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Abstract

We investigate the interplay between innovation and productivity, emphasizing the role of environmental regulations on the innovation behaviours of European firms. Anchored in the Porter hypothesis, which proposes that environmental regulations can drive technological innovation and bolster commercial competitiveness, we utilize the CDM model (Crépon, Duguet, and Mairesse, 1998) for in-depth analysis. Our approach begins by pinpointing the factors that shape firms' decisions to innovate and the associated investments, employing the Heckman correction model. Subsequently, we adopt the three-stage least squares (3SLS) methodology to analyse both innovation outputs and firm productivity in tandem. Drawing data from the Community Innovation Survey (CIS) 2018, our structured examination unveils how diverse innovation drivers can elevate labor productivity in varied institutional landscapes. By contrasting the performance of South Europe (comprising Greece, Spain, Portugal) and Central Eastern Europe (countries like Bulgaria, Estonia, Hungary) against a German benchmark, our research offers a nuanced understanding of environmental regulations' influence on innovation and productivity across European contexts.

Keywords: innovation, productivity, CDM model, CIS, Porter`s hypothesis

JEL classification: C33; C36; O31; O33

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Introduction

This paper continues the research on the relationship between innovation and productivity, as evidenced by studies from (Tevdovski et al. 2017, Toshevska-Trpchevska et al. 2019, Disoska et al. 2020, Toshevska-Trpchevska et al. 2020, and Disoska, 2023). In this study, we delve deeper, aiming to capture the influence of environmental regulation, along with other determinants, on the innovative behaviors of firms in Europe.

The primary objective of this paper is to examine the Porter hypothesis. This hypothesis posits that well-designed environmental regulations can stimulate firms' technological innovations, leading to enhanced commercial competitiveness (Porter and van der Linde, 1995). Various papers, such as those by (Jaffe and Palmer, 1997, and Jaffe et al.,1995), support this hypothesis, highlighting that innovation in technologies that mitigate pollution can result in energy savings. These energy savings can subsequently translate into cost reductions, potentially counteracting the expenses of adhering to these regulations. However, (Kozluk and Zipperer, 2013), noted that the outcomes can differ based on the specific sectors and may even be detrimental in certain contexts.

The European Commission has set an ambitious goal: to reduce net greenhouse gas emissions by a minimum of 55% by 2030 compared to 1990 figures, thus moving towards a carbon-neutral continent. Notably, in 2020, the per capita greenhouse gas (GHG) emissions for the European Union (EU-27) stood at 6.98 metric tons of carbon dioxide equivalent, marking a reduction of 24%. However, progress has been inconsistent across individual EU countries.

In this context, we endeavour to compare the ramifications of environmental regulations on innovation and productivity across different European regions. Utilizing the CDM model, we analyze two groups of EU countries – South Europe (comprising Greece, Spain, and Portugal) and Central Eastern Europe (including Bulgaria, Czech Republic, Estonia, Croatia, Hungary, Lithuania, Latvia, Romania, and Slovakia). We juxtapose their findings with data from Germany, seeking to understand the nuances of innovation's impact on productivity among these EU member states. A key area of exploration is discerning whether environmental regulation positively influences decisions to innovate, the resulting innovation output, and overall productivity. Consequently, our research poses the following questions:

1. In varied regional groupings, how does environmental regulation influence the decision to innovate, the consequent innovation output, and overall productivity? Do significant disparities emerge when comparing South and Central Eastern European countries with Germany?

2. Is the observed innovation deficit in Southern Europe and Central and Eastern Europe linked to lower environmental awareness among the population or higher energy intensity, especially when contrasted with Germany?

3. Can we validate the Porter hypothesis in the contexts of Central and Eastern European countries and South Europe?

This paper integrates both empirical and theoretical analyses to discern differences among the country groups, aiming to offer insightful policy recommendations. It's crucial to acknowledge a limitation of our study: the selection of countries is dictated by the availability of data in the CIS database. Nonetheless, we have integrated data from every accessible country. Theoretically, we intertwine discussions about the validity of the Porter hypothesis with the environmental consciousness of firms in two distinct institutional backdrops. From a pragmatic standpoint, we delineate actionable policy directives.

The paper unfolds in four sections: an initial review of related literature, followed by a detailed exposition of the adopted model and data. The subsequent section interprets the results derived from the model, finalizing in a comprehensive conclusion.

Literature review

Innovations, along with their economic significance and underlying drivers, are widely discussed in literature. This segment briefly reflects on the concept of innovation, paying special attention to eco-innovations. We also discuss the role of regulation in boosting innovations and compare the innovation capacities and economic outcomes of South European countries with those in Central and East Europe (CEE).

At the national level, the concept of innovation delves into how specific countries sustain their industrial and technological strengths. This is often influenced by distinct institutional frameworks (Toshevska-Trpchevska et al., 2019). For individual firms, the adoption of innovations depends on various factors, including firm size, workforce capabilities, marketing strategies, and the economic and social benefits of the innovations (Stojkoski et al., 2022).

Eco-innovation has garnered significant attention in both research and practical realms. At the macroeconomic policy level, initiatives like the Kyoto Protocol (1994) and the Circular Economy Action Plan (2020) emphasize environmental and sustainability goals. For research and innovation activities, the primary EU funding mechanism is the EU Framework Program for Research and Innovation, with its current iteration, Horizon Europe (2021-2027), having a budget of €95 billion to enhance innovation across Europe.

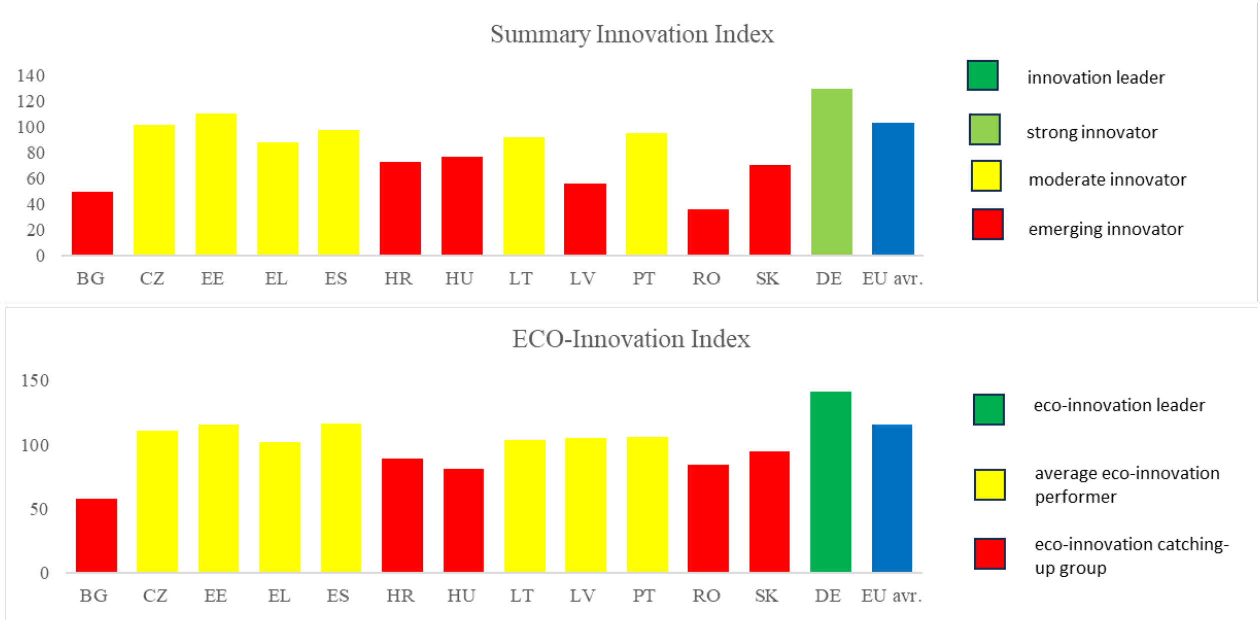
On the micro-scale, companies worldwide strive to align with these sustainability goals. Highlighting the multifaceted nature of eco-innovation, Zheng (2022) identifies five key types: process, product, technological, management innovation, and other green practices.

General innovation theory underscores the significance of technological-push and market-pull factors in driving innovations. These factors also apply to eco-innovations. What sets eco-innovations apart is the double externality problem, producing both knowledge and environmental spillovers. Given the potential lack of market incentives for eco-friendly innovations, environmental policies and institutional factors may be crucial for their realization (Rennings, 2000). A growing consensus sees environmental regulation as a vital eco-innovation driver, with regulatory measures, fees, and taxes being primary motivators (Horbach, 2008; Kijek et al., 2013).

There's a prevailing belief that effective environmental regulations can offer economic benefits beyond just environmental risk reduction. The Porter hypothesis posits that stringent environmental policies can enhance productivity, profits, and lead to organizational or product/process innovations (Porter, 1991; Porter et al., 1995). Such eco-innovations often result in competitive advantages, contributing to sustainable growth in various markets and improved organizational performance (Hofer et al., 2012; European Commission, 2012; Hojnik et al., 2017).

In assessing the innovation capacities of CEE and South European countries, the Summary Innovation Index and Eco-Innovation Index by the European Commission provide key insights (Figure 1). As of 2022, the countries under study largely fall into two categories: emerging and moderate innovators, with performances below the EU average and Germany, except for Estonia.

Figure 1. Innovation performance indices for South and CEE countries, for the year 2022



The European Innovation Scoreboard provides a comparative analysis of overall innovation performance in countries in Europe across four main types of activities – Framework conditions, Investments, Innovation activities, and Impacts – with 12 innovation dimensions, capturing a total of 32 indicators. The Eco-Innovation Index measures the environmental innovation performance of EU countries, based on the 12 indicators included in the measurement framework, categorized into five broad areas: Eco-innovation inputs, Eco-innovation activities, Eco-innovation outputs, Resource efficiency outcomes, and Socio-economic outcomes.
Source: European Commission.

Empirical studies on South and CEE countries emphasize the need for their innovation systems to evolve towards increased development and resilience. Stojcic et al. (2020) note a transition "from imitation to innovation-driven competitiveness" in new EU member states. The innovation capacities of these countries also face vulnerabilities, particularly during crises (Toshevska-Trpchevska et al., 2019). However, policies such as public procurement of innovation in CEE have shown positive impacts on innovation and output (Stojcic et al., 2020).

The drivers and impact of eco-innovations present a more complex picture. Factors like high costs and stakeholder challenges can inhibit the adoption of cleaner technology (Cecere et al., 2014). The path from pollution-intensive practices depends on a country's economic state and its access to environmentally oriented knowledge (Horbach, 2015). Earlier research indicated that changes in environmental policy can have a pronounced impact on innovation in countries deeply entrenched in pollution-intensive technologies (Acemoglu et al. 2012). However, recent findings suggest environmental regulations in CEE might spur firms to undertake eco-innovations, but not necessarily lead to the creation of new ones (Prokop et al., 2022).

In conclusion, the innovation systems of South and CEE countries are marked by limited institutional commitment, inadequate R&D, and a low emphasis on eco-innovation (Hashi et al., 2013; Hojnik et al., 2017).

Data and model

This paper employs data from the Community Innovation Survey (CIS) conducted by the European Commission in 2019 (referred to as CIS 2018). The CIS database aggregates data concerning innovation activities across various European countries. Structured around a standardized questionnaire, the survey is administered biennially. For the purposes of this paper, data from the period 2016-2018 is utilized.

Our research delves into both empirical and theoretical analyses, comparing the group of countries (Central and Eastern Europe and South Europe) with Germany. The goal is to elucidate accurate policy implications and offer actionable suggestions. A primary limitation of this study is its dependence on the availability of data in the CIS database, meaning the selected countries are determined by the dataset's scope. The analysis incorporates data for all countries that are available.

The influence of environmental regulation on innovation was first introduced in CIS 2008 and has undergone modifications in subsequent surveys. Using firm-level data from CIS 2018, our econometric model seeks answers to the following questions: Did environmental legislation or regulation spur or aid innovation activities? Did it hinder, obstruct, or elevate the costs associated with innovation activities? Or, did it neither impact nor hold relevance for innovation endeavors?

For clarity, we've included Table 1, which breaks down the dataset structure of the CIS surveys from 2016 to 2018 by country group. A comprehensive delineation of the variables used in the model can be found in Table A1 in the Appendix. A cursory examination of this data highlights notable differences in the average values of the analyzed variables across country groups. This indicates varying innovation processes among these countries. Further descriptive analysis reveals that the majority of countries exhibit a positive correlation between the decision to innovate and variables describing innovation input, output, and productivity.

Table 1. Descriptive statistics of the data

Variable	Number of observed variables			Mean			Standard deviation		
	Germany	CE Europe	South Europe	Germany	CE Europe	South Europe	Germany	CE Europe	South Europe
Decision to innovate	6271	48271	43271	0.44	0.11	0.23	0.5	0.32	0.42
Innovation input	1970	4988	9127	13.26	11.2	12.21	2.87	2.17	1.67
Innovation output	2104	10783	10940	-1.91	-1.66	-1.67	1.14	1.21	1.32
Productivity	6271	48145	43181	11.83	10.68	11.25	1.42	1.36	1.25

We use a modified version of the CDM model by using the software STATA. [1] The analytical framework of the CDM model (the acronym of the three authors' names, Crépon, Duguet and Mairesse, 1998) consists of two general stages, and each of them can be divided into two sub-stages. Factors that influence the firms' decision to innovate or to invest in research and development are included in the first general stage. We use the Heckmann correction model to treat the omitted variable problem, as a standard estimation procedure for this kind of empirical equation. In the second stage, we perform the three-stage least squares (3SLS) methodology to simultaneously estimate the innovation output and the productivity of the firm. Because we study the differences between groups of countries in their innovation systems, we estimate the CDM model separately for each group country in our sample. Under this model, we first simultaneously estimate the effect of R&D engagement and intensity on innovation outcome and then quantify the effectiveness of the innovative efforts leading to productivity gains for each country separately and account for the temporal property of the data.

[1] The methodology was implemented using Stata, and the code to replicate the findings can be found at the following link.

The two main stages can be further categorized into two sub-stages. During the initial stage, we utilize a Heckman correction model to estimate the innovation input, considering a variable that represents the decision to innovate. Mathematically, these equations elucidate this stage.

$$Prob(d_{it} = 1|x_{it}^0) = \Phi(\beta_0 x_{0it} + z_{0t}) + u_{0it}, \quad (1)$$
$$w_{it}^* = \alpha d_{it} + \beta_1 x_{1it} + z_{1t} + u_{1it}. \quad (2)$$

Equation (1) represents a probit regression, denoted by Φ (the cumulative standard normal distribution), which models the unobserved decision of a firm i at time t to innovate (d_{it}). The decision is dependent on a vector of covariates (x_{0it}) and their corresponding parameter vector (β_0). The equation also includes a time-specific variable (z_{0t}) that may affect the final decision of the firm regarding innovation.

Equation (2) is used to estimate the unobserved innovation input (w_{it}^*), which is measured as the logarithm of the amount (in Euro) spent on various activities such as intramural or extramural R&D, acquisition of machinery, equipment and software, or acquisition of external knowledge in the survey year. It uses a vector of covariates (x_{1it}) weighted by parameters (β_1). Additionally, it includes the variable d_{it} as an additional explanatory variable to account for potential selection bias that may arise when considering only data from firms that decided to invest in innovation. Like Equation (1), Equation (2) also incorporates a time-specific effect (z_{1t}).

In the second stage, the three-stage least squares (3SLS) methodology is employed to simultaneously estimate both the innovation output and the productivity of the firm. The specifics of this stage are not provided in the given text.

$$r_{it} = \beta_{w^*} w_{it}^* + \beta_q q_{it} + \beta_2 x_{2it} + z_{2t} + u_{2it}, \quad (3)$$
$$q_{it} = \beta_r r_{it} + \beta_3 x_{3it} + z_{3t} + u_{3it}. \quad (4)$$

Equation (3) introduces the innovation output (r_{it}), which is measured as the logarithm of the firm's percentage of turnover derived from new goods or services in the market or within the enterprise during the three years preceding the survey. The equation includes a time-specific effect (z_{2t}) and an error term (u_{2it}). In conjunction with this equation, we estimate equation (4), which captures the firm's productivity (q_{it}). Productivity is quantified as the logarithm of the firm's turnover divided by the number of employees in the survey year. It is modeled as a linear function of the innovation output (r_{it}) and a vector of exogenous explanatory variables (x_{3it}) with the corresponding parameter vector (β_3). Similar to the previous equations, z_{2t} represents a time-specific effect, and u_{3it} denotes the error term. In all three equations the variables regarding the environmental regulation are included.

Interpretation of the results

Decision to Innovate

The first stage of the CDM model provide insights into the factors influencing the decision of companies to engage in the innovation process (Table 2). Notably, larger companies showed a greater inclination towards innovation. These larger firms, with more significant R&D funds or already established innovation activities, more readily decided to innovate. During the studied period, companies that were part of a group with a head office in the domestic market consistently decided to innovate across all three analyzed groups of countries. Conversely, companies affiliated with a group whose head office was abroad showed a preference for innovation in Germany and South European countries, but not in Central European nations.

A history of previously abandoned innovation activities was a significant determinant in the decision to innovate across all country samples, suggesting that past innovation experiences can motivate firms to pursue further innovative activities. Additionally, marketing innovations from 2016 to 2018 had a positive and significant impact on the decision to innovate across all the groups. In contrast, organizational innovations played a role in the decision-making of companies in South and Central Europe, but not for those in Germany.

Regarding the central focus of our research—the impact of environmental regulation on innovation—results varied between the country groups. In Germany, there was a clear positive and significant influence of environmental legislation and regulation on the decision to embark on the innovation process. In the South European countries, however, environmental regulations negatively affected the decision to innovate. For companies in Central and Eastern Europe, environmental regulations seemed to neither hinder nor encourage the innovation process.

Table 2. Decision to innovate.

Variables	Germany	South	CEEC
Lfsize	0.150***	0.061***	0.141***
	(-0.017)	(-0.008)	(-0.009)
GP_nat	0.255***	0.286***	0.206***
	(-0.045)	(-0.021)	(-0.025)
GP_int	0.439***	0.230***	-0.029
	(-0.075)	(-0.028)	(-0.027)
Inaba	1.488***	1.738***	1.204***
	(-0.041)	(-0.018)	(-0.022)
Org_innov	0.044	0.335***	0.357***
	(-0.047)	(-0.025)	(-0.026)
Mark_innov	0.108**	0.436***	0.414***
	(-0.055)	(-0.027)	(-0.027)
leg_env_if	0.571***	-0.263***	0.05
	(-0.08)	(-0.049)	(-0.038)
leg_env_phic	0.188***	-0.347***	-0.322***
	(-0.066)	(-0.055)	(-0.043)
leg_env_nimpc	0.094**	-0.455***	-0.345***
	(-0.046)	(-0.024)	(-0.021)
Constant	-1.991***	-1.697***	-1.999***
	(-0.086)	(-0.032)	(-0.039)
Observations	6,271	43,271	41,047

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Innovation Input

The second stage of the CDM model sheds light on the determinants of innovation input, represented by the natural logarithm of the total innovation expenditure in 2018 (Table 3). The analysis reveals that company size, affiliation with an enterprise group (both domestically headquartered and internationally headquartered), and a history of abandoned innovation activities positively affect the innovation process across all studied company samples. While organizational and marketing activities did not significantly influence innovation input for companies in Germany and Central and Eastern Europe, these factors had a positive and significant impact for South European companies.

This phase also evaluated the impact of various funding sources on the innovation process. Divergent outcomes were observed for companies accessing funds from local/regional authorities, national governments, and EU institutions or programs. As delineated in Table 3, only EU-based funding had a positive influence on the innovation endeavors of German companies. In contrast, South European companies found all three funding channels—local/regional, national, and EU—to be vital and beneficial for their innovation processes. For Central and Eastern European companies, national and EU funding sources notably facilitated innovation.

As for the effect of environmental legislation and regulation on innovation at this stage, the outcomes differ across the three company groupings. For German companies, environmental laws and regulations did not significantly elucidate the innovation process. In South Europe, the impact was significantly negative, while in Central and Eastern Europe, it was prominently positive. These findings, albeit distinct from the factors influencing companies' innovation decisions, affirm that South European companies likely experienced a negative impact from environmental regulations, possibly due to elevated implementation costs.

Table 3. Innovation input

Variables	Germany	South	CEEC
Lfsize	0.703***	0.442***	0.538***
	(0.073)	(0.015)	(0.033)
GP_nat	0.413**	0.499***	0.360***
	(0.179)	(0.038)	(0.081)
GP_int	0.826***	0.979***	0.821***
	(0.284)	(0.050)	(0.097)
Inaba	0.906***	0.622***	0.469***
	(0.206)	(0.132)	(0.114)
Org_innov	-0.007	0.128***	0.028
	(0.152)	(0.038)	(0.082)
Mark_innov	0.062	0.194***	-0.053
	(0.159)	(0.041)	(0.082)
Funloc	0.240	0.186***	-0.095
	(0.178)	(0.032)	(0.166)
Fungmt	-0.087	0.545***	0.652***
	(0.333)	(0.030)	(0.085)
Funeu	1.103***	0.607***	0.596***
	(0.175)	(0.039)	(0.070)
leg_env_if	-0.076	-1.024***	0.326**
	(0.359)	(0.085)	(0.147)
leg_env_phic	-0.115	-1.152***	0.065
	(0.377)	(0.105)	(0.160)
leg_env_nimpc	-0.020	-1.132***	0.333***
	(0.354)	(0.058)	(0.124)
Constant	7.651	9.063***	7.649***
	(0.000)	(0.223)	(0.338)
Observations	4,207	42,536	38,749

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Innovation Output

In the third and fourth stages of the CDM model, which focus on innovation output and labor productivity, only those companies that have reported innovation activity in the first two phases are considered. Here, innovation output represents the natural logarithm of the shares of sales from new products and services in the total turnover of the companies. Table 4 presents data from companies operating in the Germany, South Europe, and Central and Eastern Europe. The Mill's ratio coefficient is significant across all three samples, indicating selectivity of the data.

From these results, it's evident that in Germany, higher productivity corresponds to a greater innovation output. However, for companies in South Europe and Central and Eastern Europe, increased productivity led to reduced innovation output. Another intriguing observation is that in Germany, an increase in innovation activity surprisingly resulted in a reduced innovation output, while in South Europe, the opposite was true.

The company size plays a distinct role in the innovation process across the regions. Specifically, in Germany, larger companies have achieved a greater level of innovation output. In contrast, in South Europe and Central and Eastern Europe, the coefficient of firm size is significant but negative, indicating that larger firms experienced reduced innovation output.

Further insights reveal that marketing innovations didn't have a pronounced effect on the innovation output across these regions. Yet, organizational innovations were significant for companies in South Europe and the Central and Eastern European market.

When examining the influence of funding on innovation output, German companies benefited positively from funds provided by local and regional authorities and from EU institutions. However, in South Europe and Central and Eastern Europe, the influence of funding from local and regional authorities was negative on innovation output.

Lastly, the environmental legislation and regulation landscape has diverging impacts. In Germany and Central and Eastern Europe, stricter environmental regulations appear to have dampened innovation output, suggesting increased costs for these innovations. In stark contrast, South European companies experienced a positive correlation, with stringent environmental norms appearing to enhance their innovation output.

Table 4. Innovation Output

Variables	Germany	South	CEEC
lProductivity	1.925***	-0.560***	-0.279*
	(0.512)	(0.154)	(0.153)
Lfsize	0.961**	-0.290***	-0.278***
	(0.438)	(0.059)	(0.104)
Mills	-7.579***	0.548**	-0.541*
	(2.802)	(0.264)	(0.314)
Einnov_input	-2.283***	0.493***	0.174
	(0.785)	(0.148)	(0.204)
Org_innov	0.175	0.115***	0.178***
	(0.117)	(0.030)	(0.038)
Mark_innov	0.147	0.034	0.049
	(0.119)	(0.033)	(0.043)
Funloc	0.563***	-0.161***	-0.175***
	(0.162)	(0.045)	(0.054)
Fungmt	-0.329**	-0.143*	-0.058
	(0.141)	(0.074)	(0.122)
Funeu	2.454***	-0.279***	-0.007
	(0.846)	(0.091)	(0.099)
leg_env_if	-1.650***	0.293***	-0.317**
	(0.519)	(0.107)	(0.147)
leg_env_phic	-0.656**	0.197*	-0.316***
	(0.313)	(0.112)	(0.116)
leg_env_nimpc	-0.370*	0.124	-0.397**
	(0.222)	(0.088)	(0.166)
Constant	-0.423	-0.490	0.905**
	(3.763)	(0.533)	(0.452)
Observations	851	10,922	8,112
R-squared	-2.486	-0.048	0.103

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Labor productivity

The final stage of the CDM model examines the influence of companies' innovation activities on labor productivity, denoted as the natural logarithm of the ratio between the firm's 2018 total turnover and total employment. Labor productivity is shaped by various factors: firm size, innovation output from the third stage, organizational and marketing innovations, and the association of an enterprise with a group (either with its head office in the home country or in a foreign country), along with the impact of environmental legislation and regulation. The findings are delineated in Table 5.

From the data, the size of a firm consistently demonstrates a positive and significant influence on labor productivity across all three analyzed samples. Bigger companies, in each of the three samples, have reported enhanced productivity due to their innovations. Furthermore, innovations from companies, whether they belong to a group with head offices domestically or abroad, have positively influenced labor productivity in all three samples. The innovation output also consistently exerts a positive effect on productivity across these samples.However, the contributions of organizational and marketing innovations on labor productivity appear to be mostly insignificant for all three groups.

In this final stage, the impact of environmental legislation and regulation on innovation activities and its cumulative effect on labor productivity were assessed. The outcomes indicate a significant and negative influence of such environmental mandates on labor productivity for companies in South and Central and Eastern Europe. This insight underscores the profound impact environmental regulations have on the innovation trajectory in these countries.

This is further supported by the findings of Prokop et al., 2022, which highlight a negative correlation between corporate environmental practices and product innovations in transitional countries. Past studies, such as those by Archibugi & Filippetti, 2011; Toshevska-Trpchevska et al., 2019; and Izsak et al., 2015, have also noted a negative relationship between innovation and productivity in Central and Eastern Europe, particularly post the financial crisis.

In stark contrast, Germany showcases a different trend. Here, innovations stimulated by environmental legislation and regulation have positively impacted productivity. This implies that for German entities, the costs linked with adopting these environmental measures were more than compensated for by the rise in company productivity.

Table 5. Labor Productivity

Variables	Germany	South	CEEC
Lfsize	0.297***	0.163***	0.259***
	(0.089)	(0.036)	(0.092)
Org_innov	-0.183	-0.132**	-0.156
	(0.141)	(0.065)	(0.121)
Mark_innov	-0.109	-0.094*	-0.090
	(0.123)	(0.053)	(0.069)
leg_env_if	0.504**	-0.379***	-0.265**
	(0.210)	(0.077)	(0.131)
leg_env_phic	0.085	-0.386***	-0.166
	(0.186)	(0.093)	(0.164)
leg_env_nimpc	0.126	-0.379***	-0.174
	(0.170)	(0.065)	(0.166)
innov_output	0.762*	1.197***	1.424***
	(0.420)	(0.338)	(0.530)
GP_int	0.718***	0.757***	1.358***
	(0.160)	(0.060)	(0.111)
GP_nat	0.354***	0.700***	0.616***
	(0.082)	(0.056)	(0.066)
Constant	13.383***	12.482***	13.250***
	(1.446)	(0.562)	(0.772)
Observations	851	10,922	8,112
R-squared	-0.247	-1.256	-1.413

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Conclusion

The central aim of this paper was to evaluate the repercussions of environmental regulations on the innovative performance of companies in South Europe, Central and Eastern Europe, and to juxtapose their performance with that of Germany. At the core of our investigation was the Porter hypothesis, which postulates that well-designed environmental regulations can ignite technological innovation in firms, thereby bolstering their market competitiveness.

However, our findings are somewhat mixed. In Germany, regulations did motivate firms towards innovative activities and enhanced productivity. But there was a noted negative association with the outputs of innovation. This indicates that while German regulations do promote innovative tendencies and amplify efficiency, they might also introduce obstacles that limit the tangible outputs from these innovations.

In Central and Eastern Europe and South Europe, while regulations incited firms to make innovative choices, mainly focusing on ecological aspects, the resultant "innovation offset" (as termed by Porter and Stern, 2002) did not consistently manifest as tangible innovation. This slightly diverges from the Porter hypothesis, which implied that countries deeply embedded in pollution-heavy technologies might see a more pronounced innovative response to shifts in environmental policies.

Historical studies concerning Central and Eastern European countries consistently highlight their low levels of institutional commitment, R&D expenditure, and environmental awareness. For these countries, the innovations birthed due to environmental regulations often didn't convert to increased productivity, potentially due to the cost-intensive nature of these eco-friendly initiatives.

We must recognize the differential in regulatory intensity across the EU nations. Some sectors, particularly those with high pollution outputs, might be subjected to stricter standards. High regulatory costs might act as deterrents to innovation, impinging on productivity. This could, in turn, lead to increased product prices, causing firms to lose market share, especially in nations with pollution-heavy production methodologies.

The crux of our findings is that the innovation frameworks in these nations seem fragile, often failing to translate innovations into quantifiable productivity enhancements. Central and Eastern European nations, when placed alongside their Western counterparts, display lesser R&D inputs and a diminished environmental cognizance. Our analysis emphasizes their dependency on tax reliefs and both national and European financial backing.

From a policymaking perspective, the state's role in instigating environmental regulations appears paramount. Supportive strategies might include championing FDIs in green projects, promoting energy efficiency uniformly across sectors, and advancing environmental awareness through product labeling. All these strategies should adhere to the World Trade Organization's guidelines.

It's imperative that innovation systems work towards eliminating barriers to knowledge distribution. This can be achieved by promoting business competitiveness, modernizing public infrastructure, curtailing bureaucratic impediments, and endorsing top-tier managerial practices. An efficient Internal Market would catalyze the seamless transition of capital, human resources, and innovative strategies. Sharing best practices and positive cases of environmental regulation from Western to South and Central and Eastern European nations could substantially augment the innovation capacities of these countries.

To derive a more granular understanding of the challenges and potential rectifications in national innovation systems, a deeper analysis, attuned to the specific scenarios in individual countries, is warranted. This could be a promising direction for upcoming research endeavors.

APPENDIX

Table A1. Definition of variables

Dependent variables	**Definition**
Eq. (1): Decision to innovate	Dummy variable: 1 if firm in 3 years before survey engaged in intramural or extramural R&D, purchased new machinery, equipment, software or other external knowledge, engaged in training of personnel, market research or did any other preparations to implement new or significantly improved products and processes
Eq. (2): Innovation input (natural logarithm)	Amount (in Euro) of expenditure on intramural or extramural R&D, acquisition of machinery, equipment, and software, or acquisition of other external knowledge in the year of the survey.
Eq. (3): Innovation output (natural logarithm)	Percent of firm's turnover in year of survey coming from goods or services that were new to market or enterprise in 3 years prior to the survey
Eq. (4): Labor productivity (natural logarithm)	Turnover divided by number of employees in the year of survey
Independent variables	
Firm size (natural logarithm)	Number of employees
Market participation	
National market	Dummy variable: 1 if firm in past 3 years sold goods on the national market
EU Market	Dummy variable: 1 if firm in past 3 years sold goods on EU, EFTA or EU candidate countries markets
All other countries	Dummy variable: 1 if firm in past 3 years sold goods on markets of other countries
Part of a group	Dummy variable: 1 if firm is part of an enterprise group
Abandoned or ongoing innovations	Dummy variable: 1 if firm in past 3 years had any abandoned or ongoing innovations
Organizational innovation	Dummy variable: 1 if firm in past 3 years introduced new or improved knowledge management system, changed management structure, integrated different activities or introduced changes in its relations with other enterprises or public institutions (alliances, partnerships or subcontracting)
Marketing innovation	Dummy variable: 1 if firm in past 3 years introduced significant changes to the packaging of goods or services or changed its sales or distribution methods
Funding	
Local	Dummy variable: 1 if firm in past 3 years received financial support for innovation activities from local/regional authorities
Government	Dummy variable: 1 if firm in past 3 years received financial support for innovation activities from central government
EU	Dummy variable: 1 if firm in past 3 years received financial support for innovation activities from EU authorities
Inverse Mill's ratio	Inverse Mill's ratio from selection equation
Environmental regulation	
The positive influence of environmental regulation	Dummy variable: 1 If the environmental regulation or regulation initiated or facilitated innovation activities.
Negative influence of environmental regulation	Dummy variable: 1 if the environmental regulation prevented, hampered or increased costs of innovation activities.
No effect of the environmental regulation	Dummy variable: 1 if the environmental regulation had no effect/was not relevant for innovation activities.

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