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Research Article

Strategic Foresight for Sustainable Development in the European Union: The Role of Entrepreneurship

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Abstract. Sustainable development has become a strategic priority for the European Union (EU), requiring coordinated institutional, economic and entrepreneurial transformations. While a growing body of literature recognises entrepreneurship as an important mechanism for advancing sustainability objectives, empirical evidence on how structural features of the business environment influence sustainability trajectories at the macroeconomic level remains fragmented. In particular, the dynamic relationships among sustainable development, business regulation and market openness across EU countries remain insufficiently understood. The objective of this study is to analyse how business regulation and market openness influence entrepreneurship-driven progress towards sustainable development in the European Union and to examine the dynamic interactions among these institutional and economic dimensions. The empirical analysis employs an annual panel dataset covering 27 EU member states for the period 2010–2024. The study applies a panel vector autoregression (PVAR) framework combined with Granger causality testing and impulse response analysis to capture short-run and long-run relationships among sustainable development, regulatory quality and market openness. The results reveal strong persistence and path dependence in sustainable development trajectories. Business regulation does not exert statistically significant short-term effects on sustainability outcomes. Conversely, sustainable development Granger-causes changes in regulatory quality, indicating feedback processes in which sustainability progress stimulates institutional adaptation. Market openness demonstrates the strongest long-term positive effect on sustainability, although short-term impacts appear negative, reflecting transitional adjustment costs. These findings suggest that sustainable development, regulatory quality and market openness form a dynamically interconnected system characterised by temporal asymmetries and feedback effects. The results highlight the importance of gradual, learning-based regulatory reforms and deeper integration into global innovation and investment networks to support sustainable entrepreneurial ecosystems in the European Union. The study also acknowledges limitations related to the selected indicators and modelling framework, which provide avenues for further research.

Keywords: sustainable development, entrepreneurship, business regulation, market openness, digital transformation, institutional quality, strategic foresight.

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1. Introduction

Sustainable development has become a core strategic priority for contemporary economic, social and environmental policymaking, particularly within the European Union (EU). The green transition, digital transformation and socioeconomic resilience are increasingly recognised as interdependent policy domains in which long-term prosperity depends on structural change, institutional quality, technological advancement and innovation capacity. Within this evolving context, entrepreneurship has emerged as a central mechanism for advancing sustainability objectives, mobilising resources, creating new business models and diffusing environmentally efficient and digitally enabled solutions [1–4].

Recent studies have shown that firms incorporating circular principles, low-carbon strategies and resource-efficient operations can contribute meaningfully to the achievement of the Sustainable Development Goals (SDGs) through innovations such as Industry 5.0 applications, digitally supported cleaner production systems and circular supply chains [5–6]. The entrepreneurial reconfiguration of value creation and delivery, particularly in agribusiness, digital public services, artificial intelligence and data-driven technologies [7–8], as well as in biobased industries, demonstrates how enterprise-level decisions can support broader sustainable development outcomes [9–11]. Furthermore, evidence from SME research highlights that sustainability-oriented practices embedded in business strategy, organisational learning and digital innovation processes can improve competitiveness, innovation performance and market positioning [12–15].

Moreover, the literature reveals that entrepreneurship is not an unconditional driver of sustainable development. Corporate social responsibility (CSR), ESG initiatives and sustainability communications may be selectively implemented, strategically framed or decoupled from core business activities, resulting in symbolic rather than substantive progress towards the SDGs [16–17]. Regulation, administrative reforms and changes in the business environment can support sustainability-oriented entrepreneurship in some contexts but may generate compliance burdens, distort incentives or fail to address structural inequalities in others [18-19]. Moreover, macroeconomic conditions, including market openness, energy price volatility, digital market integration and external shocks, shape the capacity of firms to innovate and scale sustainability-focused business models, often amplifying existing regional disparities [20–24].

Despite extensive sectoral and case-based analyses, several issues remain insufficiently addressed. First, most existing studies focus on individual industries, regions or firm-level practices rather than providing an integrated system-level perspective on the structural determinants of sustainable development. Second, the institutional dimensions of the entrepreneurial environment, particularly business regulation and market openness, are rarely analysed jointly as determinants of sustainability-oriented entrepreneurial performance. Third, empirical evidence for EU countries remains fragmented and is often limited to national case studies, lacking cross-country comparisons and longitudinal analyses that would allow the identification of dynamic institutional and economic interactions. Consequently, a policy-relevant understanding of the institutional and market conditions that foster or constrain sustainable entrepreneurship within the EU remains limited.

To address these gaps, this paper adopts a strategic foresight perspective and treats business regulation and market openness as key structural determinants of sustainable entrepreneurial ecosystems in the European Union. The study empirically evaluates how these dimensions shape entrepreneurship-driven sustainability outcomes using a cross-country panel dataset of EU member states covering the period 2010–2024. The aim of this study is to assess how business regulation and market openness influence entrepreneurship-driven progress towards sustainable development in the European Union. This paper contributes to the sustainable development literature by introducing a system-level perspective on entrepreneurship and by examining business regulation and market openness as structural determinants of sustainability within the EU institutional environment. Methodologically, the study applies a panel vector autoregression (PVAR) framework to capture dynamic and bidirectional effects among sustainable development, regulatory quality and market openness that cannot be identified in static empirical models. Empirically, using a panel dataset of 27 EU member states for 2010–2024, the study provides comparative evidence of reverse causality from sustainability performance to institutional change and identifies strong long-term effects of market openness on sustainability outcomes. The findings contribute to strategic foresight research by demonstrating that sustainable development operates both as an outcome of institutional conditions and as a driver of regulatory and market adaptation within the evolving digital and sustainability transition of the European economy.

The remainder of the paper is structured as follows. The literature review explores the theoretical background of entrepreneurship in achieving the Sustainable Development Goals. The materials and methods section describes the data sources and research methods used to test the theoretical assumptions of the study. The results section presents the empirical findings. The discussion compares the obtained results with previous research. Finally, the conclusion summarises the main findings, outlines policy implications for developing entrepreneurship in support of the SDGs, and discusses the limitations of the study together with directions for future research.

2. Literature Review

The strategic foresight of sustainable development in the European Union increasingly depends on how entrepreneurial ecosystems respond to long-term structural pressures such as digitalisation, decarbonisation and intensifying global competition. A growing body of literature conceptualises entrepreneurship not only as a micro-level behavioural phenomenon but also as a meso- and macro-level mechanism through which economies reallocate resources, diffuse innovation and internalise sustainability objectives [25–29]. From this perspective, the quality of the business environment, particularly the extent of business regulation and market openness, determines whether entrepreneurial activity amplifies or constrains progress towards the Sustainable Development Goals (SDGs) [30].

Entrepreneurship is widely recognised as a structural driver of sustainable development because it translates new technologies, innovative business models and social innovations into marketable solutions. Empirical studies demonstrate that opportunity-driven entrepreneurship can accelerate the deployment of renewable energy, eco-innovation and circular business models, thereby contributing directly to SDG-aligned development trajectories [26, 31–33].

Entrepreneurship also operates through social and institutional channels: social and corporate entrepreneurship can mobilise communities, redesign value chains and embed sustainability principles within organisational routines [34–35]. At the macroeconomic level, the composition of entrepreneurial activity—such as necessity versus opportunity entrepreneurship and green, digital or conventional forms of enterprise—shapes the trajectory of long-term economic development [29, 36].

The business environment defines the "rules of the game" within which entrepreneurs operate and is therefore central to understanding the entrepreneurship–sustainability nexus. Business regulation influences market entry and exit conditions, administrative costs and the capacity of firms to reorient their activities in response to technological and environmental change. Excessively restrictive or unstable regulation can suppress innovation, protect incumbent interests and delay structural transformation, whereas transparent, predictable and proportionate regulation creates opportunities for experimentation and risk-taking in sustainability-oriented sectors [37–38]. Studies on small business and SME development emphasise that regulatory burdens, access to licences and the enforcement of contractual rights directly affect the ability of firms to formalise, grow and invest in long-term capabilities [39–40]. From a foresight perspective, changes in regulatory architecture—such as the alignment of environmental, financial and innovation policies with the SDGs—can be interpreted as structural signals of future entrepreneurial capacity for the green transition [41–45].

Market openness, in turn, shapes both the opportunity space and the competitive pressures faced by entrepreneurs. Openness to trade, foreign investment and cross-border knowledge flows expands market size, facilitates technology diffusion and strengthens incentives for efficiency and innovation [46 – 48]. At the same time, exposure to international competition may crowd out less productive firms and regions where adjustment mechanisms are weak. Recent research on digital business transformation indicates that open and competitive markets, combined with robust digital infrastructure and innovation ecosystems, enable firms to adopt advanced technologies that improve energy efficiency, resource productivity and low-carbon business models [49–50]. For the European Union, where the single market and deep integration into global value chains are defining features, market openness therefore represents a critical dimension of entrepreneurial readiness for sustainable development.

A third stream of research highlights the mediating role of digitalisation, finance and innovation ecosystems in the relationship between entrepreneurship and sustainability. Digitalisation reduces transaction costs, improves information flows and enables new platform-based and data-driven business models to emerge, many of which directly or indirectly support SDG implementation [51–52]. Access to green and inclusive finance alleviates capital constraints and enables SMEs and start-ups to invest in cleaner technologies, eco-innovative products and resilience-enhancing capabilities [36, 53]. The innovation systems literature further emphasises that the interaction between firms, universities, governments and financial institutions determines the rate at which sustainability-oriented innovations are generated, diffused and scaled across economies [38, 54]. Within this broader ecosystem perspective, entrepreneurship is embedded in institutional networks rather than representing an isolated individual decision.

The education system is increasingly recognised as a foundational component of entrepreneurship for sustainable development, with universities integrating the SDGs into

curricula and institutional structures to reshape managerial competences and innovation capabilities [55–57]. Empirical evidence shows that reflective tools, systems thinking and project-based learning foster critical reflection, ethical reasoning and collaborative problem solving [58–61], while competence frameworks and sustainability assessments emphasise long-term strategic thinking [62–63]. In addition to education, digitalisation continues to reshape entrepreneurial environments by transforming access to information, stakeholder engagement and business model design [64–66]. Digital technologies enable smart and resource-efficient systems [9, 67], expand financial inclusion and transparency through fintech and blockchain solutions [68–72], and create new capability pathways through digital communities and youth innovation ecosystems [73–76]. However, these outcomes depend strongly on the quality of the digital business environment and the effectiveness of governance frameworks [50, 66].

Governance quality and institutional performance are also repeatedly identified as key determinants of whether entrepreneurial activity contributes to sustainable development. Studies show that entrepreneurship generates stronger developmental benefits when supported by effective public institutions, low levels of corruption and coherent policy frameworks [41, 77]. Effective governance reduces distortions in the business environment, strengthens policy credibility and facilitates public–private coordination around long-term sustainability objectives. Conversely, weak institutions and fragmented regulatory frameworks can lead to rent-seeking behaviour, short-termism and environmentally harmful business practices, even in contexts characterised by high entrepreneurial dynamism. This institutional perspective is particularly relevant for the European Union, where multilevel governance structures and differentiated national reforms generate heterogeneous business environments and entrepreneurial outcomes.

The literature on entrepreneurial ecosystems and sustainable development further suggests that the volume of entrepreneurial activity alone is not decisive; rather, its alignment with structural conditions and long-term development pathways is crucial [28, 40]. Measures of business regulation and market openness can therefore be interpreted as core dimensions of an economy's entrepreneurial sustainability readiness. These indicators summarise how conducive the institutional and competitive environment is to the emergence, growth and internationalisation of firms that support ecological transition, social inclusion and long-term economic resilience. Building on this theoretical background, the present study treats business regulation and market openness as strategic drivers within a foresight framework, examining how different configurations of these factors may shape the future trajectories of sustainable development in the European Union.

Despite the breadth of existing research, several substantive gaps remain unresolved. First, the literature does not provide a clear understanding of the dynamic and bidirectional relationships between sustainable development performance and its institutional and competitive determinants, as most empirical analyses remain static, linear or country-specific. Second, empirical evidence for the European Union as an integrated system—where cross-country spillovers, policy synchronisation and shared structural shocks are particularly strong—remains limited. As a result, existing studies do not fully capture how improvements in sustainable development propagate across economies through regulatory and market channels. This paper addresses these gaps by examining how sustainable development, business regulation and

market openness co-evolve over time, identifying whether they reinforce or constrain each other under conditions of shared structural shocks and interconnected policy environments.

3. Data and Methods

3.1. Data and Variables

The empirical analysis employs an annual panel dataset comprising 27 European Union (EU) member states over the period 2010–2024. This timeframe captures a continuous sequence of political, economic and regulatory developments within the EU, ensuring the consistency and comparability of cross-country observations. The period begins after the immediate post-crisis adjustments of the late 2000s, extends through the implementation of major EU integration and coordination initiatives during the 2010s, and includes the structural transformations associated with the European Green Deal and the post-pandemic recovery agenda after 2020. The inclusion of all 27 EU member states allows the analysis to be conducted within a common institutional and regulatory framework defined by EU-level governance mechanisms. This ensures that differences across countries reflect national trajectories rather than incompatibilities in overarching policy regimes. The EU therefore provides one of the most coherent multi-country environments for longitudinal comparative analysis, as member states operate under harmonised legal, economic and coordination frameworks, including shared legislation, long-term strategies and monitoring systems.

The dataset includes three key variables: sustainable development (SDGI), business regulation (BR) and market openness (MO). Sustainable development is proxied by the Sustainable Development Goal Index (SDGI), which captures overall progress towards the Sustainable Development Goals across economic, social and environmental dimensions. Business regulation (BR) represents regulatory quality and institutional constraints within the entrepreneurial environment. Market openness (MO) reflects the degree of international economic integration.

The selection of these indicators is grounded in both theoretical reasoning and empirical evidence. The SDGI is employed because it provides a multidimensional measure of sustainable development by integrating economic, environmental and social performance metrics into a single composite indicator. In contrast to single-domain environmental or economic indicators, the SDGI reflects structural long-term transitions relevant for assessing macro-level progress towards the SDGs [28, 41].

Business regulation is incorporated in order to operationalise institutional quality, which has been widely identified as a critical determinant of entrepreneurial activity, innovation outcomes and sustainability performance. Regulatory quality influences transaction costs, compliance burdens, contractual enforcement and policy predictability. Empirical studies demonstrate that institutional constraints shape investment decisions, determine the scalability of green innovations and affect the capacity of firms to reallocate resources towards sustainable business models [37–38]. Conversely, regulatory inefficiencies may inhibit sustainable transformation, exacerbate administrative uncertainty and reinforce path dependence in low-innovation sectors [18–19].

Market openness is included to capture external economic linkages, which constitute a primary channel for knowledge diffusion, technology transfer and international cooperation in sustainability-oriented industries. Greater openness has been associated with improved eco-innovation capacity, accelerated adoption of resource-efficient production processes and stronger participation in global value chains supporting renewable energy, circular economy initiatives and environmental technology markets [47–48, 50]. Research additionally indicates that market integration generates competitive pressure to meet international environmental standards, thereby encouraging firms to adopt sustainability-enhancing strategies [49].

All variables (Table 1) are modelled as endogenous in order to capture the bidirectional relationships and dynamic feedback among sustainability performance, institutional conditions and competitive economic integration.

Table 1. Descriptive Statistics of the Selected Variables for Analysis.

Variable Name	Symbols	Source	Mean	Min	Max	Standard deviation
Sustainable development Index	$SDGI$	Eurostat [78]	67.1513	49.8	81.7	6.4518
Business regulation	BR	Economic Freedom of the World (EFW) [79]	6.3806	3.45	8.64	1.0653
Market openness	MO		7.3352	5.31	9.95	0.9730

Source: Developed by the Author.

3.2. Methodology

To investigate the relationships among sustainable development, business regulation and market openness across European Union member states, this study employs a multistage econometric procedure. The analysis proceeds through several sequential steps designed to ensure the statistical validity of the panel estimation framework.

First, the presence of cross-sectional dependence across countries is examined. Given the high degree of economic, institutional and policy interdependence among EU member states, testing for cross-sectional dependence is necessary to ensure appropriate model specification. The Pesaran CD test is applied to assess whether cross-country residual correlations are statistically significant. Rejection of the null hypothesis of cross-sectional independence provides the basis for applying second-generation panel unit root tests that explicitly account for cross-sectional dependence.

Second, the stationarity properties of the variables—sustainable development (SDGI), business regulation (BR) and market openness (MO)—are evaluated using cross-sectionally augmented IPS (CIPS) and cross-sectionally augmented Dickey–Fuller (CADF) tests. These procedures incorporate cross-sectional averages of the variables into the regression specification, thereby allowing consistent inference in the presence of cross-sectional dependence.

Third, the dynamic relationships among the three variables are estimated using a panel vector autoregression (PVAR) model following the framework proposed by Love and Zicchino [80]. To eliminate unobserved country-specific fixed effects, the model applies the first-order deviation (FOD) transformation, which subtracts the previous-period average from each observation. This transformation preserves the sample length while avoiding correlation between the transformed regressors and the contemporaneous error term.

The PVAR system is subsequently estimated using the system generalised method of moments (system GMM), where internal instruments are constructed from deeper lags of the endogenous variables. To prevent instrument proliferation and maintain robust statistical inference, the estimation employs collapsed instruments together with the maxldep(1) restriction and robust standard errors that allow for heteroskedasticity and within-panel correlation.

Fourth, Granger causality tests are conducted within the PVAR framework in order to identify the directional relationships among SDGI, BR and MO. These tests determine whether past values of one variable contribute to explaining the future evolution of another variable, thereby providing insight into the temporal ordering of institutional, developmental and market adjustments.

Fifth, the dynamic adjustment mechanisms are analysed through orthogonalised impulse response functions (IRFs). The IRFs trace the response trajectory of each variable following a one-standard-deviation innovation in another variable, illustrating the magnitude, persistence and direction of dynamic responses within the system.

Finally, the stability of the estimated PVAR system is verified by examining the eigenvalues of the companion matrix. All eigenvalues lie within the unit circle, confirming the stability of the model and the validity of impulse response-based inference.

4. Results

The results of Pesaran's cross-sectional dependence (CD) test are reported in Table 2. The test statistics reveal a strong and systematic presence of cross-sectional dependence among all variables included in the analysis. The null hypothesis of cross-sectional independence is therefore decisively rejected, indicating that sustainable development (SDGI), business regulation (BR) and market openness (MO) exhibit significant co-movement across countries. Such interdependence likely reflects the influence of common institutional, economic and policy shocks affecting EU member states. This pronounced interconnectedness suggests that countries do not evolve in isolation and that spillover effects play a meaningful role in shaping sustainable development outcomes and business environment indicators.

Table 2. The Cross-Sectional Dependence Test.

Variables	***SDGI***	***BR***	***MO***
CD-test	90.33	55.134	50.716
p value	0.000	0.000	0.000

Source: Developed by the Author.

The results of the unit root tests are presented in Table 3. Both the CIPS and CADF statistics consistently indicate that all variables are non-stationary in levels but become stationary after first differencing. These findings confirm that SDGI, BR and MO follow an integrated process of order one, I(1), which is consistent with the presence of cross-country interdependence identified earlier.

Table 3. The Findings of the Unit Root Test.

Variables	CIPS		CADF	
	At level	At difference	At level	At difference
$SDGI$	-2.272**	-4.751***	-1.992*	-2.381***
BR	-2.848***	-5.413***	-1.890	-3.111***
MO	-2.355***	-4.831***	-2.039*	-2.686***

Note: ***, **, and * represent statistical significance at the 1 %, 5 %, and 10 % levels, respectively.
Source: Developed by the Author.

To eliminate individual fixed effects, the model applies the first-order deviation (FOD) transformation following Love and Zicchino [80]. Unlike forward mean differencing (Helmert transformation), FOD removes fixed effects by subtracting the previous-period average without relying on future observations. After removing fixed effects, the PVAR system is estimated using the generalised method of moments (GMM), with internal instruments constructed from lagged endogenous variables. To ensure robust statistical inference, the estimation employs collapsed instruments together with robust standard errors that account for heteroskedasticity and within-panel correlation. The results of the PVAR estimation are presented in Table 4.

Table 4. The Results of Testing the Research Hypotheses via the PVAR Model.

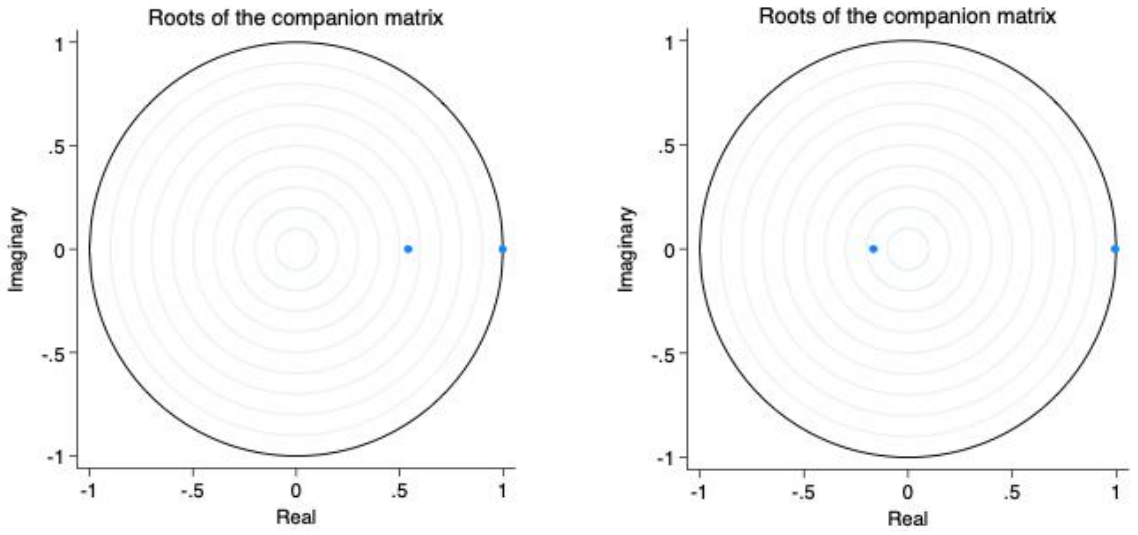
Variables	Model 1		Model 2	
	$SDGI$	BR	$SDGI$	MO
$l.SDGI$	0.996***	0.038***	0.907***	-0.643***
	(0.008)	(0.005)	(0.036)	(0.146)
$l.BR$	0.022	0.543***		
	(0.066)	(0.062)		
$l.MO$			1.567***	7.571***
			(0.603)	(1.965)
Observations	594	594	594	594
Number of id	27	27	27	27

Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.
Source: Developed by the Author.

In Model 1, the lagged SDGI coefficient is positive and highly significant, indicating strong persistence in sustainable development dynamics. The coefficient of the lagged BR variable in the SDGI equation is statistically insignificant, suggesting the absence of a short-term effect of business regulation on sustainable development outcomes. In the BR equation, both the lagged SDGI and lagged BR variables are statistically significant and positive, reflecting pronounced autoregressive behaviour and the responsiveness of regulatory quality to preceding improvements in sustainable development performance.

In Model 2, the lagged SDGI coefficient again indicates strong persistence in sustainable development dynamics. The SDGI coefficient in the MO equation is negative and statistically significant, suggesting an inverse short-term relationship between sustainable development performance and market openness. Market openness also exhibits strong autoregressive behaviour, as its lagged values display large and statistically significant coefficients in both equations of the system.

The stability conditions of the estimated PVAR models are verified through the eigenvalues of the companion matrix (Figure 1). In both specifications, all roots lie well within the unit circle, indicating the absence of explosive trajectories or non-stationary dynamics in the estimated models. Consequently, the impulse response functions derived from the PVAR system are valid, and the dynamic structure of the model is stable. This verified stability provides a consistent basis for interpreting the short-run relationships identified in the model, including the feedback mechanisms and adjustment patterns among sustainable development, business regulation and market openness.



(1) (2)

Eigenvalue	Modulus	Eigenvalue	Modulus
0.9982049	0.998205	0.9940131	0.994013
0.5413961	0.541396	-0.1662626	0.166263

Figure 1. Roots of the Companion Matrix.
Source: Developed by the Author.

Table 5. The Results of Testing the Research Hypotheses via Granger Causality.

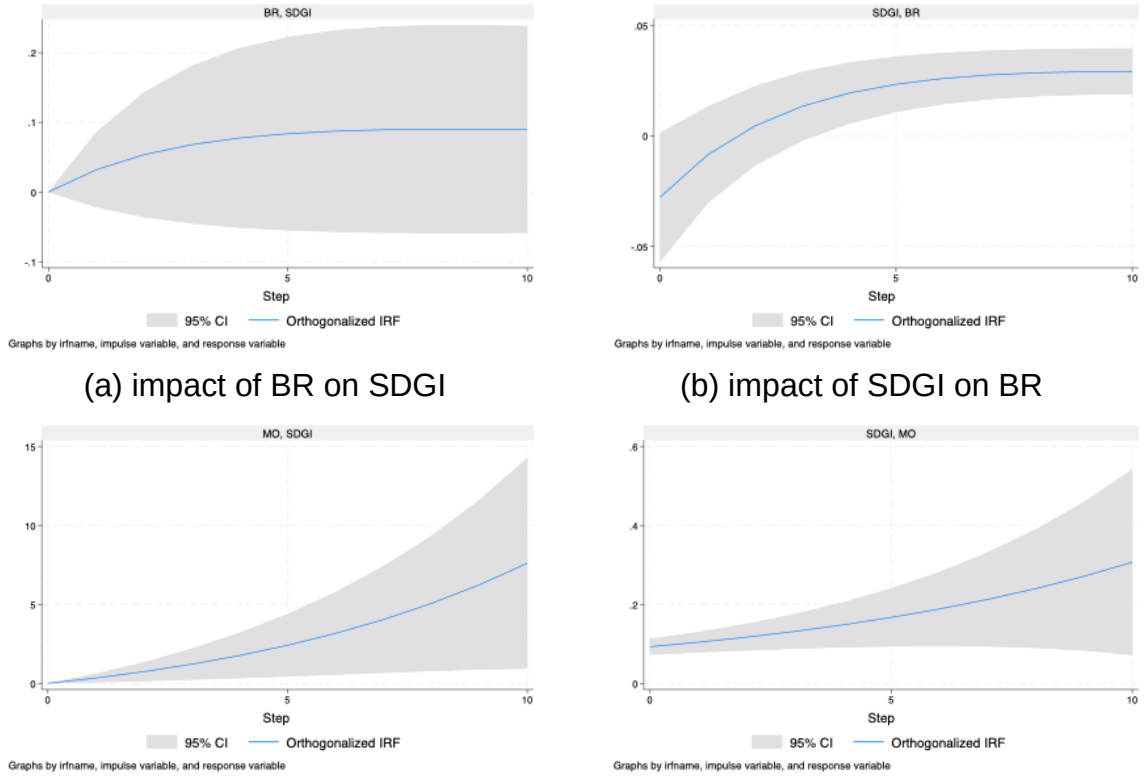
Dependent variable	Null hypothesis	Chi²	df	P value	Result
$SDGI$	BR does not Granger-cause$SDGI$	0.1077	1	0.743	Not Rejected
	MO does not Granger-cause$SDGI$	6.755	1	0.009	Reject
BR	$SDGI$ does not Granger-causeBR	57.736	1	0.000	Reject
MO	$SDGI$ does not Granger-causeMO	19.501	1	0.000	Reject

Source: Developed by the Author.

The results of the Granger causality tests are presented in Table 5. The findings reveal a heterogeneous structure of causal relationships among the examined variables. Market openness exerts a statistically significant causal influence on sustainable development, whereas business regulation does not demonstrate such an effect.

Moreover, SDGI demonstrates clear causal effects on both business regulation and market openness, indicating that improvements in sustainable development performance precede changes in institutional quality and market conditions. These results confirm the presence of unidirectional causality from MO to SDGI and from SDGI to both BR and MO.

To further examine the dynamic interactions among sustainable development performance, business regulation and market openness, an impulse response analysis is conducted. The impulse response functions trace the effect of a one-standard-deviation innovation in the structural disturbances on the current and future values of each variable within the PVAR system, thereby revealing the temporal propagation mechanisms among SDGI, BR and MO. The analysis is based on 200 Monte Carlo simulations, and Figure 2 illustrates the responses over ten periods. The horizontal axis represents the response horizon, whereas the vertical axis indicates the magnitude of the response, with shaded areas representing the 95% confidence intervals.



(a) impact of BR on SDGI

(b) impact of SDGI on BR

(c) impact of MO on SDGI

(d) impact of SDGI on MO

Figure 2. The Results of 200 Monte Carlo Simulations.
Source: Developed by the Author.

Given that the PVAR and Granger causality results already demonstrate the absence of short-run causality from BR to SDGI, and considering the weak statistical significance of the corresponding impulse responses, the interpretation below focuses on dynamically meaningful and statistically robust relationships.

The impulse response of SDGI to a one-period shock in BR displays a gradual and monotonic increase that converges towards a stable level, indicating a persistent but bounded adjustment process. Although business regulation does not exert a short-term causal influence on SDGI in the Granger sense, the IRF reveals a positive dynamic response over longer horizons, which is consistent with the gradual transmission of institutional improvements into sustainability performance.

The response of SDGI to a shock in market openness demonstrates a different adjustment pattern. SDGI increases steadily throughout the forecast horizon, with the confidence interval widening over time. This trajectory indicates that a positive innovation in market openness generates a cumulative and expanding impact on sustainable development, producing the strongest long-term response among the examined shocks.

Finally, the impulse response of MO to a shock in SDGI shows a sharp and progressively intensifying reaction. Market openness follows an accelerating upward trajectory after an innovation in sustainable development performance, reflecting a strong amplification mechanism whereby improvements in sustainability translate into wider market access and increased economic openness over time. This dynamic is consistent with the Granger causality results, which identify SDGI as a causal driver of market openness.

5. Discussion

The empirical results of this study advance understanding of the dynamic interdependencies among sustainable development, business regulation and market openness in the European Union. The statistically significant and positive coefficients of the lagged sustainable development indicator demonstrate strong persistence, implying that sustainability trajectories are inherently path dependent. Sustainable development therefore evolves cumulatively over time rather than adjusting rapidly to short-term variations. This interpretation is consistent with previous empirical evidence indicating that the attainment of the Sustainable Development Goals (SDGs) is conditioned by long-term institutional structures, innovation capacity, digital transformation processes and cumulative policy efforts rather than isolated regulatory interventions [28, 41]. Accordingly, sustainability outcomes in the EU should be understood as emergent properties of ongoing institutional and technological transformation rather than immediate responses to exogenous stimuli.

The absence of a significant short-term causal relationship from business regulation to sustainable development indicates that regulatory reforms, although relevant, do not translate into immediate improvements in sustainability outcomes. These findings challenge deterministic assumptions in the literature that portray regulation as a principal short-term driver of sustainable performance. Instead, the results support the view that regulatory effects are transmitted through gradual institutional adaptation processes, organisational learning and investment reallocation mechanisms. Empirical studies on business environment reforms

similarly show that regulatory interventions generally require extended temporal horizons to influence innovation behaviour, strategic planning and entrepreneurial decision-making [37–38]. Earlier evidence also suggests that regulatory initiatives may produce transitional inefficiencies, compliance burdens and partial or symbolic implementation, thereby limiting their capacity to generate immediate sustainability gains [16–17].

Conversely, the presence of statistically significant causality from sustainable development to business regulation indicates that improvements in sustainability performance precede regulatory adaptation. This reverse-direction effect suggests a feedback mechanism whereby favourable sustainability outcomes enhance policy awareness, administrative capacity, stakeholder coordination and demand for regulatory refinement. Such dynamics are consistent with coevolutionary governance frameworks, in which institutional change emerges as a response to demonstrated success rather than exclusively through ex ante policy design. Empirical research on policy learning supports this interpretation, emphasising that sustainability achievements often legitimise institutional reforms and stimulate further regulatory initiatives [18–19]. Thus, sustainable development may operate not only as a policy objective but also as a driver of institutional transformation.

The empirical evidence also reveals a negative short-term relationship between sustainable development and market openness. This finding indicates that progress in sustainable development may initially be associated with constraints on international economic integration. Such effects may arise from the adoption of environmental standards, climate regulations, certification requirements or sectoral restructuring processes. These transitional dynamics align with research showing that sustainability transformations frequently impose short-term adjustment costs, reduce competitive advantages in certain sectors and create barriers to export expansion or foreign investment in carbon-intensive or technologically lagging industries [47, 49]. These outcomes should therefore not be interpreted as contradictions to sustainability objectives but rather as structural reallocation processes inherent in decarbonisation, resource efficiency improvements and circular economy transformations.

In contrast, long-term dynamics indicate a pronounced and cumulative positive impact of market openness on sustainability performance. The impulse response analysis demonstrates that innovations in market openness generate sustained increases in the SDGI over extended temporal horizons, confirming the existence of diffusion, learning and competitive selection mechanisms. This finding corroborates previous studies demonstrating that trade integration, foreign direct investment, cross-border knowledge flows and participation in global value chains accelerate innovation adoption, digital transformation and eco-efficient business model deployment [48, 50].

Overall, the results indicate that sustainable development, business regulation and market openness form a reciprocally reinforcing but temporally heterogeneous system. Short-term dynamics are characterised by limited regulatory responsiveness and potential competitive constraints, whereas long-term effects reflect cumulative institutional improvements, technological adaptation and learning-based market expansion. The identification of reverse causality from sustainable development to both business regulation and market openness represents an important contribution to the literature, suggesting that sustainability achievements themselves may trigger institutional and economic transformation processes.

These results imply that policy design in the European Union should incorporate temporal sequencing, coordination across regulatory domains and targeted support during transitional phases. Rather than prioritising immediate regulatory reform as the primary instrument for accelerating sustainable development, policy frameworks should emphasise long-term institutional capacity building, continuity of sustainability investments and integration into open, innovation-oriented and digitally enabled market structures.

The results further indicate that sustainable development in the EU operates simultaneously as an outcome of structural conditions and as a determinant of institutional and economic trajectories. This finding underscores the importance of cumulative and forward-looking governance approaches in achieving SDG-oriented transformation within entrepreneurial ecosystems.

6. Conclusions

This study investigated the dynamic relationships among sustainable development, business regulation and market openness in the European Union using a panel vector autoregression (PVAR) framework for 27 member states over the period 2010–2024. The results confirm strong persistence in sustainable development trajectories, indicating that sustainability progress in the EU is largely cumulative and path dependent. Business regulation does not exert a significant short-term effect on sustainable development, whereas sustainable development Granger-causes changes in regulatory quality, revealing a reverse direction of influence and the presence of feedback effects. Market openness exhibits the strongest long-term positive impact on sustainable development, suggesting that integration into international markets accelerates sustainability-oriented innovation, knowledge diffusion and technological upgrading.

These findings have several important implications for policymakers in the European Union. The absence of a significant short-term effect of business regulation on sustainability indicates that regulatory reforms should be designed as gradual, coordinated and capacity-building processes rather than reactive short-term policy instruments. Policymakers should prioritise regulatory stability, administrative transparency and procedural simplification to support long-term strategic planning among firms. Rather than focusing solely on deregulation, policy strategies should emphasise regulatory quality, policy coherence and alignment between entrepreneurship, innovation, digital transformation and environmental objectives.

The evidence that sustainable development drives regulatory improvement implies that policy frameworks should incorporate systematic learning mechanisms. Countries demonstrating stronger sustainability performance may serve as benchmarks within EU governance processes, facilitating the transnational diffusion of regulatory best practices. This requires strengthening multilevel governance arrangements, institutional monitoring and evaluation systems and platforms for regulatory experimentation. Instruments such as pilot programmes, green innovation hubs and regulatory “sandboxes” may allow firms to test sustainability-oriented and digitally enabled business models within flexible regulatory environments.

Furthermore, the strong long-term impact of market openness suggests that EU sustainability strategies should be closely connected to external economic relations, global trade architecture

and international investment regimes. Policies should promote cross-border technology transfer, encourage green foreign direct investment and expand participation in global value chains in renewable energy, circular economy and eco-innovation sectors. The development of bilateral and multilateral sustainability clauses in trade agreements, support for cross-border research and development consortia and the harmonisation of green certification standards could further strengthen openness-driven sustainability effects.

The short-term negative relationship between sustainability performance and openness highlights the need for transitional policy instruments. Policymakers should introduce targeted support measures for sectors exposed to temporary competitiveness pressures associated with environmental standards or decarbonisation requirements. Compensation mechanisms, technical assistance programmes, retraining initiatives and green financing instruments may help firms manage adjustment costs while accelerating the adoption of sustainable and digitally enabled production processes. Public procurement schemes for sustainable goods and fiscal incentives for eco-innovative small and medium-sized enterprises may further facilitate this transition.

The identified feedback loop between sustainable development and institutional conditions suggests that EU policy should follow a sequencing logic. Investments in sustainability-oriented infrastructure, scientific capacity, digital transformation and human capital should precede institutional reforms that consolidate and scale these outcomes. In this context, sustainability should be treated not only as a policy objective but also as a strategic driver of governance transformation.

The heterogeneous effects observed across EU member states indicate the need for differentiated policy design. Cohesion policy instruments should reflect differences in institutional maturity, industrial structure and innovation capacity across regions. Economies with weaker regulatory environments or limited innovation assets require targeted technical assistance, institutional capacity building and governance support, whereas technologically advanced regions may benefit more from policies aimed at scaling green innovation and high-growth entrepreneurial ecosystems.

Long-term coordination among EU institutions, national governments, regional administrations and private actors remains essential. Cross-sector policy integration linking environmental, industrial, innovation, digital and educational strategies should be institutionalised through interministerial coordination mechanisms, sustainability-oriented budgeting frameworks and SDG-aligned strategic planning systems. The results indicate that sustainability transitions are more effective when policies are stable, sequenced across domains and supported by multi-stakeholder governance structures.

The limitations of this study also suggest several directions for further research. Future studies may apply spatial PVAR models or dynamic panel threshold approaches to examine whether different institutional regimes or competitiveness levels influence the strength of sustainability dynamics. Sector-specific analyses could provide deeper insights into how regulatory change affects energy-intensive, circular, digital or bioeconomic industries. The incorporation of additional indicators, including digital transformation, ESG finance, entrepreneurial innovation and smart specialisation metrics, could provide a more detailed understanding of the

mechanisms through which sustainability spreads across entrepreneurial ecosystems. Longitudinal analyses addressing post-crisis adjustments and geopolitical shocks may further refine understanding of the temporal sequencing of institutional and market reforms.

Taken together, this study contributes to the strategic foresight literature by demonstrating that sustainable development in the European Union functions both as an outcome of structural conditions and as a driver of institutional and competitive transformation. The results highlight the importance of long-term, coordinated and evidence-based policymaking in strengthening entrepreneurship-driven sustainability transitions within increasingly digitalised and interconnected European economies.

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