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Empirical Determinants of Innovation in European Countries: Firm-level Analysis Based on CIS 2018

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This study examines the role of perceptions about environmental regulations and their influence on the innovative performance and productivity of firms in Germany, Southern Europe, and Central and Eastern Europe. Utilizing the CDM model for innovative performance and data stemming from the Community Innovation Survey (CIS), we explore the alignment with the Porter hypothesis, which posits that well-designed environmental regulations can stimulate technological innovation and enhance market competitiveness. Our findings present a mixed view: in Germany, positive perceptions about environmental regulations correlate with the initiation of innovation activities, contributing to an increase in labour productivity. This supports the Porter hypothesis, evidencing that regulations can lead to beneficial 'innovation offsets' such as reduced resource use and pollution. Conversely, in Southern Europe and Central and Eastern Europe, the perceptions about these regulations on innovation activities are insignificant, with no considerable correlation observed between perceptions about environmental regulations and innovation output. Our findings are crucial for policymakers, environmental regulators, and business leaders aiming to leverage environmental regulations to boost innovation and competitiveness within their regions.

Introduction

This article continues the research on the relationship between innovation and productivity, as evidenced by studies from Tevdovski *et al.* (2017), Toshevska-Trpchevska *et al.* (2019), and Disoska *et al.* (2020, 2023). In this study, we aim to capture the impact of environmental regulation, along with other determinants, on the innovative behaviour of firms in Southern Europe and Central and Eastern Europe, and compare our results with the behaviour of Germany. In particular, we try to understand the decision-making process of the firms and the resulting outcomes, based on their perceptions regarding the impact of environmental regulation on innovation activities.

The role of the environmental regulation on firm behaviour is described in Porter's 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), provide results in support of 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, Koźluk and Zipperer (2015) noted that the outcomes can differ based on the specific sectors and may even be detrimental in certain contexts.

The innovation capacity of countries and their firms in Central and Eastern Europe (CEE) and South Europe is diverse and limited. This is evident from two indicators of innovation performance: the Summary Innovation Index and the Eco–Innovation Index, both developed by the European Commission. In Figure 1, we present the results as of 2022 for the countries included in the ensuing empirical estimation for both indices and use the existing taxonomy of regions grouped in categories in terms of innovative drivers and output. Regarding the summary index of the overall innovation, the results show that all countries in the sample are equally distributed into two groups: emerging and moderate innovators. Their innovation capacities are below Germany's (except for Estonia) and below the EU average. The overall innovation performance of the researched countries is translated similarly in the eco-innovation index results, with countries belonging to one of the two groups: average or eco-innovation catching-up group.

In this context, we endeavour to compare the ramifications of perceptions about environmental regulations on innovation and productivity across 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 the 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 a firm's perceptions about environmental regulation correlates with the decisions to innovate, the resulting innovation output, and overall productivity. Consequently, our research poses the following questions:

(1) In varied regional groupings, how do perceptions about environmental regulation correlate with 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?

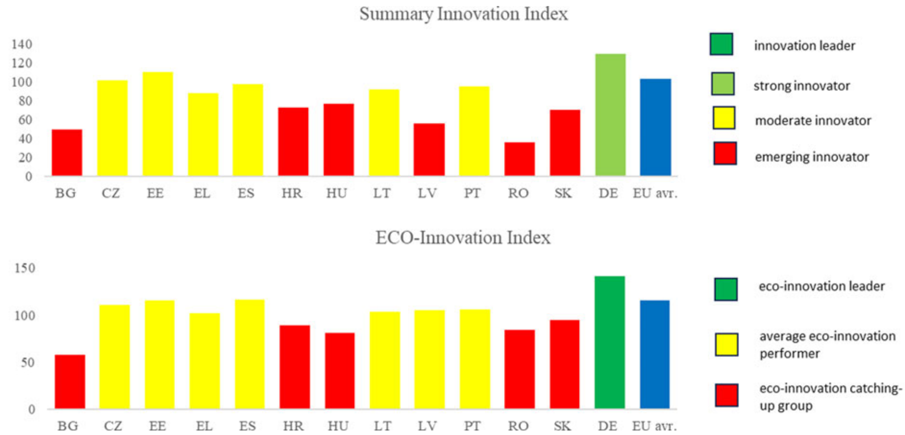

Figure 1. Innovation Performance Indexes for South, Central and Eastern European Countries, and Germany, for the year 2022.
Note: The European Innovation Scoreboard provides a comparative analysis of overall innovation performance in countries in Europe across four main types of activities – Framework 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.

(2) Is the observed innovation deficit in Southern Europe and Central and Eastern Europe linked to lower environmental awareness among the population of firms, especially when contrasted with Germany?
(3) Can we validate the Porter hypothesis in the contexts of Central and Eastern European countries and South Europe?

We find that our results present a mixed view on the impact of perceptions about environmental regulations on firm innovation and productivity across the different European regions. In Germany, positive perceptions about environmental regulations correlate with decisions to initiate innovation activities, supporting the Porter hypothesis that well-designed regulations can lead to ‘innovation offsets’ – innovations that reduce pollution or conserve resources such as materials, water, and energy (Porter and Stern 2002). These positive perceptions appear to contribute to labour productivity, although not directly to innovation output. In contrast, in Southern Europe and Central and Eastern Europe (CEE), the effects of the perceptions about the environmental regulations on innovation activities are insignificant. While Southern Europe shows some significance for facilitating innovation inputs through these regulations, this impact is not observed in CEE.

These findings improve the understanding of how environmental regulations influence innovation activities across European regions. These insights should be

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valuable for policymakers, environmental regulators, and business leaders in Southern Europe and Central and Eastern Europe, equipping them with the knowledge needed to harness environmental regulations effectively to foster innovation and boost firm competitiveness in their markets.

The rest of the article is organized as follows. In the next section we provide a detailed review of related literature. We follow with a detailed description of the adopted model and data. The subsequent section interprets the results derived from the model, and the final section summarizes our findings.

Literature Review

Innovations, along with their economic significance and underlying drivers, are widely discussed in the literature. This section 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.

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 such as 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 and Iatridis (2022) identify 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 and Kasztelan 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 and van der Linde 1995).

Most commonly, eco-innovations result in a gain of competitive advantage (Hofer *et al*. 2012), which is related to the gain of sustainable growth in domestic and international markets (European Commission 2012). As pointed out by Hojnik *et al*. (2017), this leads to improvement in firm performance and results in the achievement of global corporate sustainability goals and objectives in organizations. The 'narrow' Porter Hypothesis is supported in the study by De Santis and Jona Lasinio (2016), indicating that stringent environmental policies did not diminish competitiveness in EU member economies, but had a growth-enhancing effect.

Other studies provide more nuanced perspectives on this topic. Benatti *et al*. (2023) challenges the validity of the Porter hypothesis, based on a sample of Euro Area countries from 2003 –2019. The results show that more stringent environmental regulations adversely affect highly polluting countries and firms, leading to higher costs that persist over five years. Regarding the types of policies, non-market-based tools, such as performance standards, significantly reduce productivity growth for polluting firms, whereas market-based instruments are less harmful. Moreover, technology support policies, such as green research and development subsidies, result in temporary adjustment costs for firms, eventually enhancing their productivity. With regards to the firms' size, very big firms achieve higher productivity three years after a change in environmental policy stringency, which can be explained by their greater access to financial markets and their research experience. Underscoring the importance of sectoral heterogeneity, Baum *et al*. (2017) perform a generalized structural equation model on a panel of Swedish firms and reveals significant variations in key influence channels across sectors with varying technological and knowledge intensity. Based on Chinese data, Wang (2023) finds that environmental regulation notably promotes green innovation, propelling economic growth, but beyond a specific green innovation threshold the marginal positive effect decreases.

Empirical studies on South and CEE countries emphasize the need for their innovation systems to evolve towards increased development and resilience. Stojčić *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 (Stojčić *et al*. 2020).

The drivers and impact of eco-innovations present a more complex picture. Factors such as 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 and Gerstlberger 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 and Stojčić 2013; Hojnik *et al.* 2017).

Model and Data

Model

To explore the role of innovation and environmental regulation on firm performance, we use a modified version of the CDM model (the model's name is an acronym of its inventors' surnames: Crépon, Duguet and Mairesse 1998). The analytical framework of the CDM model consists of two general stages, and each of them can be divided into two sub-stages.

In the first stage, we model a firm's innovation input. We do this by first estimating the probability of a firm to be involved in innovation activity, and then estimating the innovation input of the firm. For this stage, we use the Heckman correction model to treat the omitted variable problem since we know the innovation input only for the firms that decided to be involved in innovation activities. The equations for the first stages are the following:

$$\text{Prob}(d_i = 1|x_i^0) = \Phi\left(\alpha_0 p_i + \beta_0 x_{0i} + z_{0c}\right) + u_{0i} \tag{1}$$

$$w_i^* = \alpha_1 p_i + \beta_1 x_{1i} + z_{1c} + \gamma d_i + u_{1i} \tag{2}$$

Equation (1) represents a probit regression, denoted by Φ (the cumulative standard normal distribution), which models the unobserved decision of a firm i to innovate (d_{it}). The decision is dependent on the perceptions about environmental legislation and regulations (p_i) and a vector of covariates (x_{0i}). In this model, as covariates, we use the firm size, the legal origin of the firm (national/international), and the firm's innovation activities (whether there were ongoing or abandoned innovations and whether there were any marketing or organizational innovations). In addition, the equation also includes a country-specific variable (z_0) that may affect the final decision of the firm regarding innovation.

Equation (2) is used to estimate the unobserved innovation input (w_i^*), which is measured as the logarithm of the amount (in euros) 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 the perceptions about environmental regulations (p_i) and vector of control variables (x_{1i}) as independent variables. As control variables, we include the same covariates as in the previous sub-step, together with three variables about the funding sources of the firm (local, government, or EU funding). Additionally, this step includes the variable d_i 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 country-specific effect (z_1).

In the second stage, we perform a three-stage least squares (3SLS) methodology to simultaneously estimate the innovation output and the productivity of the firm:

$$r_i = \alpha_3 p_i + \beta_{w^*} w_i^* + \beta_q q_t + \beta_2 x_{2i} + z_{2c} + u_{2i} \tag{3}$$

$$q_i = \alpha_4 p_i + \beta_r r_i + \beta_3 x_{3i} + z_{3c} + u_{3i} \tag{4}$$

Equation (3) introduces the innovation output (r_i), 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 the perceptions about the environmental regulations (p_i), additional control variables ($x_{2i},$ the same as in equation (2)), a country-specific effect (z_{2c}) and an error term (u_{2i}). In conjunction with this equation, we estimate equation (4), which captures the firm's productivity (q_i). Productivity is quantified as the logarithm of the firm's turnover divided by the number of employees in the survey year. It is modelled as a linear function of the environmental regulations (p_i), the innovation output (r_i) and a vector of exogenous explanatory variables (x_{3i}, the same as the ones used in equation (2)) with the corresponding parameter vector (β_3). Like the previous equations, z_{3c} represents a country-specific effect, and u_{3i} denotes the error term.

In addition, in all four equations, as explanatory variables we also include 'sector' among the regressors, with dummies relating to groupings according to Eurostat classification: high-technology manufacturing (HT), medium–high technology manufacturing (HMT), medium–low technology manufacturing (LMT), low technology manufacturing (LT), knowledge-intensive services (KIS) and other services (OS).

Data

For our analysis, we employ data from the Community Innovation Survey (CIS) conducted by the European Commission in the period 2016 –2018 (referred to as CIS 2018). The CIS database aggregates data concerning innovation activities across 13 European countries. We chose this period, as it was the latest available survey with available data.

We divide the countries into three groups: (1) Central and Eastern Europe (Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Lithuania, Latvia, Romania, and Slovakia); (2) South Europe (Greece, Portugal, and Spain); and (3) Germany, to understand the geographical differences in the impact of environmental perceptions on innovation and firm performance.

Table 1 provides summary statistics per country group for each variable, whereas Table A1 in the Appendix describes the formal definition of our variables and the abbreviations used throughout the manuscript. These statistics suggest that

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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
Dec_innov	6271	48271	43271	0.435	0.114	0.228	0.496	0.318	0.419
Einnov_input	1970	4988	9127	13.261	11.203	12.214	2.867	2.174	1.668
Inn_output	2104	10783	10940	–1.912	–1.662	–1.67	1.138	1.210	1.317
Lprod	6271	48145	43181	11.832	10.682	11.254	1.415	1.358	1.250
Lfsize	6271	48271	43271	4.432	3.901	3.999	1.333	1.046	1.081
GP_nat	6271	48271	43271	0.344	0.127	0.212	0.475	0.333	0.409
GP_int	6271	48271	43271	0.08	0.159	0.101	0.272	0.365	0.301
Inaba	6271	41047	43271	0.536	0.165	0.224	0.499	0.371	0.417
Org_innov	6271	48271	43271	0.351	0.15	0.183	0.477	0.357	0.387
Mark_innov	6271	48271	43271	0.201	0.117	0.135	0.4	0.322	0.342
Funloc	6271	48271	43271	0.106	0.024	0.109	0.308	0.154	0.312
Fungmt	6271	48271	43271	0.037	0.044	0.100	0.188	0.206	0.300
Funeu	2137	42494	43271	0.158	0.088	0.072	0.365	0.283	0.259
leg_env_if	6271	48271	43271	0.081	0.047	0.033	0.273	0.212	0.179
leg_env_phic	6271	48271	43271	0.112	0.057	0.027	0.316	0.232	0.162
leg_env_nimpc	6271	48271	43271	0.515	0.709	0.223	0.5	0.454	0.416

Germany had the highest share of firms that decided to innovate (Dec_innov), followed by firms from South Europe, whereas Central and Eastern European firms had the lowest share of firms that decided to innovate. Similarly, productivity was the highest in Germany, followed by South Europe (Lprod). In addition, German firms most often thought that environmental regulation had a positive influence on their performance (leg_env_if), and most often thought that environmental regulations hampered their innovation activities (leg_env_phic). By contrast, Southern European firms most often thought that environmental regulation had no impact on their activities (leg_env_nimpc). This indicates a varying geographical impact of environmental regulation on innovation and firm performance.

Results

In what follows, we present our results for each sub-stage of the CDM model separately. We thereby emphasize that, because we study the differences between groups of countries in their innovation systems, we estimate the CDM model separately for each country group.

Decision to Innovate

Table 2 shows the results of the first sub-stage of the CDM model, providing insights into the factors correlating with the decision of companies to engage in the innovation process.

We find that the impact of perceptions about environmental regulation on innovation varies among the country groups. In Germany, there was a clear positive and significant relationship of perceptions about environmental legislation and regulation on the decision to innovate. Firms that had positive opinion had the largest chance to decide to innovate, followed by firms that had an opinion that environmental regulations had negative influence. By contrast, in South Europe and in Central and Eastern Europe, we find no significant relationship between perceptions about environmental regulations and the decision to innovate.

Regarding the control variables, we find that larger firms showed a greater inclination towards innovation in each country group. It could be the case that these companies have higher R&D funds or could have already developed infrastructure for innovation activities, which is similar to Benatti *et al.*'s (2023) findings. The results also indicate that firms which were part of a group with the head office located in the national market and the companies which were part of an enterprise group with the head office located abroad had larger probability to decide to innovate in all three analysed groups of countries.

Moreover, a history of previously abandoned innovation activities is significantly correlated with 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

Table 2. Decision to innovate results

Variables	Germany	South Europe	CE Europe
leg_env_if	0.658***	–0.067	0.495
	(–0.085)	(–0.187)	(–0.316)
leg_env_phic	0.262***	–0.207	0.158
	(–0.071)	(–0.185)	(–0.315)
leg_env_nimpc	0.093*	–0.298	0.044
	(–0.049)	(–0.191)	(–0.317)
Lfsize	0.171***	0.077***	0.117***
	(–0.018)	(–0.008)	(–0.01)
GP_nat	0.299***	0.300***	0.201***
	(–0.047)	(–0.021)	(–0.027)
GP_int	0.283***	0.185***	–0.140***
	(–0.081)	(–0.029)	(–0.029)
Inaba	1.384***	1.666***	1.122***
	(–0.043)	(–0.019)	(–0.023)
Org_innov	0.031	0.339***	0.344***
	(–0.049)	(–0.025)	(–0.027)
Mark_innov	0.115**	0.421***	0.419***
	(–0.056)	(–0.027)	(–0.027)
Constant	–1.124***	–1.865***	–1.688***
	(–0.118)	(–0.201)	(–0.325)
Observations	6,271	43,271	41,047

Note: Robust standard errors in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. All regressions include sector dummies. Also, the equations for South Europe and CE Europe include country dummies.

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.

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).

Here, we also find that the impact of the perception of the influence of environmental legislation and regulation varies among the three groups. Nevertheless, the results are contrasting. Namely, they suggest that in Germany and in Central and Eastern Europe environmental legislation and regulation was not a statistically significant variable explaining the innovation process. For the companies in South Europe the influence of environmental regulation on innovation activities was perceived as significant in all three cases. The results obtained for South Europe are similar to those obtained in the studies of Horbach (2008) and Kijek and Kasztelan (2013). Firms that had positive opinion about the influence of environmental legislation and regulations, also had the largest innovation input.

Table 3. Innovation input results

Variables	Germany	South Europe	CE Europe
leg_env_if	0.743	0.788***	0.102
	(–0.533)	(–0.281)	(–0.39)
leg_env_phic	0.593	0.635**	0.058
	(–0.509)	(–0.275)	(–0.382)
leg_env_nimpc	0.439	0.636**	–0.072
	(–0.493)	(–0.295)	(–0.394)
Lfsize	0.811***	0.498***	0.603***
	(–0.068)	(–0.015)	(–0.035)
GP_nat	0.535***	0.482***	0.351***
	(–0.171)	(–0.034)	(–0.079)
GP_int	0.752***	0.853***	0.667***
	(–0.262)	(–0.047)	(–0.094)
Inaba	1.261***	0.478***	0.367***
	(–0.295)	(–0.075)	(–0.14)
Org_innov	0.03	0.060*	–0.027
	(–0.151)	(–0.034)	(–0.085)
Mark_innov	0.131	0.184***	0.038
	(–0.152)	(–0.033)	(–0.081)
Funloc	0.117	0.155***	–0.091
	(–0.163)	(–0.031)	(–0.154)
Fungmt	0.106	0.498***	0.500***
	(–0.311)	(–0.029)	(–0.079)
Funeu	0.968***	0.518***	0.552***
	(–0.165)	(–0.038)	(–0.067)
Constant	7.173***	7.158***	8.524***
	(–0.824)	(–0.344)	(–0.529)
Observations	4,207	42,536	38,749

Note: Robust standard errors in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. All regressions include sector dummies. Also, the equations for South Europe and CE Europe include country dummies.

In addition, for the control variables, we find that company size, affiliation with an enterprise group (both domestically headquartered and internationally headquartered), and a history of abandoned innovation activities are positively correlated with the innovation input across all studied company samples. Also, while organizational and marketing innovations were positively and significantly related with the innovation input for South European firms, they did not correlate with the innovation input for companies in Germany and Central and Eastern Europe.

In this phase, we also include funding sources as control variables. The results show that for the companies in Germany, only EU funding had a positive relationship with the innovation input. For the companies operating in South Europe all three types of funding: local or regional, national, and EU-level funding were significant and had a positive and impact on the innovation process. For the companies in Central and Eastern Europe, funding from the national government and from EU institutions had a positive and significant relationship with the

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Table 4. Innovation output results

Variables	Germany	South	CEEC
leg_env_if	–0.263	–0.355	0.227
	(–0.179)	(–0.274)	(–0.249)
leg_env_phic	–0.042	–0.454*	0.13
	(–0.179)	(–0.267)	(–0.247)
leg_env_nimpc	–0.068	–0.445	0.167
	(–0.162)	(–0.276)	(–0.25)
lProductivity	–0.119	–0.704***	–0.284**
	(–0.295)	(–0.162)	(–0.129)
Lfsize	–0.229	–0.460***	–0.252**
	(–0.154)	(–0.093)	(–0.106)
Mills	–0.603	0.730**	–0.392
	(–1.193)	(–0.295)	(–0.302)
Innov_input	0.022	0.779***	0.154
	(–0.253)	(–0.207)	(–0.195)
Org_innov	0.198**	0.139***	0.219***
	(–0.08)	(–0.032)	(–0.043)
Mark_innov	0.1	0.032	0.026
	(–0.083)	(–0.033)	(–0.036)
Funloc	–0.069	–0.256***	–0.228***
	(–0.081)	(–0.06)	(–0.062)
Fungmt	0.111	–0.264***	–0.033
	(–0.12)	(–0.099)	(–0.098)
Funeu	0.119	–0.410***	0.001
	(–0.239)	(–0.12)	(–0.094)
Constant	0.564	–0.405	0.804
	(–2.058)	(–0.512)	(–0.745)
Observations	851	10,922	8,112
R-squared	0.14	–0.175	0.087

Note: Robust standard errors in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. All regressions include sector dummies. Also, the equations for South Europe and CE Europe include country dummies.

innovation input. This is in line with the finding by Rennings (2000) that environmental policies and institutional factors are crucial for realizing eco-friendly innovations.

Innovation Output

Next, we use the three-stage least squares to estimate the impact of perceptions about environmental regulations on innovation output and labour productivity (third and fourth sub-stage). In these sub-stages of the CDM model, we consider only those companies that have reported innovation activity.

Table 4 presents results for the correlates of innovation output. Here, innovation output represents the natural logarithm of the shares of sales from new products and services in the total turnover of the companies operating in Germany, South Europe, and Central and Eastern Europe.

The results suggest that the environmental legislation and regulation perception play no role in the firms' innovation output, irrelevant of the country group.

When looking at the control variables, we find that productivity and firm size were not significantly related with the innovation output in Germany. By contrast, they were significant, but with negative coefficient sign in South and Central and Eastern Europe, suggesting that productivity and size decreased innovation output. These results can be understood as they are in line with Prokop and Gerstlberger's (2022) findings that environmental regulations in CEE might spur firms to undertake eco-innovations, but not necessarily lead to the creation of new ones.

Interestingly, innovation input is only statistically significant for the South Europe group. In addition, marketing innovations appear not to be correlated with innovation output in any of the country groups, whereas organizational innovations are significant for all country groups.

Moreover, funding from local, regional authorities, and from EU institutions had impact only on the innovation output for South Europe and Central and Eastern Europe. In the case of South Europe, all types of funding decrease innovation output, whereas in Central and Eastern European countries only local funding appears to be related with innovation output.

Labour productivity

The final sub-stage of the CDM model examines the relation of companies' activities with labour productivity, measured as the natural logarithm of the ratio between the firm's 2018 total turnover and total employment.

Our results are shown in Table 5. Unfortunately, perceptions about the impact of environmental legislation and regulation on productivity seem to be less significant than anticipated, exhibiting minimal effects overall. In Germany, perceptions that environmental regulations have positive impact over labour productivity are statistically significant. This is in line with the findings by Hofer *et al.* (2012) and Hojnik *et al.* (2017) that environmental innovations improve companies' competitiveness and their performances. On the contrary, perceptions that environmental regulations have no impact or negative impact are not statistically significant. In Southern Europe and Central and Eastern Europe, none of the variables capturing perceptions about environmental legislation and regulation show a significant relationship with labour productivity.

Moreover, it appears that a firm's size has a positive and significant effect on productivity in all three groups of countries. Larger companies have consistently demonstrated higher productivity through their innovations in each of these samples, as in the findings of Benatti *et al.* (2023). In addition, the innovation output is positively related with labour productivity in each country group. The same holds for the variables describing whether the firm is part of an enterprise group with headquarters in its home country or has headquarters abroad. Out of the innovation

Table 5. Labour productivity

Variables	Germany	South	CEEC
leg_env_if	0.588**	–0.334	–0.575
	(–0.236)	(–0.251)	(–0.419)
leg_env_phic	0.091	–0.368	–0.351
	(–0.206)	(–0.239)	(–0.398)
leg_env_nimpc	0.082	–0.37	–0.524
	(–0.186)	(–0.248)	(–0.406)
Lfsize	0.351***	0.153***	0.278***
	(–0.109)	(–0.032)	(–0.075)
Org_innov	–0.171	–0.112**	–0.147
	(–0.159)	(–0.054)	(–0.108)
Mark_innov	–0.052	0.006	0.03
	(–0.131)	(–0.042)	(–0.052)
innov_output	0.861*	0.813***	1.230***
	(–0.522)	(–0.255)	(–0.439)
GP_int	0.804***	0.964***	1.331***
	(–0.196)	(–0.05)	(–0.107)
GP_nat	0.359***	0.818***	0.644***
	(–0.125)	(–0.052)	(–0.074)
Constant	11.308***	11.511***	11.473***
	(–0.584)	(–0.484)	(–0.634)
Observations	851	10,922	8,112
R–squared	–0.731	–0.644	–1.064

Note: Robust standard errors in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. All regressions include sector dummies. Also, the equations for South Europe and CE Europe include country dummies.

types, only organizational innovations appear to be significantly related with labour productivity in South Europe, but they have a negative coefficient.

Conclusion

In this article, we explored how perceptions of environmental legislation and regulations impact the innovative performance of firms in Southern Europe, Central and Eastern Europe (CEE), and compared these results with those from Germany. Central to our analysis was the Porter hypothesis, which suggests that well-designed environmental regulations can stimulate technological innovation and enhance market competitiveness of firms.

Our findings, however, present a mixed view. In Germany, environmental regulations are perceived positively and correlate with decisions to initiate innovation activities. This supports the Porter hypothesis, indicating that such regulations may lead to innovations that reduce pollution or conserve resources such as materials, water, and energy, a phenomenon referred to as the 'innovation offset' (Furman *et al*. 2002). These perceptions about environmental regulations appear to contribute positively to labour productivity, but not to the innovation output.

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In contrast, in Southern Europe and Central and Eastern Europe, the effects of environmental regulations on innovation activities are perceived as insignificant. While environmental regulation in Southern Europe shows some significance for facilitating innovation inputs, this impact is not observed in Central and Eastern Europe.

The disparity in findings across these regions highlights the complex relationship between environmental regulations and firm-level innovation performance. It appears that while Germany has managed to harness environmental regulations as a catalyst for enhancing innovation and productivity, Southern Europe and CEE have not achieved similar benefits. Indeed, studies on innovation systems in Central and Eastern Europe (CEE) commonly highlight issues such as limited institutional commitment, low levels of R&D and environmental awareness, and minimal eco-innovation (Krasniqi and Kutllovci 2008; Krammer 2009; Nazarov and Akhmedjonov 2012; Hashi and Stojčić 2013; Abazi-Alili *et al*. 2014; Pilav-Velić and Marjanovic 2016; Hojnik *et al*. 2017; Ramadani *et al*. 2017). Our results corroborate these findings by suggesting that innovations driven by environmental regulations also have not resulted in productivity gains.

Our results could be driven by differences in regulatory stringency across EU countries. Higher regulatory costs could potentially displace investments in innovation and hinder productivity growth. Firms may lose market share owing to increased final product prices from new investments, leading them to adopt existing solutions rather than investing in R&D and human capital for innovative outputs.

To enhance the perception of environmental regulations as drivers of innovation in Southern Europe and Central and Eastern Europe, it is crucial to integrate regulatory frameworks within broader innovation systems. This integration should focus on removing barriers to knowledge diffusion by fostering competitive business environments, improving public infrastructure, and reducing bureaucratic burdens. Promoting the adoption of advanced management practices and organizational structures will also be essential (Benatti *et al*. 2024; Jungmittag 2004). Enhancing the functionality of the Internal Market could facilitate greater capital mobility, human resource mobility, and the spread of innovative technologies. Governments should actively publicize success stories and facilitate the transfer of best practices in environmental regulation and eco-innovations from Western to Southern and Eastern European countries. Such initiatives could significantly enhance the innovation capabilities of these regions and transform regulatory compliance into opportunities for technological advancement and economic growth (Horbach 2015). These efforts should be accompanied by targeted incentives, such as tax breaks and grants, and the adaptation of regulations to allow for incremental achievements, thereby fostering a more supportive environment for environmental innovation.

Despite the insightful findings and contributions of this study to understanding the role of environmental regulations in driving innovation, it is important to acknowledge that our research is not without limitations.

One of the limitations is the temporal scope of our data, which is restricted to the year 2018. This period selection was dictated by the dual challenges of data availability and reliability for more recent years, a common obstacle in longitudinal economic research. Consequently, our findings may not accurately reflect the current economic dynamics or the impact of environmental regulations on innovation in the post-pandemic era, as the global health crisis might have significantly altered economic conditions and regulatory priorities. Additionally, our analysis is based on perceptions of environmental regulations rather than direct measures of how these regulations have impacted firm performance. This approach may introduce subjective biases and it does not capture the actual efficacy or the direct outcomes of regulatory interventions on firm-level innovation and productivity. These limitations suggest that future research should include more recent data and perhaps adopt a mixed-methods approach to better understand the complex dynamics between environmental regulation and firm performance, and to validate the findings presented in this study.

However, despite these limitations, our findings improve our knowledge about the role of environmental regulations and legislation on innovation activities in Europe. They will benefit policymakers, environmental regulators, and business leaders in Southern Europe and Central and Eastern Europe by providing them with a better understanding of how to leverage environmental regulations to stimulate innovation and enhance firm competitiveness in their respective markets.

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Appendix

Table A1. Definition of variables

Dependent variables	Abbreviation	Definition
Equation (1): Decision to innovate	Dec_Innov	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
Equation (2): Innovation input (natural logarithm)	Einnov_input	Amount (in euros) 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.
Equation (3): Innovation output (natural logarithm)	Inn_output	Percentage 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
Equation (4): labour productivity (natural logarithm)	Lprod	Turnover divided by number of employees in the year of survey
Independent variables		
Firm size (natural logarithm)	lfsize	Number of employees
Part of the group		
Part of an enterprise group with the head office located in the national market	GP_nat	Dummy variable: 1 if the firm is Part of an enterprise group with the head office located in the national market.
Part of an enterprise group with the head office located abroad	GP_int	Dummy variable: 1 if the firm is Part of an enterprise group with the head office located abroad
Innovations		
Abandoned or ongoing innovations	Inaba	Dummy variable: 1 if firm in past 3 years had any abandoned or ongoing innovations
Organizational innovation	Org_innov	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

(*Continued*)

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Table A1. (*Continued*)

Dependent variables	Abbreviation	Definition
		institutions (alliances, partnerships or subcontracting)
Marketing innovation	Mark_innov	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	Funloc	Dummy variable: 1 if firm in past 3 years received financial support for innovation activities from local/ regional authorities
Government	Fungmt	Dummy variable: 1 if firm in past 3 years received financial support for innovation activities from central government
EU	Funeu	Dummy variable: 1 if firm in past 3 years received financial support for innovation activities from EU authorities
Inverse Mill's ratio	Mills	Inverse Mill's ratio from selection equation
Environmental regulation		
The positive influence of environmental regulation	Leg_env_if	Dummy variable: 1 If the environmental regulation or regulation initiated or facilitated innovation activities.
Negative influence of environmental regulation	Leg_eng_phic	Dummy variable: 1 if the environmental regulation prevented, hampered, or increased costs of innovation activities.
No effect of the environmental regulation	Leg_env_nimpc	Dummy variable: 1 if the environmental regulation had no effect/was not relevant for innovation activities.

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