7 GREEN FINANCES AND INDUSTRIAL OPTIMIZATION: PATHWAYS TO FINANCIAL DEVELOPMENT AND SUSTAINABLE GOALS IN EUROPE

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Abstract

Europe has initiated a phase characterized by heightened ecological consciousness, facilitating its advancements in pursuing the Sustainable Development Goals (SDGs) and stimulating its financial growth. This research investigates the correlation between green finance, innovation in the industrial sector, and the influence of policy instruments on financial development and attaining the SDGs in countries of the European Union (EU). The findings of the analysis, which utilizes data spanning from 2000 to 2022, demonstrate a substantial positive correlation between green finances and financial growth and SDG fulfillment. In the same way, fiscal stimulus, foreign direct investment (FDI), industrial value addition, and ecological technologies stimulate financial development. In addition, policy instruments such as carbon levies, green laws, and production-related mitigation technology have effectively contributed to advancing SDG objectives. In contrast, the study finds that challenges such as population growth, economic globalization, and traditional energy consumption greatly impede SDG advancement. Notably, the synergistic impacts of innovation combined with clean energy adoption appear critical, potentially transforming SDG outcomes in the EU. Therefore, the EU should support green finance efforts, boost sustainable industrial breakthroughs, and reform its legislative frameworks to mitigate globalization and traditional energy use faster to attain its SDG goals.

Keyword: Green Finances; Sustainable development goals; policy instruments; industrial output; Environmental Preservation; Green Innovation; Europe

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1. Introduction

Europe is undergoing a substantial change, propelled by a resolute commitment to sustainability (Khurshid et al., 2024a). This commitment is creating new avenues for social progress and redefining the limits of financial and economic progress (Khan and Khurshid, 2024). Industrial innovation convergence and its various impacts on monetary, economic development, and emission management become paramount in this scenario (Khurshid et al., 2024b). At the moment, we must achieve a harmonious equilibrium between sustainability and progress. There’s a growing fascination with examining the role of business innovation in advancing both environmental conservation and economic success as Europe embraces more sustainable practices (Li et al., 2023). The European Union recognizes the need to broaden the scope of the SDGs in light of the industrial chain’s substantial influence on ecological degradation throughout Europe (Wang et al., 2022). The EU Commission has officially embraced the Responsible Consuming and Production and Corporate Policies Plan of Action (Lélé, 1991) to endorse EU sustainable product policies. The European Union member states have exhibited a noteworthy commitment to achieving the Sustainable Development Goals (Khurshid et al., 2023a). Nevertheless, prior studies showed that the region had not managed to effectively promote ecologically sustainable industry and consumerism (Usman et al., 2022).

The current context has witnessed significant attention towards advances in technology aimed at mitigating environmental degradation and achieving the SDGs (Khurshid and Khan, 2021). The methodical analysis of the effect of scientific progress on attaining SDGs has achieved minimal advancements over the years. In recent empirical research, Khan et al. (2022) and Khurshid et al. (2024d) have shown persuasive evidence regarding the substantial influence of innovation in alleviating GHG emissions. The United Nations views innovation—crucial to technological advancement—as a key indicator of the SDGs (Saleem et al., 2024). Governments are implementing reforms in their industrial sectors to meet the SDGs’ aims, focusing on enhancing green procedures (Xie et al., 2022). Certain countries, such as Sweden, Denmark, and Norway, have made some headway toward achieving these noteworthy achievements (Chen et al., 2023). However, many countries worldwide have not adequately implemented strategies to aid the adaptation process to climate change’s consequences (Cheng et al., 2021). The industrial sector can have huge and far-reaching environmental repercussions from implementing ecologically beneficial technology, such as grid modernization, renewable energy sources, and carbon storage systems (Ulucak & Khan, 2020). However, the adoption of these technologies is hindered by various barriers, such as high costs and a lack of infrastructure. Governments, businesses, and research institutions must work together to solve these problems and accelerate the transition to a more sustainable future.

Europe’s sustainability strategy places a strong emphasis on green finance. The industry has experienced rapid and significant expansion since financial instruments have been essential in directing funding for endeavors that promote sustainable development (Khurshid et al., 2022a). These financial tools are necessary to support green infrastructure, clean energy projects, and other SDG-related activities (Khurshid et al., 2020). A notable instance of such an endeavor is the European Green Deal, which aims to make sustainable investments totaling at least €1 trillion over the next ten years to make the continent carbon neutral (Khurshid et al., 2022b). Furthermore, these financial mechanisms support environmental goals and provide attractive returns for investors, making sustainability a viable option. As the demand for sustainable investments continues to rise, more opportunities for green financing are expected to emerge in the global market. The green finances encourage investors to focus on the long-term benefits of environmentally conscious projects. This can lead to greater financial returns and a more sustainable future (Duan et al., 2024). As a result, it leads to green innovation in various industries and sectors. This shift will strengthen the financial sector and help achieve the SDGs, ultimately contributing to a healthier planet for future generations.

Industry and finance are interdependent, with innovation driving financial growth (Khurshid et al., 2024c). Similarly, technology innovation relies on the financial system for support and efficiency (Qiang et al., 2019). The process involves gathering and analyzing data, dispersing risks, and providing finance (Lv et al., 2021). Effective financial sectors boost stock market performance and economic activity, making them more enticing to investors. The financial sector is crucial for GDP growth because it encourages FDI and optimizes growth (Khan et al., 2022). The extant literature investigates the correlation between technological innovation and financial development in the theoretical framework concerning financial performance growth and development (Khurshid et al., 2024d). The financial system has a significant role in keeping up with cutting-edge technology and enhancing efficiency. This is accomplished through various processes involving acquiring data and analysis, risk diversification, and credit allocation. Finance, in opposition to the "New Normal," has been crucial to sustaining economic growth and advancing industrial restructuring (Wen et al., 2021). In addition, financial institutions have also been instrumental in providing the necessary funding and resources for research and development in emerging technologies. Integrating green finance and technology has become increasingly important in driving economic growth and achieving the SDGs.

In light of the preceding, the research aims to inspect the intricate links in the European context among green finances, industrial optimization, financial development, and sustainable growth. The research objectives can be adequately expressed in the following manner:

- How does innovation in industry and green financing contribute to attaining the SDGs in Europe?
- How are trade globalization, green finance, industrial value-added, foreign direct investment, and governmental investments contributing to the financial advancement of European economies?
- Does the convergence of industrial automation and green energy contribute to Europe's transition to a sustainable course?
- What role do financial development, industrial innovation, energy efficiency, environmental regulation, ecological taxation, and economic globalization play in Europe's green transformation?

The article's originality is derived from its comprehensive perspective, empirical verification, and pragmatic suggestions, which make noteworthy additions to the scholarly conversation surrounding green finance and industrial strategy within the framework of the European SDGs.

Firstly, the study examines the role of green financial mechanisms as both funding providers for environmentally friendly projects and crucial instruments for promoting broader financial growth that aligns with the SDGs. Its dual role facilitates understanding the multifaceted impact of green money beyond traditional environmental advantages.

Secondly, this study explores the interdependent connection between industrial optimization, encompassing enhanced efficiency and waste reduction, and its impact on the financial sector's capacity to facilitate sustainable initiatives effectively. This perspective presents a unique approach by emphasizing the role of operational enhancements in industries as a driving force for improving green financial flows. Lastly, in contrast to several studies on prospective effects, this publication intends to employ empirical SDG data to assess the efficacy of current policies that combine green financing with industrial and financial optimization to achieve SDGs. This empirical method provides a firm foundation for policy suggestions for policymakers to consider when aiming to achieve sustainable development goals.

The current investigation is organized into several segments to tackle the research objectives analytically. Unit 2 of this research paper scrutinizes earlier studies. Unit 3 details the study techniques and defines the factors. Subsequently, the findings and discussion follow. In the last part, the conclusion and implications are outlined.

2. Literature review

Europe's commitment to ecological preservation has led to a strong desire to understand the intricate relationships between green finance, innovation in industry, FD, and the SDGs. This interest has resulted in a growing amount of research investigating how the above variables relate to and affect one another. This section provides context for the present studies and critically analyzes the available literature.

2.1. Industrial innovation and sustainable development

Industrial innovation is essential to solving the socioeconomic and environmental issues associated with the global mandate of sustainable development. The literature recently examined the relationship between innovation in industry and sustainable development, highlighting the prospects and difficulties in this area.

Environmental sustainability promotion is a pivotal domain in which industrial innovation can positively impact sustainable development. Examining the ramifications of technological advancements on detrimental emissions has been inactive for a considerable time. However, a significant amount of recent research has offered empirical proof of the value of eco-innovation in reducing pollutants (Khurshid and Deng, 2021), which can help achieve the SDGs (Khurshid et al., 2024f). The necessity to investigate the effect of II on China's carbon intensity was highlighted by research by Ren et al. (2022). The results of the study showed that using II had a positive impact on sustainable development by reducing ecological repercussions. Nihal et al. (2023) conducted a study to investigate the relationship between economic growth and technological advancements in the G8 countries between 1996 and 2020. The findings point to a strong correlation between GDP growth and innovation. Lower carbon emissions were linked to green innovation, mainly when green technology was applied instead of carbon-heavy options, according to Shang et al. (2023). However, studies by academics, such as Jian and Afshan (2023) on G-10 countries, Hailiang et al. (2023) on BRICS, Zhang and Chen (2023) on 37 cities in the Yangtze River Delta, and Cao (2023) on E-7 countries, showed that II made a substantial impact on protecting the environment by lowering carbon footprints (Wang et al., 2023). However, there is still an extensive gap in the research regarding a detailed look at how industrial innovation affects pollution and sustainability from an industrial point of view. This argument is true for industrialized nations such as Europe, where pollution is mainly a result of industrial activity.

2.2. Green Finances, FD, and SDGs

Sustainable development is becoming more important in tackling environmental and social issues worldwide. However, attaining the SDGs will necessitate enormous financial backing, which conventional financial channels may be unable to offer (Khurshid et al., 2024b). Green finance has emerged as a critical tool for raising the cash required to promote sustainable development in this setting. Green finance supports ecologically sustainable economic activity with financial goods and services (Rajeev and Chakraborty, 2023). This includes green programs like green power, energy efficiency, and agricultural sustainability. The acknowledgment that traditional financial approaches may not be adequate to meet these difficulties, greater broad recognition of global warming, and the necessity for equitable growth have all led to the expansion of sustainable financing (Ngo et al., 2022). Banga (2019) and Flammer (2021) state that these financial instruments comprise ecological investments, loans, and bonds. Those looking to make their investments more environmentally conscious demand these financial systems. Therefore, numerous scholarly investigations have underscored the capacity of green finance to bolster the achievement of the SDGs (Khurshid et al., 2022a). Wang et al. (2019) explored how green finance can achieve SDG 13 and SDG 7. The study concluded that green finance efforts like renewable energy investments and energy efficiency upgrades can considerably reduce carbon footprints and promote sustainable energy availability. Green bonds have become a notable instrument within the realm of green finance. The purpose of these fixed-income instruments is to provide funding for environmentally advantageous activities (Flammer, 2021). The alignment of profits from green bonds with particular SDGs has been studied recently. Bhutta et al. (2022) examined the effects of Swedish green bonds on several SDGs. Their research found that the SDGs—SDG 11 and SDG 7—were the main beneficiaries of green bonds (Khurshid et al., 2023b). The articles stressed the significance of thorough reporting and openness procedures to efficiently guarantee that green bond funds are allocated to sustainable projects.

Green financing can significantly advance the SDGs, but several obstacles remain. These include a lack of established definitions and measures, a scarcity of green financial products, and questions about the financial sustainability of sustainable investments (Taghizadeh-Hesary and Yoshino, 2020). They also underlined the significance of fostering public-private cooperation and bolstering institutional capability to expand green financing initiatives. Recent studies have also investigated novel methodologies in the realm of green finance. For example, Arshad et al. (2023) looked into how blockchain and digital technologies could make green financing solutions possible. Their research demonstrated how artificial intelligence, blockchain technology, and big data analytics can improve the handling of risks, openness, and oversight in green finance initiatives.

The literature implies that green finance can mobilize financing for a sustainable future to help achieve the SDGs. The growing acknowledgment of green finance, supportive legislation, and novel financial tools offer significant potential to expedite the shift to a more sustainable future.

2.3. Industrial Innovation and FD

Industrial innovation can have far-reaching and intricate effects on financial growth. According to Khurshid et al. (2024a), industrial innovation can foster the development of new industries, goods, and services, thus opening up fresh avenues for investment and stimulating economic expansion. Furthermore, industrial innovation can potentially raise the profitability and investment of current industries by enhancing their competitiveness and efficiency (Khan et al., 2024). Furthermore, the emergence of fresh investments and financial instruments that facilitate financing expansion and innovation can aid in advancing financial markets. For example, ESG investments such as green bonds have emerged in response to the growing need for green investments and the necessity to fund eco-friendly initiatives and technology (Flammer, 2021; Khurshid et al., 2024d). Moreover, industrial innovation can promote financial development by improving funds' availability and alleviating financing limitations. According to Duan et al. (2024), small and medium-sized businesses can benefit from new channels for financing and a decrease in reliance on conventional banks thanks to innovative financial technologies like blockchain, peer-to-peer funding, and crowdfunding.

Notwithstanding these obstacles, the connection between FD and industrial innovation is complex. Economic innovation within the industrial sector has the potential to generate unexpected risks and uncertainties, thereby engendering financial turbulence and volatility. Elliott et al. (2021) argue that swift technological progress can result in the demise of conventional enterprises and the emergence of novel marketplaces and power dynamics. These developments can significantly impact monetary stability and regulatory frameworks (Li et al., 2023; Khurshid et al., 2022b). Financial development has various problems, even while industrial innovation presents intriguing possibilities (Ma et al., 2023). The factors above encompass the necessity of establishing strong regulations to guarantee financial stability and safeguard consumer interests, along with advancing the digital infrastructure and competencies to facilitate the integration of cutting-edge financial technology (Xuanling and Meng, 2023).

In conclusion, industrial innovation positively and negatively affects financial development; the relationship is intricate and multidimensional. Moreover, the mechanisms, dynamics, and policy and regulatory consequences of this relationship for financial development need further study.

3. Data and Method

3.1. Data

The empirical association of green finances (GFN), industrial innovation (II) with SDGs, and financial development (FD) is evaluated for 25 European nations together with other relevant independent variables. The chosen period spans from 2000 to 2022, determined by considerations of access to data and coherence. The data utilized in this study has been sourced from the OECD statistics published on the website OECD-ilibrary.org/statistics and sustainable development report (https://dashboards.sdgindex.org/explorer). The data is converted to logarithm form before the empirical testing. Table I presents a comprehensive summary of the parameters utilized in this research.

Table 1. Variables description

Variable	Abbrev.	Variable	Abbrev.
Financial Development	**FD**	Industrial Innovation	**II**
Energy efficiency	**EEF**	Fiscal expenditure	**FE**
Financial globalization	**FGB**	Economic globalization	**EGB**
Energy consumption in industries	**ECI**	Environmental Policy	**EPY**
Ecological Taxes	**ETX**	Green Finances	**GFN**
Total population	**POP**	Industrial Value added	**IVA**
Production based emission	**PBE**	Renewable energy	**RNG**

3.2. Empirical Modeling

The panel regression framework incorporates two dependent variables, namely FD and SDG. This study examines the influence of GFN and II on the FD and SDG through the individual estimation of three mathematical models, which are presented in the following formats:

$$lnFD_{it} = f(lnII_{it}, lnGFN_{it},\ lnFE_{it}, lnTGB_{it}, lnIVA_{it}, lnFDI_{it}) \quad (1)$$

where FD is the dependent variable while parameters II, GFN, FE, TGB, IVA, and FDI exhibit independent variables. The following two models, which incorporate the concepts of SDGs, FD and GFN, can be expressed in Equations 2 and 3.

$$lnSDG_{it} = f(lnGFN_{it}, lnEPY_{it},\ lnECI_{it}, lnPBE_{it}, lnPOP_{it}, lnINRE_{it}) \quad (2)$$

$$lnSDG_{it} = f(lnETX_{it}, lnEPY_{it},\ lnRNG_{it}, lnMTP_{it}, lnFD_{it}, lnEGB_{it}) \quad (3)$$

The subject parameter SDG_{it} in Equations 2 and 3 is dependent variables, whereas GFN, RD, ECI, EPY, ETAX, and REG coefficients exhibit temporal variability.

3.3. Methodology

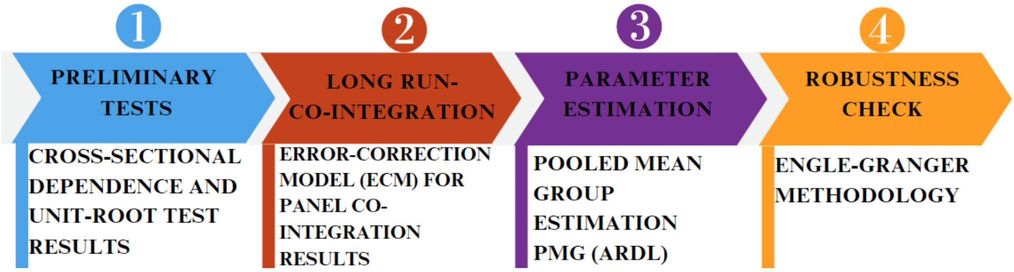
This investigation uses the following techniques to achieve its objectives. Figure 1 shows the process flow chart. Following descriptive stats, the investigators conducted a cross-section dependence (CRSD) analysis to assess the influence of perturbs on panel data (Wang et al., 2022). The absence of CRSD in a study can lead to misleading results (Pesaran, 2015). The data is tested for cross-sectional dependence using the CRSD test suggested by Pesaran (2015). The Westerlund panel co-integration approach (2007) is used to examine the correlations between the variables. The results of this method rely on panel statistics (Pt, Pa) and group statistics (Gs, Ga). The Westerlund (2007) error-correction-based tests are founded on the theorem of Engle and Granger (1987). It states that the two variables co-integrate if an error correction representation exists for either or both of the variables.

The reliability of first-generation unit-root tests is undermined if it is demonstrated that CRSD exists in the panel data. The second-generation tests, especially Pesaran's (2007) CIPS test, are used in this study to find a unit root. Next, test for co-integration after reviewing the variable's integration order. This is done with the Westerlund (2007) co-integration panel test. This technique addresses autocorrelation, CRSD, and structural break. The null hypothesis states that the parameters have no long-term association. Pedroni (2004) highlighted that this approach can help reduce estimation bias when factors are stationary at both the level and first difference.

This study uses the Pooled MG approach (PMG-ARDL) to examine the long-term and short-term association among the parameters under investigation. This examination verifies the assessments' reliability (Pesaran et al., 1999, 2001). Furthermore, variables must be co-integrated in the same integration sequence in order to reveal the long-term correlations (Johnsen, 1988; Phillips & Hansen, 1990). However, the Pesaran & Shin (1995) ARDL approach applies when the variables are mixed correlated or stationary at the level or first difference. According to Pesaran et al. (1999), the PMG-ARDL technique incorporates reaction slacks and descriptive properties, hence yielding dependable coefficients even in the presence of endogeneity.

The current study utilizes the Engle and Granger approach to validate the results. The Engle-Granger methodology is a commonly employed technique for examining the presence of co-integration among two or more time series. The following is a detailed step-by-step description of the Engle-Granger methodology. The initial stage entails evaluating whether the individual time series integrate in the same order. Next, an OLS regression will be conducted to calculate the residuals and represent the long-run relationship. The series are co-integrated if the residuals are stationary. Finally, conducting tests on short-term fluctuations while also considering the long-term equilibrium of variables (Engle and Granger, 1987).

Figure 1. Research Flow Chart



4. Results and Discussion

4.1. Primary Results

Table 2 presents the descriptive statistics for all variables prior to analysis, allowing for statistical investigation of the variables. PBE has the greatest average value among the parameters that indicate different facets of industrialization. On the other hand, the indicator EPY shows the smallest mean value. It is also important to note where the PBE approach yields the most notable standard deviation, with FD displaying the next-highest number. This suggests that a significant amount of volatility is present in each of PBE and FD. However, most variables have modest standard deviation values, indicating that the variability is restricted while their averages fairly represent the true values. The findings of the CSRD test validate the alternative hypothesis. The results of this investigation confirm the existence of CRSD in a sample that includes all EU nations, thus emphasizing their interdependence. Furthermore, Table 2 illustrates the results of the CIPS test. It is apparent from the outcomes that stationarity is present for each of the factors concerning the first difference. As a result, few of these characteristics show stationarity at the level, whereas the majority are incorporated at the first difference. Therefore, in the case of PMG (ARDL), the error correction-based panel co-integration techniques are more appropriate (Khurshid et al., 2023a).

Table 2. Descriptive-unit root and Cross-Sectional outcomes

								CIPS		CD-test
Stats	**MEAN**	**STD. DEV.**	**VAR**	**SKN**	**KTS**	**MAX**	**MIN**	*Level*	*1-diff*	
SDG	77.96	3.520	12.39	0.220	2.645	86.76	69.66	-2.489**	-4.983***	56.49***
PBE	140.7	189.2	358.1	2.093	7.028	846.9	1.470	-2.516**	-4.351***	38.47***
GFN	9.119	1.703	2.901	-0.240	2.220	12.28	5.159	-1.864	-4.505***	55.99***
II	46.59	12.85	165.2	1.608	8.767	130.5	17.48	-3.33***	-5.643***	8.54***
EGB	78.77	6.969	48.57	-0.261	2.221	92.85	57.80	-1.94	-4.568***	34.02***
ECI	16.06	20.24	409.5	1.854	5.696	85.91	0.564	-2.344	-4.916***	10.99***
EPY	1.975	1.009	1.019	-0.087	2.054	4.222	0.001	-5.08***	-6.047***	-2.05***
FD	89.09	40.66	1653.5	1.160	5.186	304.6	23.38	-1.323	-3.315***	13.52***
TGB	77.17	7.370	54.32	-0.284	2.180	90.06	56.97	-2.128**	-4.09***	29.99***
IVA	24.61	1.712	2.930	-0.243	2.086	27.71	21.04	-1.442	-3.683***	51.12***
REG	31.11	45.22	2044.6	2.026	7.060	250.2	0.010	-1.918	-4.218***	48.58***

4.2. Panel Co-integration Results

The estimation results of the four co-integration analyses recommended by Westerlund (2007) are reported in Table 3. The outcomes reject the null hypothesis of no co-integration. This indicates that the variables exhibit long-term co-integration in all three models, indicating a stable long-term equilibrium relationship among them.

Table 3. Co-integration Outcomes

Statistic	Value	Z-value	Value	Z-value	Value	Z-value
	1		2		3	
Gt	-3.58***	-1.27	-3.25***	1.05	-2.82**	1.701
Ga	-11.04***	-4.71	-10.65***	4.87	-11.37**	6.373
Pt	-6.48***	-5.35	-11.83***	5.87	-13.98***	5.229
Pa	-8.15***	-4.29	-8.98***	3.21	-11.76***	4.689

Note: *** $p < .01$, * $p < .10$, ** $p < .05$,

4.3. PMG-ARDL outcomes

This study investigates how II and GFN affect FD and SDGs in a panel setting through the PMG-ARDL method. The outcomes produced by using the three models are summarized in Table 4.

The results of empirical model 1, which has FD as the dependent variable, show that all of the independent variables—II, GFN, FE, IVA, FDI, and TGB—significantly drive up FD in EU countries in the long and short run. This confirms the significance of the variables chosen in determining the FD status of the European countries and, additionally, pinpoints the possible areas that policymakers should focus on to improve the FD of the EU countries. The results display that II causes a 31% change in FD, whereas GFN promotes it by 121.2% in the countries' understudy in the long run. Whereas 33.6% and 210.8% in the short run. The outcomes support the findings of Khurshid et al. (2024d) and Khan et al. (2024). This underscores the significance of these factors in shaping the financial development environment of EU countries. Moreover, the findings provide specific guidance to policymakers seeking to enhance regional financial development. Policymakers can contribute to the economic growth of EU member states and enhance the financial sector in several distinct ways. For example, through financial development, green investment via FE or FDI can facilitate a transition to a more resilient and sustainable economy. It will enhance the IVA, thereby bolstering the TGB's status. This will ultimately lead to long-term sustainable growth and stability in the region.

Models 2 and 3 show that GFN and MTP positively influence the SDGs, whereas PBE has a negative impact in both the short and long-run. The results illustrate that GFN and MTP cause a 277.7% and 6.1% positive change in SDGs in the long run and 292.3% and 6.6% in the short run. In contrast, PBE restricts it to 1.1% and 3.1% in the long-run and short-run, respectively. The research findings suggest that aligning production processes with mitigation technologies and green finance helps achieve the SDGs. On the contrary, emissions stemming from production activities hurt the SDGs. This suggests that conventional production methods might impede advancements toward these global objectives by exacerbating environmental degradation. The results align with those of Khurshid et al. (2023a). Policy tools such as EPY and ETX are working well, benefiting the environment and positively linking to SDGs in both the short and long run. Environmental advancements significantly aid policy instruments such as ecological taxes and policies. These instruments have a positive relationship with the SDGs, emphasizing their importance in encouraging sustainable practices. The results endorse the empirical findings of Khurshid *et al.* (2024f). The results further revealed that ECI, POP, and EGB are hindering the SDGs in EU countries. The ECI contributes 3.84%, EGB 17.0% in the long run, and POP contributes the most with a coefficient value of 2.283 in the long run; as it upsurges the industrial demand, so do emissions. These results highlight the obstacles to sustainable development in the EU that come from population growth, economic globalization, and industrial energy demands. The significance of the interaction term INRE (innovation*renewable energy) in reaching the SDGs emphasizes the critical need for proactive legislative action and technical advancements. The coefficient value indicates that INRE helps the EU achieve the SDGs by 134.1% and 199.1%

in the long and short run, respectively. This shows how combining clean energy with new industrial technologies can help the EU achieve its goal of making better products for the world.

The study shows that green financing boosts financial development and makes SDGs easier to accomplish. Industrial value addition, green innovation, FDI, and government expenditures further promote financial development, strengthening economic resilience and sustainability. Similarly, environmental laws, production-related mitigation technology, and carbon taxes have advanced the SDGs, highlighting the necessity for targeted regulatory measures to advance environmental progress. In contrast, growing populations, economic globalization, and industry energy consumption are major SDG obstacles in EU countries. The potential transformative impact of renewable energy and innovation collaboration on the SDGs suggests that EU member states could attain more sustainable goals in both sectors. This detailed analysis highlights the complexity of financial, ecological, and policy concerns in sustainable development scenarios.

Table 4. PMG-ARDL Results

	FD			1. SDGs			2. SDGs	
	LR	***SR***		***LR***	***SR***		***LR***	***SR***
__ec		-0.217*** (0.014)			-0.193*** (0.051)			0.072*** (0.001)
II	0.310*** (0.101)	0.336** (0.116)	***GFN***	2.777*** (0.121)	2.923*** (0.101)	***ETX***	2.234** (1.011)	2.146*** (0.959)
GFN	1.212** (0.545)	2.108** (0.928)	***EPY***	0.402** (0.161)	0.781** (0.360)	***EPY***	0.0611* (0.028)	0.255* (0.108)
FE	1.402*** (0.677)	0.77** (0.320)	***ECI***	-0.384* (0.123)	-0.056** (0.018)	***RNG***	0.050*** (0.0091)	0.055*** (0.002)
TGB	1.16*** (0.460)	0.96*** (0.275)	***PBE***	-0.011*** (0.0025)	-0.031*** (0.009)	***MTP***	0.061** (0.028)	0.066* (0.021)
IVA	2.28** (1.04)	1.041*** (0.366)	***POP***	-2.283*** (0.936)	-3.352*** (0.916)	***FD***	0.433** (0.196)	0.124** (0.024)
FDI	3.645*** (1.035)	1.904*** (0.841)	***INRE***	1.341*** (0.461)	1.991*** (0.852)	***EGB***	-0.170*** (0.022)	-1.555*** (0.421)
Con.	-16.2** (7.92)	-66.3*** -26.1		47.18*** (17.03)	-31.63** (13.67)		43.37*** (16.93)	44.65*** (17.85)
Obs.	414	414		414	414		414	414

*Note: *** p < 0.001, ** p < 0.01, * p < 0.05*

4.4. Robustness Outcomes

The current study utilizes the Engle and Granger two-step process approach to validate the results. The results are summarized in Table A (see appendix). The results show that GFN, II, MTP, and policy tools all help reach the SDGs and promote financial growth. The results also show the significance of II and RNG in putting this region on a path to sustainability. It also reinforces what was previously found with the PMG-ARDL. The independent factors had an effect similar to what was seen before regarding direction and significance.

5. Conclusion and Implications

This study is significant because it evaluates the effects of green finance, industrial sector innovation, and various policy instruments on financial development and the achievement of the

SDGs in EU member states. The analysis is based on data collected between 2000 and 2022. The study sheds light on the interconnected effects of these variables on EU finances and ecosystems.

The results show that green finances positively impact both financial development and advancement toward the SDGs. This underscores how important sustainable investment is for supporting an eco-friendly economy. Similarly, it has been noted that enhancing financial development is greatly facilitated by integrating green innovation and industrial value addition. The improvement is facilitated by fiscal expenditures and foreign direct investment (FDI), which boost financial growth and support sustainability initiatives. In addition, the study shows the effectiveness of policy instruments. The evidence shows that carbon levies, environmental laws, and manufacturing-related mitigation solutions all contribute to the successful completion of the SDGs. The EU's policy framework understands the importance of these tools in lowering environmental damage and encouraging environmentally friendly business practices. Nonetheless, the SDGs are not readily achievable due to conventional energy consumption patterns, population growth, and economic globalization. These traits create complications requiring new policy solutions to lessen the detrimental impacts they cause.

The potential synergy between innovation and renewable energy significantly impacts the SDGs. This correlation suggests an essential way for EU member states to enhance their efforts towards sustainability. The EU can effectively confront the obstacles presented by the current financial globalization process and conventional energy consumption by prioritizing the development of renewable energy.

Policy Implications:

Strengthening Green Finance Structures: EU officials should contemplate augmenting incentives for green finance decisions to optimize their beneficial impact on sustainable environmental objectives and long-term economic expansion.

Encouraging Industrial Innovation: Promoting industrial innovation and implementing eco-friendly technologies can positively impact economic development and environmental sustainability.

Revision of Policy Frameworks: Revising policy frameworks is imperative to mitigate the detrimental impacts of globalization, population growth, and traditional energy consumption. This may necessitate stricter environmental regulations and laws to reduce the industrial sector's carbon footprint.

Investments in innovations and renewable energy: Renewable energy and related developments have demonstrated a substantial capacity to further the SDGs; therefore, the EU should prioritize investing in them. Strategic investments in these areas possess the capacity to significantly impact the energy sector and contribute to the achievement of broader sustainability goals.

References

Arshad, A., Shahzad, F., Rehman, I.U. and Sergi, B.S., 2023. A systematic literature review of blockchain technology and environmental sustainability: Status quo and future research. *International Review of Economics & Finance*, 88, pp.1602-1622. https://doi.org/10.1016/j.iref.2023.07.044

Banga, J., 2019. The green bond market: a potential source of climate finance for developing countries. *Journal of Sustainable Finance & Investment*, *9*(1), pp.17-32. https://doi.org/10.1080/20430795.2018.1498617

Bhutta, U.S., Tariq, A., Farrukh, M., Raza, A. and Iqbal, M.K., 2022. Green bonds for sustainable development: Review of literature on development and impact of green bonds. *Technological Forecasting and Social Change*, *175*, p.121378. https://doi.org/10.1016/j.techfore.2021.121378

Cao, L., 2023. How green finance reduces CO2 emissions for green economic recovery: Empirical evidence from E7 economies. *Environmental Science and Pollution Research*, *30*(2), pp.3307-3320. https://doi.org/10.1007/s11356-024-34164-2

Chen, Y., Khurshid, A., Rauf, A., Yang, H. and Calin, A.C., 2023. Natural resource endowment and human development: Contemporary role of governance. *Resources Policy*, 81, p.103334. https://doi.org/10.1016/j.resourpol.2023.103334

Cheng, C., Ren, X., Dong, K., Dong, X. and Wang, Z., 2021. How does technological innovation mitigate CO2 emissions in OECD countries? Heterogeneous analysis using panel quantile regression. *Journal of Environmental Management*, 280, p.111818. https://doi.org/10.1016/j.jenvman.2020.111818

Duan, W., Khurshid, A., Khan, K. and Calin, A.C., 2024. Transforming industry: Investigating 4.0 technologies for sustainable product evolution in china through a novel fuzzy three-way decision-making process. *Technological Forecasting and Social Change*, *200*, p.123125. https://doi.org/10.1016/j.techfore.2023.123125

Elliott, M., Georg, C.P. and Hazell, J., 2021. Systemic risk shifting in financial networks. *Journal of Economic Theory*, *191*, p.105157. https://doi.org/10.1016/j.jet.2020.105157

Engle, R.F. and Granger, C.W., 1987. Co-integration and error correction: representation, estimation, and testing. *Econometrica: journal of the Econometric Society*, pp.251-276. https://doi.org/10.2307/1913236

Flammer, C., 2021. Corporate green bonds. *Journal of financial economics*, *142*(2), pp.499-516. https://doi.org/10.1016/j.jfineco.2021.01.010

Hailiang, Z., Iqbal, W., Yin Chau, K., Raza Shah, S.A., Ahmad, W. and Hua, H., 2023. Green finance, renewable energy investment, and environmental protection: empirical evidence from BRICS countries. *Economic research-Ekonomska istraživanja*, *36*(2), p.2125032. https://doi.org/10.1080/1331677X.2022.2125032

Jian, X. and Afshan, S., 2023. Dynamic effect of green financing and green technology innovation on carbon neutrality in G10 countries: fresh insights from CS-ARDL approach. *Economic Research-Ekonomska Istraživanja*, *36*(2), p.2130389. https://doi.org/10.1080/1331677X.2022.2130389

Khan, K. and Khurshid, A., 2024. Are technology innovation and circular economy remedy for emissions? Evidence from the Netherlands. *Environment, Development and Sustainability*, *26*(1), pp.1435-1449. https://doi.org/10.1007/s10668-022-02766-w

Khan, K., Khurshid, A., Cifuentes-Faura, J. and Xianjun, D., 2024. Does renewable energy development enhance energy security?. *Utilities Policy*, *87*, p.101725. https://doi.org/10.1016/j.jup.2024.101725

Khan, K., Su, C.W. and Khurshid, A., 2022. Circular economy: the silver bullet for emissions?. *Journal of Cleaner Production*, *379*, p.134819. https://doi.org/10.1016/j.jclepro.2022.134819

Khurshid, A. and Deng, X., 2021. Innovation for carbon mitigation: a hoax or road toward green growth? Evidence from newly industrialized economies. *Environmental Science and Pollution Research*, *28*, pp.6392-6404. https://doi.org/10.1007/s11356-020-10723-1

Khurshid, A., Huang, Y., Cifuentes-Faura, J. and Khan, K., 2024a. Beyond borders: assessing the transboundary effects of environmental regulation on technological development in Europe. *Technological Forecasting and Social Change*, *200*, p.123212. https://doi.org/10.1016/j.techfore.2024.123212

Khurshid, A., Huang, Y., Khan, K. and Cifuentes-Faura, J., 2024d. Innovation, institutions, and sustainability: Evaluating drivers of household green technology adoption and environmental sustainability of Africa. *Gondwana Research*, *132*, pp.88-102. https://doi.org/10.1016/j.gr.2024.03.012

Khurshid, A. and Khan, K., 2021. How COVID-19 shock will drive the economy and climate? A data-driven approach to model and forecast. *Environmental Science and Pollution Research*, *28*(3), pp.2948-2958. https://doi.org/10.1007/s11356-020-09734-9

Khurshid, A., Khan, K., Chen, Y. and Cifuentes-Faura, J., 2023a. Do green transport and mitigation technologies drive OECD countries to sustainable path?. *Transportation Research Part D: Transport and Environment*, *118*, p.103669. https://doi.org/10.1016/j.trd.2023.103669

Khurshid, A., Khan, K. and Cifuentes-Faura, J., 2023b. 2030 Agenda of sustainable transport: Can current progress lead towards carbon neutrality?. *Transportation Research Part D: Transport and Environment*, *122*, p.103869. https://doi.org/10.1016/j.trd.2023.103869

Khurshid, A., Khan, K., Cifuentes-Faura, J. and Chen, Y., 2024c. Asymmetric multifractality: Comparative efficiency analysis of global technological and renewable energy prices using MFDFA and A-MFDFA approaches. *Energy*, *289*, p.130106. https://doi.org/10.1016/j.energy.2023.130106

Khurshid, A., Khan, K., Khan, S. and Cifuentes-Faura, J., 2024f. Tackling sustainable development challenges: A fuzzy set examination of textile industry 4.0 and green supply chain barriers. *Sustainable Development*. https://doi.org/10.1002/sd.3061. https://onlinelibrary.wiley.com/doi/abs/10.1002/sd.3061

Khurshid, A., Khan, K., Rauf, A. and Cifuentes-Faura, J., 2024b. Effect of geopolitical risk on resources prices in the global and Russian-Ukrainian context: A novel Bayesian structural model. *Resources Policy*, *88*, p.104536. https://doi.org/10.1016/j.resourpol.2023.104536

Khurshid, A., Kedong, Y., Calin, A.C., Zeldea, C.G., Qiang, S. and Wenqi, D., 2020. Is the relationship between remittances and economic growth influenced by the governance and development of the financial sector? New evidence from the developing countries. *Romanian Journal of Economic Forecasting*, 23(1), pp.37-56.

Khurshid, A., Qayyum, S., Calin, A.C., Saleem, S.F. and Nazir, N., 2022a. The role of pricing strategies, clean technologies, and ecological regulation on the objectives of the UN 2030 Agenda. *Environmental Science and Pollution Research*, 29, pp.31943-31956. https://doi.org/10.1007/s11356-021-18043-8

Khurshid, A., Rauf, A., Calin, A.C., Qayyum, S., Mian, A.H., Qayyum, S. and Fatima, T., 2022b. Technological innovations for environmental protection: role of intellectual property rights in the carbon mitigation efforts. Evidence from western and southern Europe. *International Journal of Environmental Science and Technology*, *19*(5), pp.3919-3934. https://doi.org/10.1007/s13762-021-03491-z

Lélé, S.M., 1991. Sustainable development: a critical review. *World development*, *19*(6), pp.607-621. https://doi.org/10.1016/0305-750X(91)90197-P

Li, Z., Khurshid, A., Rauf, A., Qayyum, S., Calin, A.C., Iancu, L.A. and Wang, X., 2023. Climate change and the UN-2030 agenda: Do mitigation technologies represent a driving factor? New evidence from OECD economies. *Clean Technologies and Environmental Policy*, *25*(1), pp.195-209. https://doi.org/10.1007/s10098-022-02396-w

Lv, C., Shao, C. and Lee, C.C., 2021. Green technology innovation and financial development: do environmental regulation and innovation output matter?. *Energy Economics*, *98*, p.105237. https://doi.org/10.1016/j.eneco.2021.105237

Ma, C., Li, H., Saleem, S.F. and Mone, F., 2023. Balancing progress and sustainability: industrial innovation's impact on Europe's emission management, economic expansion, and financial growth. *Romanian Journal of Economic Forecasting*, *26*(3), pp.129-147.

Ngo, Q.T., Tran, H.A. and Tran, H.T.T., 2022. The impact of green finance and Covid-19 on economic development: capital formation and educational expenditure of ASEAN economies. *China Finance Review International*, *12*(2), pp.261-279. https://doi.org/10.1108/CFRI-05-2021-0087

Nihal, G., Mounia, C., Hussain, M., Humayun, S., Perveen, N., Yousaf, N.R. and Akhtar, S., 2023. impact of innovation on economic growth of G8 countries-analysis over 1996-2020. *International Journal of Professional Business Review*, *8*(5), pp.e01413-e01413. https://doi.org/10.26668/businessreview/2023.v8i5.1403

Pesaran, M.H. and Shin, Y., 1995. *An autoregressive distributed lag modelling approach to co-integration analysis* (Vol. 9514, pp. 371-413). Cambridge, UK: Department of Applied Economics, University of Cambridge.

Pesaran, M.H., 2015. Testing weak cross-sectional dependence in large panels. *Econometric reviews*, *34*(6-10), pp.1089-1117. https://doi.org/10.1080/07474938.2014.956623

Pesaran, M.H., Shin, Y. and Smith, J.R., 1999. Bond testing approach to the analysis of long run relationship. *Journal of the American Statistical Association*, *94*(446), pp.621-634.

Pesaran, M.H., Shin, Y. and Smith, R.J., 2001. Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*, *16*(3), pp.289-326. https://doi.org/10.1002/jae.616

Phillips, P.C. and Hansen, B.E., 1990. Statistical inference in instrumental variables regression with I (1) processes. *The review of economic studies*, *57*(1), pp.99-125. https://doi.org/10.2307/2297545

Qiang, S., Khurshid, A., Calin, A.C. and Khan, K., 2019. Do remittances contribute to the development of financial institutions? New evidence from the developing world. *Romanian Journal of Economic Forecasting*, *22*(2), pp.78-97. https://ipe.ro/rjef/rjef2_19/rjef2_2019p78-97.pdf

Rajeev, M. and Chakraborty, O., 2023. Green Finance for a Greener Economy. In The Palgrave Handbook of Socio-ecological Resilience in the Face of Climate Change: Contexts from a Developing Country (pp. 553-576). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-99-2206-2_32

Ren, X., Tong, Z., Sun, X. and Yan, C., 2022. Dynamic impacts of energy consumption on economic growth in China: Evidence from a non-parametric panel data model. *Energy Economics*, *107*, p.105855. https://doi.org/10.1016/j.eneco.2022.105855

Saleem, S.F., Khan, M.A. and Tariq, M., 2024, January. Moderating role of government effectiveness and innovation in sustainable economic growth relationship in Middle East & North Africa countries. In *Natural Resources Forum*. Oxford, UK: Blackwell Publishing Ltd. https://doi.org/10.1111/1477-8947.12397

Shang, M., Ma, Z., Su, Y., Shaheen, F., Khan, R., Mohd Tahir, L., Khalid Anser, M. and Zaman, K., 2023. Understanding the importance of sustainable ecological innovation in reducing carbon emissions: investigating the green energy demand, financial development, natural resource management, industrialisation and urbanisation channels. *Economic research-Ekonomska istraživanja*, *36*(2), p.2137823. https://doi.org/10.1080/1331677X.2022.2137823

Taghizadeh-Hesary, F. and Yoshino, N., 2020. Sustainable solutions for green financing and investment in renewable energy projects. *Energies*, *13*(4), p.788. https://doi.org/10.3390/en13040788

Ulucak, R. and Khan, S.U.D., 2020. Determinants of the ecological footprint: role of renewable energy, natural resources, and urbanization. *Sustainable Cities and Society*, *54*, p.101996. https://doi.org/10.1016/j.scs.2019.101996

Usman, O., Alola, A.A. and Saint Akadiri, S., 2022. Effects of domestic material consumption, renewable energy, and financial development on environmental sustainability in the EU-28: Evidence from a GMM panel-VAR. Renewable Energy, 184, pp.239-251. https://doi.org/10.1016/j.renene.2021.11.086

Wang, X., Chai, Y., Wu, W. and Khurshid, A., 2023. The empirical analysis of environmental regulation's spatial spillover effects on green technology innovation in China. *International Journal of Environmental Research and Public Health*, *20*(2), p.1069. https://doi.org/10.3390/ijerph20021069

Wang, X., Khurshid, A., Qayyum, S. and Calin, A.C., 2022. The role of green innovations, environmental policies and carbon taxes in achieving the sustainable development goals of carbon neutrality. *Environmental Science and Pollution Research*, 29, 8393-8407, pp.1-15. https://doi.org/10.1007/s11356-021-16208-z

Wen, H., Lee, C.C. and Zhou, F., 2021. Green credit policy, credit allocation efficiency and upgrade of energy-intensive enterprises. *Energy Economics*, *94*, p.105099. https://doi.org/10.1016/j.eneco.2021.105099

Westerlund, J., 2007. Testing for error correction in panel data. *Oxford Bulletin of Economics and statistics*, *69*(6), pp.709-748.

Xie, H., Khurshid, A., Rauf, A., Khan, K. and Calin, A.C., 2023. Is geopolitical turmoil driving petroleum prices and financial liquidity relationship? Wavelet-based evidence from middle-east. *Defence and Peace Economics*, *34*(6), pp.810-826. https://doi.org/10.1080/10242694.2022.2039525

Ma, X. and Ji, M., 2023. Analysis on liquidity risk management of monetary and financial services based on the goal of financial stability. *Romanian Journal of Economic Forecasting*, *26(2)*, pp.72-91.

Zhang, Y. and Chen, X., 2023. Spatial and nonlinear effects of new-type urbanization and technological innovation on industrial carbon dioxide emission in the Yangtze River Delta. *Environmental Science and Pollution Research*, *30*(11), pp.29243-29257. https://doi.org/10.1007/s11356-022-24113-2.

Appendix

The study adopted the Engle and Granger (Engle and Granger, 1987) 2-step process to examine the robustness of outcomes. The results in Table A show that lagged residual term (ECT) is significant at the 1% and 5% significance levels in all three models. The presence of a negative coefficient suggests that any deviations from the long-term equilibrium will be gradually rectified over some time. The lagged difference variables exhibit the short-run relationship, and their impact is tested on the difference FD and SDG to test the short-run relationship. The dependent FD shows the dependent variable with the modeled variables, illustrating the long-run nexus between the variables. The outcomes are in line with the findings of PMG(ARDL).

Table A. Robustness Outcomes

	Model 1			**Model 2**			**Model 3**	
D.FD	**Coef.**	**FD**	**D.SDG**	**Coef.**	**SDG**	**D. SDG**	**Coef.**	**SDG**
L1. resid	-0.041***			-0.079**			-0.012***	
	(0.011)			(0.039)			(0.003)	
LD. FD	0.408***		LD.SDG	0.204***		LD. SDG	0.194***	
	(0.046)			(0.050)			(0.050)	
LD. II	0.310***	0.253***	LD.GFN	2.273***	2.522***	LD.ETX	1.965***	2.672***
	(0.044)	(0.060)		(0.113)	(0.315)		(0.173)	(0.304)
LD. GFN	1.438**	1.452**	LD.EPY	0.370**	0.487*	LD.EPY	0.043*	0.099***
	(0.709)	(0.610)		(0.158)	(0.243)		(0.020)	(0.028)
LD.FF	0.989**	0.948***	LD.ECI	-0.331**	-0.384***	LD.RNG	0.047***	0.061***
	(0.431)	(0.292)		(0.120)	(0.073)		(0.013)	(0.020)
LD. TGL	1.200***	1.525***	LD.PBE	-0.017***	-0.015**	LD.MTP	0.051**	0.074*
	(0.253)	(0.413)		(0.004)	(0.006)		(0.023)	(0.036)
LD.IVA	3.095*	2.682**	LD.POP	-3.092**	2.134***	LD.FD	0.277**	0.565***
	(1.437)	(1.070)		(1.382)	(0.169)		(0.102)	(0.117)
LD.FDI	3.214**	4.097**	LD.INRE	1.016***	1.185***	LD.EGL	-0.109***	-0.160***
	(1.151)	(1.773)		(0.348)	(0.142)		(0.031)	(0.034)
_cons	0.658		_cons	0.347***		_cons	0.325***	
	(0.491)			(0.028)			(0.027)	
R^2	0.873	0.830		0.915	0.913		0.860	0.905
F-stats.	13.87***	446.8***		4.97***	215.5***		2.46***	606.8***

*Note: *** = 1% and ** =5%.*