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Green economic development and entrepreneurship transformation

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ABSTRACT

Objective: The article aims to analyse the role of entrepreneurship transformation in attaining green economic development among EU countries for the 2007-2022 period.

Research Design & Methods: This study applied the following methods to check the hypothesis of the study: the Malmquist–Luenberger productivity index for measuring green economic development; fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS), systems and first-difference generalized method of moments (GMM) – to check the entrepreneurship transformation effect on green economic development.

Findings: The findings of the study demonstrate a strong positive correlation between green economic development and the transformation of entrepreneurship, highlighting the crucial link between economic prosperity and initiatives in the green economy. The analysis confirms that historical changes in productivity related to green economic practices have a positive effect on future developments. Furthermore, the significant coefficients for green economic development emphasize the enduring nature of green economic practices.

Implications & Recommendations: The empirical results allowed us to outline the following suggestions: 1) government policies should focus on initial investments in green practices, incentivizing businesses through financial mechanisms and robust regulations to foster economic and environmental sustainability; 2) enhancing green economic development requires simplifying the process for creating new businesses, particularly green startups, and offering financial and procedural support to inject innovation and economic vitality into the sector; 3) trade openness is crucial for boosting green economy productivity, necessitating policies that lower trade barriers while incorporating environmental standards to ensure sustainable growth; 4) fostering innovation in environmental technologies with increased government funding and strategic partnerships between academia, industry, and government needed to propel sustainable economic transformation.

Contribution & Value Added: The value added by this article lies in its empirical grounding and practical implications, which guide policymakers regarding the importance of supporting entrepreneurial initiatives to drive green economic development. It suggests targeted government policies that incentivize the adoption of green practices, simplify processes for new green startups, promote trade openness, and foster innovation through increased funding and collaboration.

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INTRODUCTION

The EU countries have embraced a strategy of green transformation with the ambitious goal of becoming the first fully green economies in the world (Hussain *et al.,* 2021; Kedward & Ryan-Collins, 2022; Titko *et al*., 2023b). This commitment is part of a broader initiative to strengthen their green economic development on the global stage. By prioritizing sustainable practices and policies, such as the European Green Deal (Madaleno & Nogueira, 2023), the EU aims to reduce carbon emissions, increase renewable energy usage (Jin *et al*., 2023), and promote sustainable industry practices across all member states. This proactive approach positions the EU as a leader in environmental stewardship and enhances its competitiveness in the rapidly growing global green economy (Sulich & Zema, 2023; Szczepańska-Woszczyna *et al.,* 2022; Tkachenko *et al.*, 2019).

Scholars widely acknowledge entrepreneurship as a pivotal driver of a country's development, particularly when aligned with the concept of green transformation (Chygryn *et al.,* 2022; Ziabina & Dzwigol-Barosz, 2022). Entrepreneurs are at the forefront of innovation, job creation, and economic diversification, which are essential elements for achieving sustainable growth. Their input in addressing environmental, social, and economic challenges helps directly advance green transformation goals (Ashraf, 2024; Chkareuli *et al*., 2024; Dacko-Pikiewicz, 2019a; Huseynov, 2021; Chygryn *et al*., 2023; Us & Gerulaitiene, 2023; Titko *et al*., 2023a; Yang & Liu, 2024). Thus, governments must foster a supportive environment that stimulates the growth and sustainability of entrepreneurial ventures. Effective incentive mechanisms are crucial in this regard. For example, recognizing the significant impact of entrepreneurship, the European Union reported that SMEs alone provide two-thirds of the total private sector employment in the EU (Saura *et al.*, 2023; Sannikova *et al.*, 2023; Sánchez-Robles *et al.,* 2024), demonstrating the extensive role of entrepreneurship in job creation and economic stability. As studies show (Li *et al.*, 2024; Hakhverdyan & Shahinyan, 2022; Khalatur & Dubovych, 2022; Yu & Zheng, 2024), governments should consider financial support such as grants, low-interest loans, tax incentives, and subsidies specifically targeted at green businesses and social enterprises. In 2020, the European Commission launched the European Green Deal Investment Plan (2020) aiming to stimulate investment in sustainable projects and additional measures to support up to 1 trillion of investment over the next decade. This kind of financial backing not only encourages new business ventures but also supports their development and scalability. Moreover, scholars have outlined the importance of a regulatory environment that promotes innovation while minimizing unnecessary burdens (Lagodiienko & Yakushko, 2021; Gobniece & Titko, 2024). Streamlining administrative processes, protecting intellectual property rights, and ensuring transparent and fair market access are key components. For example, the EU's Digital Single Market strategy is designed to open up digital opportunities for business and enhance Europe's position as a world leader in the digital economy (Michulek & Gajanova, 2023; Dabrowski *et al.*, 2023; Zhanibek *et al.,* 2022; Szczepańska-Woszczyna & Muras, 2023; Saura *et al*., 2022a). Beyond financial and regulatory frameworks, governments should promote an entrepreneurial culture through education and training programs that equip individuals with the necessary skills and mindset. The EU countries should implement the necessary mechanisms to support business development, which, in turn, could enhance the green economic development of EU countries. This strategic support is essential for fostering a business environment that aligns with the goals of sustainable development and environmental stewardship. To effectively design and apply these mechanisms, it is crucial to understand and empirically justify the impact of entrepreneurship on the green economic development of EU countries. This understanding will enable the effective tailoring of the right mix of incentives and stimuli to promote entrepreneurship. This could consequently strengthen the green competitiveness of the EU.

This article aims to analyse the transformative impact of entrepreneurship on green economic development among EU countries from 2006 to 2022. It seeks to bridge the gap between entrepreneurial ventures and sustainable economic practices, providing insights into how the entrepreneurial landscape fosters a more sustainable and economically viable green economy. The article is original in several ways. Firstly, the study enhances the understanding of the dynamic relationship between green economic development and entrepreneurship transformation by providing a comprehensive empirical framework through the use of advanced econometric models such as GMM-SYS and GMM-FD. This study offers a nuanced perspective on how past performance in green practices influences future outcomes, thus significantly contributing to the academic literature on sustainable economic development. Secondly, the study underscores the foundational role of new business density in the economic landscape, particularly within the context of European Union policies. The adopted research methodology allows for a detailed examination of how entrepreneurial activities contribute to broader economic and environmental goals, emphasizing the integration of new business dynamics into sustainable policy frameworks. Thirdly, the study broadens the empirical base concerning the impact of macroeconomic factors such as gross national income and trade openness on green economy productivity. By doing so, it enriches the dialogue on how economic strength and openness influence sustainable practices, providing valuable insights for policymakers and stakeholders involved in shaping economic policies that support environmental sustainability.

The article is structured as follows. The first section will present a literature review – an analysis of the theoretical landscape linking green competitiveness and entrepreneurship to justify the research hypothesis. Next, there will come research methodology – an explanation of variables and sources, methods, and instruments for testing the research hypothesis. Then, we will move to results and discussion – exploration of the empirical results of the investigations. Finally, we will present conclusions summarizing the core results, policy implications, limitations, and further directions for investigation.

LITERATURE REVIEW

The interplay between entrepreneurship and green economic development in EU countries is intricately connected to the evolving policy landscape and innovative business practices, as highlighted by recent scholarly research. A significant study by Sulich and Zema (2018) delves into how EU nations are fostering environments conducive to green entrepreneurship. They noted the considerable positive spillover effects that supportive policies can have on enhancing green economic development across the region (Sulich & Zema, 2018). Bogoslov *et al.* (2022) explore this idea further in the context of the European Green Deal. They examine how this sweeping policy initiative redefines the entrepreneurial landscape, boosting both green innovation and competitiveness within the EU. Avlogiaris *et al.* (2023) highlight the dynamic relationship between state policies and entrepreneurship in Europe's transition to green growth in the post-lignite era. They question whether governmental policies and entrepreneurial actions are in sync or at odds in driving the green transition. Their findings suggest that achieving green growth necessitates a collaborative approach where both the state and entrepreneurs work as allies rather than adversaries. In a different context, Chen *et al.* (2024) explore how the trade of mineral resources and the development of financial markets influence green entrepreneurship within resource-rich economies. They argue that financial development and resource management are critical in fostering an environment conducive to green entrepreneurial ventures, indicating that strategic financial policies and resource trade can bolster or hinder green innovation. Studies have examined the significance of green finance in supporting sustainable business start-ups (Raza *et al.,* 2023; Kwilinski *et al*., 2023a; 2023b; Luo *et al.*, 2024; Wu *et al.*, 2024). They highlight that green finance mechanisms are essential for enabling entrepreneurs to launch and sustain businesses that contribute to environmental sustainability, thus enhancing green economic development across Asian markets. Moreover, Sifa *et al.* (2021), Kwilinski *et al*. (2023d), Lesniak *et al.* (2023), Letunovska *et al.* (2022) and Szczepańska-Woszczyna *et al.* (2024) address the compounded challenges posed by climate change and the COVID-19 pandemic in Bangladesh. They discuss how entrepreneurship can mitigate these crises by promoting sustainable development and poverty eradication through innovative and environmentally friendly business practices. Wei *et al.* (2023) provide empirical evidence on the role of environmental entrepreneurship in promoting sustainable green development in emerging Asian economies. Their study underscores the positive impact of environmental entrepreneurship on sustainable development, demonstrating that innovative green business practices are crucial for achieving long-term sustainability goals.

Furthermore, Fankhauser *et al.* (2013) enriched the concept of green economic development by introducing the 'sailing ship effect.' This phenomenon suggests that traditional industries may innovate in response to advancements in green technologies, thereby not only preserving but also enhancing their competitive edge in the environmental sector (Fankhauser *et al.,* 2013). Complementing this perspective, Dabbous *et al.* (2023) investigate the impact of digitalization on green entrepreneurship. Their findings indicate that the twin transitions of digital and green innovations are pivotal, showing how digitalization underpins green entrepreneurial ventures and bolsters sustainable competitiveness (Dabbous *et al.,* 2023; Kwilinski, 2023a; 2023b). In a more technologically focused analysis, Makhloufi (2023) investigated the influence of big data analytics capabilities and green absorptive capacity on fostering green entrepreneurial orientation and eco-innovation. His study suggested that leveraging technological and cognitive capacities to interpret environmental data significantly boosts eco-innovation and, consequently, a country's green economic development (Makhloufi, 2023). Sotarauta *et al.* (2021) outline the roles of change agents in promoting green path development in Northern Europe. Their work underscores how leadership, policy advocacy, and grassroots initiatives are crucial in driving regional transformations toward sustainability, highlighting the multifaceted approach needed to achieve green economic development. Previous studies have outlined the role of eco-innovation strategies in identifying and capitalizing on new business opportunities that enhance enterprise growth and sustainability (Ben *et al*., 2019; Gu, 2024; Kwilinski *et al.*, 2023c; 2024). They argue that by integrating eco-innovation, businesses not only support environmental goals but also gain a competitive edge in the market, which has a positive effect on the green economic development of the country. In contrast, Hinderer and Kuckertz (2024) examine the potential conflict between degrowth attitudes and venture scaling among entrepreneurs. They suggest that while entrepreneurship enhances green economic development, the emphasis on degrowth – prioritizing sustainability over traditional growth metrics – may impede the rapid scaling that is often necessary for competitive success. In the Pacific region, Michalena (2017) discusses the integration of knowledge and innovation as key drivers for building countries' green economic development and entrepreneurship. We did not include the studies of Michalena (2017) and Rajiani and Kot (2020). Szczepańska-Woszczyna and Gatnar (2022), Vaníčková and Szczepańska-Woszczyna (2020), and Wróblewski and Lis (2021) underscore the importance of coopetition, *i.e.* cooperative competition among firms and the government to leverage shared knowledge and innovation for entrepreneurial success in green sectors. Ngondjeb *et al.* (2020) explore how green entrepreneurship could lead to sustainable economic and social development. Their research is pivotal for understanding how green entrepreneurship serves as a pathway to a green economy, particularly in emerging markets where aligning business practices with sustainability principles is both a challenge and an opportunity.

Ansah and Sorooshian (2019) emphasize the significant role of the private sector in responding to climate change, suggesting that businesses are crucial to the transition towards a green economy. Their analysis highlights that proactive corporate strategies are essential for enhancing environmental quality and achieving sustainability goals within the EU, positioning the response of the private sector as a key driver of green economic development. Drago and Gatto (2022) contribute to the methodology by proposing an interval-valued composite indicator for measuring energy efficiency and green entrepreneurship. This tool aids in evaluating the performance of businesses in achieving energy efficiency and fostering green growth within the EU, offering a measurement approach to assess and enhance green economic development. Liargovas *et al*. (2017) highlight the effectiveness of support mechanisms and initiatives for SMEs in promoting green growth. They argue that well-designed support systems are crucial for enabling small and medium enterprises to contribute to green economic development in the Western Balkans, providing a blueprint that could be extended to broader EU contexts. Nadiroh and Emilkamayana (2021) examine the efficiency of green economic development in supporting environmental policy. Their findings underscore the importance of aligning policy frameworks with green economic development initiatives to enhance environmental and economic sustainability. Singh *et al*. (2023) discuss policy implications from selected countries for promoting a sustainable future through green entrepreneurship. Their analysis highlights the critical role of policy frameworks in enabling green entrepreneurial activities that contribute to sustainable economic development.

RESEARCH METHODOLOGY

This study examined the impact of entrepreneurship transformation on green economic development utilizing data from 2007-2022 from 26 European countries. We excluded the Netherlands due to data limitations. In this analysis, green economic development is considered the dependent variable. The Malmquist-Luenberger productivity index is employed to compute the measures of green economic development (Oh, 2010; Zhao *et al.,* 2022; Chen *et al*., 2023). The Malmquist-Luenberger productivity index is an extension of the traditional Malmquist productivity index, which is specifically adapted to include undesirable outputs such as environmental pollutants. This index is particularly valuable for assessing productivity changes over time in contexts where environmental impact plays a crucial role. It decomposes total factor productivity change into efficiency change and technological change, providing insights into how technological advancements and efficiency improvements contribute to green economic development. The Malmquist-Luenberger productivity index is calculated using distance functions that accommodate both desirable and undesirable outputs. We can express the general formula for the Malmquist-Luenberger productivity index between two time periods (t and t+1) as:

$$TFPCH = \sqrt{\left(\frac{D_{t+1}(x_{t+1}, y_{t+1}^{+}, y_{t+1}^{-})}{D_t(x_{t+1}, y_{t+1}^{+}, y_{t+1}^{-})}\right) \times \left(\frac{D_{t+1}(x_t, y_t^{+}, y_t^{-})}{D_t(x_t, y_t^{+}, y_t^{-})}\right)} \tag{1}$$

in which $TFPCH$ represents green economic development; $D_t(x_t, y_t^{+}, y_t^{-})$ and $D_{t+1}(x_t, y_t^{+}, y_t^{-})$ are the distance functions at time t and t+1, respectively; x represents input quantities; and y^{+} and y^{-} represent desirable and undesirable output quantities, respectively.

Carbon dioxide is considered a major undesirable output, mirroring its common classification in environmental economic studies, such as those by Ang (2004), who emphasizes the significance of accounting for environmental externalities in productivity assessments. Traditional economic factors such as capital and labour were included, reflecting the methodology used by Kumar and Russell (2002), who explored the dynamics of productivity under varying input conditions. Furthermore, this study incorporates renewable energy as one of the input variables, drawing on the innovative approach of Zhou and Ang (2008), who argue for the inclusion of renewable resources to capture the evolving nature of energy consumption and its effects on productivity. The choice of gross domestic product (GDP) as the desirable output follows the precedent set by Kumar and Managi (2009), who examined the relationship between environmental performance and economic output, providing a comprehensive view of how economic activities correlate with environmental sustainability.

A $TFPCH$ greater than 1 indicates an improvement in total factor productivity from period t to t+1, meaning that the unit has become more efficient, benefitted from technological advancements, or both. A $TFPCH$ less than 1 signifies a decline in productivity, indicating reduced efficiency or technological regression. An $TFPCH$ equal to 1 suggests no change in productivity between the two periods.

To measure entrepreneurship transformation ($Business$), we selected the indicator of the new business density rate. This metric, which quantifies the number of new business registrations per 1000 people, provides a direct measure of the rate at which new enterprises are being created, which is crucial for understanding the dynamic nature of economic transformation and innovation (Zheng *et al*., 2023). Studies by Acs *et al*. (2009; 2013) demonstrated the relevance of this metric in capturing the entrepreneurial trends that significantly impact economic growth and structural change. Moreover, this indicator is used in the Global Entrepreneurship Monitor reports (GEM, 2024), which underscore its wide international comparisons for entrepreneurial activity.

In addition to $Business$, we selected several other explanatory variables: $Innov$ represents the number of patents in environment-related technologies. This indicator is pivotal for understanding the role of technological innovation in driving environmental sustainability and economic growth (Urbaniec *et al.,* 2021). It helps assess how advancements in technology can spur green practices and solutions within industries; GNI measures the total domestic and foreign output claimed by residents of a country, encompassing wages, profits, and taxes minus subsidies. The GNI is a broad measure of economic activity and prosperity and is used to gauge the economic strength of a nation and its capacity to support sustainable practices through available financial resources (Gracia & Siregar, 2021); trade openness (TO) is included as a variable to examine the effects of economic integration and global market access on green economic practices. Trade openness reflects the extent to which a country engages in international trade, with higher values indicating greater openness. This metric is essential for analysing how external economic relationships influence the adoption and diffusion of green technologies and practices, facilitated by increased competition, innovation, and knowledge transfer from more developed markets (Wu, 2022). We collected the data for the chosen variables from the World Development Indicators (WDI) of the World Bank, Eurostat, and the Global Entrepreneurship Monitor reports (GEM, 2024). Table 1 summarises the statistics of the collected data.

Table 1. Summary statistics

Variables	N	Mean	SD	Min	Max
$TFPCH$	416	0.997	0.045	0.535	1.183
$Business$	416	6.138	5.350	0.309	38.196
TO	416	126.765	69.475	45.419	393.141
$Innov$	416	12.589	4.751	0.840	45.210
GNI	416	31756.923	18923.349	4820.000	89200.000

Source: own study.

We constructed the following econometric model to identify the role of entrepreneurship transformation in promoting green economic development:

$$TFPCH_{it} = \alpha + \beta Business_{it} + \gamma Controls_{it} + \varepsilon_{it} \quad (2)$$

in which $Controls$ are control variables, including TO, $Innov$, and GNI; i is the country; t is the time; and ε is the error term.

To analyse the impact of entrepreneurship transformation on green economic development, we initially used the Shapiro–Wilk W test to assess the normality of the data distribution. In the subsequent stage, we calculated pairwise correlations and variance inflation factors (VIFs) to investigate the relationships between variables and detect potential multicollinearity (Shrestha, 2020). High VIF values indicate problematic multicollinearity, which could distort regression outcomes. Given the panel data structure, we employed several unit-root tests to ensure the stationarity of the series. These included first-generation unit root tests such as the Levin–Lin–Chu, Breitung, and Hadri LMs, as well as second-generation tests such as Pesaran's CADF and CIPS (Pesaran, 2021; Im *et al.,* 2023). Pesaran's CADF test differs from standard unit root tests because it accounts for cross-sectional dependence among panel data series, enhancing its applicability to datasets where economic variables are influenced by common factors across entities. The CADF test modifies the traditional ADF test by including the cross-sectional averages of lagged levels and the first differences of the individual series. This approach helps mitigate the bias that might arise from ignoring cross-sectional dependencies. On the other hand, the CIPS test, an extension of the CADF test, averages the individual CADF statistics across cross-sections to provide a single statistic. This test is particularly useful when dealing with heterogeneous panels where there are variations in the dynamic properties across series. It is robust against both cross-sectional dependence and individual unit root processes, making it suitable for analysing more diverse and complex datasets. We utilized the cointegration tests of Pedroni (2004), Kao (1999), and Westerlund (2008) to ascertain long-term equilibrium relationships among variables. These tests help determine whether a stable, long-term relationship persists despite short-term deviations among the integrated series. We employed fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) techniques to estimate long-term relationships once cointegration was established. These methods are tailored to correct problems such as endogeneity and serial correlation in error terms, which are common in cointegrated panels (Merlin *et al.,* 2021). To address potential endogeneity issues among explanatory variables, the systems generalized method of moments (System GMM) and first-difference GMM were utilized. System GMM combines level and first-differenced equations to enhance estimator efficiency, whereas first-difference GMM focuses on differenced data to eliminate unobserved fixed effects.

RESULTS AND DISCUSSION

The results of the Shapiro-Wilk W tests for normality (Table 2) indicated that none of the data distributions were normal, with V statistics greater than 1 and probabilities less than 1% for all indicators. To address this, we transformed all variables using logarithms to approximate a normal distribution, which enhances the validity of statistical tests that assume normality. This transformation also helps to mitigate the impact of extreme values or outliers. Moreover, when logarithms are used, the coefficients in the regression can be interpreted as elasticities, representing percentage changes.

Table 2. Shapiro-Wilk W test for normal data

Variable	Obs	W	V	z	Prob>z
$TFPCH$	416	0.240	216.710	12.821	0.000
$Business$	416	0.788	60.420	9.777	0.000
$Innov$	416	0.936	18.110	6.904	0.000
GNI	416	0.912	25.182	7.690	0.000
TO	416	0.965	10.013	5.492	0.000

Source: own study.

The results of pairwise correlations (Table 3) show that higher national income and greater openness significantly enhanced green competitiveness. Moreover, $TFPCH$ also exhibited positive correlations with $Business$ and $Innovation$, suggesting that business activity and innovation modestly contribute to green competitiveness.

Table 3. Pairwise correlations and statistical VIFs

Variables	$TFPCH$	$Business$	$Innov$	GNI	TO	VIF
$TFPCH$	1.000	–	–	–	–	–
$Business$	0.150	1.000	–	–	–	1.03
	(0.003)		–	–	–	
$Innov$	0.104	-0.031	1.000	–	–	1.00
	(0.040)	(0.542)		–	–	
GNI	0.220	0.115	-0.024	1.000	–	1.05
	(0.000)	(0.023)	(0.642)		–	
TO	0.294	0.148	-0.043	0.209	1.000	1.06
	(0.000)	(0.003)	(0.397)	(0.000)		

Source: own study.

The VIFs for all variables range from 1.00 for $Innov$ to 1.06 for TO, indicating minimal multicollinearity. Specifically, a VIF of 1 signifies no correlation with other variables, and as values slightly increase – while still remaining close to 1 – it indicates only a minimal increase in variance due to weak correlations with other variables in the model. The VIF results demonstrate that each variable contributes uniquely to the regression model without much redundancy from overlapping information with other predictors. This suggests that the model parameters are well estimated, and the predictors provide distinct and valuable insights into the model.

At the next stage, we applied unit-root tests (Levin–Lin–Chu, Breitung, Hadri LM, Im–Pesaran–Shin) to check the data stationarity (Table 4). The findings show that most variables were nonstationary at the level. However, at the 1st difference, all the data tend to be stationary.

In comparison to other traditional unit root tests such as the Levin–Lin–Chu, Breitung, and Hadri LMs, both Pesaran's CADF and the CIPS provide a more nuanced approach by considering cross-sectional dependence, which is often present in macroeconomic panels. Pesaran's CADF test results indicate that some of the variables in their natural log form show stationarity on their own ($TFPCH$, $Innov$), whereas others require differencing to achieve stationarity ($Business$, GNI, TO), as seen from significant CADF statistics and corresponding p values. The CIPS test, which aggregates individual unit root tests across a cross-section, shows that variables generally became stationary when differenced. The critical values at different significance levels for a sample size of N = 27 and T = 17 were -2.14, -2.25, and -2.45 for the 1%, 5%, and 10% significance levels, respectively.

We used the Pedroni, Kao, and Westerlund tests to assess the long-term equilibrium relationships among the analysed variables (Table 5). The results of the Pedroni tests were compelling and strongly indicated the presence of cointegration. This suggests a strong and statistically significant long-term relationship among the variables.

Table 4. The findings of the unit-root test

Variables	Levin–Lin–Chu		Breitung		Hadri LM		Im–Pesaran–Shin		Pesaran's CADF		CIPS
	St.	p	St.	p	St.	p	St.	p	St.	p	St
$TFPCH$	-1.819	0.035	0.608	0.728	32.106	0.000	1.725	0.958	-2.092	0.039	-1.749
$d.TFPCH$	-9.417	0.000	-7.509	0.000	-0.971	0.834	-8.317	0.000	-2.549	0.000	-3.447
$Business$	-0.118	0.453	0.665	0.747	30.224	0.000	2.178	0.985	-1.939	0.160	-1.945
$d.Business$	-8.804	0.000	-7.395	0.000	-0.242	0.596	-8.359	0.000	-2.292	0.004	-3.205
$Innov$	-6.972	0.000	-2.410	0.008	4.037	0.000	-7.341	0.000	-2.588	0.000	-3.756
d.$Innov$	-12.695	0.000	-7.882	0.000	-4.223	1.000	-10.908	0.000	-3.932	0.000	-4.799
GNI	6.597	1.000	5.268	1.000	31.869	0.000	3.953	1.000	-0.746	1.000	-1.330
d.GNI	-2.752	0.003	-5.121	0.000	0.931	0.176	-8.122	0.000	-2.259	0.006	-3.329
TO	0.704	0.759	1.679	0.954	30.294	0.000	2.772	0.997	-1.713	0.554	-1.429
d. TO	-14.028	0.000	-9.831	0.000	-1.157	0.876	-7.848	0.000	-2.473	0.000	-2.585

Note: St. – Statistic; p – p value.
Source: own study.

Table 5. The cointegration results for the analysed variables

Test	Statistic	p value
Pedroni tests		
Modified Phillips–Perron t	4.863	0.000
Phillips–Perron t	-5.044	0.000
Augmented Dickey–Fuller t	-5.988	0.000
Kao tests		
Modified Dickey–Fuller t	-0.615	0.269
Dickey–Fuller t	-2.239	0.013
Augmented Dickey–Fuller t	1.472	0.071
Unadjusted modified Dickey–Fuller t	-1.963	0.025
Unadjusted Dickey–Fuller t	-3.051	0.001
Westerlund test		
Variance ratio	2.251	0.012

Source: own study.

However, the modified Dickey–Fuller t-statistic indicated a weaker cointegration, with a statistic of -0.615 and a p value of 0.269. However, other Kao test results, the Dickey–Fuller (t-statistic of -2.239, p value of 0.013) and the Augmented Dickey–Fuller (t-statistic of 1.472, p value of 0.071) provided moderate to marginal evidence of cointegration. Morerover, the unadjusted modified Dickey–Fuller t-statistic and the unadjusted Dickey–Fuller t-statistic, with p values of 0.025 and 0.001, respectively, strengthen the argument for a significant long-term relationship. The Westerlund test's variance ratio statistic of 2.251, with a p value of 0.012, further supports the presence of cointegration among the variables. This test confirms that despite short-term variations, there is a stable long-term equilibrium relationship that binds these variables together, maintaining balance over time. These results underscore the robustness of the cointegration among the variables, highlighting a consistent, long-term comovement.

To check for the presence of cointegration among variables, this study applied fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS). Considering the findings (Table 5) that all analysed variables were statistically significant in both models (FMOLS and DOLS), excluding *Innov* in DOLS was not statistically significant.

The robust t-statistics underscore the reliability of the FMOLS and DOLS results, indicating that variables such as *business, innovation*, *GNI*, and TO play pivotal roles in influencing the dependent variable (green economic development) over the long term.

In the systems GMM model, as presented in Table 7, the lagged variable of TFPCH has a coefficient of 0.0104, which is significant at the 1% level, indicating a notable but moderate impact of past changes in green economy productivity on current economic conditions. The first-difference GMM model shows a stronger effect with a coefficient of 0.0196, which is also significant at the 1% level, suggesting that immediate past changes in green economy productivity have a more pronounced influence on current outcomes. Regarding business activity, the systems GMM model reveals a coefficient of 0.000190 for business, with a highly significant p value, highlighting its stable influence within the model. The first-difference GMM model provides a slightly higher coefficient of 0.000305, indicating an incrementally stronger effect of recent changes in new business density rates on economic conditions. For *Innov*, which focuses on patents in environment-related technologies, the coefficients show a stronger relationship: 0.00669 in the systems GMM and 0.00857 in the first-difference GMM, both of which are statistically significant at the 1% level. These results underscore the importance of innovations in environmental technologies as having a more substantial and consistent impact compared to the more marginal impacts observed with new business density rates.

Table 6. FMOLS and DOLS results

Variables	FMOLS	DOLS
Business	0.121***	0.001***
	(7.465)	(2.291)
Innov	0.056***	0.001
	(9.404)	(0.579)
GNI	0.054***	0.012***
	(81.482)	(2.712)
TO	0.075***	0.007**
	(87.884)	(1.795)
Observations	390	390
Number of id	26	26

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; in brackets – values of t-statistics.
Source: own study.

Table 7. The outputs of the systems GMM (1) and first-difference GMM (2) techniques

Variables	(1)	(2)
	GMM-SYS	GMM-FD
$L.TFPCH$	0.0104***	0.0196***
	(0.000670)	(0.000770)
$Business$	0.000190***	0.000305***
	(5.92e-05)	(7.11e-05)
$Innov$	0.00669***	0.00857***
	(0.000297)	(0.000417)
GNI	0.00309***	0.00273***
	(0.000591)	(0.000569)
TO	0.00969***	0.0152***
	(0.000545)	(0.000628)
$Constant$	0.892***	0.856***
	(0.00599)	(0.00659)
Sargan	1.000	0.003
Hansen	1.000	0.785
AR(1)	0.015	0.015
AR(2)	0.432	0.785

Note: Standard errors in parentheses *** p < 0.01, ** p < 0.05, * p < 0.1
Source: own study.

The GNI coefficients are also positive and significant in both models (0.00309 in GMM-SYS and 0.00273 in GMM-FD). This indicates that an increase in the GNI tends to positively influence green economy productivity, possibly reflecting that higher national income levels facilitate better resource allocation towards sustainable practices. Trade Openness showed coefficients (0.00969 in GMM-SYS and 0.0152 in GMM-FD), both of which were significant at the 0.01 level. This finding implies a robust positive relationship between trade openness and green economy productivity. Higher levels of trade openness are associated with increased exchange of green technologies and practices, which in turn boosts productivity in this sector.

The models' diagnostics, including the Sargan test and Hansen test, confirmed the validity of the instruments used, showing no rejection of the model. Furthermore, the AR(1) and AR(2) tests indicated no autocorrelation in the first-differenced errors, underscoring the models' robustness and the findings' reliability.

CONCLUSIONS

The study results indicate that there is a significant positive relationship between green economic development and entrepreneurship transformation, emphasizing the interconnectedness of economic prosperity and green economy initiatives. Firstly, the analysis supports the theory that past productivity changes in green economic practices (TFPCH) positively influence future developments. The significant coefficients for lagged TFPCH in both the GMM-SYS and GMM-FD models underscore the persistence of green economic practices, suggesting that once established, these practices tend to generate continuous improvements over time. He and Farouk (2015) support this finding. They discuss how such initial investments may create a foundation for sustainable growth and continuous improvement in environmental practices. Furthermore, it aligns with Horbach *et al.* (2012), who found that established green business practices generate ongoing improvements, reinforcing the results regarding the persistence of green economic practices. Secondly, the impact of new business density is relatively significant, underscoring the foundational role that new enterprises play in fostering economic dynamics. The systems GMM model reveals a coefficient of 0.000190 for business, with a highly significant p value, highlighting its stable influence within the model. The first-difference GMM model provides a slightly higher coefficient of 0.000305, indicating an incrementally stronger effect of recent changes in new business density rates on economic conditions. Similar to the findings in the paper by Cumming and Groh (2018), these results align with the conclusion that new enterprises are pivotal in driving economic and environmental resilience. These results are vital for EU policies aimed at supporting the integration of economic growth with sustainable practices, suggesting that encouraging new business formation, particularly in the green sector, could be a potent driver of broader economic and environmental resilience. Furthermore, the data suggest that a higher GNI within European countries facilitates the advancement of green economy productivity. According to the findings of Aghion *et al.* (2009), the broader economic strength provided by higher GNI in these countries significantly enhances the advancement of green economy productivity. Therefore, the economic strength of a nation provides the necessary resources and infrastructure for sustainable practices more effectively than new business density alone. Moreover, the results contradict the claims that trade openness could have a detrimental effect on green practices. Instead, the positive coefficients associated with trade openness in enhancing green economy productivity reinforce the view, as Frankel and Rose (2005) indicated, that openness to international markets encourages the adoption and diffusion of green technologies. For $Innov$, which focuses on patents in environment-related technologies, the coefficients show a stronger relationship: 0.00669 in the systems GMM and 0.00857 in the first-difference GMM, both of which are statistically significant at the 1% level. These results underscore the importance of innovations in environmental technologies, as they have a more substantial and consistent impact than the more marginal impacts observed with new business density rates. $Innov$ suggested that technological advancements in the green sector are crucial for driving the transformative processes of green competitiveness and entrepreneurship.

Considering the empirical results, we can outline the following policy implications for enhancing green economic development through entrepreneurship:

1. Governments should focus on policies that promote initial investments in green economic practices, as such investments have demonstrated lasting impacts and a tendency to generate continuous improvements over time (Mesagan *et al.,* 2020; Moskalenko *et al*., 2022a; 2022b). The foundational investments in green practices create a sustainable growth model that continues to yield

environmental improvements. The initiating robust green practices not only contribute to immediate environmental benefits but also sets a precedent for ongoing economic and ecological gains. This cyclical reinforcement of green initiatives through policy leads to a self-sustaining model where economic development and environmental sustainability are mutually reinforcing. This suggests that government interventions, such as providing financial incentives for businesses adopting sustainable practices, could accelerate the adoption of green technologies (Gavkalova *et al.,* 2022). Such incentives might include tax breaks, subsidies, or preferential lending rates for projects that demonstrate clear environmental benefits. Furthermore, establishing strong regulatory frameworks that require or encourage environmental reporting and sustainable practices can further reinforce the importance of these investments. By fostering an economic environment that values sustainability, governments can induce a paradigm shift where businesses begin to view green investments as vital to their competitiveness and not just as regulatory compliance or public relations efforts. This approach not only benefits the environment but also enhances the long-term viability of businesses that adopt these practices, as it can lead to increased consumer and investor support for companies, leading to sustainability (Saura *et al.,* 2022b).

2. The influence of new business density on green economic development is significant, highlighting the role of new enterprises in fostering economic dynamics. Policies to simplify business creation and support for green startups could significantly impact the green economy. As noted by researchers, the emergence of new businesses, especially those committed to sustainable practices, injects innovation and vitality into the market, which can lead to broader economic and environmental benefits (Audretsch *et al.,* 2006). Facilitating the growth of green startups not only supports job creation but also promotes the dissemination of innovative green technologies and practices. To this end, governments can implement specific measures such as providing streamlined processes for business registration, reducing bureaucratic hurdles, and offering financial incentives such as grants, low-interest loans, or tax relief specifically targeted at green enterprises. Furthermore, establishing eco-industrial parks and offering preferential treatment for green businesses in public procurement can substantially boost these startups (Cohen & Winn, 2007). Moreover, fostering partnerships between academic institutions, industry leaders, and startups can accelerate the development and commercialization of sustainable technologies. By creating an ecosystem that nurtures collaboration, governments can ensure that green startups not only survive but also thrive and lead the way in sustainable development.
3. The importance of trade openness in enhancing green economy productivity is highlighted, suggesting that policies encouraging greater market openness could foster the adoption of green technologies. This connection between trade liberalization and environmental sustainability has been explored extensively in the literature, where it is argued that open markets facilitate the exchange of goods, services, and knowledge, including environmentally friendly technologies and sustainable practices (Frankel & Rose, 2005; Dean *et al.,* 2009). By lowering trade barriers, countries can access advanced technologies that might be too costly or complex to develop domestically, thereby accelerating their green transformation. Policies that promote trade openness should also be accompanied by measures that ensure that these technologies are adapted and utilized effectively within local contexts. This includes investing in domestic capabilities to absorb and implement new technologies, such as improving educational systems, supporting technical training, and fostering PPPs (Grossman & Helpman, 1991). Furthermore, to mitigate any potential negative impacts of trade on the environment, such as increased pollution from higher production volumes, trade agreements must include strong environmental provisions. These provisions enforce standards for environmental protection, encourage the use of green technologies, and promote sustainable resource management among trading partners (Copeland & Taylor, 2004; Dacko-Pikiewicz, 2019b).
4. The significant impact of innovation in environmental technologies suggests an area for policy support. Funding for research and development in green technologies should be a priority (Drożdż, 2019; Kwilinski, 2024). This emphasis is well supported by the literature that highlights how technological innovation drives the transformation toward a more sustainable economy (Jaffe *et al.,* 2005; Brych *et al.,* 2021; Kolosok *et al.*, 2022; Çidik *et al.,* 2023; Kwilinski, 2019). Governments should increase

the allocation of funds dedicated to the research, development, and diffusion of green technologies. This can include direct funding for public research institutions as well as incentives for private sector participation, such as tax credits or innovation grants. Moreover, fostering a supportive regulatory environment that encourages the adoption of new technologies is critical. Policies that reduce the risk associated with investing in new technologies catalyse private sector investment and innovation. For example, establishing predictable and stable policy frameworks can provide certainty that businesses need to invest in long-term R&D projects (Hall & Helmers, 2013). Collaboration between universities, government research institutions, and industry can further enhance the effectiveness of innovation in environmental technologies. Such partnerships can facilitate the transfer of knowledge and technology from research labs to market applications, accelerating the pace of innovation and its adoption in the marketplace (Cohen *et al.,* 2002; Kiselicki *et al.,* 2022; Veckalne *et al.,* 2023).

This article adds scientific value by providing a comprehensive empirical framework using advanced econometric models (GMM-SYS and GMM-FD) to analyse the dynamic relationship between entrepreneurship and green economic development in the EU from 2006 to 2022. It highlights the critical role of new business density in driving sustainable economic practices within the context of EU policies. Furthermore, it enriches the empirical understanding of how macroeconomic factors such as gross national income and trade openness impact green economy productivity, offering valuable insights for policymakers and stakeholders.

Despite these valuable findings, this study has several limitations that future investigations could address. Constraints related to data availability and quality may have restricted the breadth and depth of the analysis, potentially limiting the representativeness of the results. Furthermore, the study's focus on specific variables might have overlooked other influential factors, leading to potential bias from omitted variables. Concerns regarding the stationarity of variables, as well as the adequacy of the sample size and scope, further underscore the need for cautious interpretation of the findings. Future research could benefit from enhanced data collection efforts, methodological refinements, and broader considerations of variables such as technological advancements, regulatory changes, consumer behaviour, and environmental policies. Incorporating cross-country comparisons and assessments of long-term dynamics would also contribute to a more comprehensive understanding of green economic development. These endeavours would strengthen the empirical base, provide deeper insights into the multifaceted nature of green economic practices, and offer more robust policy recommendations for fostering sustainable economic growth.

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