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Determinants of Labor Shortage – with particular Focus on the German Environmental Sector

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Abstract

Despite the ongoing discussion on labor shortage in the German economy there is still a lack of empirical analyses of this problem based on adequate econometric methods. The paper explores the determinants of labor shortage in the environmental sector supplying products and services that help to reduce environmental impacts and energy use. Labor shortages occur when the price adjustment mechanism is too slow to balance labor demand and supply. The empirical analysis of labor shortage uses recent data of the establishment panel of the Institute for Employment Research in Nuremberg. A descriptive analysis shows that the environmental sector seems to be over-proportionally affected by labor shortage. Following the results of an econometric analysis innovative firms are significantly more likely to be characterized by labor shortage problems. For climate protection technologies, analytics/consulting or environmental research and development labor shortage seems to result from the respective innovative activities of the firms requiring high-skilled and specialized staff whereas labor shortage in the recycling sector is due to a lack of low-paid personnel. Further econometric estimations show that firms characterized by labor shortage problems are significantly more likely to pay wages above average.

Zusammenfassung

Trotz der andauernden aktuellen Diskussion über einen Fachkräftemangel in Deutschland besteht immer noch ein Mangel an empirischen Analysen auf der Basis ökonometrischer Methoden. Der Beitrag untersucht die Determinanten des Arbeits- bzw. Fachkräftemangels im Umweltsektor. Dieser Wirtschaftsbereich umfasst Produkte und Dienstleistungen, die dazu beitragen, Umweltschädigungen zu verringern oder den Energieverbrauch zu senken. Ein Mangel an Arbeitskräften kann auftreten, wenn der Preismechanismus zu langsam ist, um Nachfrage und Angebot am Arbeitsmarkt ins Gleichgewicht zu bringen. Die empirische Analyse basiert auf Daten des Betriebspanels des Instituts für Arbeitsmarkt- und Berufsforschung (IAB) in Nürnberg. Eine deskriptive Analyse zeigt zunächst, dass der Umweltsektor überproportional von einem Arbeitskräftemangel betroffen ist. Die Ergebnisse einer ökonometrischen Analyse belegen dann, dass dies insbesondere für innovative Umweltbetriebe zutrifft. Vor allem in den Umweltbereichen Klimaschutz, Analytik/Consulting und Umweltforschung und –entwicklung ist der Arbeitskräftemangel im Wesentlichen mit den Innovationsaktivitäten der Betriebe verknüpft, die hochqualifiziertes und spezialisiertes Personal benötigen. Der Arbeitskräftemangel im Recyclingsektor ist dagegen vor allem auf die geringe Verfügbarkeit sehr niedrig bezahlter Arbeitskräfte zurückzuführen. Weitergehende ökonometrische Schätzungen zeigen, dass Betriebe mit Fachkräftemangel überdurchschnittlich hohe Löhne zahlen.

JEL classification: J23, J63, Q55, C35

Keywords: Labor shortage, environmental sector, bivariate probit model

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1 Introduction

“Although there is much talk of a skills shortage there has been little economic analysis carried out to explain the determinants of a shortage and the implications of a shortage on the functioning of the labour market.” (Junankar 2009:8). This statement of an Australian author seems to be also valid for Germany where there are only few econometric analyses on this topic. The paper tries to contribute to fill this gap taking labor shortage problems in the environmental sector as an example. Shortly defined, the environmental sector produces goods and services contributing to a reduction of environmental impacts or energy use. This sector contains relatively young and emerging product fields such as renewable energy technologies that may be specifically affected by skill shortages. In middle or long term, these shortages may restrict the growth potential of these emerging technology fields. Therefore, it is useful to learn more about the scope and the driving forces of labor shortage in the environmental sector.

The paper raises the main definition and measurement problems of (skilled) labor shortage and summarizes the literature on the reasons and determinants of this phenomenon from a supply and demand perspective. From a pure neoclassical point of view, labor shortages would immediately disappear because of the adjustment of prices and wages. In real world, an adjustment of wages may be very slow so that especially a shift of the demand curve may lead to labor shortage.

The empirical analysis relies on the 2012 wave of the establishment panel of the Institute for Employment Research (IAB) containing detailed questions on labor shortage problems of firms that can be connected with a question on different environmental technology fields. Besides descriptive statistics, the determinants of labor shortage problems are explored using econometric methods. The econometric analysis has to address an endogeneity problem because innovation activities may trigger labor shortage but, on the other side, labor shortage may also restrict innovation activities. Therefore, a bivariate probit model has been applied.

The paper is organized as follows: After a discussion of definition and measurement problems of labor shortage, Section 2 summarizes the main theoretical background of labor shortage problems. The specificities of the environmental sector are discussed. Section 3.1 presents the data basis of the establishment panel of the IAB and shows descriptive statistics capturing labor shortage problems in the environmental sector. In Section 3.2, the structure and the results of the econometric model explaining the determinants of labor shortage are presented. Section 3.3 analyzes the relationship between labor shortage and wages. The role of labor shortage for over tariff payment and wages per employee is explored by using two different econometric models. Section 4 summarizes and concludes.

2 Definition, measurement and determinants of labor shortage

Following the OECD (2003), a universally accepted definition of (skilled) labor shortage does not yet exist. In fact, from a strict neoclassical point of view, the price mechanism always leads to equilibrium of demand and supply of labor so that labor shortage cannot occur. Therefore, labor shortage may only be explained by a too low adjustment speed of prices (wages). But these adjustment processes may last for a long time because of high adjustment costs. E.g., it is problematic for a firm to pay higher wages to new employees because this would also signify to raise the wages of the personnel already employed by the firm (Arrow and Capron 1959). The slow adjustment of wages as a reason for labor shortage has been confirmed empirically. In a study for Australia, Junankar (2009:3) states that "Standard neoclassical economics predicts that if there is a skills shortage, the labour market would respond with large increases in wage rates. Our results, however, show that real wages were growing at a relatively slow rate (compared to productivity growth) and even in Western Australia and Queensland the wage rates of skilled occupations were growing very slowly."

Shah and Burke (2003:v) define labor shortage as follows: "A shortage occurs when the demand for workers for a particular occupation is greater than the supply of workers who are qualified, available and willing to work under existing market conditions"… "Over time, the market might adjust in a number of ways, including price and/or quantity adjustment, and the imbalance clears." In line of this definition, upward shifts of the labor demand curve may also be causal for labor shortages. Especially the environmental sector may be affected by such an upward shift of the labor demand curve because of new qualifications required (e.g. in the relatively young technology field of renewable energy) accompanied by a dynamic development of the branch.

Besides wage adjustment problems and a higher labor demand there are further determinants of labor shortage (see Table 1). Both labor supply and demand has to be observed. In the long run, in Germany, labor shortage problems may result from the expected population decline if there will be no compensation by an increased migration or a higher willingness to participate in the labor market. Following a recent study of Fuchs and Söhnlein (2013), without migration effects the active population (between the age of 15 and 66) would shrink from now 55 millions to 30 millions in 2060. Including migrations, the most optimistic scenario shows an active population of 45 millions in 2060.

There is a vast theoretical and empirical literature (see e. g. Berlingieri and Erdsiek 2012 for an overview) analyzing further supply side factors such as personal characteristics of job searchers (e. g. over-qualification, family/partner related reasons) that may lead to an mismatch of labor supply and demand. As our empirical analysis concentrates on the labor demand side, we renounce summarizing this literature.

Concerning labor demand, the innovativeness of a firm may be highly correlated to (skilled) labor shortage problems because innovative firms may need more qualified personnel compared to other firms. High-qualified employees are much more scarce compared to unskilled workers. In 2012, the German unemployment rate of persons with a university degree only amounted to 2.5% whereas the respective figure for no-trained persons is 19% (IAB 2013). Furthermore, especially new and rapidly emerging innovation fields such as renewable energy technologies may require new specific qualification profiles leading to a scarcity. Firms may reduce this kind of labor shortage by an increase of further education activities or a more intensive use of elder personnel.

Table 1
Determinants of shortage of (skilled) labor

Labor supply	Labor demand
• Demographic changes • Lack of migration, regional immobility • Reservation wages and willingness to participate in the labor market • Over-qualification, • Family/work conflicts • Too small public investment in education systems	• Innovation activities requiring new qualified personnel • High product demand (business cycle) • High recruiting costs • Qualification-related mismatch because of structural change • Lack of further education measures • Home-made labor shortage: making no use of inexperienced graduates or elder personnel

Source: Summarized and complemented from Kettner (2012).

Labor shortage is difficult to measure (see also Shah, Burke 2003). Vacancy rates in combination with unemployment would be a good indicator but reliable statistics of job vacancies are difficult to collect. In Germany, the Institute for Employment Research now uses a survey to capture the number of vacancies in the German economy (see Müller et al. 2012 for an overview, Brücker et al. 2013). Furthermore, a measure of "normality" is problematic: "How many applicants per job offer may be defined as labor shortage? Therefore, most empirical analyses use surveys to capture labor shortage. Firms are questioned about their individual perception of labor and skill shortages. This procedure may lead to the problem that representatives of firms may answer strategically with a tendency to exaggerate labor shortage (see also Barnow et al. 2013 and Green et al. 1998). Furthermore, in their seminal paper on labor shortage, Arrow and Capron (1959) point to the fact that if firm representatives are asked about labor shortage they talk about "… unfilled vacancies with salaries equal to those of engineers and scientists now employed by the firm and performing equivalent services." In fact, in their answers they do not have in mind to raise wages but they always depart from existing conditions.

Specificities of the environmental sector

The environmental sector may be specifically concerned by an upward shift in the labor demand curve because of new qualifications required e.g. in the relatively young and fast growing technology field of renewable energy. Furthermore, recent analyses show that the environmental sector is more R&D intensive compared to other technology fields (Horbach et al. 2013) so that it is more likely to require more rare qualified personnel. Therefore, qualification mismatch may be a specific problem for the environmental sector.

On the other side, there are environmental technology fields such as the recycling sector requiring a high amount of very low paid workers. Depending on prices for raw materials some recycling activities are only economically efficient if the wages are very low or even subsidized. The insolvency of the RELUM recycling firm in Paderborn may serve as anecdotal evidence (RELUM 2013). The recycling activities (especially electric scrap) of this company were only profitable when employing subsidized handicapped employees or long-term unemployed. As a result of the introduction of the WEEE directive (Waste Electrical and Electronic Equipment), RELUM was forced to employ regularly paid employees so that the recycling activities led to high financial losses.

In any case, the heterogeneity of the environmental sector thus requires a distinction between different environmental innovation fields when analyzing labor shortage problems.

3 Empirical analysis of (skilled) labor shortage

3.1 Data basis and descriptive analysis

The analysis of labor shortage problems is based on data of the establishment panel of the Institute for Employment Research in Nuremberg. This survey was founded in 1993 to get a representative picture of German establishments which have at least one employee subject to social security. The survey is characterized by very high response rates of more than 70%. The 2012 wave contains a filter question that allows determining whether the firm belongs to the environmental sector or not. The environmental sector comprises goods and services which prevent environmental damage in different fields such as air or water pollution. A share of 15.4% (2352 firms) of all the firms in the sample of the wave 2012 declared to belonging to the environmental sector. Furthermore, different questions are suitable for describing labor shortage problems such as “Expected problems to get qualified personnel during the next two years”, “Lack of personnel”, “Would have hired additional personnel” or “not able to fill vacancies for qualified personnel” (IAB 2012).

Table 2
Labor shortage in the German environmental sector 2011

Environmental Technology field	Problems to find (skilled) employees during the next two years	Lack of personnel during the next two years
	Share of answers "yes" in %	
Water pollution, waste water treatment	50.2	12.0
Waste disposal, recycling	51.3	13.8
Air pollution	48.6	9.7
Climate protection, renewable energies, energy saving	51.1	11.6
Noise abatement	57.1	10.7
Removal of hazardous waste, soil protection	48.1	7.4
Protection of nature, landscape management	39.1	12.3
Measurement technology	58.7	11.1
Analytics, consulting	41.3	6.7
Environmental research and development	54.0	16.0
Other environmental fields	43.7	11.4
All firms in the environmental sector	49.9	12.0
All firms in the whole sample	36.0	7.2

Source: IAB establishment panel 2012.

Table 2 shows that the environmental sector seems to be over-proportionally affected by labor shortage. Nearly 50% of the questioned environmental firms pretend to have difficulties to find skilled employees whereas only 36% of all firms are affected by labor shortage. Especially noise abatement, measurement technologies, environmental research and waste and recycling are above the average labor shortage (49.9%) in the environmental sector. On average, the answers to the question about an expected lack of personnel during the coming two years show lower values but once again the environmental sector seems to be over-proportionally affected (12% versus 7% for all firms). The environmental research field (16%) and the waste disposal and recycling sector (13.8%) show the highest values (see Table 2).

A further analysis by qualification and innovative behavior shows that the labor shortage problems in the different environmental fields seem to have different reasons (see Table 3). In the waste and recycling sector, employees having no professional training dominate (share of 28%). Here, it seems to be difficult to find enough low-paid personnel. On the other side, fields such as environmental research and development or analytics and consulting are characterized by a high share of employees with a university degree (38% and 27%, respectively) so that these fields seem to have a lack of high-skilled labor. These results are confirmed by an analysis of the innovative behavior in different environmental fields (see Table 3). The innovation activities of the waste and recycling sector (41%) are clearly beyond average whereas especially the fields "measurement technology" and "hazardous waste" are more innovative.

Table 3
Qualification of employees and innovativeness in the German environmental sector in 2011

Environmental technology field	Share of employees (means in %) with …		Share of innovative firms (in %)
	University education	No professional training	
Water pollution, waste water treatment	13.4	17.4	49.3
Waste disposal, recycling	8.9	28.5	41.1
Air pollution	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
Removal of hazardous waste, soil protection	9.5	15.9	58.5
Protection of nature, landscape management	12.8	22.8	32.2
Measurement technology	16.4	13.3	57.0
Analytics, consulting	26.8	14.9	52.3
Environmental research and development	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: IAB establishment panel 2012.

3.2 Econometric analysis of the determinants of labor shortage

In a further step, the determinants of labor shortage are analyzed using econometric methods. As already mentioned in Section 2, the innovativeness of a firm may be closely correlated to labor shortage problems. Innovative firms may need more qualified personnel to realize innovations so that innovation activities may be accompanied by a higher degree of labor shortage. But this relationship is not one-sided because, on the other side, a lack of skilled labor may reduce a firms´ ability and capacity to innovate. This endogeneity problem has to be addressed within the econometric analysis. Therefore, a so-called recursive bivariate probit model has been applied to explore the relationship between the innovative behavior of a firm and labor shortage problems. The model reads as follows (for a detailed description of the model see Greene 2008: 823, Wooldridge 2002: 477 or Maddala 1983):

$$(1)\; labor short_i = \theta\, innovation_i + x_i'\alpha + \varepsilon$$
$$(2)\; innovation_i = y_i'\beta + \mu$$

This model is different from the “normal” bivariate probit model because the second dependent variable, innovation, appears on the right-hand side of the first equation. Because of identification problems the two sets of exogenous variables x_i and y_i can contain common variables but they are not allowed to be identical (see Greene 2008). For our problem, this so-called recursive bivariate probit model is adequate because it allows, at least partially, addressing the possible endogeneity of a shortage of labor and innovation activities. The correlation coefficient (rho, see Table 4)

measures the correlation between the disturbances of our two equations (Greene 2008: 825). If rho equals 0, the likelihood of the bivariate probit model would be equal to the sum of the likelihoods of two univariate probit models. If the hypothesis that rho equals 0 has to be rejected, the use of two independent probit models is not adequate, a bivariate probit model has to be applied to address the simultaneity bias. Interestingly, and in contrast to the corresponding linear regression model, the endogenous nature of the second dependent variable *innovation* can be ignored within the recursive bivariate probit model (see Greene 2008: 823 for a proof of this feature). Therefore, the recursive bivariate probit model also allows for the analysis of the direct effects of innovation on labor shortage.

The correlation coefficient rho is significantly different from zero so that the use of a simple probit model is not appropriate. The estimation results of the two equations of the recursive bivariate probit model can be interpreted as follows: The first equation shows the direct effects of innovation activities, different eco-innovation fields and other control variables on labor shortage (variable: *laborshort*). The second equation reveals different determinants of innovation activities of firms (variable: *innovation*). These determinants can be interpreted as indirect influence factors of labor shortage. The binary variable *laborshort* describing labor shortage problems gets the value one if the firm a) expected difficulties to get skilled personnel during the coming two years or b) expected lack of personnel during the next two years or c) would have employed more personnel in 2012 (for a detailed description of all variables see the Appendix). *Innovation* gets the value 1 if the questioned firm realized a product or a process innovation in 2011. Furthermore, the following correlated variables have been used:

Age describes the age of the firm, the variable gets the value one if the firm has been founded after 1990, zero otherwise. The state of a firms´ capital stock is indicated by *capitalnew*. *Competition* denotes a high competition pressure perceived by the firm. The share of employees with a university degree on all employees is captured by *highqual*. *Invest* gets the value one if the firm realized any investment in 2011. A value one of *profitsituation* denotes a very good or a good self-perceived profit situation of the firm in 2011. *Size* denotes the number of employees in 2012. The variables *air, climate, measuring, nature, noise, project, recycling, research, soil, water, other* get the value one if the respective environmental field was the most important one among the different fields. Furthermore, dummies for the German Länder and sectors were included.

The results of the recursive bivariate probit model (see Table 4) show that innovative firms (*innovation*) are significantly more likely to be characterized by labor shortage problems (*laborshort*). Concerning direct effects of environmental technology fields on labor shortage, the results show that a firm belonging to the *water* or *recycling* sector is more likely to have labor shortage problems. Especially in the recycling and waste disposal sector low-skilled and low wage personnel is required so that the reason for labor shortage stems from low wages due to low productivity

levels. There is no significantly positive and direct effect of further environmental fields on labor shortage. The analysis of the direct effects on labor shortage allows controlling for further control variables. A higher product demand indicated by the *profit situation* of the firm and a higher *invest*ment level trigger labor shortage. Not surprisingly, firms with a higher share of high qualified labor are more likely to be characterized by labor shortage problems. Furthermore, labor shortage is positively correlated to firm *size* and *competition* pressure. Competition pressure may lead to lower wages paid by the firm thus leading to a higher labor shortage. From a regional perspective, especially *Bavaria*, *Schleswig*-Holstein and, surprisingly, the *Saarland* seem to be over-proportionally affected by labor shortage whereas this is not the case especially for East Germany. A recent analysis has shown that these East German regions already offer good location conditions for the environmental sector (see Horbach 2014) so that a higher mobility of physical capital would at least partially remedy labor shortage in the environmental sector.

Table 4
Determinants of labor shortage

Variables	Labor short	Innovation	Regional dummies	Labor short	Innovation
Innovation	1.33 (15.7)**	-	Baden	0.02 (0.33)	0.36 (5.93)**
Age	-0.01 (-0.38)	0.05 (1.94)*	Bavaria	0.14 (2.48)**	0.38 (6.45)**
Capitalnew	-0.06 (-2.62)*	0.25 (10.5)**	Berlin	-0.06 (-0.93)	0.13 (1.93)*
Competition	0.06 (2.34)*	0.24 (9.95)**	Brandenburg	0.00 (0.04)	0.03 (0.48)
Highqual	0.0 (2.14)*	0.01 (8.24)**	Bremen	-0.22 (-3.63)**	0.52 (8.19)**
Invest	0.19 (5.20)**	0.58 (24.2)**	Hamburg	0.07 (0.80)	0.30 (3.09)**
Profitsituation	0.13 (6.55)**	-	Hesse	-0.05 (-0.83)	0.49 (7.85)**
Size	0.0 (3.03)**	0.0 (11.1)**	LowSax	0.10 (1.63)+	0.37 (6.09)**
Air	-0.07 (-0.47)	0.22 (1.27)	MeckPom	0.03 (0.54)	0.30 (4.94)**
Climate	0.01 (0.25)	0.37 (6.80)**	NorthWestf	0.02 (-0.42)	0.35 (6.21)**
Measuring	-0.08 (-0.62)	0.29 (2.16)*	Rhineland	0.01 (0.10)	0.14 (2.18)
Nature	0.04 (0.49)	0.09 (0.99)	Saarland	0.13 (2.01)*	0.20 (2.93)**
Noise	0.05 (0.26)	0.34 (1.82)+	Saxonia	0.04 (0.63)	0.26 (4.47)**
Project	-0.21 (-1.34)	0.64 (3.80)**	SaxonyAnh.	0.03 (0.47)	0.02 (0.26)
Recycling	0.23 (3.29)**	0.33 (4.77)**	Schleswig	0.16 (2.58)**	0.30 (4.59)**
Research	0.02 (0.12)	0.42 (1.96)*			
Soil	-0.08 (-0.48)	0.52 (2.94)**			
Water	0.14 (1.83)+	0.12 (1.41)			
Other	-0.26 (-2.56)**	0.59 (5.36)**			

Recursive bivariate probit estimation. Number of observations: 14824. Wald $\chi2$ (100) = 6736. Z-statistics are given in parentheses; +, * and ** denote significance at the 10%, 5% and 1% level, respectively. Rho = -0.65. Likelihood-ratio test of rho=0: $\chi2$ (1) = 39.1. Prob > $\chi2$ = 0.00. Sector dummies are included but not reported.

The recursive bivariate probit model also allows analyzing indirect effects on labor shortage via the innovation equation. As already mentioned, innovative firms are more likely for labor shortage. Except “old” and already established technology fields such as air, nature and water protection, all other environmental technology fields are more innovative compared to firms that do not offer such products and services (see Table 4). Especially for technologies for climate protection, analytics/consulting or environmental research and development the labor shortage seem to result from the respective innovative activities of the firm requiring high-skilled and specialized staff. Furthermore, the results for the innovation equation show that innovation activ-

staff. Furthermore, the results for the innovation equation show that innovation activities are positively correlated to a higher *competition* pressure, a *high qual*ification level of the staff of the firm, the *size* and *invest*ment activities.

3.3 Wages and labor shortage

In a further step, the relationship between wages and labor shortage is analyzed using a probit model. As already discussed in Section 2, a fast adjustment of wages would lead to less labor shortage problems. Therefore, it is useful to analyze the reactions of firms that are characterized by labor shortage problems. The establishment panel of the IAB captures indicators such as over tariff payment and wages paid per capita as a potential result of labor shortages.

Table 5
Determinants of over-tariff payment

Dependent variable: OverTariff 1 Firm pays wages over tariff, 0 No payment of wages over tariff			
Correlates			
Age	-0.05 (-8.84)**	Water	-0.01 (-0.40)
Capitalnew	0.03 (6.31)**	Other	0.04 (1.40)
Competition	0.05 (8.13)**		
Highqual	-0.00 (-0.27)	Baden	0.15 (7.54)**
Innovation	0.04 (6.20)**	Bavaria	0.14 (6.93)**
Invest	0.03 (5.83)**	Berlin	0.08 (3.76)**
Laborshort	0.07 (12.3)**	Brandenburg	0.00 (0.16)
Profitsituation	0.03 (5.59)**	Bremen	0.13 (6.05)**
Size	0.00 (3.14)**	Hamburg	0.16 (5.10)**
Air	0.05 (1.14)	Hesse	0.17 (8.14)**
Climate	0.00 (0.03)	LowSax	0.17 (8.16)**
Measuring	0.03 (0.97)	MeckPom	0.05 (2.73)**
Nature	0.03 (1.12)	NorthWestf	0.19 (9.49)**
Noise	0.01 (0.22)	Rhineland	0.17 (7.56)**
Project	-0.03 (-0.93)	Saarland	0.14 (6.33)**
Recycling	0.01 (0.63)	Saxonia	-0.01 (-0.39)
Research	-0.08 (-1.56)	SaxonyAnh.	0.03 (1.40)
Soil	-0.07 (-2.11)*	Schleswig	0.14 (6.45)**

Probit regression reporting marginal effects. Number of observations: 14824. Z-statistics are given in parentheses. LR Chi^2 (52) = 1664. Pseudo R^2 = 0.14. +,*, ** 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 included but not reported.

The variable *overtariff* gets the value one if the questioned firm pays more compared to the conditions fixed in the current wage agreement. As a further indicator, we use the wages paid per capita in June 2012 (*wagepc*) to test the hypothesis if a shortage of labor perceived by the firm leads to higher wages. The binary character of *overtariff* requires the application of an adequate non-linear estimation procedure. The results of our respective probit model (see Table 5) confirm that there is a tendency to adapt wages in response to labor shortage. Firms characterized by a high lack of (skilled) labor are significantly more likely to pay *over tariff*, the respective marginal

effect equals 7%. Not surprisingly, over tariff payment is promoted by a good *profit situation* and a high *competition* pressure.

Concerning the different environmental technology fields, there is no significantly positive influence on over tariff payment. Large (*size*) and "old" (*age*) firms are more likely to pay over tariff. *Inves*ting and innovating (*innovation*) firms and those having a new capital stock (*capitalnew*) are also characterized by over tariff payment. Taking Thuringia as the base category, all West German Länder are significantly more likely to pay over tariff pointing to the fact that labor mobility is still too low to compensate for regional differences.

Table 6
Determinants of per-capita wages

Dependent variable: Wagepc (log of wages per employee in EUR)			
Correlates			
Age	-0.27 (-19.8)**	Water	0.11 (3.21)**
Capitalnew	0.13 (9.54)**	Other	0.06 (1.07)
Competition	0.03 (2.63)**		
Highqual	0.01 (29.1)	Baden	0.15 (4.78)**
Innovation	0.09 (7.15)**	Bavaria	0.11 (3.33)**
Invest	0.20 (14.2)**	Berlin	0.02 (0.42)
Laborshort	0.21 (17.6)**	Brandenburg	-0.02 (-0.58)
Profitsituation	0.06 (4.35)**	Bremen	0.13 (3.53)**
Size	0.00 (2.84)**	Hamburg	0.28 (5.29)**
Air	0.14 (2.08)*	Hesse	0.16 (4.62)**
Climate	0.08 (3.31)**	LowSax	0.10 (3.11)**
Measuring	0.07 (1.29)	MeckPom	0.09 (2.84)**
Nature	0.26 (5.48)**	NorthWestf	0.14 (4.77)**
Noise	0.15 (1.63)+	Rhineland	-0.01 (-0.28)
Project	0.04 (0.45)	Saarland	0.10 (2.90)**
Recycling	0.07 (2.34)*	Saxonia	-0.06 (-2.01)*
Research	-0.00 (-0.04)	SaxonyAnh.	0.02 (0.67)
Soil	0.17 (2.17)*	Schleswig	0.15 (4.38)**
Regression with robust standard errors. Number of observations: 11825. Z-statistics are given in parentheses. F (52, 11772) = 111.7. R^2 = 0.32. +, *, ** denote significance at the 10%, 5% and 1% level, respectively. Sector dummies are included but not reported.			

In a further step, the impact of labor shortage on wages is analyzed using a standard multiple regression approach taking the wages per capita (*wagepc*) as dependent variable (see Table 6).

The results show that the existence of labor shortage problems within a firm is significantly correlated to a higher per capita wage (*wagepc*). Furthermore, the impacts and the signs of *age*, *capitalnew*, *competition*, *innovation*, *invest*ment and *size* confirm the results of the probit model for over tariff payment. The coefficients of the environmental technology fields *air*, *climate*, *nature*, *noise, recycling, soil* and *water* show significantly positive signs signifying that within these fields over-proportionally high wages are paid. A look on Table 3 shows that these fields are also characterized by high shares of employees with a university education. The results for the

dummies of the German Länder confirms the East – West differences already detected in the over tariff model.

4 Summary and conclusions

The paper explores the determinants of labor shortage problems in the environmental sector supplying products and services helping to reduce environmental impacts and energy use. Labor shortages occur when the price adjustment mechanism is too slow to balance labor demand and supply. In that case, a shift in labor demand may trigger labor shortage. Especially the environmental sector may be affected by such an upward shift of the labor demand curve because of new qualifications required (e.g. in the relatively young technology field of renewable energy) accompanied by a dynamic development of the branch. Besides other supply and demand factors the relationship between innovation activities and (skilled) labor shortage is crucial. Innovative firms may need more qualified personnel compared to other firms causing (skilled) labor shortage problems. On the other hand, labor shortage may restrict innovative activities of firms. Therefore, a so-called recursive bivariate probit model has been applied to cope with this problem. This model accounts for the endogeneity of the innovation behavior when explaining labor shortage.

The empirical analysis of labor shortage problems uses recent data of the establishment panel of the Institute for Employment Research in Nuremberg. The 2012 wave contains a filter question that allows determining whether the firm belongs to the environmental sector or not. A share of 15.4% (2352 firms) of all the firms in the sample of the wave 2012 declared to belonging to the environmental sector. Furthermore, different questions are suitable for describing labor shortage problems such as “Expected problems to get qualified personnel during the next two years” or “Lack of personnel”.

A descriptive analysis shows that the environmental sector seems to be overproportionally affected by labor shortage. Nearly 50% of the questioned environmental firms pretend to have difficulties to find skilled employees whereas only 36% of all firms are affected by labor shortage. Especially noise abatement, measurement technologies, environmental research and waste and recycling are above the average labor shortage (49.9%) in the environmental sector.

A further analysis by qualification and innovative behavior shows that the labor shortage problems in the different environmental fields seem to have different reasons. In the waste and recycling sector, employees having no professional training dominate (share of 28%). Here, it seems to be difficult to find enough low-paid personnel. On the other side, fields such as environmental research and development or analytics and consulting are characterized by a high share of employees with a university degree (38% and 27%, respectively) so that these fields seem to have a lack of high-skilled labor.

Our recursive bivariate probit model contributes to find the determinants of labor shortage problems. The results show that innovative firms are significantly more

likely to be characterized by labor shortage problems. Concerning direct effects of environmental technology fields on labor shortage, the results show that a firm belonging to the *water* or *recycling* sector is more likely to have labor shortage problems. Especially in the recycling and waste disposal sector low-skilled and low wage personnel is required so that the reason for labor shortage stems from low wages due to low productivity levels. Furthermore, a higher product demand and a higher investment level trigger labor shortage. Labor shortage is also positively correlated to firm *size* and *competition* pressure. From a regional perspective, especially *Bavaria*, *Schleswig*-Holstein and, surprisingly, the *Saarland* seem to be affected by labor shortage problems. The recursive bivariate probit model also allows analyzing indirect effects on labor shortage via the innovation equation. Except "old" and already established technology fields such as air, nature and water protection, all other environmental technology fields are more innovative compared to firms that do not offer such products and services. Especially for technologies for climate protection, analytics/consulting or environmental research and development the labor shortage seem to result from the respective innovative activities of the firms requiring high-skilled and specialized staff.

In a further step, the reactions of firms with respect to labor shortage are analyzed. Do firms pay over tariff or do they pay higher wages if they are confronted by labor shortage? The econometric results show that firms characterized by a labor shortage are significantly more likely to pay over tariff and that the per capita wages of these firms are above average.

From a policy perspective, a high focus on the improvement of the qualification and education infrastructure for rapidly growing environmental technology fields is still necessary because especially environmentally innovative firms are more likely to be characterized by labor shortage. On the other side, some environmental fields such as recycling are also characterized by a lack of low-paid employees. Due to low productivity levels, it is not possible to increase these wages. Therefore, if these environmental activities are socially desired they have to be subsidized by the State, otherwise they will disappear or re-located in low wage countries. A further option to reduce labor shortage would be a better regional division of labor as our results show that not all German regions are affected by labor shortage. A higher mobility of labor but also the (re) location of physical capital in under-developed regions would moderate labor shortage problems.

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Appendix: Description of the variables

Variables	Description	Mean	St. Dev.
Endogenous var.			
Laborshort	1 Firm a) expected difficulties to get skilled personnel during the coming two years or b) expected lack of personnel during the next two years or c) would have employed more personnel in 2012 0 Otherwise	0.45	0.50
Overtariff	1 Questioned firm pays more compared to the conditions fixed in the current wage agreement 0 Otherwise	0.14	0.35
Wagepc	Log of wages per employee in June 2012	7.27	0.78
Environmental technology fields	1 main environmental tech. field, 0 otherwise		
Air	Air pollution	0.004	0.07
Climate	Climate protection, renewable energy, energy savings	0.046	0.21
Measuring	Measuring technologies, analytics	0.008	0.09
Nature	Nature protection, landscape management	0.015	0.12
Noise	Noise abatement	0.003	0.06
Project	Environmental analytics, consulting and engineering	0.005	0.07
Recycling	Recycling, waste management	0.026	0.16
Research	Environmental research and controlling	0.003	0.06
Soil	Soil protection and remediation of contaminated sites	0.003	0.06
Water	Water protection, waste water treatment	0.018	0.13
Other	Other environmental fields	0.010	0.10
Control variables			
Age	Foundation of the firm after (1) or before 1990 (0)	0.58	0.50
Capitalnew	State-of-the-art capital stock (1), older capital stock (0)	0.64	0.48
Competition	High competition pressure (1), middle, low or no comp. p. (0)	0.34	0.47
Highqual	Share of employees with university degree (in %)	9.87	19.3
Inno	(1) Firms with process or product innovations, (0) otherwise	0.40	0.49
Invest	Investment activities in 2011 (1 yes, 0 no)	0.61	0.49
Profitsituation	Good or very good profit situation (1 yes, 0 other)	0.41	0.49
Size	Number of employees in 2012	138.9	907.3
German Länder	1 yes, 0 Other Land		
Baden	Baden-Wuerttemberg	0.07	0.26
Bavaria	Bavaria	0.08	0.27
Berlin	Berlin	0.05	0.22
Brandenburg	Brandenburg	0.06	0.25
Bremen	Bremen	0.06	0.23
Hamburg	Hamburg	0.02	0.12
Hesse	Hesse	0.06	0.24
LowSax	Lower-Saxonia	0.07	0.25
MeckPom	Mecklenburg-Western Pomerania	0.07	0.25
NorthWestf	Northrhine-Westfalia	0.10	0.30
Rhineland	Rheinland-Palatinate	0.05	0.22
Saarland	Saarland	0.05	0.22
Saxonia	Saxonia	0.07	0.26
SaxonyAnh.	Saxony-Anhalt	0.07	0.25
Schleswig	Schleswig-Holstein	0.06	0.23
Thuringia	Thuringia	0.07	0.25

Sector dummies	1 yes, 0 no (for all sector dummies)		
Agri	Agriculture, forestry and fishery	0.02	0.15
Mining	Mining, quarrying of stones, energy supply	0.02	0.14
Food	Food products, beverages and tobacco	0.02	0.15
Textiles	Textiles, leather	0.01	0.10
Wood	Wood, paper, printing	0.02	0.14
Chemical	Chemical industry, rubber and plastics, glass	0.04	0.19
Metal	Basic metals and fabricated metals	0.05	0.21
Electric	Electrical machinery and apparatus	0.02	0.14
Machinery	Machinery	0.04	0.19
Motor	Motor vehicles and other transport equipment	0.01	0.12
Furniture	Furniture and other products	0.02	0.13
Construction	Construction sector	0.08	0.27
Sale	Wholesale and retail trade	0.15	0.35
Transport	Transport and logistics	0.04	0.19
Information	Information and communication	0.02	0.14
Service	Services: banking sector, assurances etc.	0.17	0.38
Architecture	Architectural and engineering offices	0.03	0.16
Public	Public sector and other services	0.25	0.43

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