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The Importance of regional Spill-over Effects for Eco-Innovations in German Start-ups

by

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Abstract

Eco-innovation activities are crucial for the mitigation of climate change and further environmental problems. Start-up firms might play an important role for this relatively new innovation field as they are predestinated for realizing completely new ideas compared to incumbent firms that are not willing to abandon their established innovation paths. On the other side, start-ups have limited resources and need external regionally available input of knowledge. Based on data of the German IAB/ZEW Start-up Panel in combination with regional data at the NUTS 3 level, the paper analyzes the determinants of eco-innovation in start-up firms. The econometric results show that regional spill-over effects seem to be very important for eco-innovation activities of start-up firms. In regions where the existing stock of environmentally related patents is already high, the probability that a start-up firm realizes eco-innovations is significantly higher. Furthermore, eco-innovative start-ups show disproportionally more difficulties to get financing from external investors.

JEL: Q55, R11, C25

Keywords: Regional spill-over effects, environmental innovation, probit models

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1. Introduction

The adoption and diffusion of eco-innovations are crucial for reducing the environmental damage arising from the production and consumption of goods and services. Whereas the determinants of eco-innovation for the whole economy are widely explored little research has been done on the eco-innovation activities of young start-up firms. For these firms, regional factors such as the existence of specialized knowledge or a fitting labor supply might be especially important. Due to their limited resources compared to incumbent firms they especially rely on the existing (scientific) infrastructure, specialized suppliers and firms using similar technologies so that they can profit from spill-over effects.

For the first time, the newest wave (reference year 2018) of the "IAB/ZEW-Start-up panel" of the Institute for Employment Research (IAB) in Nuremberg and the Centre for European Economic Research in Mannheim (ZEW) includes a question module on eco-innovation similar to the one in the Community Innovation Survey (CIS) that can be combined with regional data at the NUTS 3 level. The paper explores the specific starting conditions, the motives and skill requirements of eco-innovation start-ups. A special focus lies on the importance of regional factors. Which role do agglomeration and localization effects play for eco-innovation activities of start-ups? Are regional political framework conditions and subsidies relevant for eco-innovation related start-up activities?

The paper is organized as follows. Section 2 describes the theoretical background with a focus on the specificities of start-up firms. In Section 3, the still scarce existing empirical evidence is discussed. Section 4 presents the database and contains descriptive results. In Section 5 the estimation strategy and the econometric results are discussed. Section 6 concludes.

2. Theoretical background and specificities of green start-ups

The analysis of the eco-innovation activities of start-up firms is based on the Knowledge Production Function (KPF) approach (see e.g. Slavtchev and Fritsch 2005, Wagner 2006, Czarnitzki et al. 2009). This concept assumes that the generation of new knowledge in a firm i (ΔKP_i) does not only depend on R&D expenditure ($R\&D_i$) but especially on the availability of skilled labor (human capital, HC_i). Besides these important inputs, the information flows within the firm (IF_{ii}) and with other firms j (IF_{ij}), e.g. via regional spill-over effects, are crucial for firms' innovation performance. Furthermore, factors such as firm size, industry, international activities or the competition situation (X_i) are important for the production of new knowledge.

$$\Delta KP_i = f(R\&D_i, HC_i, IF_{ii}, IF_{ij}, X_i)$$

The literature on the determinants of eco-innovation has shown that eco-innovations tend to be more complex compared to other innovation activities thus requiring knowledge inputs from a more diverse set of external knowledge sources (see e. g. Rennings and Rammer 2009, Horbach et al. 2013, Barbieri et al. 2020). Faced with the high complexity of eco-innovations in connection with limited resources start-up firms might especially need a good already existing regional knowledge stock and network capacities. Cojoianu et al. (2020:3) confirms this argumentation stating that "Knowledge and innovation partnerships of green firms tend to be very diverse, ranging from firms across the full spectrum of sectors, research organizations, governments and not-for-profit organizations". Therefore, the thickness of regional input markets (Dohse, Vaona 2014) seems to be especially important for eco-innovative start-ups. Besides other factors, a thick input market for eco-innovators might be characterized by a high employment and human capital density connected with fitting qualifications for eco-innovations, a high investment density and the existence of environmentally relevant patent activities. Furthermore, the existence of regional universities and research institutes and a highly available and flexible regional labor force pool are crucial. Start-ups particularly have difficulties to get highly qualified personnel because big firms can pay higher wages, furthermore these firms are often more attractive for applicants. Based on these arguments, Hypothesis 1 can be derived:

H1 The available regional knowledge stock and labor market pool is especially important for green start-ups because of the complexity of eco-innovation.

A further argument stems from the literature on related (or unrelated variety): "The relatedness concept rests on the idea that knowledge has an architecture that is based upon similarities and differences in the way that different types of knowledge can be used. When knowledge subsets are close substitutes for one another, or when they demand similar sets of cognitive capabilities and skills for their use, we think of them as being related or proximate to one another in some form of 'knowledge space'" (Balland et al. 2019:1253). An already existing regional specialization on eco-innovation activities should thus be advantageous for eco-innovative start-ups to cope with the complexity of eco-innovation leading to Hypothesis 2:

H2 Specialized knowledge and related variety in a region favor eco-innovative start-ups.

A further barrier for the emergence of green start-ups might be the availability of external financing. On the one hand, small firms might be more flexible and more likely to develop totally new ideas and products but on the other hand, high fixed innovation costs could reduce the availability of external financing because of high economic risks whereas big firms may finance the failure of an innovation project with the success of other projects. Furthermore, limited internal know-how and resources, missing possibilities to enter foreign markets because of the lack of an adequate logistic structure may reduce the ability to manage innovation processes for start-ups. Additionally, bureaucratic hurdles such as long administrative procedures may be more problematic for start-ups due to their limited resources. Due to the double-externality problem (Rennings 2000), eco-innovators might specifically suffer from a lack of financial resources as the private return of eco-innovation activities on R&D is often less than its social return. Thus, Hypothesis 3 can be formulated:

H3 Subsidies and external financing are crucial for green start-ups.

3. Literature overview: Empirical evidence

There is an extensive and rapidly growing literature on the determinants and the effects of eco-innovation (see e.g. Horbach 2019 for an overview) but the empirical evidence for green start-up firms is still scarce.

Fritsch and Wyrwich (2019) analyze the role of knowledge, skills, and agglomeration economies for the emergence of firms in the IT sector. The authors find out that the number of IT-related start-ups seems to be significantly higher in regions with larger cities compared to less densely populated areas. Their econometric analysis shows that a high number of employees in IT manufacturing and services and the existence of universities with computer science education and research in the region are positively correlated to the regional number of start-ups in the respective industry.

Colombelli and Quatraro (2019) analyze the importance of regional knowledge stocks for the creation of green start-ups. The authors consider the technological composition of local stocks distinguishing between “clean” and “dirty” and related and unrelated technological variety. Their empirical analysis is based on patent information of 3712 innovative Italian start-up firms from 2009 to 2015 matched with OECD RegPat data using the WIPO Green Inventory as classification scheme. The results show that green start-ups especially rely on diverse and heterogeneous knowledge sources, although in related and complementary technological fields. Giudici et al. (2019) also use data on 393 Italian innovative clean-tech start-ups created from 2012 to 2014. The authors confirm the before-mentioned results of Colombelli and Quatraro. The local availability of scientific and technological knowledge and furthermore the regional environmental awareness are crucial for the creation of green start-ups.

The important role of locally available environmental knowledge creation in incumbent firms, research institutes and universities for new start-up firms is also confirmed by Cojoianu et al. (2020). Their study covers 24 OECD countries and 293 regions over the period 2001-2013. The authors emphasize the importance of environmental policy for the financing of green start-ups.

Corradini (2019) uses a broad patent database over 900 NUTS 3 regions for 15 European countries from 1996 to 2006 analyzing the location determinants of new green technology-based firms. Regions already specialized in environmental technologies seem to support interactive learning and knowledge spillovers thus triggering new green entrepreneurship. Interestingly, the author finds an inverted-U relationship between regional technological relatedness and green technological entry: "… too much relatedness and cognitive proximity might lead to cognitive and technological lock-in" (Corradini 2019:848). Similar results are reported by van den Berge et al. (2020). Using data on patent applications for European regions from 1987 to 2010, the authors show that a highly developed already existing regional knowledge base in fossil fuel technologies led to a subsequent regional diversification into cleantech knowledge production.

Sunny and Cheng (2019) analyze the role of regional factors for sustainable entrepreneurship for the USA. Based on a negative binomial random effects model, the authors find that knowledge networks, policies, resource availability, and environmental awareness are crucial for the creation of green startups in the USA.

Further analyses that are related to the research on start-ups are based on data for SME´s. Ben Arfi et al. (2018) show that the success of the innovative green French SME´s is strongly dependent on the access to external knowledge sources that can be combined with internal sources.

Cecere et al. (2020) analyze the role of different funds on the realization of eco-innovation in European SME´s. Their results show that especially a lack of internal funding reduces the probability to introduce eco-innovations, whereas private external funds are less important. Public funding seems to be only effective when there are already other funding possibilities and thus plays a complementary role. Ghisetti and Montresor (2020) analyze the adoption of Circular Economy (CE) practices by SME´s. They use data on 2000 SME´s of the 2016 Eurobarometer. Focusing on the role of different forms of financing, the authors find out that SME´s do not need alternative and specialized forms of financing (e. g. reverse factoring, supply-chain finance or collaborative chain financing) but that standard financing sources are sufficient for the implementation of CE measures.

Doblinger et al. (2019) analyze the role of government partners financing R&D and the value-creation mechanisms of network resources for cleantech start-ups in the U.S. Their analysis is based on a dataset of 657 U.S. cleantech startups and 2,015 alliances with governments, firms, research organizations, and not-for-profit organizations from 2008 to 2012. The authors find that additional governmental technology alliances significantly increase the patent activities of cleantech start-ups.

4. Data basis and descriptive results

Whereas there is an extensive empirical literature on the determinants of eco-innovation in well-established firms, analyses of the eco-innovation activities of young start-up firms are still rare. This is especially true for Germany because of the lack of adequate data. In 2018, for the first time, a question module on eco-innovation has been introduced in the IAB/ZEW Start-up Panel. This yearly panel-survey is organized by telephone interviews with approximately 6,000 new firms from all industries. The wave of 2018 contains 6,044 start-ups. The question is an adapted version of a module on eco-innovation in the Community Innovation Survey (CIS) of 2014. The IAB/ZEW Start-up panel can be combined with regional variables at the NUTS 3 level stemming from the regional database of the German statistical office (Statistisches Bundesamt 2020) and the OECD REGPAT Database (OECD 2018).

Table 1 shows descriptive results for eco-innovation activities of the start-up firms in the 2018 sample. In general, product-related eco-innovations are more important for eco-innovation start-ups compared to process-related eco-innovations. The most important eco-innovations are new products leading to a reduction of energy use and/or CO_2 footprint.

Table 1: Eco-Innovation fields in German start-up firms in 2018

Eco-innovation fields	Share of "important" effects in all firms (%)	
	Product-related eco-innovations	**Process-related eco-innovations**
Reduced energy use or CO_2 emissions	23.1	12.6
Reduction of further emissions	14.3	6.9
Reduction of the use of resources	15.1	10.5
Improvement of the recyclability of products	9,3	8.9
Improvement of the durability of products	16.3	11.1

Source: IAB/ZEW Start-up panel 2018, own calculations.

Compared to other innovative firms, eco-innovative start-ups show a higher share (9%) of innovative products that are worldwide new to the market (see Table 2). In general, eco-innovators show a higher percentage of products new to the market.

Table 2: Eco-innovators and new products and services

Innovation field	Products or services new to the market			
	No	Regional/National	Worldwide	Total
Eco-innovator	79.9	11.4	8.7	100
Other innovator	85.4	9.4	5.3	100
Total	81.6	10.8	7.6	100

Source: IAB/ZEW Start-up panel 2018, own calculations.

5. Econometric analysis

Using econometric methods, the determinants of eco-innovation activities of start-up firms are explored. The focus lies on the analysis of the importance of regional spill-over effects and on the role of personal characteristics of the start-up founders for the introduction of eco-innovations.

Eco-innovation as the dependent variable gets the value one if at least one of the eco-innovation fields (see Table 1) shows a positive effect on the environment. To analyze the determinants of eco-innovation activities of start-up firms binary probit models are estimated. A start-up firm decides whether to introduce an eco-innovation (Y = 1) or not (Y = 0). According to our theoretical analysis, different factors such as the regional knowledge capital stock or personal characteristics of the founder summarized by a vector **x** influence this decision. Therefore, we need an estimation of the probability

$Prob\ (Y = 1|\ \mathbf{x}) = F\ (\mathbf{x}, \beta).$

Due to the binary nature of our dependent variable, we use the probit model assuming normal distribution. The β parameters reflect the impact of changes in x on the probability (Greene, 2008: 772). The database contains variables at the firm and the regional level. As the outcomes within the regional NUTS 3 units might be correlated, clustered standard errors are calculated.

The regional variables are available for the NUTS 3 level denoting the German districts. *Popdens* describes the population density of the German NUTS 3 units and is an indicator for agglomeration effects. The variable *ecopatpc* covers the cumulated eco-patents from 2013 to 2017 per capita thus describing the existing environmentally oriented technological regional knowledge capital stock. *Allpatpc* denotes the corresponding variable for all patents. The data for these variables stem from the OECD database REGPAT (OECD 2018). The definition of eco-patents is based on the work of Haščič and Migotto (2015). This indicator shows if already existing related eco-innovation activities in a region favor start-up activities in similar fields. Unfortunately, a construction of a more detailed relatedness indicator it is not possible because the survey database does not contain information on the exact technologies (e. g. by IPC classes) of the eco-innovative start-ups. *Dedomainpc* captures the number of de-domains per capita and indicates the digitalization level of a region. The green orientation of the region is indicated by the voting share of the green party (*greenvotes*). The general innovative potential of a region is furthermore described by the share of knowledge intensive sectors (*knowledgeintens*) and the students per capita (*studentpc*). A further indicator for the economic performance of a region is the unemployment rate (*unemprate*). The variable *secshare* measures the share of a firm's sector in the number of establishments in the district.

The database also allows for analyzing personal characteristics of the founder of the firm. The years of professional experience of the founder is captured by *profexperience*. The gender of the founder by is captured by *womenshare* denoting the share of female staff. *Academic* describes the share of founders with a university degree. The education of the founder is represented by different fields of study: *qualconstruction*, *qualeconomics*, *qualengineering*, mathematics and informatics (*qualmathinf*) and *qualnaturalsciences*. Furthermore, *highrisk* captures the self-perceived readiness to accept risk of the founder. *Motivself* describes self-controlled work as the main motive for the foundation of the firm, *motivother* describes the motives "escaping from unemployment" or "better income possibilities".

Concerning control variables at the firm level the *size* of the firm is measured by the number of team members. For R&D activities, four dummy variables are used: *Processinno* (*productinno*) gets the value one if the firm introduced process (product) innovations. *RDex-*

tern describes external R&D services from other firms, *RDintern* denotes the existence of internal R&D.

The rentability of the firm is measured by profits per capita (*profitpc*). *Financeextern* denotes difficulties to get external financing from private investors whereas *subsidies* capture the financial support from public authorities. The variable *exports* gets the value one if the start-up realized export activities. *Investor* captures investment activities since the founding. Furthermore, sector dummies are included.

The results of the econometric analysis (Table 3, Model 1) show that regional spill-over effects seem to be very important for eco-innovation activities of start-up firms supporting H1. In regions where the existing stock of environmentally related patents is already high (*ecopatpc*), the probability that a start-up firm realizes eco-innovations is significantly higher. This result also supports the Hypothesis 2 because specialized knowledge and related technological activities in a region seem to favor eco-innovative start-ups. To confirm this hypothesis, a second model (Model 2) has been estimated containing the general patent stock per capita (*allpatpc*) in the region instead of the eco-related patents. Contrary to the variable *ecopatpc*, there is no significant relevance of *allpatpc* for the introduction of eco-innovations. A high digitalization level of a region measured by the number of .de domains per capita (*dedomainpc*) also seems to be important for eco-innovation activities.

On the other side, mere agglomeration effects measured by the population density (*popdens*) are negatively correlated to eco-innovation activities of start-ups. General localization effects measured by the share of a firm's sector in the number of establishments in the district (*secshare*) are not significant for eco-innovation start-ups, too. Surprisingly, the green orientation (*greenvotes*) of the region is not significantly important for eco-innovation start-ups.

Concerning personal characteristics of the founders, the results show that the share of female team members (*womenshare*) in the eco-innovation start-ups is lower compared to other firms which might be explained by the focus of eco-innovators on production technologies in the manufacturing sector requiring skill fields where women are still underrepresented. This is confirmed by the significant coefficient of *qualengineering* denoting founders´ study fields mechanical and electrical engineering and mechatronics. Compared to other start-ups, the eco-innovators seem to need more experienced founders documented by the positive sign of *profexperience* denoting the length of the professional experience of the founder. The possibility of self-controlled work seems to be an important motivation for eco-innovators (*self*) whereas motives such as escaping from unemployment or better income possibilities play a less important role.

Table 3: Determinants of eco-innovation in German start-up firms in 2018

Dependent variable: Eco-innovation: 1 Eco-Innovator, 0 Other start-ups		
Correlates	Model 1	Model 2
Regional variables		
Allpatpc	-	0.00 (1.37)
Ecopatpc	0.002 (2.98)**	-
Dedomainpc	0.001 (2.43)**	0.001 (2.35)**
Greenvotes	-0.004 (-1.22)	-0.004 (-1.16)
Knowledgeintens	-0.00 (-0.16)	-0.00 (-0.05)
Popdens	-0.00 (-3.12)**	-0.00 (-2.80)**
Secshare	-0.003 (-1.30)	-0.003 (-1.27)
Studentpc	0.00 (1.40)	0.00 (1.46)
Unemprate	0.002 (0.44)	0.001 (0.29)
Personal characteristics		
Academic	-0.07 (-2.55)**	-0.07 (-2.57)**
Highrisk	0.02 (0.76)	0.02 (0.75)
Motivself	0.04 (2.01)*	0.04 (2.01)*
Motivother	0.02 (0.64)	0.02 (0.66)
Profexperience	0.002 (2.88)**	0.002 (2.87)**
Womenshare	-0.00 (-1.59)	-0.00 (-1.61)
Qualconstruction	0.04 (1.30)	0.04 (1.34)
Qualeconomics	-0.02 (-1.12)	-0.02 (-1.11)
Qualengineering	0.07 (2.23)*	0.07 (2.28)*
Qualmathinf	0.01 (0.14)	0.01 (0.12)
Qualnaturalsciences	-0.05 (-1.01)	-0.05 (-1.02)
Firm characteristics		
Exports	-0.01 (-0.72)	-0.01 (-0.76)
Financeextern	0.05 (1.89)+	0.05 (1.89)+
Investor	0.10 (6.19)**	0.10 (6.23)**
Processinno	0.10 (5.09)**	0.10 (5.08)**
Productinno	0.07 (4.01)**	0.07 (4.00)**
Profitpc	-0.00 (-0.22)	-0.00 (-0.23)
RDextern	0.04 (1.38)	0.04 (1.37)
RDintern	0.01 (0.52)	0.01 (0.50)
Size	0.001 (0.90)	0.001 (0.94)
Subsidies	0.05 (2.10)*	0.05 (2.13)*
Number of observations	3129	3129
Wald Chi^2	576	567
Pseudo R^2	0.09	0.09

Probit regressions with clustered standard errors. Z-statistics are given in parentheses. +, *, and ** denote significance at the 10%, 5%, and 1% levels, respectively. Instead of coefficients, average marginal effects are reported. Concerning dummy variables, the values report changes in probability for discrete changes of dummy variables from 0 to 1. Sector dummies are included but not reported.

Source: IAB/ZEW Start-up panel 2018, own estimations.

From the perspective of the firm, eco-innovators seem to have more difficulties to get financing from external investors (*financeextern*). Thus, *subsidies* from public authorities are more important for eco-innovators compared to other start-ups supporting H3.

To answer the question whether other, non-environmentally related innovations have different determinants compared to eco-innovations, two further models are estimated (see Table 4). Model 3 relates other innovations to all other start-ups, in Model 4 the sample has been restricted to innovative firms.

Table 4: Determinants of other innovations in German start-up firms in 2018

Dependent variable: Other innovations: 1 Other innovators, 0 Other start-ups		
Correlates	Model 3: All firms	Model 4: Only innovators
Regional variables		
Allpatpc	-0.0002 (-2.42)**	-0.001 (-3.45)**
Dedomainpc	-0.003 (-2.64)**	-0.003 (-2.45)**
Greenvotes	0.005 (1.67)+	0.006 (1.72)
Knowledgeintens	-0.00 (-0.27)	-0.00 (-0.01)
Popdens	0.00 (1.47)	0.00 (3.13)**
Secshare	0.001 (0.34)	0.004 (1.61)
Studentpc	0.00 (0.82)	-0.00 (-0.25)
Unemprate	-0.001 (-0.16)	-0.004 (-0.95)
Personal characteristics		
Academic	0.06 (2.96)**	0.10 (3.97)**
Highrisk	0.02 (1.25)	-0.01 (-0.46)
Motivself	-0.05 (-3.97)**	-0.06 (-3.58)*
Motivother	-0.03 (-1.52)	-0.04 (-1.91)+
Profexperience	-0.001 (-1.49)	-0.003 (-3.76)**
Womenshare	0.00 (0.25)	0.0003 (1.17)
Qualconstruction	-0.04 (-1.56)	-0.07 (-2.36)*
Qualeconomics	0.01 (0.46)	0.004 (0.20)
Qualengineering	-0.03 (-1.00)	-0.06 (-1.95)*
Qualmathinf	-0.003 (-0.14)	-0.01 (-0.46)
Qualnaturalsciences	0.02 (0.62)	0.01 (0.33)
Firm characteristics		
Exports	0.09 (5.21)**	0.003 (0.18)
Financeextern	-0.01 (-0.68)	-0.03 (-1.13)
Investor	-0.004 (-0.26)	0.02 (1.58)
Profitpc	0.0002 (2.11)*	0.00 (0.01)
RDextern	0.02 (0.82)	-0.02 (-0.84)
RDintern	0.16 (7.42)**	0.07 (3.25)**
Size	0.001 (1.71)+	-0.005 (-2.95)**
Subsidies	0.06 (3.34)**	0.12 (5.28)**
Number of observations	3850	2932
Wald Chi^2	404	390
Pseudo R^2	0.09	0.08
Probit regressions with clustered standard errors. Z-statistics are given in parentheses. +, *, and ** denote significance at the 10%, 5%, and 1% levels, respectively. Instead of coefficients, average marginal effects are reported. Concerning dummy variables, the values report changes in probability for discrete changes of dummy variables from 0 to 1. Sector dummies are included but not reported.		

Source: IAB/ZEW Start-up panel 2018, own estimations.

Both models show that regional spillovers of the existing knowledge capital stock (*allpatpc*, *dedomainpc*) seem to be less important for other innovations but these innovators rely significantly more on internal R&D measures (*RDintern*) compared to eco-innovators.

This result is confirmed by the significant relevance of *academic* qualifications for these firms. On the other side, professional experience matters less for other innovators (*profexperience*). Compared to eco-innovators, other innovators are also more profit-oriented (*profitpc*), furthermore they rely more on export activities (*exports*). The existence of *subsidies* seems to be important for all innovative start-ups and even more important for other innovators.

6. Summary and conclusions

There is a large amount of studies on the determinants of eco-innovation but the role of start-up firms in this growing research field is still underdeveloped. The present paper uses a unique new database on German start-up firms, the Start-up panel of the Centre for European Economic Research (ZEW) in Mannheim and the Institute for Employment Research (IAB) in Nuremberg. In 2018, the database contained a detailed question on eco-innovation. For the analysis of regional effects, the data has been combined with district-related variables at the NUTS 3 level.

For two reasons, regional factors might be especially important for eco-innovative start-up firms: On the one hand, these firms have limited financial and human resources so that they disproportionally rely on external knowledge sources. Regional spill-over effects might thus be very important for these firms. On the other hand, some studies on eco-innovations show that they tend to be more complex compared to other innovation activities thus requiring knowledge inputs from a more diverse set of external knowledge sources. In the present paper, regionally available specific technological knowledge is measured by the already existing eco-patent capital stock.

The results of the econometric estimations show that an extensive existing eco-patent capital stock per capita is significantly connected with a high probability that a start-up firm realizes eco-innovations. An alternative estimation with a high stock of general patents instead of the eco-patent variable which is not significant for eco-innovative start-ups provides evidence that these start-ups seem to need environmentally specialized knowledge spillovers. The analysis also captures the role of personal characteristics of the founder of the start-up. Eco-innovators have a longer professional experience compared to other founders, the share of women is lower, certainly because the required qualifications concentrate on mechanical and electrical engineering and mechatronics. Interestingly, self-controlled work seems to be an important motivation for eco-innovators whereas motives such as escaping from unemployment or better income possibilities play a less important role. Other, non-environmentally related innovators seem to be more profit-oriented compared to eco-innovators.

From a political perspective, the analysis shows that the support of eco-innovation clusters might also trigger start-up activities in this field. Strengthening an already existing specialization in a region by additional university capacities or research institutes seems to be useful because this can also encourage the foundation of new eco-innovative firms.

A limitation of the econometric analysis is its cross-sectional character because the eco-innovation question is only available for one year so that a thorough analysis of causal relationships is not yet possible. A regular question on this interesting research field in the ZEW/IAB Start-up panel would thus be useful.

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Table A1: Definition of variables and descriptive statistics

Variable	Definition	Mean	SD
Dependent variables			
Ecoinnovation	1: Eco-innovator, 0: Other Startups	0.68	0.46
Other innovator	1: Other innovations, 0: All other start-ups	0.20	0.40
Innovators	1: Other innovations, 0: Eco-innovators	0.26	0.44
Regional variables (NUTS 3)			
Allpatpc	Stock of all patents per capita in 2016	44.2	76.0
Ecopatpc	Stock of eco-patents per capita in 2016	2.51	5.02
Dedomainpc	Number of de-domains per capita 2016	20.0	10.8
Greenvotes	Voting share of the German green party in 2013	9.16	3.32
Knowledgeintens	Employee share of knowledge intensive industries 2016	9.39	6.35
Popdens	Population density in 2016	1119	1264
Secshare	Share of a firm's sector in the number of establishments in the district in 2016	10.8	5.96
Studentpc	Students at universities per 100 inhabitants in 2015	41.1	53.6
Unemprate	Unemployment rate in 2016	6.15	2.51
Personal characteristics of the founder			
Academic	1: Academic qualification of the founder; 0: Other	0.54	0.50
Highrisk	1: High willingness to take risks; 0 Other	0.15	0.36
Motivself	1: Founding motive: Self-determined work; 0: Other	0.42	0.49
Motivother	1: F. motive: Unemployment, higher income; 0: Other	0.21	0.41
Profexperience	Professional experience of the founder in years	24.0	11.2
Womenshare	Share of women in the founder team	14.4	32.1
Qualconstruction	1: Field of study construction engineer; 0: Other	0.09	0.29
Qualeconomics	1: Field of study economics; 0: Other	0.22	0.41
Qualengineering	1: Field of study engineering; 0: Other	0.12	0.32
Qualmathinf	1: Field of study mathematics, informatics; 0: Other	0.10	0.30
Qualnaturalscienc-es	1: Field of study natural sciences; 0: Other	0.04	0.20
Firm characteristics			
Exports	1: Turnover from export activities; 0: Other	0.20	0.40
Financeextern	1: Difficulties to get external financing; 0: Other	0.11	0.32
Investor	1: Investment activities since founding, 0: Other	0.66	0.47
Processinno	1: Process innovations; 0: Other	0.24	0.43
Productinno	1: Product innovations; 0: Other	0.38	0.49
Profitpc	Profit per employee/1000	11.3	47.9
RDextern	1: Existence of external R&D; 0: Other	0.10	0.30
RDintern	1: Existence of internal R&D; 0: Other	0.29	0.45
Size	Number of employees	4.36	8.66
Subsidies	1: State subsidies; 0: Other	0.20	0.40
Sector dummies			
Sec1	Top technologies in the manufacturing sector	0.06	0.23
Sec2	High-grade technology in the manufacturing sector	0.05	0.22
Sec3	Technology intensive services	0.19	0.39
Sec4	Software	0.10	0.30
Sec5	Not-technology intensive branches in the manufacturing	0.09	0.29
Sec6	Knowledge intensive services	0.09	0.29
Sec7	Other industry-related services	0.08	0.27
Sec8	Creative consumer-related services	0.08	0.26

Sec9	Other consumer-related services	0.07	0.25
Sec10	Construction sector	0.10	0.29
Sec11	Retail trade	0.10	0.30

Source: IAB/ZEW Start-up panel 2018, own estimations.