13	−0.20 (−3.24)**
Demand	0.07 (3.20)**	Sec14	−0.00 (−0.05)
Self commitment	−0.06 (−3.20)**	Sec15	−0.12 (−2.22)*
Rad	0.09 (4.88)**	Sec16	−0.26 (−3.44)**
Control variables		Sec17	−0.05 (−1.10)
		Sec18	0.03 (0.62)
		Sec19	−0.14 (−2.55)**
International	0.15 (7.92)**	Sec20	−0.12 (−3.01)**
Size	0.00 (1.48)		

Probit regression reporting marginal effects. Number of observations: 3706. Z-statistics are given in parentheses. LR Chi^2 (62) = 314. Pseudo R^2 = 0.06. $^{+}$, *, ** denote significance at the 10%, 5% and 1% level, respectively.
The marginal effects for the continuous independent variables were calculated at their means. Concerning dummy variables the values report the change in probability for a discrete change of the dummy variable from 0 to 1. Sector dummies are not reported. Only firms showing at least low environmental effects in one or more environmental fields ("environmental firms") are included.

allow comparing the influence of the different environmental innovation areas.

Besides the variables already described in Section 4.1, we use indicators for different types of eco-innovations. *Materialenergy* captures environmental innovations within the firm leading to a high reduction of material and energy use and CO_2-emissions. *Airwater*, *soilnoise and dangrecyc* represent the respective variables for other air emissions and water pollution, soil and noise pollution, dangerous substances and recycling. *Envproduct* denotes environmental product innovations with highly positive environmental effects. Regulations as determinant of eco-innovations are represented by *present* and *future*, anticipated *regulations*. Furthermore, environmentally related subsidies (*envsubsidies*), *customer demand* and the *self-commitment* of the respective branch as determinants for eco-innovations are considered.

Consistent with the results in Section 4.1, the estimation of our probit model shows that material and energy savings are positively correlated to employment (*materialenergy)*. Material and energy savings induce cost savings leading to a higher competitiveness of the firm. The increased competitiveness then leads to a higher demand and more employment. This result is in line with the famous Porter hypothesis (see also Section 2) and with Rexhäuser and Rammer (2011) detecting a positive relationship between the realization of material and energy savings and the profitability of the firm. On the other side, air and water process innovations (*airwater*), where end-of-pipe technologies are dominating, are slightly negatively significant. Product innovations (*envproduct*) are again not significant. If customer *demand* is especially relevant for the realization of eco-innovations, the employment performance of the firm is better – not a surprising result because these innovations are mainly introduced to increase the performance and the profitability of a firm. In firms where eco-innovations are driven by *regulations* and *subsidies* there is no significant increase of employment. This may be due to the fact that regulations often trigger additional end-of-pipe measures leading to higher production costs. The result for self-commitments aiming at preventing future regulations confirms this argumentation: If self-commitments are an important factor for eco-innovations, the employment performance seems to be even worse. Internationally oriented and R&D intensive firms show a better employment performance confirming our results in Section 4.1.

5. Summary

Due to the fact that environmental technologies from end-of-pipe to cleaner technologies are not homogenous, an analysis of the employment effects differentiating between different environmental technology fields seems to be necessary. Nevertheless, there are only few studies in the literature because of the lack of adequate data. We use the 2009 wave of the German part of the Community Innovation Survey (CIS) allowing for such an analysis at the firm level. The main focus of the analysis lies on the adaptation behavior of firms with respect to the relationship of employment and (environmental) innovation. We use an endogenous switching regression approach to take the simultaneous character of innovation activities and employment demand into consideration.

A descriptive analysis shows that firms having realized environmental process innovations are characterized by a much higher employment dynamic. The theoretical background of this finding is that e.g. material and energy saving process innovations induce cost-savings which lead to a higher competitiveness and a higher demand resulting in an increase of employment. Our econometric analysis confirms this result showing that innovative firms are characterized by a significantly more dynamic employment development compared to non-innovative firms. Especially the realization of environmental process innovations leads to a higher employment within the firm. Furthermore, the employment dynamics and the innovativeness of a firm are positively correlated to their export performance and the average qualification level of the firms' staff.

A more detailed analysis by different environmental innovation fields shows that material and energy savings are positively correlated to employment because they help to increase the profitability and competitiveness of the firm. On the other side, air and water process innovations that are still dominated by end-of-pipe technologies have a negative impact on the employment development. On the one hand, the introduction of end-of-pipe technologies requires additional staff, but, on the other hand, leads to higher costs accompanied by negative employment effects. According to our empirical results, the second effect seems to be stronger.

In a nutshell, the employment effects of the introduction of cleaner technologies seem to be more advantageous within a firm compared to more end-of-pipe oriented technologies.

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Appendix. Definition of variables and descriptive statistics

Variable	Description	Mean	St. Dev.
Endogenous variables			
Empdynamic	Growth rate of employment within the firm from 2006 to 2008, in %	11.0	72.5
Empdynamicbin	1 Increasing employment, 0 Constant or decreasing employment	0.54	0.50
Inno	1 Innovator, 0 No innovator	0.62	0.49
Types of Eco-Innovation			
Envprocess	1 Process innovations with high environmental impact, 0 Other	0.06	0.24
Envproduct	1 Product innovations with high environmental impact, 0 Other	0.14	0.35
Airwater	1 High reduction of air and water related emissions, 0 Other	0.09	0.28
Dangrecyc	1 High reduction of dangerous substances and recycling, 0 Other	0.11	0.32
Materialenergy	1 High reduction of material, energy use and CO_2 emissions, 0 Other	0.15	0.36
Soilnoise	1 High reduction of soil and noise pollution, 0 Other	0.06	0.23
Determinants			
Present regulations	Fulfillment of present laws and standards (1 yes, 0 no)	0.32	0.47
Future regulations	Anticipation of future regulations (1 yes, 0 no)	0.27	0.44

(*continued on next page*)

(*continued*)

Variable	Description	Mean	St. Dev.
EnvSubsidies	Public support of eco-innovations (1 yes, 0 no)	0.10	0.30
Demand	Customer demand for eco-innovations (1 yes, 0 no)	0.27	0.45
Self-commitment	Self-commitments of the branch (1 yes, 0 no)	0.28	0.45
	1 highly relevant, 0 other:		
Competition1	Market position threatened by entry of new competitors	0.36	0.48
Competition2	Products and services are rapidly obsolete	0.18	0.38
Competition3	Products and services are easily replaceable by competitors	0.51	0.50
Competition4	High competition intensity by foreign firms	0.33	0.47
Highqual	Share of employees with university degree 2008 in %	20.3	25.1
International	1 Exports to other (EU) countries, 0 No exports	0.46	0.50
Invintens	Gross investment 2008 per employee, in 1000 EUR	26.3	366.3
Perform	Growth rate of turnover from 2006 to 2008, in %	31.8	552.1
Rad	1 Internal or external R&D, 0 No R&D activities	0.61	0.49
Control variables			
Age	Age of the firm (2008 − year of foundation + 0.5)	31.8	38.3
Region	1 East Germany, 0 West Germany	0.31	0.46
Size	Number of employees 2008	578.7	9551.6
Sec1	Agriculture, mining, quarrying of stones	0.02	0.13
Sec2	Food products and beverages, tobacco	0.05	0.21
Sec3	Textiles, leather	0.03	0.17
Sec4	Processing of wood, paper, printing	0.06	0.24
Sec5	Chemical Industry	0.04	0.18
Sec6	Rubber and plastic products	0.03	0.17
Sec7	Glass, ceramics	0.02	0.15
Sec8	Basic metals and fabricated metals	0.07	0.25
Sec9	Machinery	0.07	0.25
Sec10	Electrical machinery and apparatus	0.05	0.21
Sec11	Precision and optical instruments	0.04	0.20
Sec12	Motor vehicles, other transport equipment	0.03	0.17
Sec13	Furniture	0.02	0.14
Sec14	Recycling, waste and waste water removal	0.01	0.10
Sec15	Energy and water supply	0.04	0.19
Sec16	Construction sector	0.02	0.13
Sec17	Wholesale and retail trade	0.05	0.22
Sec18	Transport and communication,	0.08	0.26
Sec19	Banking sector, assurances, renting of cars and other products	0.05	0.21
Sec20	Data processing, research and development, consulting	0.14	0.35
Sec21	Other services	0.12	0.32

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