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A question of regulation or motivation? Environmental innovation activities in transition economies

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Abstract

Environmental innovation (EI) plays an important role in decoupling economic growth and environmental harm. This paper focuses on the environmental innovation behavior of companies in transition countries of Eastern Europe and Central Asia, which have been little studied so far. These countries share the Soviet legacy of environmental mismanagement, and have restructured their innovation systems relatively recently in the course of transition. The EBRD-EIB-WB Enterprise Survey (2018-2020) allows us to examine the determinants of environmental innovation in 29 transition countries. Although the theory places a greater emphasis on external sources of knowledge in EI, the results indicate that collaborative R&D is still quite weak in these countries. Moreover, environmental regulation increases the likelihood of adopting energy efficiency measures, while customers demanding environmental standards increase the likelihood across all innovation activities, indicating an increasing sustainability awareness among consumers.

Keywords
Environmental innovation, transition economies, firm-level data, logit model

JEL Classifications
O12, O31, O32, O5, Q55

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1. Introduction

Many countries of the Central and Eastern Europe, the Caucasus and Central Asia (CEECCA) region are particularly vulnerable to the impacts of climate change (Xenarios et al. 2019; Peng et al. 2020; Fay et al. 2010) and are facing increasing extremes such as droughts, floods, heat waves, and forest fires (Fay et al. 2010; Kharuk et al. 2021; Gozlan et al. 2019). In addition, these countries are burdened with the Soviet legacy of environmental mismanagement, which has reduced natural resilience in many areas (e.g. the disappearing of the Aral Sea) (Fay et al. 2010). Regarding environmental conservation, transition economies can be described relatively to Western countries by lower environmental priorities and vague institutional commitments, as well as less environmental awareness among the general public[1] (Crotty und Rodgers 2012; OECD 2020; Horbach 2016; Biscione et al. 2020). Furthermore, they are marked by an energy and resource intensive economy[2], and inefficient energy systems (OECD 2019a, 2019b; OECD und IEA 2015; Cornillie und Fankhauser 2004) and a lower level of research and development (R&D) activities (Kleibrink et al. 2017; Kammerer 2009; Veugelers und Schweiger 2016).

Environmental problems on this scale often cannot be addressed with existing technologies and business as usual (Popp et al. 2010). Therefore, the transition to a low-carbon, climate-resilient economy is important. Greening the economy enables new opportunities for economic diversification, access to new markets and increases competitiveness (OECD 2019a). A way to achieve this is by environmental innovation that combine business objectives and environmental pollution reduction (Porter und van der Linde 1995). They are therefore an important component of climate protection, as environmental innovations contribute to the decoupling of economic growth and environmental impacts (Horbach 2016; Stern 2017; Shi et al. 2021).

The aim of this paper is to empirically investigate the main determinants affecting the environmental innovation behavior of firms in transition economies. I recognize that the transition from a planned to a market economy in terms of institutional change has been formally completed in many of these economies. Hence, the term ‘transition economies’ covers a rather heterogeneous group of countries.

[1] According to results from the EU barometer 2017 and 2019 environmental awareness among the population in EU transition countries increased in the last three years. However, besides Bulgaria and Hungary, it is still below the EU average. Moreover, the Levada Center 2019 survey results show that in Russia, pollution (48%) is considered the biggest threat worldwide, while climate change (34%) ranks fourth. The most serious environmental problem for Russian citizens seems to be air pollution and waste. This can be explained by the fact that climate change is still abstract, while environmental problems such as pollution are more tangible and often associated with direct negative consequences. Nevertheless, 67 percent see man-made pollution as the main cause of global warming.

[2] In the CEECCA region, for example, natural resource extraction contributes significantly to export earnings, employment and public revenues. Moreover, the mining sector is closely intertwined with other parts of the economy OECD 2019a.

Several studies already exist on environmental innovation (see e.g. Lubacha und Wendler 2021; Ghisetti et al. 2017; Cainelli et al. 2020). Though, results differ depending on the characteristics of the nationality under study (del Río et al. 2015). The recent environmental literature mostly focuses on Western countries in Europe (see e.g. Arranz et al. 2019; Kesidou und Demirel 2012; Marchi und Grandinetti 2013). Furthermore, cross-country studies are rare (Ghisetti et al. 2015; Horbach et al. 2013) and there are only a few studies looking at Eastern European countries, but only within the EU context (e.g. Biscione et al. 2020; Horbach 2016; Hojnik und Ruzzier 2016). Therefore, my study is broadening the scope by including all 29 transition countries of the CEECCA region[3]. In addition, previous studies use survey data conducted between the years 2004 and 2014 (see e.g. Arfaoui 2018, Arranz et al. 2019). However, climate change is a dynamic issue that due to increasing weather extremes, is progressively getting more societal and political recognition and action (Hulme 2014; Ummenhofer und Meehl 2017; Bell und Masys 2020; Petrova 2020). Thus, it is relevant to analyze more recent data on innovation activities.

Using the most recent firm-level EBRD-EIB-WB Enterprise Surveys (ES) from 2018-2020, the results show that environmental regulation increases the likelihood to introduce energy efficiency measure in firms. Companies that state that environmental regulation is an obstacle for their current business are positively associated with developing environmental innovations (EI) within the company. Moreover, customer requiring environmental standards increase the probability across all environmental and general innovation activities. These findings are in contrast to Horbach (2016) and Biscione et al. (2020). In addition, companies that suffer losses due to extreme weather events are more likely to adapt environmental measures. Furthermore, the results do not suggest that outhouse R&D collaborations (or the purchase of external knowledge) play a more important role for EI than for general innovation which aligns with Marchi and Grandinetti 2013, Ghisetti et al. 2015 but not with da Silva Rabêlo und Azevedo Melo (2019). This indicates that R&D cooperation is still quite weak in these countries. Nonetheless, external knowledge transfer stimulates EI but to a lesser extent than inhouse R&D.

The contribution of this paper is multifold. First, many studies are limited to less recent data and sometimes to smaller samples (Arfaoui 2018; Demirel und Kesidou 2011).The data used here provides a large number of observations (17,191 companies) across different countries and allows us to gain insights into the current (2018-2020) environmental innovation behavior of companies. Second, this study offers a comparative analysis of different environmental innovation activities such as adapting energy efficiency measures, adapting general environmental measures to reduce environmental harm and introducing EI developed within the company as well as general innovation activities. Finally, there is an overrepresentation of studies that focus on

[3] Countries included: Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, FYR Macedonia, Georgia, Hungary, Kazakhstan, Kosovo, Kyrgyzstan, Latvia, Lithuania, Moldova, Montenegro, Mongolia, Poland, Russia, Romania, Serbia, Slovak Republic, Slovenia, Tajikistan, Ukraine, and Uzbekistan

environmental innovation in Western countries, while few analyses are available for less developed countries. Furthermore, as less developed countries are relatively more affected by the consequences of climate change (Chinowsky et al. 2011), it is therefore important to obtain a deeper understanding of their environmental innovation behavior.

The paper is structured as follows: Section Two provides the theoretical and empirical literature review as well as the hypotheses. Section Three lays a descriptive foundation for the following empirical analysis by presenting the data sample and introducing the econometric model. The empirical results are presented in Section Four. Finally, in section Five, a brief summary is given, the limitations of the study are addressed and a conclusion is drawn

2. Literature review: Theoretical background

Containing the global rise in temperature and achieving sustainability without a significant deviation from 'business as usual' is not possible. A deviation from business as usual can be innovation as defined by Schumpeter: a combination of factors in a new way (Schumpeter 1939), however, processes toward sustainability are essential. Environmental Innovations (EI) are thereby broadly defined as product, process, organizational, social or institutional methods that are novel to the firm and contribute to reduce environmental harms and resource use (Rennings 2000; Kemp 2010; OECD 2009; Kemp und Pearson 2007). However, not all invented green technologies (e.g. patents) have an influence on the company's environmental performance (Albrizio et al. 2017). Therefore, focusing on EI adoption provides an advantage as not all inventions are launched (Cainelli et al. 2020). Furthermore, referring to EI-adoption allows a better understanding of a firm's green capabilities (Ghisetti et al. 2015).

It is common to distinguish environmental process measures further into cleaner production and end-of-pipe technologies (Horbach et al. 2012; Frondel et al. 2007; Demirel und Kesidou 2011). The term cleaner production describes the reduction of resource use and/or pollution directly at the source by introducing cleaner production methods and products. End-of-pipe means that emissions are reduced by implementing add-on-measures that hinder the direct release of pollutants into the environment (e.g. filters) (Frondel et al. 2007; Rennings und Rammer 2009; Rennings und Zwick 2003).

Environmental innovation not only differs in its environmental focus from other innovations, differences can also be found in the neoclassical and evolutionary theoretical perspective. General innovation as well as environmental innovations create knowledge externalities in research and innovation phases. Environmental innovation have the peculiarity that they additionally produce environmental externalities in the adoption and diffusion phase[4] (Rennings 2000; Jaffe et al. 2005). These externalities benefit society by reducing environmental damage. This can lead to lower incentives for

[4] An invention describes an idea or model for a new, improved product or process. Through the first market introduction, the invention becomes an innovation in the economic sense. The use and adoption of the innovation over time represents the diffusion phase (Rennings 2000).

firms to engage in EI as the firms' return is lower than the social return. This is called the "double externality problem" of EI (Rennings 2000). As long as markets do not penalize environmentally damaging effects, there is a distortion of competition between eco- and non-ecological innovations (Rennings 2000). This leads to another peculiarity of environmental innovation. While technology push factors and market pull factors drive general innovation (Pavitt 1984; Hemmelskamp 1997), environmental innovation behavior can be in need of additional support of a regulatory and institutional framework (regulatory push/pull effect) (Rennings 2000). Thus, policy intervention tools such as subsidies or implementation of environmental taxes can mitigate these negative externalities (Acemoglu et al. 2016) .

From an evolutionary perspective, the learning processes of innovation are more in focus. For a firm's knowledge base and technological capabilities R&D cooperation with other firms can be an important input source of innovation (Veugelers 1997), as long as a firm invest in its own R&D, building up its "absorptive capacity" which allows to understand and apply knowledge generated outside the company (Cohen und Levinthal 1989, 1990). EI require knowledge and skills that are not necessarily part of the traditional core competencies of the company or industry (Marchi 2012; Horbach et al. 2013; Arranz et al. 2019). In addition to this inexperience, there is uncertainty about differences in standards, specific technological solutions and measures to assess the environmental performance of products and processes (Marchi 2012). Therefore, external knowledge sources are even more important compared to other innovation activities (Ghisetti et al. 2015; Marchi und Grandinetti 2013; Horbach et al. 2013; Cainelli et al. 2012).

Empirical research and hypotheses

Based on the theoretical assumptions about the particularities of EI described above, I now present empirical literature findings and derive hypotheses on the environmental innovation behaviour of companies in transition countries.

As explained above, the neoclassical perspective assumes that regulation, along with other market pull and push factors, plays an important role in the introduction of EI. Regulations can have both a direct impact on the innovation behaviour of companies, by imposing technological standards and emission limits, and an indirect impact, by granting tax incentives and public subsidies (Ghisetti et al. 2017; Lubacha und Wendler 2021; Cainelli et al. 2020; Kesidou und Demirel 2012; Arfaoui 2018; Horbach 2016).

While Cleff und Rennings (1999) results indicate that civil law enforcement is rather unimportant with regard to EI, Cai et al. (2020) find for Chinese firms that direct environmental regulation in form of law enforcement is positively associated with EI adoption. Furthermore, del Río et al. (2015) investigated environmental innovation of Spanish firms in 2009 and argues that regulatory instruments such as environmental, health and safety regulation positively influences EI. This suggests that companies in countries where they face stricter environmental regulations are more likely to innovate in an environmentally friendly way. Based on these findings, I assume:

H1: Environmental regulations that restrict a firm's current business provide incentives to introduce EI.

Some studies focus mainly on subsidies (Horbach 2016; Aldieri et al. 2019), however, taxes can also be an efficient environmental policy instruments (Cleff und Rennings 1999; Rennings und Rammer 2011). Veugelers (2012) shows for Flemish firms that environmental taxes provide incentives to EI. This aligns with Cainelli et al. (2020). In addition, Biscione et al. (2020) show for EU transition countries that taxes have a stimulating effect on EI but only if the tax rate is particularly high for the company. Hence, the next hypothesis is:

H2: Environmental taxes increase the likelihood of firms to engage in EI.

While some findings suggest that regulation prevails when it comes to incentives for EI, other studies find that at least in some countries demand pull and technology push factors such as customer requirements are also driving determinates for EI (Kesidou und Demirel 2012; Veugelers 2012; Cainelli et al. 2020). For instance, Kesidou und Demirel (2012) show for UK firms that next to regulation also customer environmental requirements are positively associated with EI. However, this is in contrast to del Río et al. (2015) who do not find significant effects of other market determinants on EI. This is in line with results from studies on companies in Eastern EU countries (Horbach 2016; Biscione et al. 2020). Here, too, the findings indicate that regulation triggers environmental innovation to a greater extent than demand-promoting factors These findings suggest that environmental awareness differs among countries and I therefore assume:

H3: Customer environmental preferences provide incentive to introduce EI.

Another external factor besides regulatory and market push factors can be the environment itself. As weather extremes become more and more frequent, the changes in the environment affect companies and push them to adapt (Nelson et al. 2007; Linnenluecke und Griffiths 2010). This especially applies for the countries under study. Hence, I expect that:

H4: Firms which suffer from losses due to weather extremes are more likely to introduce EI.

The evolutionary perspective presented above argues that external sources of knowledge are a key factor in the adoption of EI as environmental innovations are generally more complex.

Renning and Rammer (2009) find that German companies explore information sources more broadly in innovation related to energy and resource efficiency compared to other innovation. In the case of Brazilian firms external cooperation facilitates the adoption of EI and with increasing complexity firms strive to cooperate (da Silva Rabêlo und Azevedo Melo 2019). In the same vein, Frigon et al. (2020) argues that for the Canadian wine sector, eco-innovation it is more closely linked to external information sources relative to conventional innovation. Furthermore, Marchi (2012) and Marchi und

Grandinetti (2013) findings show that Spanish and Italian companies cooperate to a greater extent with partners outside the company in environmental innovations compared to other innovations. However, they also find indications that internal R&D activities can substitute external cooperation. This result aligns with Ghisetti et al. 2015. Similarly, they find that for eleven European countries, external knowledge sourcing positively affects EI performance. However, they further show that these effects fade when firms possess internal innovation capabilities and knowledge.

According to the empirical literature external R&D cooperation are relevant to introduce EI, whereas, internal R&D can be equally important. Although, in Central and Eastern (CEE) transition countries have a lower level of cooperation and opportunities for knowledge spillovers are limited (Poghosyan 2017; Hájek und Stejskal 2018). Horbach et al. (2016) finds that Eastern EU countries are more reliant on information sources like competitors and external R&D for EI. Therefore, my hypothesis is:

H5: Firms engaged in collaborative R&D activities are more likely to introduce EI.

Nonetheless, external R&D cooperation may also involve more effort and expense to gain access to additional or complementary knowledge. Search, coordination and transaction costs may exceed the corresponding benefits (Gkypali et al. 2017). This could be particularly crucial in transition economies, as their market-based innovation systems are relatively young, as are their innovation networks between actors and institutions. Hence, I assume:

H6: Firms engaged in in-house R&D activities are more likely to introduce EI*.*

3. Data

The analysis uses the latest EBRD-EIB-WB Enterprise Surveys (ES) which was conducted in 2018 until 2020. The ES is the successor to the Business Environment and Enterprise Performance Surveys (BEEPS) and combines now the BEEPS and the Middle East and North Africa Enterprise Surveys (MENA ES). As a result, the ES covers responses from nearly 28,000 enterprises in 41 economies. As this study focuses only on transition countries, data from Middle East countries, North African countries, South European countries and Turkey have been omitted. The final sample comprises 17,191 observations for 29 transition economies[5].

[5] The ES covers 17 countries from Central and Eastern Europe including Albania, Bosnia and Herzegovina, Kosovo, North Macedonia, Montenegro, Serbia, and the EU member states Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovak Republic and Slovenia, as well as 11 countries from the former Soviet Union among including Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Ukraine, and Uzbekistan. The country of Mongolia is also listed.

The ES aims to provide a representative sample of each country's private sector in respect of industry sectors[6], company size[7] and regional allocation. In addition, the ES data is a firm-level survey based on face-to-face interviews with managers and covers a wide range of standard company characteristics as well as topics related to the business environment. It also has the benefit that enterprises self-report different types of their innovation activity, e.g. whether the enterprise has introduced new or significantly improved products or services in the last three years, or acquired a new or improved production technology. ‚New' in this case refers to new to the company, not being necessarily new to the market. This is because firms from transition economies tend to innovate by imitating or adapting rather than inventing entirely new things from the existing state of the art (Aghion et al. 2002; Gorodnichenko et al. 2009; Gorodnichenko und Schnitzer 2013; Acemoglu et al. 2006).

Finally, it includes a Green Economy module, covering green management practices and green investments. This green economy module also offers the opportunity to identify environmental innovation behaviour such as: whether the establishment adopted any measures to reduce its environmental impact over the last three years; whether it adopted any measures to enhance energy efficiency over the last three years; and whether any of these measures were developed by the establishment over the last three years[8]. R&D and innovative activities cover a 3-year period from 2016 until 2018.

3.1. Descriptive Data

This section presents the data sample with Table 1, reporting summary statistics by country. It shows the proportions of enterprises in relation to firms' different (environmental) innovation and R&D activities in 2016 until 2018 across countries. Looking at the shares of companies included in the sample, 64.3 percent of Latvia-based companies implement energy efficiency measures and 93.9 percent have adapted environmental measures. At the other end, companies located in Azerbaijan and Romania have the lowest shares of environmental innovation with 12.2 percent or 17.9 percent of firms implementing energy efficiency measures and 59.5 percent or 44.7 percent environmental measures. Comparing this to general innovation in form of services or process innovation, the highest share with 51.7 percent of companies involved in process and 66.8 percent in product innovation are from Slovenia. This is closely followed by companies from Latvia. Both, Slovenian and Latvian firms exhibited above average spending on R&D (inside the company or in cooperation with others).

[6] The manufacturing sector describes companies with ISIC rev. 3.1 industry classification codes 15-37. Basic industries such as mining or agriculture are not included. The services sector includes enterprises classified with codes 45, 50-52, 55, 60-64 and 72. Not part of the sample are companies that are subject to state price regulation, such as electricity, gas and water supply, as well as companies that are 100 per cent state-owned.
[7] While there is a wide range in terms of number of employees (from 1 to over 100,000), the majority (44.09%) of the sample firms are classified as small and 92.49% of the firms are SMEs.
[8] However, the last question should be treated with caution, as a total of only 5707 companies answered this question (see also Table A1). This indicates that EIs that are new to the firm are more common than EIs that are new to the market.

Polish and Russian firms have the lowest share of innovation and firms' spending on R&D are below average.

Grouping the responses of the sample with respect to EU membership, Table 2 shows additional statistic measures. Companies from EU member countries are on average more environmental active as well as involved in process innovation compared to companies from non-EU members. In addition, a regulation measure is included in this table showing that on average more firms located in EU member states are subject to energy taxes. This could be explained by the EU's environmental policy objectives (Kelemen 2010; European Commission 2019). However, the opposite applies for product innovation and R&D activities carried out within the company or in cooperation with other companies. Here companies from non-EU members lead the average. From the wide standard deviations, it can be seen that a general classification is not possible and that companies from some EU countries (e.g. Romania) are also less innovative than companies from non-EU countries (e.g. Ukraine).

Table 1: Indicators of companies' different innovation activities by country

	Eco innovation developed by firm	Adapt energy efficiency measures	Adapt environmental measures	Process inno-vation	Product inno-vation	R&D (in-house)	R&D (out-house)
Albania	.713	.236	.84	.246	.393	.189	.056
Armenia	.684	.331	.799	.13	.408	.375	.143
Azerbaijan	.583	.122	.595	.1	.286	.446	.111
Belarus	.417	.535	.786	.239	.408	.214	.099
Bosnia and Herz.	.592	.235	.817	.303	.515	.36	.228
Bulgaria	.612	.398	.688	.127	.201	.148	.04
Croatia	.656	.182	.864	.156	.349	.119	.059
Czech Rep.	.144	.331	.894	.291	.395	.369	.153
Estonia	.432	.481	.898	.236	.406	.272	.133
Georgia	.388	.178	.774	.168	.427	.238	.14
Hungary	.235	.437	.852	.129	.182	.133	.046
Kazakhstan	.234	.323	.664	.137	.253	.209	.084
Kosovo	.753	.364	.886	.13	.313	.231	.076
Kyrgyz Rep.	.376	.361	.701	.265	.429	.265	.133
Latvia	.589	.643	.939	.483	.508	.221	.153
Lithuania	.664	.423	.763	.223	.328	.078	.067
Moldova	.556	.365	.801	.213	.322	.204	.129
Mongolia	.686	.24	.934	.412	.506	.44	.2
Montenegro	.429	.188	.572	.127	.3	.18	.081
North Macedonia	.629	.405	.688	.274	.507	.267	.131
Poland	.816	.32	.715	.082	.206	.084	.04
Romania	.723	.179	.447	.202	.268	.162	.106
Russia	.228	.297	.642	.115	.151	.18	.074
Serbia	.736	.398	.782	.287	.423	.219	.12
Slovak Rep.	.621	.348	.865	.084	.166	.128	.091
Slovenia	.261	.459	.887	.517	.668	.4	.2
Tajikistan	.578	.368	.663	.099	.219	.211	.073
Ukraine	.471	.531	.804	.212	.371	.306	.111
Uzbekistan	.443	.439	.882	.175	.296	.136	.07
Total	.481	.361	.763	.191	.318	.214	.098

Source: EBRD-EIB-WB Enterprise Surveys 2018-2020

Table 2: Indicators of companies' different innovation activities by EU membership

		Eco innovation developed by firm	Adapt energy efficiency measures	Adapt environ-mental measures	Process innovation	Product innovation	R&D in-house	R&D out-house	Energy tax
EU member	mean	.52	.363	.772	.193	.293	.171	.085	.201
	sd	.5	.481	.42	.395	.455	.377	.279	.401
	N	2192	6253	5132	6524	6550	6533	6539	6096
Non-EU member	mean	.457	.359	.758	.189	.334	.241	.106	.185
	sd	.498	.48	.428	.391	.472	.428	.307	.389
	N	3515	10093	8892	10451	10527	10515	10509	10241

Source: EBRD-EIB-WB Enterprise Surveys 2018-2020

3.2. Operationalization of key variables

To capture the determinants of the different EI, the following variables are considered. A detailed description of the variables is provided in Table A1, while their correlations are presented in Table A2. To determine the influence of regulation measures on environmental innovation in relation to Hypotheses 1 and 2, I rely on information provided by the ES. The two dummies 'energy tax' and 'obstacle of environmental regulation' are used. These describe whether the company is subject to energy taxes and whether it views environmental regulation as a constraining factor on its business activities. To investigate the third hypothesis, customer preferences are described through the dummy 'customer push' (if customers required environmental certifications or standards as a condition to do business or not[9]). To analyses hypothesis four, I include the dummy whether the company experienced monetary losses due to extreme weather/ pollution or not. With respect to the hypothesis five and six, the firm's R&D activities are described through the dummies 'inhouse R&D spending' and 'R&D spending contracted with other companies'. Alternatively, to collaborative R&D, I include the dummy whether the company purchased or licensed external knowledge in form of patents and non-patented inventions, know-how, and other types of knowledge from other businesses or organizations.

Furthermore, several controls are included. As incumbent firms can benefit from accumulated internal capabilities and more longstanding knowledge network relationships, age can have an impact on EI (del Río et al. 2017). Moreover, firm size can be an important factor as small firms have generally less resources in the areas of human labor, technology and finances compared to large companies (del Río González 2009; Ghisetti et al. 2017). Additionally, Garrone et al. (2018) finds that larger firms are

[9] It is not clear from the questionnaire whether customer means business-to-consumer (B2C) or business-to-business (B2B). I therefore assume that both are meant, since the environmental certifications mentioned as examples are relevant for B2B transactions as well as for certified end products.

relatively more responsive to high regulatory pressure. Therefore, in accordance with the OECD definition, company size measures the number of full-time employees (at the end of the fiscal year) and ranges from micro, small, middle to large firms.[10]. Besides, age is measured as the number of years the business has been operating.

In addition, competitive pressure can create incentives for companies to introduce eco-innovations (Cai und Li 2018; Hojnik und Ruzzier 2016; Horbach 2016). Hence, the variable ‘main market’ is included and coded ‘1’ regional, ‘2’ nation, and ‘3’ international. Moreover, voluntary internal measures such as environmental management and auditing can have a stimulating impact on environmental innovation (van den Bergh 2013; Frondel et al. 2007; Rennings et al. 2006; Wagner 2008). Hence, the following dummies are also considered: whether a manager for environmental matters is employed and whether a company pursues self-set environmental targets regarding energy, CO2 emissions or other pollution, as well as whether external audits are performed. Furthermore, sales expectation for the next year and employee growth over the last three years are included.

3.3. Model Specification

Five dependent variables are analyzed: three related to environmental innovations and two related to general innovations. For each innovation type, a company must decide whether it wants an (environmental) innovation or not. Due to the binary nature of each dependent variable, a logit model is employed for each environmental and general innovation activity to enable a comparison.

$$(1)\ Innovation\_activity = \beta_0 + \beta_1 * obstacle\_of\_regulation_i + \beta_2 * energy\_tax_i + \beta_3 * customer\_push_i + \beta_4 * collaborative\_R\&D_i + \beta_5 * inhouse\_R\&D_i + \beta_6 * losses_i + \beta_7 * Controls_i + \mu_i$$

Equation (1) comprehends the main variables used in the regression models. The vector of controls encompasses variables such as firm size and age, main market, as well as voluntary internal measures. The vectors ß capture the coefficient[11], and i index firms. To facilitate interpretation, the coefficients in Section 4 are exponentiated and expressed in odds ratios. Standard errors are clustered on the sector level. Finally, country and industry dummies capture other country- or industry-specific fixed effects such as differences in the institutional environment across countries and differences in industry characteristics. The industry dummies are based on a four-digit industry classification code, for more details see Table A3.

[10] In accordance with the OECD criteria, enterprise size is divided into micro enterprises (5 to 10 employees), small enterprises (10 to 49 employees) and medium-sized enterprises (50 to 249 employees), as well as large enterprises with 250 or more employees.
[11] The possibility of reverse causality must be considered and the results should be interpreted with caution. There could be endogeneity issues, especially with regard to the choice of different innovation inputs. Following Horbach's (2016) procedure, I conducted endogeneity tests for these variables. In each case where the Smith-Blundell test suggested the presence of endogeneity, I estimated the respective models without the suspected variables to check robustness. In all verified cases, the results remained similar.

4. Empirical Results

4.1. Main results

We start with the results of the baseline models which are presented in Table 3. Each column (1-5) shows the result for a specific (environmental) innovation activity. The results show that environmental regulation plays an important role in EI while it is not significant for general innovation. Being a subject to energy tax increases the odds for firms to develop environmental innovation within the firm about 33 percent (see column 3). The odds of engaging in EI enhancing energy efficiency increases 29 percent for energy taxed companies compared to those that are not being taxed (see column 4). Companies stating that environmental regulation is a moderate-to-great obstacle only show for EI developed within the company a statistically significant positive relation. Here, the odds increase about 25 percent. Although, I do not find a significant relationship between all EI forms, overall, I confirm the first two hypotheses.

Concerning the influence of customer preferences, we see that the odds of adopting energy efficiency measures increase about 24 percent when the companies' customer require environmental standards, while the odds of adopting general environmental measures increase about 55 percent (column 5). Only for EI developed within the company customer environmental requirements does not have a significant influence. Thus, I confirm hypothesis three. Interestingly, dealing with customers who require environmental standards also increases the chances for companies to engage in general innovation. The odds for product increase about 28 percent and the odds for process innovation even about 44 percent (see column 1 and 2). Hence, it seems that customer environmental requirements provide innovation incentives that goes beyond environmental activities.

Furthermore, there is an overall significant and positive link between EI and suffering from losses due to weather or pollution extremes. The highest odds occur for adopting environmental measures. Companies that experienced losses have almost 80 percent higher odds to introduce environmental measures compared to companies that did not suffer from losses. The odds for process innovation or adopting energy efficiency measures are both around 39 percent when the companies suffered from losses. It seems that being exposed to extreme environmental influences stimulates companies to find innovative solutions in their process behavior to be more prepared against extreme weather events. Hence, I accept hypothesis four.

Looking at the R&D, companies engaged in internal R&D have about 31 percent higher odds to EI within the company and 62 percent higher odds to adopt energy efficiency measures compared to companies that are not involved in internal R&D. The odds for product or process innovation, however, are even higher and raise by a factor of over 2.2 if the companies involve in internal R&D. Comparing this to collaborative R&D, while the overall relationship is positive and significant the odds are lower compared to companies engaged in internal R&D. Being engaged in R&D in cooperation with others increases the odds for EI within the company by 26 percent and for energy efficiency by 40 percent, while it is not significant for adapting environmental measures. Overall, I confirm my last two hypotheses.

Table 3. Logit estimation results

	(1)	(2)	(3)	(4)	(5)
	Process innovation	Product Innovation	EI developed within firm	Energy efficiency	Environmental measures
Energy tax	1.013	0.872*	1.326***	1.292***	1.141
	(0.0694)	(0.0694)	(0.111)	(0.0905)	(0.143)
Obstacle regulation	0.935	1.032	1.253**	0.951	0.945
	(0.0571)	(0.0584)	(0.0980)	(0.0635)	(0.0944)
Customer push	1.436***	1.279***	1.064	1.239**	1.553**
	(0.0891)	(0.0903)	(0.0980)	(0.0912)	(0.218)
Losses weather	1.386***	1.205**	1.230*	1.390***	1.791***
	(0.102)	(0.0886)	(0.133)	(0.118)	(0.248)
RD inhouse	2.243***	2.788***	1.315***	1.622***	2.103***
	(0.160)	(0.206)	(0.109)	(0.104)	(0.230)
RD outhouse	1.424***	1.409***	1.265**	1.408***	1.288
	(0.122)	(0.133)	(0.148)	(0.132)	(0.261)
Green targets	1.261***	1.240***	1.800***	3.375***	3.435***
	(0.0747)	(0.0613)	(0.142)	(0.171)	(0.353)
Green manager	1.077	1.010	1.413***	1.565***	1.648**
	(0.0871)	(0.0776)	(0.145)	(0.134)	(0.305)
Ext audit	1.127*	1.067	1.395***	1.470***	1.810***
	(0.0772)	(0.0602)	(0.116)	(0.0915)	(0.174)
Employee growth	1.001	1.000	1.000	1.001	1.003**
	(0.000614)	(0.000344)	(0.000539)	(0.000587)	(0.00126)
small firm	1.294**	1.272**	1.284**	1.077	1.119
	(0.112)	(0.0998)	(0.161)	(0.0779)	(0.119)
medium firm	1.751***	1.331***	1.106	1.451***	1.561***
	(0.172)	(0.113)	(0.149)	(0.112)	(0.190)
large firm	1.674***	1.361**	1.523**	1.724***	2.249***
	(0.204)	(0.160)	(0.270)	(0.237)	(0.489)
Age	1.000	1.000	1.001	1.002	0.998
	(0.00194)	(0.00184)	(0.00256)	(0.00193)	(0.00371)
sales will increase	1.502***	1.507***	0.984	1.207**	1.316**
	(0.100)	(0.0859)	(0.0850)	(0.0769)	(0.112)
sales will decrease	1.176	1.177*	0.985	1.014	1.175
	(0.143)	(0.0985)	(0.120)	(0.0965)	(0.157)
national market	1.257**	1.266***	1.074	1.260***	1.112
	(0.0982)	(0.0696)	(0.106)	(0.0726)	(0.0857)
international market	1.266**	1.162	1.118	1.234**	1.357
	(0.125)	(0.110)	(0.168)	(0.107)	(0.267)
Country FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
N	8067	8091	3759	7995	7064

Note: The dependent variable is binary. Reference groups: for firm size: micro firms; employee growth: unchanged; main market: local. Exponentiated coefficients: to better interpret the results, I transform the coefficients into odds ratio; standard errors in parentheses are clustered at sector level, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Moving to the control variables, the results show the odds to innovate increase with firm size. This corresponds to the results of del Río et al. (2015). Age is not statistically significant, indicating that there are no significant differences between new entrants and incumbents in terms of participation in EI. This is in line with (Horbach et al. 2012; del Río et al. 2015) Employee growth over the last three years is also not significant. Companies that expect an increase in sales for the next year have 50 percent higher odds to innovate in process or products. The odds for adapting environmental measures and energy efficiency are lower with 32 percent or 20 percent respectively. Having a manager for environmental issues increases the odds for EI while it does not have an impact on general innovation. The highest odds (65 percent) occur here for adopting environmental measures. If the company sets itself green targets it also increases the odds to EI (EI within the firm about 41 percent, enhancing energy measures and adapting environmental measures by a factor over three). It even shows a positive relationship between general innovation activities and having green targets. Companies that are doing external audits have higher odds to innovate. This applies for all innovation activities except product innovation. This can be explained that auditing reflexes more the processes within a company then company's products. The highest odds (81 percent) occur for environmental measures, while the smallest with 12 percent are for product innovation. Compared to local markets, having the national or the international market as its main operation area is positively associated with measures enhancing energy efficiency and general innovation.

4.2. Robustness Check

As the acquisition of e.g. patents is another form of access to externally generated knowledge, I consider alternately to 'collaborative R&D' 'acquiring external knowledge'. The findings are presented in Table 4. Overall, the results hold. The results show that the acquisition of external knowledge in companies has higher odds to EI than collaborative R&D in the previous estimates. The odds of companies that acquire external knowledge increase by 2.1 to introduce general environmental measure compared to the companies that do not acquire knowledge. Only for adapting energy efficiency measures the odds are 20 percent points lower than using collaborative R&D. This could again suggest that there is a lower level of cooperation in transition economies, while external sources of knowledge are nevertheless important. These results indicate a high importance of knowledge transfer from external sources. Compared to general innovation, it does not look like external knowledge plays a more important role for EI, even though odds for adapting environmental measures are slightly higher than internal R&D but this is also the case for process innovation.

Table 4. Logit estimation results with acquiring external knowledge

	(1)	(2)	(3)	(4)	(5)
	Process innovation	Product Innovation	EI developed within firm	Energy efficiency	Environmental measures
Energy tax	1.014	0.861*	1.335***	1.309***	1.181
	(0.0697)	(0.0726)	(0.110)	(0.0918)	(0.151)
Obstacle regulation	0.930	1.023	1.242**	0.973	0.964
	(0.0563)	(0.0580)	(0.0978)	(0.0649)	(0.102)
Losses weather	1.351***	1.171**	1.228*	1.404***	1.686***
	(0.104)	(0.0858)	(0.130)	(0.120)	(0.216)
RD inhouse	2.055***	2.660***	1.345***	1.709***	1.905***
	(0.166)	(0.184)	(0.117)	(0.100)	(0.209)
Ext knowledge	2.225***	1.961***	1.291**	1.222**	2.108***
	(0.129)	(0.134)	(0.125)	(0.104)	(0.346)
Green targets	1.251***	1.230***	1.813***	3.407***	3.503***
	(0.0746)	(0.0631)	(0.142)	(0.169)	(0.382)
Green manager	1.063	1.008	1.391**	1.573***	1.672**
	(0.0833)	(0.0757)	(0.144)	(0.132)	(0.304)
Ext audit	1.098	1.059	1.408***	1.460***	1.750***
	(0.0765)	(0.0588)	(0.116)	(0.0913)	(0.169)
Country FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
N	7992	8018	3740	7920	6995

Note: The dependent variable is binary. Controls included. Exponentiated coefficients: to better interpret the results, I transform the coefficients into odds ratio; standard errors in parentheses are clustered at sector level, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Since the findings of the different environmental innovation types may be correlated, resulting in inconsistent estimates of the simple logit models, a multinomial logit model is estimated in Table 5 as a further robustness check.

Overall, the results remain similar. The findings indicate a significant, positive correlation of customer requirements and experience losses (due to weather extremes) with the introduction of all environmental innovation measures. Differences occur when looking at regulation. Here, we can see that energy tax only show significant results for EI developed within the company. Being energy taxed increases the relative risk to EI within the company about 50 percent compared to companies not involved in innovation. Furthermore, if companies state that regulation is moderate to great obstacle the relative risk to introduce EI to no innovation decrease by a factor of 0.7 for adopting energy efficiency measures and environmental measures.

Table 5. Multinomial logit estimation results

	(1)	(2)	(3)	(4)
	General innovation (product or process)	Energy efficiency	EI developed within firm	Environmental measures
Energy tax	0.881	1.086	1.492**	1.173
	(0.109)	(0.132)	(0.190)	(0.153)
Obstacle regulation	0.788**	0.701***	0.849*	0.701**
	(0.0786)	(0.0653)	(0.0842)	(0.0803)
Customer push	1.588**	1.548**	1.539**	1.113
	(0.241)	(0.235)	(0.240)	(0.199)
Losses weather	1.349*	1.760***	1.970***	1.503**
	(0.219)	(0.255)	(0.287)	(0.224)
RD inhouse	3.811***	3.209***	4.407***	1.591**
	(0.680)	(0.517)	(0.717)	(0.260)
RD outhouse	1.773**	1.925**	2.324***	1.014
	(0.448)	(0.492)	(0.575)	(0.282)
Green targets	1.855***	4.057***	7.132***	1.654***
	(0.201)	(0.461)	(0.786)	(0.175)
Green manager	1.157	1.526**	2.154***	1.272
	(0.172)	(0.270)	(0.341)	(0.212)
Ext audit	1.637***	1.937***	2.689***	1.707***
	(0.174)	(0.202)	(0.282)	(0.204)
Country FE	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES
N	8128	8128	8128	8128

Note: The base category is "no innovation activity"; Controls included; Exponentiated coefficients: to better interpret the results, I transform the coefficients into Relative Risk Ratio; Standard errors in parentheses are clustered at sector level; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

4.3 Further Analysis of Subsamples

The post-socialist economies of CEECCA are far from being a homogeneous group. To investigate possible heterogeneity in innovation activities across country groups, I estimate two subsamples in terms of EU membership and non-membership.

Starting with adopting environmental measures (see Table 6), energy tax only shows for EU members a significant positive correlation. This again indicates that the EU has stronger environmental policy objectives compared to countries outside the EU. Furthermore, companies whose customers demand environmental standards have higher odds of introducing environmental measures in both groups of countries. However, it is about 7 percentage points higher in the EU member countries, which could be explained by possibly higher environmental awareness within the EU. Companies that experienced losses due to weather extremes are positively associated with the adoption of environmental measures in both country groups. This is also the case for internal R&D, while the odds are about 30 percentage points higher among EU member states. Collaborative R&D is not significant for adapting environmental measures which is in line with my baseline results above. Estimating it in column 3 and 4 alternatively with acquiring external knowledge, we see a strong significant positive correlation only for non-EU states. This is again indicating a high relevance of external knowledge transfer.

Table 6. Logit estimation results: adopting environmental measures in EU and non-EU members

	(1)	(2)	(3)	(4)
	environmental measures		environmental measures	
	EU members	Non -EU members	EU members (a)	Non -EU members (a)
Adopt env. measure				
Energy tax	1.612**	1.062	1.648**	1.105
	(0.367)	(0.134)	(0.395)	(0.145)
Customer push	1.704**	1.638**	1.764**	1.626**
	(0.460)	(0.265)	(0.474)	(0.254)
Losses weather	1.977**	1.878***	1.888**	1.761***
	(0.438)	(0.334)	(0.431)	(0.278)
RD inhouse	2.136**	1.863***	2.285**	1.591***
	(0.572)	(0.227)	(0.614)	(0.193)
RD outhouse	1.774	1.249		
	(0.655)	(0.269)		
Ext knowledge			1.591	2.729***
			(0.450)	(0.536)
Green targets	4.156***	2.984***	4.380***	2.997***
	(0.742)	(0.333)	(0.790)	(0.346)
Green manager	1.417	1.723**	1.433	1.671**
	(0.330)	(0.401)	(0.347)	(0.408)
Ext audit	0.933	2.326***	0.925	2.215***
	(0.201)	(0.248)	(0.204)	(0.228)
Obstacle regulation	0.760*	0.971	0.745*	0.988
	(0.122)	(0.110)	(0.123)	(0.115)
FE	YES	YES	YES	YES
N	2644	5034	2608	4977

Note: The dependent variable is binary. Controls included. Exponentiated coefficients: to better interpret the results, I transform the coefficients into odds ratio; standard errors in parentheses are clustered at sector level, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Looking at energy efficiency measures (see Table 7), companies being energy taxed are positively associated with EI in both country groups, while in EU members the odds to adapt energy efficiency measures are 10 percentage points higher. This is consistent with above results. Customer requirements only increases the likelihood to introduce energy efficiency in non-EU states. This could be related to backward technologies that are still often used in these countries and that might not meet customer standards. Internal R&D increase the likelihood for companies to adapt energy efficiency measures in both country groups, while the odds are about 15 percentage points higher among non-EU member states. The opposite is the case for collaborative R&D where the odds are 25 percent points higher among EU members. This suggests that firms from EU transition countries are on average more involved in collaborative R&D than those from non-EU transition countries (see Table 2). Estimating it with acquiring external knowledge (see column 3 and 4) shows only significant and positive results for EU member states. The EU actively promotes cleaner energy technologies and updates its regulations, this could pressure companies from EU transition countries and make them more reliant on external knowledge sources.

Table 7. Logit estimation results: adopting energy efficiency measures in EU and non-EU members

	(1)	(2)	(3)	(4)
	energy efficiency measures		energy efficiency measures	
	EU members	Non -EU members	EU members (a)	Non -EU members (a)
Energy efficiency				
Energy tax	1.384**	1.273**	1.397**	1.290**
	(0.155)	(0.107)	(0.159)	(0.111)
Customer push	1.129	1.369***	1.174	1.362***
	(0.128)	(0.128)	(0.140)	(0.128)
Losses weather	1.287*	1.475***	1.291*	1.521***
	(0.187)	(0.163)	(0.192)	(0.166)
RD inhouse	1.459**	1.669***	1.582***	1.774***
	(0.181)	(0.121)	(0.174)	(0.120)
RD outhouse	1.759***	1.390**		
	(0.280)	(0.157)		
Ext knowledge			1.420**	1.159
			(0.157)	(0.126)
Green targets	3.997***	3.114***	3.960***	3.175***
	(0.354)	(0.211)	(0.358)	(0.212)
Green manager	1.428**	1.598***	1.457**	1.588***
	(0.191)	(0.164)	(0.194)	(0.166)
Ext audit	1.620***	1.494***	1.612***	1.486***
	(0.163)	(0.102)	(0.168)	(0.0987)
Obstacle regulation	1.024	0.921	1.042	0.955
	(0.106)	(0.0750)	(0.107)	(0.0759)
FE	YES	YES	YES	YES
N	3103	5582	3064	5518

Note: The dependent variable is binary. Controls included. Exponentiated coefficients: to better interpret the results, I transform the coefficients into odds ratio; standard errors in parentheses are clustered at sector level, * p < 0.10, ** p < 0.05, *** p < 0.001

Finally, in Table 8, we look at EI developed with the company. Companies shows again higher likelihood to EI when faced energy taxes, while here companies from non-EU members have 15 percentage points higher odds to EI. Customer requirements is as in the baseline results not significant. Furthermore, experience losses due to weather events does not show a significant result. Companies engaged in internal R&D have in both country groups a higher likelihood to EI, while collaborative R&D (and acquiring external knowledge) only show for EU member states a significant, positive relation. This is similar to the results before.

Table 8. Logit estimation results: EI within company in EU and non-EU members

	(1)	(2)	(3)	(4)
	Eco Innovation		Eco Innovation	
	EU members s	Non -EU members	EU members (a)	Non-EU members (a)
EI within company				
Energy tax	1.293*	1.447***	1.286*	1.419***
	(0.174)	(0.151)	(0.175)	(0.144)
Customer push	0.873	1.144	0.867	1.127
	(0.133)	(0.127)	(0.131)	(0.128)
Losses weather	1.288	1.200	1.271	1.181
	(0.230)	(0.145)	(0.225)	(0.140)
RD inhouse	1.434**	1.248**	1.477**	1.297**
	(0.246)	(0.120)	(0.268)	(0.127)
RD outhouse	1.462*	1.146		
	(0.306)	(0.153)		
Ext knowledge			1.537**	1.116
			(0.220)	(0.134)
Green targets	1.521**	1.759***	1.519**	1.756***
	(0.198)	(0.169)	(0.194)	(0.170)
Green manager	1.379**	1.461**	1.342**	1.420**
	(0.205)	(0.194)	(0.199)	(0.192)
Ext audit	1.298	1.558***	1.315*	1.536***
	(0.218)	(0.131)	(0.214)	(0.130)
Obstacle regulation	1.044	1.316**	1.022	1.294**
	(0.126)	(0.119)	(0.130)	(0.120)
FE	YES	YES	YES	YES
N	1501	2539	1482	2492

Note: The dependent variable is binary. Controls included. Exponentiated coefficients: to better interpret the results, I transform the coefficients into odds ratio; standard errors in parentheses are clustered at sector level, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Empirical studies show that determinants of EI can vary depending on the type of eco-innovation (Horbach et al. 2012; del Río et al. 2017; Biscione et al. 2020; Demirel und Kesidou 2011; Frondel et al. 2007). Since the ES questionnaire allows further differentiation of firms' environmental measures, the variables End-of-Pipe (EOP) and Cleaner Productions (CP) were created whose estimation results are presented in Table 9.

The findings suggest that environmental regulation that is an obstacle to companies and energy tax increase the odds over 20 percent to introduce EOP measures in companies, while there is no significant relation to CP. This is in line with Frondel et al. (2007). Regulatory pressure seems to play a significant role in the application of EOP measures. Environmental customer requirements and experience of losses due to weather extremes increase the likelihood to introduce both EOP and CP. Regarding R&D, companies involved in internal R&D have 34 percent points higher odds to introduce CP then EOP. These findings indicate that CP are more knowledge intense then EOP. This is also reflected in the results for collaborative R&D. While there is no significant relationship for EOP, the odds of engaging in CP increases by more than 50 percent when firms are involved in collaborative R&D.

Table 9. Logit estimation: Cleaner production and end of pipe

	(1) EOP	(2) CP
Energy tax	1.247**	1.113
	(0.0987)	(0.100)
Obstacle regulation	1.237**	1.071
	(0.0857)	(0.0836)
Customer push	1.501***	1.469***
	(0.109)	(0.146)
Losses weather	1.436***	1.694***
	(0.128)	(0.217)
RD inhouse	1.457***	1.797***
	(0.113)	(0.156)
RD outhouse	1.106	1.555**
	(0.103)	(0.241)
Green targets	2.400***	3.003***
	(0.138)	(0.236)
Green manager	2.519***	1.667***
	(0.219)	(0.235)
Ext audit	1.559***	1.586***
	(0.110)	(0.128)
Country FE	YES	YES
Industry FE	YES	YES
N	8120	8631

Note: The dependent variable is binary. Controls included. Exponentiated coefficients: to better interpret the results, I transform the coefficients into odds ratio; standard errors in parentheses are clustered at sector level, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

5. Discussion & Conclusion

This study examined the environmental innovation behavior of companies in 29 transition economies within the CEECCA region and compares it to their general innovation. Using the most recent ES survey data conducted between 2018 and 2020, I analyzed over 17,000 companies.

The results of this study confirm a positive role of regulation on EI development, thus supporting hypothesis 1 and 2. Companies stating environmental regulation is an obstacle for their current business are more likely to EI within the companies. The weaker results for regulation as an obstacle to do business across other EI may indicate that environmental regulation is subject to less stringent policies in transition economies (OECD 2020). In addition, the findings indicate that environmental regulation in the form of energy taxes is positively associated with the adoption of energy efficiency measures. These results align with the findings of Biscione et al. (2020). The importance of government tax regulation for energy efficiency measures is noteworthy given that transition countries are partly still entrenched in energy-intensive technologies or industries (OECD 2019a, 2019b), indicating a more important role of the state. Moreover, I found that this link is stronger for transition countries that are part of the EU compared to non-EU transition economies. This could be related to the stronger environmental policy goals of the EU.

Hypothesis 3 is confirmed as well. Customer demand for environmental protection stimulates innovation in all areas of environmental innovation as well as general product and process innovation. This is indicating that market pull factors create incentives that go beyond environmental activities. These findings are in contrast to Horbach (2016) and Biscione et al. (2020) who found the demand push factor is less relevant than environmental regulation in Eastern EU states. My results, however, indicate the opposite. This might be an indication of increasing sustainability awareness on the part of consumers over the years. Furthermore, I confirm hypothesis 4. Companies experiencing losses due to extreme weather events are more likely to engage in EI. The strongest link is here found with adapting environmental measures. This suggests that these losses stimulate companies to find innovative solutions and might raise environmental awareness. As many countries of the CEECCA region are vulnerable to consequences of climate change and are confronted with increasing weather extremes, it is important that companies prepare for these environmental challenges. My results indicate that firms use EI as a coping strategy.

Finally, internal R&D is an important input factor for all firms' innovation activities (general and environmental). This supports hypothesis 5. Also, collaborative R&D is positively associated with the introduction of EI. Thus, confirming hypothesis 6. However, the results do not indicate that external R&D cooperation (or buying access to external knowledge) have a more important role for EI then for general innovation. The results could be an indication that the absorptive capabilities within companies are not advanced enough to implement the knowledge gained from cooperation. However, it seems more likely that R&D collaborations are less common in transition economies (Hájek und Stejskal 2018). Therefore, internal R&D compensates for these which is in line with the findings of Ghisetti et al. (2015) and Marchi und Grandinetti (2013) but in contrast to the findings of da Silva Rabêlo und Azevedo Melo (2019) and Rennings und Rammer (2009). Here, however, it should be accounted for the special background of the countries under study. The transformation from a planned to a market economy was accompanied by heavy losses in scientific and industrial R&D (Meske 2000). Existing structures in and between science institutes dissolved and fragmented (Radosevic 1998; Radosevic 2002). This means that market-based innovation systems, even in the transition countries of the EU, are relatively young and networks between actors and institutions are less established. Nevertheless, knowledge transfer from external sources is conducive to companies' EI in these countries, as the finding of the alternative measure 'acquiring external knowledge' show.

The countries studied have undergone a massive transformation process and have achieved varying degrees of modernization and technological performance. Overall, the results show parallels in many parts to the findings of the non-transition countries. It is plausible to assume that the transition countries still take their cue from the non-transition countries and draw lessons from the successes and failures of their environmental and energy policies. However, since the transition countries have the distinction of having already transformed their economic system once in the 1990s, this experience could also prepare them for the renewed challenge of transforming their economic system to a low-carbon economy.

Analysis of ES data is useful for gaining insights into firms' environmental innovation behavior over a large number of observations, but has several limitations. First, because I am limited to cross-sectional data, the direction of causality is difficult to determine. Second, since only one wave of the survey is available, it is not possible to include a time dimension in this analysis. This limitation underscores the need for further research on this topic, as the availability of more survey waves or a panel data set would provide deeper insights. In addition, the firms studied are affected by regulations that may vary at the industry and country level. These variations cannot be captured in this empirical analysis. Furthermore, the data do not allow further differentiation of the types of external R&D partners. Hence, I cannot show whether the links are national or international and whether they are collaborations between companies or with universities or research institutions, leaving room for further research on this topic. Finally, I acknowledge that there is a vulnerability to measurement error and cultural bias in self-reported data.

This topic of environmental innovation is of great importance as countries face and will continue to face major challenges caused by global climate change. Therefore, it is important to grasp the feature of environmental innovation in order to take appropriate measures to better address the pressing task of policy makers, business and society to create green industries. Overall, policy makers should be encouraged by my findings to continue and strengthen their environmental regulations. Furthermore, the results suggest that there is still room for more cooperation in the area of R&D. Decision-makers should see this as an opportunity to promote more external R&D linkages and facilitate the possible costs of cooperation. Finally, these results have shown the positive stimulation of environmental demands of customers on environmental innovations. This should reinforce policy makers to further raise sustainability awareness among the population.

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Appendix

A1: Summary statistics

	Description	N	Mean	Std. Dev.	Min	Max
Process innovation	Takes value 1 if any new or improved process were introduced during last 3 years, 0 otherwise	16975	.19	.393	0	1
Product innovation	Takes value 1 if any new or improved products/services were introduced during last 3 years, 0 otherwise	17077	.318	.466	0	1
EI within firm	Takes value 1 if any environmental measures were developed within company over last 3 years, 0 otherwise	5707	.481	.5	0	1
Adopt energy efficiency measures	Takes value 1 if any energy efficiency measures were adapted over last 3 years, 0 otherwise	16346	.361	.48	0	1
Adopt energy efficiency measures	Takes value 1 if any environmental measures were adapted over last 3 years, 0 otherwise	14024	.763	.425	0	1
End of pipe	Takes value 1 if any end of pipe measures were adapted over last 3 years, 0 otherwise	14939	.243	.429	0	1
Cleaner production	Takes value 1 if any cleaner production measures were adapted over last 3 years, 0 otherwise	15975	.73	.444	0	1
RD inhouse	Takes value 1 if R&D were spent on within company during last 3 years, 0 otherwise	17048	.214	.41	0	1
RD outhouse	Takes value 1 if R&D were spent on contracted with other companies during last 3 years, 0 otherwise	17048	.098	.297	0	1
Ext. knowledge	Takes value 1 if external knowledge was purchased over last 3 years, 0 otherwise	17029	.142	.349	0	1
Green targets	Takes value 1 if environmental targets (energy, CO2 or pollution) were defined over last 3 years, 0 otherwise	16249	.307	.461	0	1
Green manager	Takes value 1 if environmental manager was employed last year, 0 otherwise	16847	.12	.325	0	1
Ext. audit	Takes value 1 if external audits are performed over last 3 years, 0 otherwise	10432	.294	.455	0	1
Customer push	Takes value 1 if customers required environmental certifications or standards as a condition to do business last year, 0 otherwise	16756	.147	.354	0	1
Losses weather	Takes value 1 if experienced monetary losses due to extreme weather/ pollution over last 3 years, 0 otherwise	16939	.099	.299	0	1
Obstacle regulation	Takes value 1 if environmental regulation is a moderate to great obstacle to the current operations of this establishment, 0 otherwise	16431	.270	.444	0	1
Energy tax	Takes value 1 if establishment is subject to an energy tax or levy, 0 otherwise	16337	.191	.393	0	1
Firm size	Firm size bases on employee figures ((1) micro, (2) small, (3) middle or (4) large)	16997	2.133	.878	1	4
Firm age	Firm age in years	17032	18.04 9	13.752	0	205
Employee growth	Employee growth over last 3 years	15132	4.513	55.314	-1750	221[illegible]
Sales expectation	Sales expectation for next year	16421	1.548	.699	1	3
Main market	Establishment's main market ((1) local, (2) national or (3) international)	17070	1.712	.684	1	3

Source: EBRD-EIB-WB Enterprise Surveys 2018-2020

A2: Correlation matrix

	RD inhouse	RD other	Ext. know	Customer push	energy tax	losses	regu obstcle	Ext. audit	Green targets	Green manager	Firm size	Sales exp	Main market
RD inhouse	1												
RD outhouse	0,469	1											
Ext. knowledge	0,342	0,299	1										
Customer push	0,180	0,172	0,137	1									
Energy tax	0,079	0,092	0,104	0,067	1								
Losses weather	0,093	0,088	0,104	0,149	0,072	1							
Obstacle regulation	0,043	0,053	0,030	0,124	0,019	0,094	1						
Ext. audit	0,140	0,120	0,103	0,190	0,040	0,087	0,051	1					
Green targets	0,110	0,098	0,087	0,194	0,085	0,091	-0,015	0,231	1				
Green manager	0,159	0,152	0,131	0,351	0,051	0,095	0,083	0,213	0,211	1			
Firm size	0,205	0,193	0,165	0,205	0,039	0,063	0,071	0,185	0,177	0,314	1		
Sales expectation	-0,099	0,088	0,073	-0,038	-0,022	0,002	0,053	0,043	-0,045	-0,040	0,058	1	
Main market	0,194	0,151	0,118	0,184	0,038	0,048	0,079	0,099	0,104	0,203	0,327	0,018	1

A3: Distribution of firm by industries

Variable	Industry labels	Number of firms	Percent
sec15-16	Food, Tobacco	2,206	12.84
sec17-19	Textile, clothing, leather	1,413	8.22
sec20-22	Wood, paper, printing	745	4.34
sec23-25	Coke, Chemical, rubber and plastics	886	5.16
sec26	Non-metallic mineral products	864	5.03
sec27-28	Metals	1,252	7.29
sec29_34-35	Machinery	1,103	6.42
sec30-33	Electronics, instruments	367	2.14
sec36-37	Other manufacturing	579	3.36
sec45	Construction	1,273	7.41
sec50-52	Retail and wholesale	4,694	27.31
sec55	Hotel, restaurants	779	4.53
sec60-64	Transport	784	4.56
sec72	IT	240	1.40
Total		17,185	100

Source: EBRD-EIB-WB Enterprise Surveys 2018-2020

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