The role of innovation and agglomeration for employment growth in the environmental sector

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Abstract

The environmental sector is supposed to yield a dual benefit: its goods and services are intended to tackle environmental challenges and its establishments should create new jobs. However, it is still unclear in empirical terms whether that really is the case. This paper investigates whether employment growth in establishments with green products and services is higher compared to other establishments. Furthermore, the main factors determining labor demand in this field are analyzed. We use linked employment and regional data for Germany. The descriptive results show that the environmental sector is characterized by disproportionately high employment growth. The application of both a generalized linear mixed model and an instrumental variables regression reveals that especially innovation and industry agglomeration foster employment growth in establishments in the environmental sector. Establishments without green products and services show a smaller increase in employment, even if they are also innovative.

JEL classification: J21, O33, Q55, R23

Keywords: Employment, environmental sector, eco-innovation, green jobs, technological change, industrial agglomeration

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1 Introduction

The environmental sector is supposed to yield a dual societal benefit. First, its goods and services help to tackle today's global challenges of climate change and environmental pollution. Second, it may create new jobs and could thus help to improve economic well-being. Because of these potential environmental and employment benefits, the environmental sector has received a great deal of political attention in recent years and has become an essential element of many green economy approaches (Allen and Clouth, 2012; OECD/cedefop, 2014; United Nations Environmental Programme, 2011). However, depending strongly on regulation and subsidies, the societal benefit of the environmental sector – particularly in terms of employment - is an ongoing matter of discussion. Whereas green products and services are often seen as a driving force for employment growth (e.g EU 2014, OECD/cedefop, 2014), there are also studies that question the efficiency of those investments and its impacts on productivity and employment growth (e.g. Deschenes, 2013; Elliott and Lindley, 2014).

In Germany, approximately two million people are employed in the environmental sector (Edler and Blazejczak, 2014; Federal Environmental Agency, 2014) but this figure does not indicate whether the environmental sector exhibits more dynamic employment growth compared to other sectors of the economy. Furthermore, the determinants of employment growth in the environmental sector have not been examined in detail to date.

This paper contributes to fill this gap. We analyze labor demand in the environmental sector empirically and compare it to other sectors of the German economy. Our research questions are as follows: (1) Do labor demand and employment growth differ between *environmental establishments*[3] and establishments that do not produce environmental goods or services? (2) Which determinants of labor demand foster employment growth and which determinants hinder it in the environmental sector?

In addition to analyzing standard factors of a labor demand function, such as product demand, wages or export orientation, we focus on the role of innovation and agglomeration forces for employment growth in the environmental sector compared to the German economy as a whole. As the environmental sector is not homogeneous, our econometric estimations take differences between environmental technology fields into account. Relatively new environmental technology fields such as renewable energies may be more dynamic compared to already established fields, e.g. filter systems to reduce air or water pollution. Furthermore, we consider barriers to employment growth: high competitive pressure may force firms to lower

[3] *Environmental establishments:* Short for ‚Establishments within the environmental goods and services sector'

labor costs, or collective wage agreements accompanied by higher labor costs may decrease labor demand.

For our empirical analysis we combine three data bases: the IAB Establishment Panel, the Establishment History Panel, and statistical data of the Federal Employment Agency (Bundesagentur für Arbeit) at NUTS 3 level to capture the role of agglomeration forces. We estimate different regression models to analyze the development of employment in the environmental sector compared to the rest of the economy. The data bases permit analyses of the short-term (from 2009 to 2012, 2011 to 2012 and 2011 to 2014) and the long-term (from 2002 to 2012) development of employment.

The paper is organized as follows: Section 2 contains a detailed definition of the environmental sector (2.1) and summarizes the determinants of labor demand from a theoretical perspective (2.2). The data basis is presented in Section 3.1 followed by a descriptive analysis in Section 3.2. The results of different econometric estimations of our labor demand function are shown in Section 3.3. Section 4 concludes.

2 Employment development in the environmental sector: theoretical background and hypotheses

2.1 The environmental sector

Generally speaking, the environmental sector (short for 'Environmental goods and services sector' - EGSS) deals with the supply side of environmental protection and resource management activities. In this paper we use the definition of the System of Environmental-Economic Accounting (SEEA, (United Nations, 2014), which defines the EGSS as follows:

'The EGSS consists of producers of all environmental goods and services. Thus, all products that are produced, designed and manufactured for purposes of environmental protection and resource management are within scope of the EGSS.' (United Nations, 2014: 111).[4]

[4] In terms of data collection and the organization of data, the SEEA refers to Eurostat's data collection handbook, which provides a more precise definition: *'The environmental goods and services sector consists of a heterogeneous set of producers of technologies, goods and services that:*

- Measure, control, restore, prevent, treat, minimize, research and sensitise environmental damages to air, water and soil as well as problems related to waste, noise, biodiversity and landscapes. This includes 'cleaner' technologies, goods and services that prevent or minimise pollution.

- Measure, control, restore, prevent, minimise, research and sensitise resource depletion. This results mainly in resource-efficient technologies, goods and services that minimise the use of natural resources. These technologies and products (i.e. goods and services) must satisfy the end purpose criterion, i.e. they must have an environmental protection or resource management purpose […] as their prime objective.' (Eurostat, 2009)

The SEEA distinguishes between four types of environmental goods and services (United Nations, 2014): environmental specific services (e.g. waste and waste water management and treatment services; energy- and water-saving activities), environmental sole-purpose products and services (e.g. catalytic converters, the installation of renewable energy production technologies), adapted goods (e.g. cars with lower air emissions, recycled paper), and environmental technologies: *end-of-pipe technologies*, e.g. air pollution filters (Eurostat, 2009: 10); *cleaner technologies*, e.g. technical processes to avoid air pollution (Eurostat, 2009: 12). There are considerable differences between end-of-pipe technologies and integrated technologies. Whereas end-of-pipe technologies are mostly regulation-driven, cleaner technologies are often more market-driven (e.g. as a source of cost savings) and triggered by general or environmental management systems (Frondel et al., 2007).

A further relevant definition of green jobs has been developed by the Bureau of Labor Statistics of the U.S. Department of Labor (BLS). Their definition also involves the basic distinction between output and process. Whereas the output-related approach covers the *green goods and services*, the process approach *'... identifies establishments that use environmentally friendly production processes and practices ...'* (Sommers, 2013: 5).

As we will show below (Section 3.1), we focus solely on employment in the production of environmental outputs. Therefore, we do not deliver any conclusions for green jobs on the whole in this paper, but for employment in the environmental sector, or, more precisely, for employment in the production of environmental outputs.[5]

However – even using a standard environmental sector definition – the problem still remains of where exactly the line should be drawn between environmental and non-environmental establishments. For example, many establishments do not produce or deliver only environmental goods and services. They often follow a multi-purpose strategy (e.g. technical facilities like pumps that can be applied both in biogas plants and in coal-fired power plants). It is also difficult to identify the environmental share of employment, as many employees are not only engaged in environmental-related tasks but also perform work for non-environmental goods and services (in the case of multi-purpose firms). Moreover, the environmental impact of

[5] Based on the SEEA definition of environmental goods and services, the International Labour Organization (ILO) emphasizes in their definition of employment in environmental activities the difference between employment in the production of environmental outputs and employment in environmental processes (ILO 2013a, 2013b, 2013c). Furthermore, the ILO introduces a tighter definition of green jobs by adding a decent work dimension to the environmental dimension (ILO 2012, 2013a, 2013b, 2013c). In the sense of the ILO definition, green jobs include only employment in environmental activities that fulfill the conditions of decent work (decent work indicators according to ILO 2012). Our analysis only captures the environmental dimension of the ILO definition.

products and services may differ. There is a huge difference between the climate impact of a zero-emission e-car and a large SUV with a cleaner hybrid drive but still high fuel consumption. Nevertheless, both help to reduce air pollution and thus are regarded as environmental goods and services. To tackle some of these challenges, Eurostat (2009) published a data collection handbook for the environmental sector, which contains some recommendations that we also used in our empirical work (see also Section 3.1).

2.2 Determinants of employment growth

We use the notion of employment growth[6] as the increase or decline of employment between two dates. This corresponds to the definition of *standard employment change* as used by Hamermesh et al. (1996) in their *taxonomy of employment dynamics:* the standard employment (E) change measures the difference between the number of jobs available at the end of the period (J_{t+1}) and the jobs available at the beginning of the measurement period (J_t). For our estimations we use the growth rate of employment:

$$\frac{\dot{E}}{E} = \frac{J_{t+1} - J_t}{J_t} * 100$$

The extent of employment growth is determined by various factors. In the following, we briefly present central determinants of employment growth that are widely used in literature:

Many recent studies have described innovation as one of the major factors for employment growth (e.g. Buerger et al., 2012; Capello and Lenzi, 2011). The Oslo Manual (OECD/Eurostat, 2005: 46) defines innovation as: *'... the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organisation or external relations.'* and differentiates between four types of innovation: product innovations, process innovations, marketing innovations and organizational innovations.

Besides these standard types of innovation and particular relevant for the environmental sector, the notion of eco-innovation has emerged in recent years. Kemp and Pearson (2008) denote eco-innovation as follows:

[6] The notions of employment growth and employment dynamics are used differently in the literature. According to many authors (e.g. Carlsson et al. 2013, Dauth 2013, Hyatt and Spletzer 2013, Konigsberg et al. 2009), employment dynamics are seen as the growth or decline of employment between two dates, which corresponds to the concept of employment growth. Other authors (e.g. Bauer et al. 2007, Hamermesh et al. 1996, Kölling 2012) define employment dynamics in the sense of labor turnover or worker flows. In the paper in hand, we focus on employment growth.

'Eco-innovation is the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organisation (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives.' (Kemp and Pearson, 2008: 7).

The analysis of the employment effects of eco-innovation requires a distinction between process and product innovations. The employment effects of eco-process innovations may be negative because of the implementation of end-of-pipe technologies (e. g. additional air emission filters) leading to higher costs. On the other hand, these end-of-pipe measures may require additional employees. The introduction of process-integrated, resource- and energy-saving measures may improve a firm's profitability and competitiveness, which may lead to an increase in the number of employees but the introduction of these measures may also lead to labor saving effects. Horbach and Rennings (2013) empirically detected positive employment effects of eco-process innovations. In the present paper, eco-product innovations are in the focus of the analysis because we analyze the development of the environmental sector. In fact, the employment effects of environmental product innovations are also theoretically unclear. Product innovations may induce new demand for the firm by creating completely new markets or by substituting products of competitors leading to positive employment effects at the firm level. The macroeconomic employment effects remain undetermined as they also depend on the labor intensity of the substituted products. Furthermore, the introduction of a new product may cause a monopolistic position accompanied by a reduction of output. In that case, negative employment effects may be observed (Hall et al. 2006, Horbach and Rennings 2013). Empirical studies focusing on general innovations mostly find positive effects of product innovations on labour demand (see for instance Smolny 2002, Piva and Vivarelli 2005, Zimmermann 2009). Similar results are observed for the UK (van Reenen 1997), for France (Greenan and Guellec 2000) and in a study for France, Great Britain, Germany and Spain based on harmonised data of the Community Innovation Panel (CIS) (Harrison et al. 2008). Due to the lack of suitable data, there are only few analyses on the employment effects of eco-innovations. In most cases, these studies also show positive effects of eco-innovations on employment (Bijman and Nijkamp 1988, Pfeiffer and Rennings 2001, Rennings and Zwick 2002). Horbach (2010) detects a positive and significant influence of eco-product innovations on employment. The positive effects of eco-innovation appear to be greater compared to other non-environmental innovation fields.

Licht and Peters (2013, 2014) use the Community Innovation Survey (CIS) of 2009 to analyze employment effects of products and process innovations for different European countries and for Germany. The authors find that both environmental and non-environmental product innovations are correlated to employment growth, but that still non-environmental product innovations are more likely to increase employment. Following their estimation results, the displacement effect of process innovations seems to be quite small. The paper of Gagliardi et al. (2014) also analyses the link between eco-innovation and job creation at the company level for Italian companies matched with patent records for the period from 2001 to 2008. The results show a strong positive impact of eco-innovation on the creation of long-run jobs. The effects are substantially greater compared to the effects of other innovations.

Agglomeration is recognized as a further important factor concerning labor demand (e.g. Alyan, 1999; Morrison et al., 2006; Mulligan et al., 2014; Reggiani et al., 2011). Hence, the positive role of eco-innovation for the development of employment may be reinforced by the existence of agglomeration effects.

Agglomeration in the sense of the *New Economic Geography* (e.g. Krugman, 1998; Puga, 2010) describes mainly the magnitude, causes and consequences of firms located close to each other. Agglomeration economies have been identified across a large range of different fields, including the US carpet production industry in the Georgian city of Dalton (Krugman, 1991) and composers of classical music (Borowiecki, 2013). According to Duranton and Puga (2004), the causes of agglomeration are a more efficient sharing of the local infrastructure, a better matching between market partners – e.g. between employers and workers – and a better environment for inter-organizational learning. The latter includes the prerequisites for knowledge spillovers. The literature on spillovers (see e.g. Audretsch and Feldman, 2004; Feldman, 1999; Kaiser, 2002) is closely related to innovation and agglomeration. Since knowledge is strongly linked to workers, innovation intensity increases when workers share their knowledge across firms. Although modern information and computer technology makes it possible to collaborate easily across large distances, physical proximity to those network partners is helpful for knowledge spillovers especially for so-called tacit knowledge, which requires face-to-face contacts (Horbach et al., 2013).

Up to now, there are only few articles available concerning the relationship between agglomeration and the environmental sector or eco-innovation. Sensier et al. (2013) show that connections to local governments have positive impacts on the growth of small and medium-sized environmental firms. On the other hand, the growth of these firms benefits from interna-

tional networks with companies and universities outside the local region. The authors conclude that environmental firms should be both locally and globally oriented in order to be most successful. Horbach (2014b) shows that external knowledge sources such as the regional proximity to research centers and universities are more important for eco-innovations compared to other innovations.

According to Hamermesh (1993), the product market, or more specifically product demand, influences labor demand significantly. In addition, high productivity plays a key role in determining labor demand because it helps to improve a firm's (international) competitiveness, thereby leading to increased product demand. The simple neo-classical labor demand function shows that the demand for labor depends on the development of real wages. The 'normal' case describes a situation where higher real wages lead to a reduction of labor demand. But the relationship is more complicated: successful firms (which are characterized by positive employment growth) are also more likely to pay higher wages. In econometric analyses, this causes endogeneity problems that have to be considered.

Further labor demand factors that are discussed in the relevant literature are binding wage agreements, union membership (Dittrich and Schirwitz, 2011), labor shortage (Horbach, 2014a) as barriers to employment development, skills (Addison et al., 2008), firm size (Kölling, 2012), occupations and sectors of industry (Cörvers and Dupuy, 2010). Finally, conditions of the establishment's organizational environment may also influence labor demand: regional effects (Fuchs, 2011; Fuchs and Weyh, 2010), regulation (Beise and Rennings, 2005; David and Sinclair-Desgagné, 2005), economic development activities (e.g. Kölling, 2014), external shocks (e.g. economic crisis, see Bohachova et al., 2011), industry structure (Cörvers and Dupuy, 2010; Dauth and Suedekum, 2014) and changes in factor markets (e.g. energy prices, see Hamermesh, 1980).

All in all, our theoretical considerations show the important role of high product demand, wages and wage agreements, innovation activities, agglomeration forces and competitive pressure for the development of a firm's employment. The empirical questions of whether environmental establishments exhibit higher employment growth compared to other firms and what factors are crucial for such a development are yet to be answered (see Section 3).

3 Empirical analysis of employment growth in the environmental sector

3.1 Data

Our empirical analysis combines data from four sources in order to analyze the determinants of employment development: the IAB Establishment Panel survey, the Establishment History Panel (Betriebs-Historik-Panel – BHP), the IAB Employment History (Beschäftigtenhistorik – BEH) and regional employment statistics data at NUTS 3 level *(Landkreise* and *kreisfreie Städte*).

The Establishment Panel of the Institute for Employment Research (IAB) was set up in 1993 to obtain a representative picture of German establishments that have at least one employee subject to social security. The annual survey is characterized by very high response rates of more than 70 percent and covers over 15,000 German establishments. It contains both a standard yearly program of questions and additional questions on special topics of current interest. As one of those specific topics, environmental-specific questions were asked in the 1999, 2005 and 2012 waves. Those questions made it possible to identify and analyze environmental establishments, their employment development and other organizational characteristics. Furthermore, the establishments are asked to report their share of turnover in the field of environmental goods and services. The answers to this question make it possible to calculate the share of environmental-related employees. This applies especially for firms producing multi-purpose goods and services as well as for firms producing both environmental and non-environmental goods and services.

15.4 percent (2,352 firms) of all the firms in the sample of the 2012 wave declared that they produce or deliver environmental goods and services. Similar filter questions were introduced in 1999 and 2005. However, we cannot use the 1999 and 2005 waves for the econometric analyses, because the questions regarding the environmental sector were changed between 2005 and 2012. Products associated with renewable energies and nature conservation were mentioned explicitly only in 2012. Because of these changes, comparisons of the results of 1999/2005 with those of 2012 are limited. A further restraint is due to panel mortality. Owing to the fact that too few of the environmental establishments surveyed in 2012 were included in the previous waves, there are strong limitations when following the environmental establishments surveyed in 2012 within the longitudinal set of the survey panel data. It is therefore not possible to conduct an econometric analysis of employment dynamics based on differences between 1999/2005 and 2012. Nevertheless, we report the descriptive results of the 1999, 2005 and 2012 waves by different environmental technology fields in section 3.2. The use of

further waves (here: 2009 and 2010) of the Establishment Panel permits the inclusion of lagged independent variables to reduce endogeneity problems.

For the econometric analysis the question on the environmental goods and services in the 2012 wave is used to identify the firms belonging to the environmental sector. Combining the 2009, 2012 and 2014 waves then enables us to calculate the development of employment in the environmental sector from 2009 to 2012, from 2011 to 2012 and from 2011 to 2014. The limitation of this procedure is that it is not known whether a firm already offered environmental goods and services before 2012 because the filter question is only available for 2012. Therefore it may occur that the employment development of firms that did not offer environmental products or services in 2009 is analyzed.

Facing the limitations concerning panel data in terms of the environmental sector from the Establishment Panel, we merged the survey data with data from the German Establishment History Panel (BHP)[7] [8] in order to form an appropriate data set for our project. The BHP contains longitudinal data at establishment level that is obtained from mandatory employer notifications to the German social security system, which leads to highly accurate and reliable data. All German establishments are included in the annual BHP data set, if they register at least one dependent employee as of the reference date of June 30. The BHP provides data about establishments' workforces, wage distributions, sectors and locations. Regarding our econometric analysis, we used the BHP data for an analysis of the long-term development of employment from 2002 to 2012.

After merging the data sets of the Establishment Panel data, the BHP and the regional data at NUTS 3 level, our data file contains data on 15,544 establishments that participated in the 2012 Establishment Panel survey and could be identified within the administrative data of the BHP data. Our analysis of firm-level data gives us the opportunity to isolate the effects of different labor demand factors. Therefore, we can analyze those factors at firm and industry level as well as at regional level and over time. The following section provides an overview of the descriptive results based on this linked project data set.

[7] This study uses the IAB Establishment Panel waves of 2012, 2010, 2009, 2005, 1999 and the Establishment History Panel (BHP) version 7510 (here: years 1993-2010). Data access was provided by the Research Data Centre (FDZ) of the German Federal Employment Agency (BA) at the Institute for Employment Research (IAB). For detailed data documentation see Ellguth et al. (2014), Fischer et al. (2009) and Gruhl et al. (2012).

[8] We would like to thank the data management team of the IAB department 'IT Services and Information Management' for their kind help; special thanks go to Ali Athmani, Steffen Kaimer, Jonas Krüger and Cerstin Rauscher.

3.2 Descriptive analysis

In 2012 the German environmental sector employed 1.47 million persons (Table 1). The largest share of these employees – almost two thirds – works in connection with the provision of services, while about one third works in the production of goods.

Table 1: Employment in the environmental sector in 2012 – number of employees

Environmental goods/services	Employees 2012	
	Number	Share
Environmental goods	520,516	35.5%
Environmental services	945,165	64.5%
Total	1,465,682	100.0%

Source: IAB Establishment Panel 2012, own calculations, projected results.

Table 2 shows the development of the employment shares between the panel waves of 1999, 2005 and 2012. Since the environmental sector comprises a broad range of goods and services, it is necessary to distinguish between different subfields. In 2012, the question on the composition of the different environmental fields was changed significantly such that the results obtained in 1999/2005 are not fully comparable with those obtained in 2012. The results document the considerable importance of the subfield of *climate protection and renewable energies* (2012: 35.2 percent) for employment whereas the shares of subfields such as water or recycling decreased (e.g. recycling from 29.8 percent in 2005 to 19.0 percent in 2012).

Table 2: Employment in the environmental sector by different subfields

Subfield	Distribution of employment in %		
	1999	2005	2012
Prevention of water pollution, waste water treatment	18.9	13.0	12.3
Waste management, recycling	27.4	29.8	19.0
Air purification, climate protection	16.3	22.1	-
Air purification	-	-	3.8
Climate protection, renewable energies, energy saving	-	-	35.2
Noise abatement	2.3	2.1	4.5
Environmental remediation, soil conservation	3.7	5.4	1.6
Nature conservation, landscape management	-	-	9.7
Measurement, analysis and control technology	6.6	6.5	3.9
Analytics, consultancy, project planning	4.7	5.4	2.9
Environmental research, development and monitoring	1.5	4.7	2.0
Other environmental fields	18.6	11.0	5.1
Total	100	100	100

Source: IAB Establishment Panel 2012, Horbach et al. (2009), own calculations, projected results.

In a further step, we analyze the employment growth from 2009 to 2012. For this reason, we have to identify environmental establishments based on questions from one wave of the IAB Establishment Panel. This enables us to trace these establishments in previous panel waves – if they had participated in those waves. We use the questions asked in 2012 to identify the firms in the environmental sector, as the filter questions in 2012 are not comparable to those asked in 2005 and 1999. Furthermore, it has to be borne in mind that firms may be incorrectly assigned to the environmental sector for the period from 2009 to 2011 if they had not yet provided environmental goods and services prior to 2012. Employment development denotes the growth rate of the total number of employees between 2009 and 2012.

Table 3: Employment growth from 2009 to 2012 by different subfields compared to non-environmental establishments

Subfield	**Employment growth 2009 – 2012 in %**
Prevention of water pollution, waste water treatment	2.7
Waste management, recycling	0.6
Air purification	12.0
Climate protection, renewable energies, energy saving	6.2
Noise abatement	6.1
Environmental remediation, soil conservation	16.8
Nature conservation, landscape management	1.2
Measurement, analysis and control technology	9.5
Analytics, consultancy, project planning	16.3
Environmental research, development and monitoring	14.0
Other environmental fields	11.7
Environmental sector in total	4.7
Other establishments	4.2

Source: IAB Establishment Panel 2012, own calculations.

Table 3 shows the employment growth from 2009 to 2012 by different subfields of the environmental sector compared to non-environmental establishments. Overall, employment growth is slightly higher in the environmental sector as a whole (4.7 percent) compared to non-environmental establishments (4.2 percent). Within the environmental sector, pronounced differences between subfields are visible. The subfield of *environmental remediation, soil conservation* shows the highest value (16.8 percent), whereas *waste management, recycling* has the lowest value (0.6 percent). *Climate protection, renewable energies, energy saving*, the

subfield with the largest employment share, grew by 6.2 percent, which is stronger than the average of the environmental sector in total (4.7 percent).

In the light of this employment growth, we want to know what qualification level the environmental establishments demand and how the establishments differ in terms of innovation.

Table 4 provides an overview of these two aspects. Again, we observe significant differences between subfields. Compared with the overall sample, most subfields of the environmental sector have a larger share of employees with a university education and a smaller share of employees with no vocational training. This situation is reflected in the share of innovative establishments. In this case, all subfields show larger innovation shares than the overall sample. The subfields with the largest shares of innovative establishments (more than 50 percent) are *measurement, analysis and control technology*, *environmental research, development and monitoring*, *environmental remediation, soil conservation*, and *analytics, consultancy, project planning.* Among other things, the largest subfield, *climate protection, renewable energies, energy saving,* also has an above-average share of innovative establishments (44.7 percent).

Table 4: Qualification level of employees and innovativeness in the German environmental sector in 2011

Subfield	Share of employees with …		Share of innovative establishments in %
	university education in %	no vocational training in %	
Prevention of water pollution, waste water treatment	13.4	17.4	49.3
Waste management, recycling	8.9	28.5	41.1
Air purification	8.6	21.3	37.8
Climate protection, renewable energies, energy saving	13.4	15.8	44.7
Noise abatement	13.1	26.2	49.3
Environmental remediation, soil conservation	9.5	15.9	58.5
Nature conservation, landscape management	12.8	22.8	32.2
Measurement, analysis and control technology	16.4	13.3	57.0
Analytics, consultancy, project planning	26.8	14.9	52.3
Environmental research, development and monitoring	38.4	13.8	50.5
Other environmental fields	12.1	23.3	54.2
All firms in the whole sample	9.9	24.2	31.2

Source: Horbach (2014a), IAB Establishment Panel 2012.

All in all, the environmental sector accounts for a considerable share of employees and a large share of environmental services. Compared with the sample average, the environmental sector

has grown more strongly and most of its subfields have a larger share of employees with a university education and a smaller share of employees with no vocational training. Furthermore, all subfields of the environmental sector show larger innovation shares than the overall sample. However, the environmental sector is not homogeneous. In terms of both employment growth and other environmental sector characteristics there are pronounced differences between its subfields.

3.3 Econometric analysis

Our econometric analysis aims at exploring the determinants of employment development in the environmental sector compared to the German economy as a whole. In a first step, we analyze the short-term development of employment from 2009 to 2012. Furthermore, the time periods of 2011 to 2012 and from 2011 to 2014 are considered to reduce problems of endogeneity. Combining the Establishment Panel with the so-called Establishment History Panel enables us to observe the firms belonging to the environmental sector for a longer time period from 2002 to 2012, so we also estimate such a long-term model. Separate models are estimated for all firms including environmentally relevant explanatory variables and for the environmental sector alone.

As the baseline estimation, we use an OLS model with clustered standard errors at NUTS 3 level, because variables at the establishment and the regional level are considered. Furthermore, we apply a two-level mixed-effects linear regression. The two models take into account the problem that the employment growth of firms within a region may be correlated. The mixed-effects model contains both random and fixed effects. We have to consider a two-level model for a series of 411 clusters (411 regional German NUTS 3 units). The model reads as follows (StataCorp, 2013):

$$empdev_{ij} = \beta_0 + \beta_1 reg_{ij} + \beta_2 inno_{ij} + \beta_3 pdem_{ij} + \beta_4 wagedev_{ij} + \beta_5 \psi_{ij} + \mu_j + \varepsilon_{ij}$$

for $j = 1; \ldots; 411$ clusters, with cluster j consisting of $i = 1; \ldots; n_j$ observations. The random effect u_j serves to shift the regression line up or down according to the NUTS 3 unit (StataCorp, 2013). Because of the small numbers of cases in many regions, a random intercept model was estimated assuming fixed slopes. The log-likelihood function is approximated by Gauss-Hermite quadrature (Cameron and Trivedi, 2009). Following the theoretical analysis in Section 2, we consider vectors of regional variables (reg_{ij}), innovation ($inno_{ij}$), indicators for product demand ($pdem_{ij}$), the development of wages ($wagedev_{ij}$) and further control variables ψ_{ij} such as export shares, state of technical equipment, firm size, firm age, competitive pres-

sure, qualification structure, sector dummies and dummies for the German *Länder* (NUTS 1 units).

To reduce the problem of endogeneity regarding wages, we already lagged this variable by one period. In fact, this endogeneity problem may be minor because the possibilities for a single establishment to alter wages are restricted due to the pressure from national and international competitors. Therefore, wages are probably influenced more by developments in specific industries than by single establishments. Nevertheless, as a robustness check, we also estimate an instrumental variable regression to take into consideration the endogeneity of wages. The model reads as follows:

(1) $empdev_i = \alpha_0 + \alpha_1 wagedev_i + \alpha_2 x_{1i} + u_i$

(2) $wagedev_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + v_i$

The employment development ($empdev_i$) of firm i depends on wages ($wagedev_i$) and further exogenous variables x_{1i}. $Wagedev_i$ as an endogenous regressor is instrumented on the exogenous regressors in equation (1) and a vector of further exogenous regressors x_{2i}. The zero-mean error terms u_i and v_i are presumably correlated.

As a further robustness check, we estimate a treatment effects model regarding the environmental innovation intensity as treatment variable. This model helps to answer the question as to whether firms with intensive innovation in the environmental sector demonstrate better employment growth compared to the economy as a whole. The so-called propensity score matching estimator calculates the conditional probability that an observation receives a specific treatment given certain covariates. The unknown potential output without treatment is estimated using an average of the outcomes of similar subjects (StataCorp, 2013).

Description of variables

For our econometric analysis, we use the following variables (for a precise definition see Appendix Table A-1). *Empdev0912* describes the growth rate of the number of employees from 2009 to 2012, *empdev1112*, *empdev1214* and *empdev0212*, the respective employment developments.

The dummy variables *ecoinnointens*, *waterinno*, *recycinno*, *airclimateinno* and *natureinno* are given the value one if the firm belongs to the respective environmental field and has implemented a product or process innovation in 2011. Unfortunately, we only have data for 2011 concerning the different environmental innovation fields so that it is difficult to cope with possible endogeneity problems of these innovation activities. Furthermore, reliable exogenous

instruments for the different innovation fields are not available. Therefore, as a robustness check, we analyze two further short term periods from 2011 to 2012 and from 2011 to 2014 that follow the innovation activities of 2011 (Table 6). These results can be better interpreted in the sense of causality rather than mere correlation. The disadvantage of this procedure is on the one hand that the time period of 2011 to 2012 is very short. On the other hand, from 2011 to 2014, the panel mortality is high so that many observations are lost leading to less significant results.

Otherinno captures firms that are innovative but not active in the environmental sector. *Age* describes the age of the firm, the variable has the value one if the firm was founded after 1990, zero otherwise. The state of a firms' capital stock is indicated by *capitalnew*. The value one characterizes a modern capital stock. The dummy variable c*ompetition* denotes high competitive pressure perceived by the firm. The share of employees with a university degree in the firm's entire workforce is captured by *highqual*. The value one for *profitsituation* denotes the firm having a very good or good self-perceived profit situation before the analyzed time period. Besides the profit situation, o*vertime* is a further proxy variable for the product demand. If a firm made use of overtime, this variable is given the value one. The product demand also reflects the influence of environmental policy because German environmental policies such as the German feed-in-tariff system foster the demand for environmental goods and services. However, because of a lack of data, we cannot include further regulation indicators in our model.

Size denotes the number of employees of the establishment. Furthermore, dummies for the German *Länder* and sectors were included. *Invest* has the value one if the establishment made investments. We also include the variables *popdens* and *secshare* at NUTS 3 level. *Popdens* denotes the population density of the respective NUTS 3 unit; *secshare* captures the sector share of the sector to which the firm belongs in the respective NUTS 3 unit, thus signaling localization advantages (or disadvantages).

Table 5: Determinants of employment growth from 2009 to 2012

Dependent variable: Empdev0912 - Employment growth rate from 2009 to 2012, in %				
Regressors	**All establishments**			**Only env. estab.**
	OLS (clustered standard errors)	**Two-level mixed GLM**	**IV-regression[1] (2SLS)**	**Two-level mixed GLM**
Innovations				
Ecoinnointens	7.91 (2.49)***	7.93 (2.66)***	8.19 (2.53)***	7.30 (2.09)**
Otherinno	3.76 (4.43)***	3.74 (3.76)***	3.34 (3.03)***	-
Airclimateinno	5.00 (1.94)**	4.99 (1.95)**	4.62 (1.75)*	4.34 (1.40)
Natureinno	-5.50 (-1.42)	-5.42 (-0.94)	-5.10 (-1.36)	-3.64 (-0.60)
Recycinno	1.78 (0.64)	1.75 (0.50)	2.00 (0.72)	0.20 (0.05)
Waterinno	0.20 (0.08)	0.19 (0.04)	1.02 (0.35)	-0.48 (-0.10)
Regional var.				
Popdens	0.03 (0.55)	0.05 (0.62)	0.02 (0.29)	0.22 (1.09)
Secshare	0.18 (2.89)***	0.18 (2.56)***	0.18 (2.78)***	0.61 (3.02)***
Control var.				
Age	4.59 (4.85)***	4.62 (4.82)***	3.88 (2.44)***	4.60 (1.82)*
Capitalnew	4.02 (4.59)***	4.02 (4.42)***	3.96 (4.28)***	5.14 (2.16)**
Competition	-3.55 (-3.90)***	-3.55 (-3.99)***	-3.55 (-3.80)***	-4.90 (-2.14)**
Exportshare	-0.01 (-0.40)	-0.01 (-0.36)	-0.01 (-0.45)	0.05 (0.77)
Highqual	-0.02 (-0.83)	-0.02 (-0.79)	-0.01 (-0.40)	-0.09 (-1.35)
Overtime	2.38 (2.37)**	2.37 (2.42)***	3.23 (1.72)*	0.31 (0.11)
Profitsituation	4.06 (4.57)***	4.06 (4.62)***	3.91 (4.04)***	1.25 (0.55)
Size	0.01 (0.50)	0.01 (0.15)	-0.00 (-0.13)	-0.04 (-0.47)
Tariff	-0.58 (-0.64)	-0.60 (-0.64)	-	-2.52 (-1.06)
Wagedyn0911	-0.00 (-0.02)	-0.00 (-0.03)	0.14 (0.64)	-0.05 (-1.99)**
German Länder				
Baden	6.11 (2.93)***	6.04 (2.82)***	5.69 (2.39)**	8.90 (1.56)
Bavaria	5.42 (2.54)***	5.37 (2.46)***	5.18 (2.34)**	6.31 (1.14)
Berlin/Bre./Ham.	3.68 (1.89)*	-	4.14 (1.91)*	-
Berlin	-	2.40 (0.67)	-	-0.60 (-0.06)
Brandenburg	3.18 (1.63)	3.21 (1.51)	3.35 (1.65)*	9.11 (1.60)
Bremen	-	3.89 (1.50)	-	9.91 (1.45)
Hamburg	-	3.85 (0.95)	-	9.48 (0.77)
Hesse	3.43 (1.58)	3.39 (1.42)	3.31 (1.46)	8.91 (1.47)
Lowsax	5.74 (1.90)*	5.75 (2.56)***	5.14 (1.54)	19.0 (3.41)***
Meckpom	1.72 (0.80)	1.74 (0.76)	1.92 (0.89)	11.1 (1.76)*
Northwestf	2.95 (1.64)*	2.85 (1.36)	2.64 (1.26)	4.51 (0.84)
Rhineland	6.42 (2.94)***	6.41 (2.62)***	5.48 (1.85)*	14.8 (2.27)**
Saarland	3.23 (0.90)	3.20 (1.23)	3.65 (0.91)	5.69 (0.88)
Saxony	3.81 (2.07)**	3.77 (1.87)*	4.34 (2.03)**	7.00 (1.38)
Saxonyanh	1.81 (0.91)	1.81 (0.87)	1.84 (0.88)	12.1 (2.39)**
Schleswig	8.74 (2.64)***	8.71 (3.20)***	9.01 (2.73)***	13.8 (2.05)**
	No. obs.: 6677 F (48, 394) = 6.24***	No. obs.: 6677 Wald $\chi2$ (50) = 206***	No. obs.: 6677 Wald $\chi2$ (47) = 274***	No. obs.: 1035 Wald $\chi2$ (49) = 71.0***

Z-statistics are given in parentheses; *, ** and *** denote significance at the 10%, 5% and 1% level, respectively. Sector dummies and constants are included but not reported.

[1]The variable *tariff* is used as additional instrument in the IV-regression. Wooldridge test of endogeneity (for the IV-regression): F(1,394) = 0.42

Table 6: Determinants of employment growth from 2011 to 2012 and from 2011 to 2014

Dependent variable: Empdev1112/Empdev1114 - Employment growth rate from 2011 to 2012/2011 to 2014, in %

Regressors	**All establishments**		**Only environmental establishments**	
	2011-2012	**2011-2014**	**2011-2012**	**2011-2014**
Innovations				
Ecoinnointens	3.02 (2.71)***	3.61 (1.65)*	2.64 (1.65)*	6.25 (2.44)***
Otherinno	2.34 (4.52)***	2.93 (3.51)***	-	-
Airclimateinno	2.75 (1.58)	-0.36 (-0.14)	2.29 (1.32)	2.75 (0.95)
Natureinno	-1.42 (-0.41)	2.84 (0.52)	-2.18 (-0.56)	7.30 (1.29)
Recycinno	0.84 (0.75)	0.34 (0.13)	1.07 (0.74)	3.00 (0.92)
Waterinno	0.96 (0.78)	0.49 (0.16)	0.75 (0.48)	3.73 (1.04)
Regional var.				
Popdens	0.05 (1.75)*	0.10 (2.06)**	0.02 (0.29)	0.11 (0.96)
Secshare	0.06 (1.61)*	0.06 (0.89)	0.21 (1.58)	0.06 (0.43)
Control var.				
Age	-0.06 (-0.14)	1.29 (1.45)	-1.05 (-0.84)	-2.10 (-1.15)
Capitalnew	0.40 (0.78)	1.64 (1.73)*	-0.95 (-0.54)	2.51 (1.27)
Competition	-1.49 (-2.77)***	-3.52 (-4.30)***	-0.02 (-0.01)	-2.34 (-1.13)
Exportshare	-0.00 (-0.05)	-0.00 (-0.1)	0.01 (0.31)	-0.03 (-0.51)
Highqual	-0.01 (-0.30)	0.05 (1.46)	-0.05 (-1.39)	-0.00 (-0.06)
Overtime11	2.13 (4.35)***	3.57 (4.17)***	1.66 (1.21)	1.91 (0.78)
Profitsituation11	3.56 (8.04)***	6.18 (7.34)***	6.06 (4.26)***	9.57 (4.08)***
Size	0.01 (0.59)	-0.02 (-1.13)	-0.00 (-0.01)	-0.00 (-0.01)
Tariff	-0.71 (-1.51)	-2.05 (-2.39)**	-0.26 (-0.19)	-2.39 (-1.18)
Wagedyn0911	0.01 (1.58)	0.01 (0.75)	0.00 (0.32)	0.02 (0.82)
German Länder				
Baden	0.27 (0.27)	3.64 (2.40)**	0.80 (0.21)	-0.94 (-0.27)
Bavaria	1.17 (1.20)	6.31 (3.94)***	1.26 (0.42)	5.20 (1.45)
Berlin/Bre./Ham.	0.22 (0.20)	1.44 (0.97)	1.49 (0.48)	-0.43 (-0.09)
Brandenburg	2.69 (2.35)**	2.58 (1.51)	5.14 (1.70)*	1.48 (0.36)
Hesse	2.34 (2.12)**	6.03 (3.43)***	1.57 (0.49)	8.79 (1.43)
Lowsax	0.81 (0.65)	3.80 (2.41)**	1.84 (0.55)	0.04 (0.01)
Meckpom	1.88 (1.31)	2.41 (1.46)	4.76 (0.84)	-7.88 (-2.21)**
Northwestf	-0.31 (-0.29)	5.63 (3.63)***	2.13 (0.63)	6.38 (1.49)
Rhineland	0.10 (0.08)	1.41 (0.69)	2.52 (0.81)	-0.31 (-0.07)
Saarland	0.49 (0.35)	4.96 (2.02)**	1.37 (0.44)	6.77 (1.58)
Saxony	0.72 (0.73)	3.63 (2.68)***	1.28 (0.47)	2.37 (0.65)
Saxonyanh	0.18 (0.19)	0.89 (0.70)	5.38 (1.77)*	4.08 (1.34)
Schleswig	1.89 (1.23)	5.93 (2.00)**	6.20 (1.88)*	12.70 (2.36)**
	No. obs.: 6689 F (48, 394) = 7.45***	No. obs.: 5255 F (48, 389) = 6. 86***	No. obs.:1035 F (47, 285) = 1.85***	No. obs.: 832 F (47) = 3.47***

OLS – Regressions with clustered standard errors. Z-statistics are given in parentheses; *, ** and *** denote significance at the 10%, 5% and 1% level, respectively. Sector dummies and constants are included but not reported.

Results of the short-term models

The estimation results of a model for all the firms in the sample show that highly innovative environmental technology fields such as measurement, analytics, engineering or environmental research (*ecoinnointens*) and air/climate (*airclimateinno*) are significantly positively correlated with the employment development from 2009 to 2012 (Table 5).[9] The positive influence of *ecoinnointens* is confirmed for the time periods of 2011 to 2012 and 2011 to 2014 (Table 6). For the other, also innovative environmental technology fields, no significant positive effects on the employment development are detected. Other, not environmentally related innovations (*otherinno*) also trigger employment growth in all analyzed time periods but the coefficient is clearly smaller compared to innovation-intensive eco-innovations (Tables 5/6).

Table 7: Eco-innovation and employment growth from 2009 to 2012 – results of a treatment effects model

Dependent variable: Empdev0912 - Employment growth rate from 2009 to 2012, in %	
Treatment variable:	Propensity score matching
	The propensity score of each subject is estimated using the following probit model: $Ecoinnointens_i = \beta_0 + \beta_1 size_i + \beta_2 invest_i + \beta_3 highqual_i + \beta_4 age_i + \beta_5 secshare_i + \beta_6 westeast_i + \varepsilon_i$
	Average treatment effect:
Ecoinnointens	9.87 (2.37)**
	Number of observations: 10138

Z-statistics are given in parentheses; *, ** and *** denote significance at the 10%, 5% and 1% level, respectively. For the other eco-innovation fields there are no observable significant treatment effects, so they are not reported.

To check the robustness of this interesting result that eco-innovativeness is crucial for employment, we also estimated a treatment effects model (see Table 7). The analysis shows that *ecoinnointens* as treatment variable is highly significant, which confirms the finding that specific innovative technology fields in the environmental sector, such as measurement technologies, are associated with higher employment. On the other hand, this is not the case for "older" technology fields, such as water purification technologies. For these fields, corresponding treatment effect models were not significant.

Firms profiting from localization effects measured by a strong presence of similar firms in the NUTS 3 unit (*secshare*) are characterized by disproportionately positive employment growth from 2009 to 2012. This result is not confirmed for the time period of 2011 to 2014. Em-

[9] This result only holds for innovative environmental establishments. Models including dummies for all establishments for the different environmental subfields did not yield significant results. Only innovative firms in the respective environmental technology fields show a better employment development.

ployment growth is also triggered by a high product demand measured by the proxies *profit situation* and *overtime* (see Table 5/6). Firms equipped with modern capital stock (*capital-new*) also exhibit better employment growth. Furthermore, the employment growth of younger firms (*age*) was disproportionally dynamic from 2009 to 2012, whereas high competitive pressure (*competition)* seems to force firms to reduce their employment. In both models (two-level mixed GLM and the IV-regression) no significant influence of the wage development (*wagedyn0911*) on employment is observable. From 2009 to 2012, the German *Länder Baden, Bavaria, Lower Saxony* (*lowsax*), *Rhineland, Saxony* and *Schleswig* show a more dynamic development compared to *Thuringia* as the base category.

Concerning our different estimation approaches, the two-level mixed GLM and the IV-regression show only marginal differences and are also very similar to our OLS estimates with clustered standard errors so that in Table 6 only the OLS estimates are reported.

A separate estimation restricted to the sample containing only firms in the environmental sector shows some interesting specificities of the determinants of employment growth in this sector. From 2009 to 2012, the importance of localization effects seems to be higher for the environmental sector, the respective coefficient for the variable *secshare* is more than three times higher in the model restricted to the sample of environmental firms compared to the model with all firms (Table 5). Furthermore, the environmental sector seems to provide employment opportunities in some eastern German *Länder*, especially for Saxony-Anhalt, which confirms the results of a recent analysis of Horbach (2014b).

Specificities of the long-term models (2002-2012)

Combining the Establishment Panel with the Establishment History Panel allows a long-term analysis of the employment growth in the environmental sector compared to the economy as a whole from 2002 to 2012. The main shortcoming of such an analysis is that the filter question of whether a firm belongs to the environmental sector is only available in 2012, so firms may be assigned to the environmental sector although they did not produce environmental goods and services in 2002. Furthermore, it is not useful to include short-term variables such as the profit situation or overtime in the long-term model.

Table 8: Determinants of employment growth from 2002 to 2012

Dependent variable: EmpDev0212 - Employment growth rate from 2002 to 2012, in %		
Regressors	**All establishments**	**Only environmental establishments**
	Two-level mixed GLM	**Two-level mixed GLM**
Innovations		
Ecoinnointens	15.9 (3.18)***	13.2 (2.26)**
Otherinno	6.43 (3.67)***	-
Airclimateinno	7.27 (1.73)*	5.61 (1.12)
Natureinno	36.3 (3.45)***	39.1 (3.56)***
Recycinno	6.87 (1.24)	3.5 (0.56)
Waterinno	14.7 (2.03)**	12.2 (1.58)
Regional variables		
Popdens	0.11 (0.76)	-0.31 (-0.92)
Secshare	0.45 (3.68)***	0.36 (1.16)
Control variables		
Firm age	-1.3 (-11.9)***	-1.05 (-4.05)***
Capitalnew	12.2 (7.41)***	12.0 (3.02)***
Competition	-6.16 (-3.9)***	-4.29 (-1.15)
Exportshare	0.08 (1.83)*	0.16 (1.54)
Highqual	-0.18 (-2.74)***	-0.06 (-0.37)
Size	0.07 (0.76)	-0.09 (-0.58)
Tariff	-8.41 (-5.07)***	-12.5 (-3.13)***
Wagedev0111	0.03 (1.76)*	0.05 (0.67)
German Länder		
Baden	20.6 (4.88)***	15.0 (1.5)
Bavaria	20.7 (4.95)***	7.53 (0.77)
Berlin	5.24 (0.78)	18.4 (1.12)
Brandenburg	-0.51 (-0.12)	-5.28 (-0.49)
Bremen	13.2 (2.72)***	13.3 (1.14)
Hamburg	27.4 (3.81)***	25.4 (1.37)
Hesse	16.0 (3.64)***	12.9 (1.24)
Lowsax	22.1 (5.14)***	16.2 (1.6)
Meckpom	2.18 (0.51)	-2.95 (-0.27)
Northwestf	23.0 (5.68)***	13.9 (1.52)
Rhineland	22.2 (4.71)***	13.3 (1.23)
Saarland	21.7 (4.87)***	21.4 (2.11)**
Saxony	7.92 (2.03)**	0.77 (0.08)
Saxonyanh	1.18 (0.29)	-1.63 (-0.18)
Schleswig	24.9 (5.65)***	22.2 (2.19)**
	No. obs.: 5817	No. obs.: 1018
	Wald $\chi 2$ (48) = 466	Wald $\chi 2$ (47) = 117

Z-statistics are given in parentheses; *, ** and *** denote significance at the 10%, 5% and 1% level, respectively. Sector dummies and constants are included but not reported.

All in all, the long-term models (2002-2012) corroborate our findings presented above for the short-term period from 2009 to 2012 (Table 8). The result that highly eco-innovative technology fields lead to higher employment effects compared to the overall economy is also confirmed for the long-term period. Interestingly, in contrast to the short-term analysis, innovative firms operating in the field of nature protection also showed disproportionately large positive employment growth compared to the economy as a whole. Concerning the results for the German *Länder* (NUTS 1 level), there are some differences between the two time periods. In the long-term model, the environmental sector did not yet provide a disproportionately large number of employment opportunities for the eastern German *Länder* because – in contrast to the short-term model - the dummy variables for Saxony-Anhalt and Mecklenburg-Western Pomerania remain insignificant from 2002 to 2012.

4 Summary and conclusions

This paper provides an empirical analysis of labor demand in the environmental sector compared to other sectors of the German economy. Our research questions were: (1) Do labor demand and employment growth differ between environmental establishments and establishments that do not produce environmental goods or services? (2) Which determinants of labor demand foster employment growth and which determinants hinder it in the environmental sector?

For our empirical analysis we combined three data bases: the Establishment History Panel, the IAB Establishment Panel and regional data at NUTS 3 level (*Landkreise* and *kreisfreie Städte*). The main data source was the IAB Establishment Panel containing a detailed question on the environmental sector in 2012. The environmental sector comprises goods and services which prevent environmental damage in different fields such as air or water pollution. 15.4% (2,352 firms) of all the firms in the 2012 wave of the sample reported that they belonged to the environmental sector. Similar filter questions were introduced in 1999 and 2005, but unfortunately, the panel mortality due to the long time lags did not allow an econometric analysis of employment dynamics based on these questions. The question on environmental goods and services in the 2012 wave was used to identify the firms belonging to the environmental sector. Combining the 2009, 2012 and 2014 waves then made it possible to calculate the employment development in the environmental sector from 2009 to 2012, from 2011 to 2012 and from 2011 to 2014. The use of further waves of the Establishment Panel enabled us to include lagged independent variables to avoid endogeneity problems. To capture the role of agglomeration forces, we combined our two datasets with official data at NUTS 3 level.

For the estimation of a labor demand function the following drivers were considered: innovation activities for different environmental and other innovation fields, proxies for product demand; export shares to take into account the fact that the growth of international trade may boost employment in export-oriented firms and innovation activities. Furthermore, we analyzed the influence of wages on labor demand using lagged values for the wage growth rate. We also explored the question of whether regional agglomeration forces foster employment growth in the environmental sector compared to the German economy as a whole. Barriers to employment growth, such as high competitive pressure and collective wage agreements were also analyzed.

We estimated different regression models to analyze the employment dynamics of the environmental sector compared to the rest of the economy. A general model including all firms in the sample shows that highly innovative environmental technology fields such as measurement, analytics, engineering or research are characterized by a significantly positive employment development from 2009 to 2012 and from 2011 to 2014 compared to all other firms in the sample. Other innovations also boost employment but the coefficient is lower compared to eco-innovation-intensive establishments. A good profit situation as a proxy for demand is positively correlated with employment. As expected, high competitive pressure is negatively correlated with employment growth whereas the existence of positive agglomeration effects boosts employment significantly. Young firms exhibit more dynamic employment growth.

A regression restricted to environmental firms shows that agglomeration effects seem to be quantitatively more important for environmental establishments. Furthermore, the environmental sector appears to provide employment opportunities for eastern German Länder – political measures to reinforce positive localization effects in these regions seem to be fruitful.

All in all, our analysis confirms that environmental policy promoting the environmental sector may be accompanied by positive employment effects but this result highly depends on the technology fields that are supported. A support of firms that are active in innovative environmental technologies seems to be preferable.

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Appendix

Table A-1: Descriptive statistics and definitions of the variables

Variables	Description	Mean	St. Dev.
Endogenous variables			
Empdev0912	Growth rate of number of employees from 2009 to 2012	6.69	36.26
Empdev1112	Growth rate of number of employees from 2011 to 2012	2.01	22.36
Empdev1114	Growth rate of number of employees from 2011 to 2014	6.31	35.42
Empdev0212	Growth rate of number of employees from 2002 to 2012	14.38	60.96
NUTS 3 level			
Popdens	Population density / 100	7.54	10.07
Secshare	Share of a firm's sector in the NUTS 3 unit	11.81	9.48
Innovation variables			
	Innovative firms (at least one innovation in 2011) in the environmental fields (1 yes, 0 no):		
Ecoinnointens	Measurement, analytics, project, research, noise, soil, other	0.02	0.14
Airclimateinno	Air, climate technologies, renewable energy, energy saving	0.03	0.17
Natureinno	Protection of nature, landscape management	0.01	0.07
Recycinno	Waste disposal, recycling	0.01	0.12
Waterinno	Water pollution, waste water treatment	0.01	0.09
Otherinno	Other innovative firms (at least one innovation in 2011) (1 yes, 0 no)	0.32	0.47
Control variables			
Age	Foundation of the firm after (1) or before 1990 (0)	0.58	0.49
Competition	High competitive pressure (1), little or no comp. p. (0)	0.34	0.47
Export	Export share of turnover (as %)	6.60	17.7
Invest	Investments carried-out in 2011 (1 yes, 0 no)	0.65	0.48
Overtime	Overtime in 2008 or 2009 (1 yes, 0 no)	0.50	0.50
Overtime11	Overtime in 2011 (1 yes, 0 no)	0.63	0.48
Profitsituation	Good/very good profit situation in 2008 or 2009 (1 yes, 0 other)	0.32	0.47
Profitsituation11	Good/very good profit situation in 2011 (1 yes, 0 other)	0.41	0.49
Size	Number of employees / 100	1.36	8.67
Tariff	Existence of a wage agreement (1 yes, 0 no)	0.42	0.49
Wagedyn0911	Growth of wages per employee from 2009 to 2011	12.1	63.9
Wagedyn0111	Growth of wages per employee from 2001 to 2011	18.2	46.2
WestEast	Located in western Germany (1) or eastern Germany (0)	0.61	0.49
Technological capabilities			
Capstocknew	State-of-the-art capital stock (1), older capital stock (0)	0.65	0.48
Highqual	Share of employees with university degree (as %)	9.87	19.3
Sector dummies	*1 yes, 0 no (for all sector dummies)*		
Sec1	Agriculture, forestry and fishery	0.02	0.15
Sec2	Mining, quarrying of stones, energy supply	0.02	0.14
Sec3	Food products, beverages and tobacco	0.02	0.15
Sec4	Textiles, leather	0.01	0.10
Sec5	Wood, paper, printing	0.02	0.14
Sec6	Chemical industry, rubber and plastics, glass	0.04	0.19
Sec7	Basic metals and fabricated metals	0.05	0.21
Sec8	Electrical machinery and apparatus	0.02	0.14
Sec9	Machinery	0.04	0.19
Sec10	Motor vehicles and other transport equipment	0.01	0.12
Sec11	Furniture and other products	0.02	0.13
Sec12	Construction sector	0.08	0.27
Sec13	Wholesale and retail trade	0.15	0.35
Sec14	Transport and logistics	0.04	0.19
Sec15	Information and communication	0.02	0.14

Sec16	Services: banking sector, insurance etc.	0.17	0.38
Sec17	Architectural and engineering offices	0.03	0.16
Sec18	Public sector and other services	0.25	0.43
German Länder	*1 yes, 0 other Land*		
Baden	Baden-Wuerttemberg	0.07	0.26
Bavaria	Bavaria	0.08	0.27
Berlin/Brem/HH	Berlin, Bremen, Hamburg	0.12	0.34
Berlin	Berlin	0.05	0.22
Brandenburg	Brandenburg	0.07	0.25
Bremen	Bremen	0.06	0.23
Hamburg	Hamburg	0.02	0.12
Hesse	Hesse	0.06	0.24
Lowsax	Lower Saxony	0.07	0.25
Meckpom	Mecklenburg-Western Pomerania	0.07	0.25
Northwestf	North Rhine-Westphalia	0.10	0.30
Rhineland	Rhineland-Palatinate	0.05	0.23
Saarland	Saarland	0.04	0.20
Saxony	Saxony	0.07	0.26
Saxonyanh.	Saxony-Anhalt	0.07	0.25
Schleswig	Schleswig-Holstein	0.05	0.23
Thuringia	Thuringia	0.07	0.25

Source: IAB Establishment Panel, own calculations.